NUTRITIONAL STUDIES WITH POTTING MIXES — SULFUR AND VERMICOMPOSTS: PRELIMINARY RESULTS

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INTRODUCTION

In this paper I give preliminary results from experiments on two aspects of potting mixes. Not all of the relevant analytical data are yet available, nevertheless, the results so far are so clear cut that I am confident that further data will not alter the broad conclusions.

SULFUR

In 1983 I examined (4) the properties of 73 potting mixes bought from retail shops around Australia. They were analysed chemically for their ability to supply nutrients. Plants were grown in them, with Aquasol® being used as a source of nutrients for half of the pots. After the experiment had been terminated, it became clear that the combination of a low level of S in the Aquasol feed (ca. 1 ppm) and low levels in at least some mixes probably limited growth in those mixes. The S levels in 1:1½ volume aqueous extracts of the mixes (1) ranged from 0.6 to 712 ppm (mean 133.6 ± 156.9). At the time, I had no means of interpreting these extraction figures. The experiment described here was designed to provide this interpretation.

Bare-rooted young plants of *Matthiola incana* (cv. Austral stock), *Brassica oleracea* (cv. Lion Heart cabbage), *Tradescantia fluminensis* (wandering jew) and *Brachycome multifida* (rock daisy) were transplanted on January 21, 1985 into 175 mm pots of a mix comprising ground *Pinus radiata* bark and acid-washed quartz sand (3:1 by volume). The mix contained (in g/L) KH_2PO_4 (0.5), NH_4NO_3(0.5), $Ca(NO_3)_2 \cdot 2H_2O$(0.75), KNO_3(0.3), $MgCl_2.6H_2O$(0.3), FeEDTA(0.03), $MnCl_2.4H_2O$(0.02), $CuCl_2.2H_2O$(0.004), $Na_2B_4O_7.10H_2O$(0.002), $(NH_4)_6 Mo_7O_{24} \cdot 4H_2O$ (0.00002), $ZnCl_2$(0.01) and GU-49 (Embecon Corp. — a slow-release source of Fe (0.5). The pH of the mix was 5.3 (1:1½ volume in water), and air-filled porosity was 22%.

Eight pots of each species were assigned at random to each of seven levels of sulfur addition, with the sulfur being added via liquid feeds containing 250 ppm N and 150 ppm K, supplied by ammonium nitrate and potassium nitrate. Levels of 0, 1, 2.5, 5, 10, 15 and 30 ppm S were produced by replacing varying proportions of the ammonium nitrate used with ammonium sulfate. The pots were housed in a shaded, evapora-

tively cooled greenhouse and watered as required with the appropriate solutions.

Samples of mix were taken from the pots on day 16 and days 32-43 (at harvest) and extracted with water (1:1½ by volume [1]) and 0.01 M $Ca(H_2PO_4)_2$ (1:5 by volume, 24 hr shake [2]). Sulfur levels in the calcium phosphate extracts were not correlated with treatments or growth so nothing further will be said about this extractant.

RESULTS AND DISCUSSION

As shown in Figure 1 and Table 1, growth was negligible for all species at the three lowest levels of sulfur application. The data in Figure 3 suggest that for *B.multifida* there must be at least 5 ppm S in a 1:1½ volume extract and for *T.fluminensis* at least 3 ppm S. The relatively large rooted cuttings of *T.fluminensis* used would have brought with them much S, so lessening the need for S from the liquid feed. For maximum growth of these two species, pot drainage water should contain at least 16 ppm S (Figure 4). If a liquid feed is the sole source of S, it should contain at least 20 ppm S.

Figure 1. Some of the cabbage plants at harvest. *From left to right*, the levels of sulfur in the liquid feeds applied were 0, 1, 2.5, 5, 10, 15, and 30 ppm.

Neither the *M.incana* nor the *B.oleracea* plants reached maximum growth rates at the top level of S supplied. A further experiment is in progress to check on the response of these species to higher applications of S, but in the meantime a tentative conclusion for them might be that there should be more than 8 ppm S in a 1:1½ volume extract and 25 ppm S in drainage water. For these minimum levels to be maintained, a liquid feed as sole source of S would need to contain about 35 ppm S.

Table 1. Top growth of test plants as affected by sulfur supply.

S concentration in liquid feed (ppm)	Dry weight of tops (g/pot)			
	Brassica oleracea	*Matthiola incana*	*Brachycome multifida*	*Tradescantia fluminensis*
0	0.97 ± 0.46	0.29 ± 0.09	0.92 ± 0.17	3.92 ± 1.44
1	1.00 ± 0.48	0.36 ± 0.11	0.97 ± 0.25	4.27 ± 0.93
2.5	1.18 ± 0.33	0.35 ± 0.09	1.02 ± 0.19	5.03 ± 0.65
5	1.44 ± 0.34	0.84 ± 0.32	1.16 ± 0.24	7.69 ± 1.95
10	4.13 ± 0.88	2.56 ± 0.40	2.31 ± 0.24	10.30 ± 2.05
15	5.77 ± 0.99	4.25 ± 0.39	3.09 ± 0.82	11.26 ± 1.41
30	6.75 ± 1.75	6.48 ± 1.10	3.59 ± 0.39	11.63 ± 0.81

The species used here may or may not represent the full range of S requirements in plants likely to be grown in pots. If they do, then a liquid feed used as a sole source of S should contain about 40 ppm S, but it could contain rather less if an adequate level of slow-release source of S (e.g. gypsum or a coated fertilizer) is included in the mix — *and replenished as needed*. Further analysis of the data indicates that 1:1.5 volume extracts should contain at least 6 ppm S, drainage waters at least 16 ppm S, and liquid feeds as sole source of S about 30 ppm.

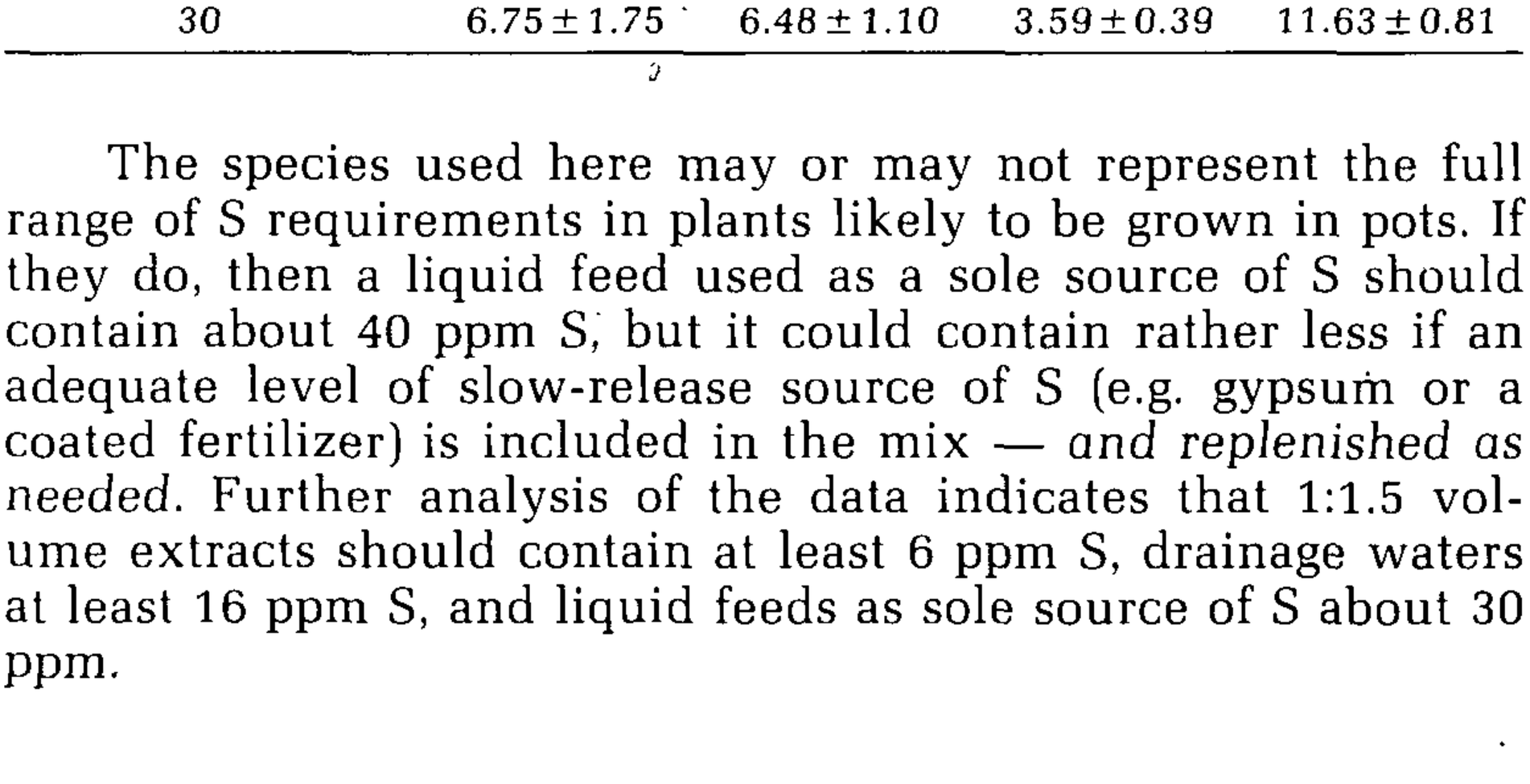

Figure 2. Relationships between sulfur in 1:1½ volume extracts of the growing media and sulfur in the liquid feeds used. The solid line gives the concentrations in extracts expected given that the mix contained water equivalent to 40 % of its volume when drainage had stopped.

Some simple arithmetic is helpful here. A common rate of use of gypsum is 0.75 g/L (from about 1.5 g/L superphosphate). If drainage water is saturated with respect to gypsum (2.41 g/L) and if 30 mL of water per L of mix drains from the pot at each watering, then the gypsum could all be lost in 11 days. A more realistic figure is 60 to 90 days, because of the slow rate of dissolution of gypsum.

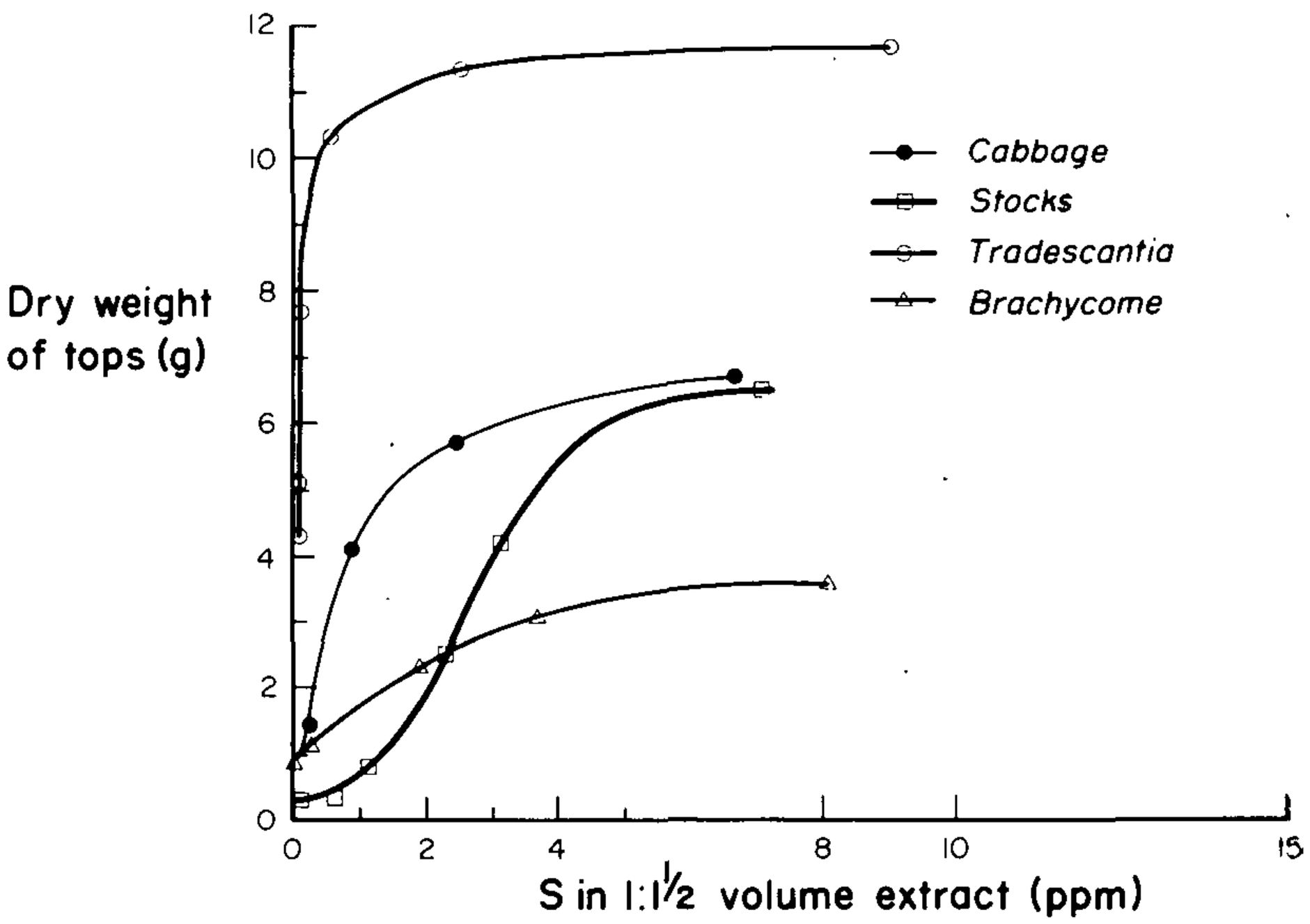

Figure 3. Relationships between dry weights of tops and the concentrations of sulfur in 1:1½ volume extracts of the growing media.

Clearly, if the only fertilizer used is a liquid feed containing substantially less than 35 ppm S, sulfur deficiency is possible within a "few" months. Just how long the "few" is will depend on local conditions. I am currently attempting to determine the range more precisely.

I now believe that the preference of many home gardeners for products such as Nitrosol® and Phostrogen® is due as much to their sulfur contents (122 and 22 ppm in the applied liquid, respectively) as to any other difference between them and competing products such as Thrive® and Aquasol® (~1 ppm S).

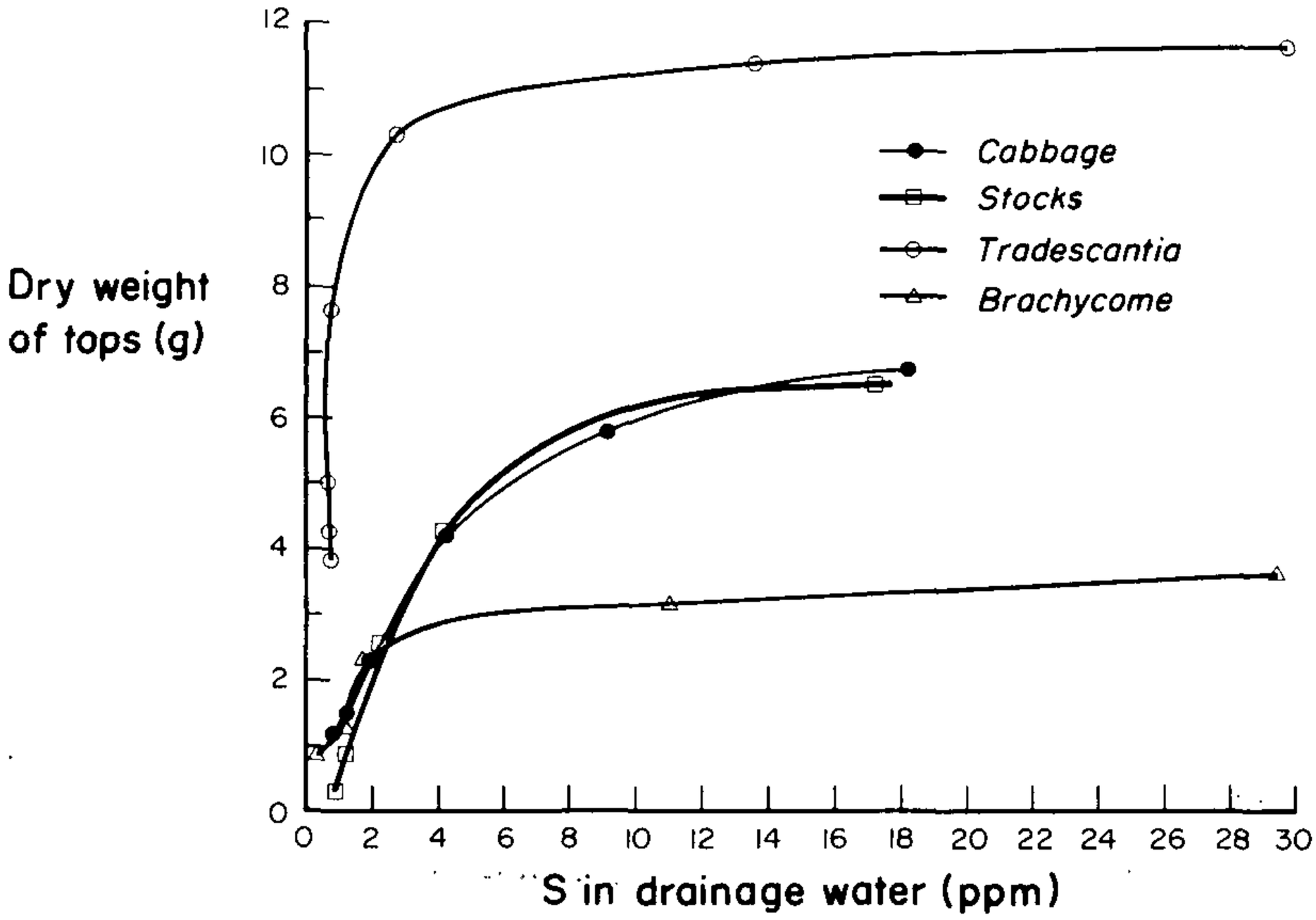

Figure 4. Relationships between dry weights of the tops and the concentrations of sulfur in pot drainage waters.

VERMICOMPOSTS

I come to the second part of my presentation. We all know that earthworms are good for soils. Organic gardeners have for some time extolled the virtues of earthworm castings (vermicompost). I once thought that vermicompost would be a useful component of potting mixes. I am now less enthusiastic, as you will see.

In late 1984 I acquired samples of 7 vermicomposts produced from materials as listed in Table 2. The sieved (<3 mm) vermicomposts were mixed at a rate of 30% by volume into a base potting mix consisting of ground *Pinus radiata* bark and quartz sand (4:1 by volume) to which had been added Aqua Soil Wetter® wetting agent and $MgSO_4.7H_2O$ at 0.375 g/L. The pH values of the mixtures were adjusted to ca. 5.6 as required with dilute sulfuric acid. Thirty-two equal lots (approx. 900 mL) of each mixture were weighed into plastic bags. Aliquots of solutions supplying N (1.35 g NH_4NO_3/bag), P (0.68 g Ca $(H_2PO_4)_2$), K(0.26 g KCl) and trace elements (0.03 g FeEDTA, 0.675 g GU-49, 0.02 g $MnCl_2.4H_2O$, 0.01 g $ZnCl_2$, 0.004 g $CuCl_2.2H_2O$, 0.002 g $Na_2B_4O_7.10H_2O$ and 0.00002 g $(NH_3)_6Mo_7O_{24}.4H_2O$) were added to the bags in all 16 possible combinations (O, N, P, K, NP; NK, PK, NPK, and these plus trace elements), so giving two bags of each combination. After thor-

ough mixing, the total contents of a bag was transferred to a 125 mm nursery pot. The pots were randomised on individual saucers on benches in a shaded, evaporatively cooled glasshouse. There were two series of control pots: one received a full complement of nutrients; the other received all major nutrients but no trace elements.

Sufficient distilled water was applied to each pot to give at least some drainage. For those mixes whose salinities were above an acceptable level, about half a pot volume of water was added and the leachate retained in a separate container. This leachate was returned to the pots in small aliquots over the first few weeks of the growing period. In this way the young plants were not deprived of any of the soluble nutrients in the vermicompost.

On January 25, 1985 one bare-rooted seedling of *Matthiola incana* (cv. Austral stocks) was planted into each pot. For the first week, watering was with distilled water but subsequently watering was with either distilled water or solutions containing 150 ppm N (as NH_4NO_3) and/or 100 ppm K (as K_2SO_4), as indicated by treatment. The only P and trace elements applied were those given before potting.

After 2 weeks it was clear that most plants in pots receiving no N were deficient in N. This deficiency intensified in all pots except V6 (which contained residual meatmeal). There seemed little point in retaining the saucers so they were removed on day 27. All subsequent watering was with enough of the appropriate solution to give a small amount of drainage.

The visual appearance of the plants was scored on a 0-10 scale on days 20 and 50. This scoring, examples of which are given in Figure 5, and the data for final dry weights of the tops, have been interpreted as given below. Future statistical analysis and chemical analysis of the tops will enable this interpretation to be refined.

Unless modified, the vermicomposts were inadequate for plant growth for the following seasons:

V1 high pH; deficiencies - N (severe), S (slight)
V2 high pH; deficiencies - N (severe), P (mild), trace elements (slight), S (slight)
V3 high pH; deficiencies - N (severe), P and K and trace elements (slight), S (slight)
V4 high pH; deficiencies - N (severe), K (mild); suspected toxicities - Zn (severe), Cu (?)
V5 deficiencies - N (severe), S (severe), trace elements
V6 high pH; deficiencies - P (slight), S (slight)
V8 deficiencies - N (medium), P and trace elements (possibly induced by high Zn and/or Cu), S (slight)

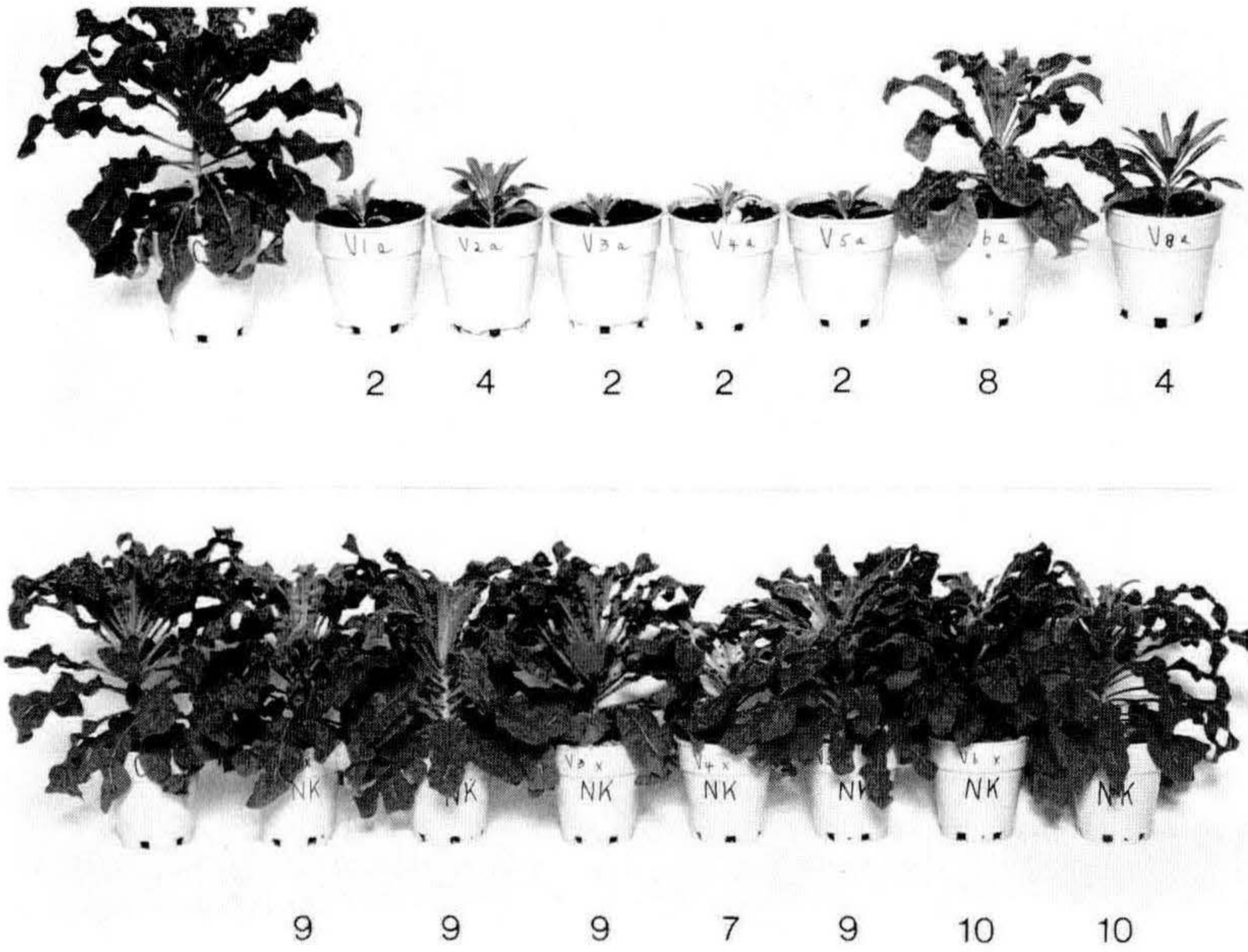

Figure 5. Control plant and plants grown in the vermicompost mixes which received (above) no added nutrients, and (below) all nutrients.

On the basis of these results I conclude that vermicomposts are extremely variable in composition. Assessing their quality will be difficult, and must be on a better basis than appearance. When used as a component of mixes based on pine bark or sawdust, supplemental N must be used from potting. In this experiment the use of sulfuric acid to acidify five mixes obscured S deficiency in them. A later check showed that plants became deficient in S in all pots within two months of potting. The most troublesome problem could be coping with trace element problems ranging from deficiency to severe toxicity. One would usually expect vermicomposts based on animal manures to have adequate levels of trace elements but the results for V8 show that this is not always so. The severe toxicity of V4 shows the need for care when producing vermicomposts from domestic (and municipal?) wastes.

Vermicomposts do impart a rich-humus appearance to a potting mix and will increase cation exchange and buffer capacities. These benefits have to be weighed against possible nutritional problems and decrease air-filled porosity as the level of addition goes over 30 percent by volume.

Acknowledgements. I thank Barbara Graham for dedicated technical help, Adrian Beech for most of the analyses, Ray

Table 2. Some properties of the potting mixes containing vermicomposts.

Vermicompost	Water extract (ppm)*						DTPA extract (ppm)+				B$^{\Delta}$ (ppm)	Air-filled porosity (Vol %)	Unamended pH of vermicompost	EC° (mS/cm)
	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn				
V1 (sheep)	0	43	70	45	21	36	7.4	56	3.6	7.1	0.2	20.5	6.9	0.68
V2 (cow)	45	56	274	31	26	59	21.5	20	1.5	13.3	<0.1	13.6	6.7	1.55
V3 (poultry)	0	45	74	44	18	29	5.5	28	0.7	8.2	<0.1	18.9	6.7	0.60
V4 (domestic)	0	93	350	27	19	60	10.3	77	5.8	6.3	0.1	17.1	7.8	1.47
V5 (kitchen)	0	22	99	28	12	35	20.6	20	0.7	6.7	<0.1	18.2	5.9	0.69
V6 (domestic)	500	80	429	57	43	36	9.1	38	1.9	9.5	<0.1	20.7	6.6	2.49
V8 (pig)	50	101	126	60	45	52	10.7	63	25	7.1	<0.1	11.1	5.8	1.07
Control 1	450	70	190	109	140	40	21.1	3.8	1.8	21.1	0.1	21.8	-	2.62
Control 2	400	87	160	94	134	39	4.9	1.6	0.4	4.9	<0.1	21.8	-	2.46

* 1:1½ volume; ppm in the extract
\+ 10 g and 20 mL extractant [5]; ppm on dry weight basis
Δ In mannitol/$CaCl_2$ extract [3]
° 1:1½ volume (before acidification)

Correll for advice on experimental design, and Dan Pogson, Jim Williams, Alan McKay, Jim Harmon, John Sabine, Victorian Prisons Industries, Brian Ferrier and John Jenkins for gifts of vermicomposts, and Falgs Nurseries for bedding plant seedlings.

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THE USE OF TISSUE CULTURE IN THE SEARCH FOR PANAMA DISEASE RESISTANT CLONES OF BANANA

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The banana is one of the most important fruit crops in Queensland with a gross annual value of $45M in 1984. According to Simmonds (20) all current banana cultivars have been derived from two species. They are *Musa acuminata*, which is the source of the "A" genome, and *Musa balbisiana*, which is the source of the "B" genome. Commercial cultivars are usually seedless triploids and tetraploids comprising various combinations of these two genomes.

Panama disease, also known as fusarium wilt, is caused by *Fusarium oxysporum* Schlecht ex Fr. f. sp. cubense (E.F. Smith) Snyd. & Hans. This disease has been known for a long time in Queensland where it is the major limiting factor in the production of the 'Lady Finger' (AAB group) banana.

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The first world recording of fusarium wilt in bananas was made by Bancroft in Queensland in 1874 (1). He found the disease to be prevalent in the Brisbane district and noted that the 'Sugar' (AAB group) banana was most susceptible and the 'Dwarf Cavendish' was not affected. Tryon (26) when describing wilt of 'Sugar' and 'Gros Michel' (AAA group) (the latter being introduced into Queensland in 1910) stated that the Cavendish banana either "escapes its onslaught altogether" or is highly resistant. Subsequently 'Lady Finger' was found to be much less susceptible than 'Sugar' (Purss, unpublished); however, the disease has been devastating in 'Lady Finger' and has forced many growers to replant with resistant 'Cavendish' (AAA group) cultivars.

Purss (18) found a disease resembling Panama disease on three 'Williams' ('Giant Cavendish') plants at Woongoolba in southern Queensland. An unidentified *Fusarium* sp. was isolated and proved to be pathogenic to 'Lady Finger' and 'Williams' but, in the same experiment, Purss found that *F. oxysporum* f. sp. *cubense*, isolated from 'Lady Finger', did not attack 'Williams' but produced symptoms typical of Panama disease in 'Lady Finger' plants.

In a field experiment at Nambour in southern Queensland (17) a number of cultivars were planted into a site where 'Lady Finger' plants had been devastated by Panama disease. 'Lady Finger', 'Mysore' (AAB group), and 'IC2' (AAAA group) were susceptible, but 'Mons Mari' ('Giant Cavendish'), '2390-2' (AAAA group), and 'Bodles Altafort' (AAAA group) were not affected.

During 1976, symptoms resembling Panama disease were detected in 'Mons Mari' plants growing at Wamuran in southern Queensland. In 1977 Peterson (pers. comm.) isolated *F. oxysporum* from these plants and found, in limited pathogenicity tests using suckers, that the isolate did not attack 'Williams' bananas. He concluded that a new race of the fungus had not evolved and suggested that the resistance in the 'Mons Mari' plants had broken down under unfavourable soil conditions. During 1981, Mayers (pers. comm.) provided conclusive evidence that a new race of *F. oxysporum* f. sp. *cubense*, capable of attacking Cavendish cultivars, had evolved in Queensland. Fusarium wilt of these cultivars has now appeared in fifty plantations between Caboolture and Eumundi in southern Queensland. As Cavendish cultivars represent the majority of commercial plantings in Australia, it now appears that the Australian banana industry is threatened by Panama disease. There are reports of Cavendish cultivars succumbing to fusarium wilt in Canary Islands, Taiwan, Natal, Jamaica, and Central America (21, 22, 27), but these outbreaks were

considered to be due to adverse growing conditions or excessively high inoculum levels in the soil overcoming host resistance, rather than a new race of *Fusarium*. However, the outbreak of Panama disease in Cavendish cultivars in southern Taiwan has subsequently been attributed to Race 4 of *F. oxysporum* f. sp. *cubense* (23). There are also indications that a new race capable of attacking Cavendish cultivars has evolved in South Africa (B.Q. Manicom, pers. comm.) and Philippines (D. Littman, pers. comm.) Four races of the pathogen have been defined. Race 1 attacks AAA triploids such as 'Gros Michel'; race 2 is pathogenic to certain ABB triploids such as 'Bluggoe'; race 3 causes wilt of Heliconia spp.; and race 4 attacks Cavendish cultivars.

Thus there is a need to produce Cavendish cultivars that are resistant to the new race of fusarium wilt. As plant breeding is limited by the scarcity of seeds in edible bananas (13) we are studying the potential of tissue culture for the production of natural and induced variation, and subsequent selection of disease-resistant plants.

There have been a number of reports on tissue culture of banana and successful regeneration of plantlets. Berg and Bustamante (2) and Bower and Fraser (3) have described techniques for meristem culture of lateral bud apices for removal of pathogens from Cavendish cultivars. The first report of rapid multiplication of banana cultivars using tissue culture was that of Ma and Shii (11, 12). They cultured shoot apices from suckers on both agar-based media and liquid media. Subsequently, various techniques and media for the rapid multiplication of bananas via shoot-tip culture from suckers have been described by de Gusmán and Tolentino (7), Cronauer and Krikorian (5), Hwang, Chen, Lin and Lin (10) and Swamy, Sriniv and Chacko (24). Hwang *et al.* (10) reported the production of one million pathogen-free plants in 1983 to prevent the spread of fusarium wilt in commercial plantations in Taiwan.

Callus cultures have been produced from sections of banana fruit (6, 15, 25); however there have been no reports of organogenesis or production of plants from this callus. Cronauer and Krikorian (4) have reported somatic embryogenesis using 2,4,5-T in their growth medium.

Genetic variability has been observed in banana plants produced by rapid multiplication of shoot-tip cultures *in vitro*. Reuveni, Israeli, Degani and Eshdat (19) noted three common mutants in Israel. They were dwarfed plants; plants with thick curled leaves with streaks similar to mosaic virus infection; and a mutant characterised by reddish colour of the leaves

and petioles. In plantings of 'Grand Naine', 7.2% of plants were identified as off-types and, with the cultivar 'Williams', 9.3% of the plants were mutants. In Taiwan, where multiplication is via culture of shoot apices of banana suckers, 3% of plants in field plantings have been identified as off-types (28). In Alstonville, Australia, plants were produced from inflorescence-section cultures. Ten percent of the resultant plants were observed as off-types in large field plantings (Turner, pers. comm.). Off-types observed were variations in leaf type and thickness, variegated and chlorophyll deficient leaves, and dwarf plants.

There have been some reports on the use of mutagenic agents to produce variability in bananas. Menéndez (14) used ethyl methane sulphonate on seeds of *M. acuminata*. De Guzmán, Decena and Ubalde (8) treated shoot-tip explants of 'Lacatan' with gamma radiation. Low dosage (1.0 Kr/hr) was stimulatory to bud formation and high dosage (10.0 kr/hr) was lethal. A highly proliferating tissue strain was isolated from a culture of an irradiated explant. Epp (pers. comm.) has added fusaric acid and fungal filtrates to tissue cultures of Cavendish clones in an attempt to distinguish levels of resistance between clones.

We are using plant tissue culture in an attempt to produce Cavendish clones resistant to race 4 *Fusarium* wilt. This involves the development of screening techniques to identify resistant clones. We are also assessing other banana cultivars for possible sources of resistance to Panama disease. Our approach to this work is presented in the summaries below.

Multiplication of Shoots from Cultures of Apical Tips of Inflorescences in Cavendish Clones. Explants were taken from inflorescences because similar cultures produced more variation in field-grown plants than those cultured from sucker explants in Alstonville (Turner pers. comm.). Initial explants consisted of apical tips from inflorescences of cultivar 'New Guinea Cavendish', removed when the fruits were mature green and ready for harvest. Apical tips (1 cm in length), with bracts and flowers removed, were cultured in 250 ml Erlenmeyer flasks on a horizontal orbital shaker at 120 rpm. They were transferred monthly into a fresh solution containing Murashige and Skoog (MS) salts and vitamins (1972) plus (per litre) 5 mg BAP and 20 g sucrose. After six months, the explants had doubled in size and had developed small lateral buds. At this stage, they were bisected longitudinally and placed either into liquid medium on a roller drum at 4 rpm or onto agar-based medium (8 g/l) of similar composition as used previously.

Multiplication rates were higher in the liquid medium than on agar-based medium. For the next 18 months, resultant multiplying shoots were sub-cultured monthly onto fresh medium. Rooted plantlets were then produced on a medium containing MS salts, 0.1% activated carbon, and (per litre) 20 g sucrose and 8 g agar, before being transferred to a steam-sterilized potting mix of peat and perlite.

Of the first 800 plants produced 8 have survived two root dip inoculations in race 4 Fusarium at an inoculum density of 1 million conidia per ml. These, and other surviving plants, will be planted in a field where outbreaks of race 4 *Fusarium* have occurred.

This work is now being repeated with cultivar 'Williams' (Figure 1).

Figure 1. Rooted plantlets of 'Williams' bananas on a medium containing M.S. salts and vitamins plus (per litre) 20g sucrose and 8g agar.

In vitro Propagation of Other Banana Cultivars from Suckers. Twenty-two cultivars representing six genomic types have been cultured from shoot tips isolated from suckers on a modified de Guzman, *et al.* (8) medium containing (per litre) 5 mg BAP and 0.1 mg IBA: The survival rate for these explants in culture was much higher (with all cultivars) when the apical dome was not removed. Cultivars varied widely in their response to different growth regulators in terms of multiplication rates, shoot elongation, root growth and development. These results have been discussed more fully in a paper by Wong (in press).

Plantlets of the diploid SH-3362 and the tetraploid SH-3436 have been obtained from Dr. P. Rowe in Honduras and are being multiplied in tissue culture. SH-3142, the parent of both these cultivars, is reported to be resistant to race 4 *Fusarium* and we are hopeful that this resistance will be found in its progeny.

All these cultivars are being screened for resistance to Fusarium.

Callus Culture of Banana. Callused leaves and stems were produced on banana shoots when 2μM 2,4-D was added to the multiplication medium of freshly sub-cultured shoots of cultivar 'New Guinea Cavendish', (Figure 2). Sections of callused leaf and stem were removed and grown on a number of media. Mineral formulations (B5 and M5) of Gamborg (1982) have been compared with MS and half-strength MS salts. Various concentrations of BAP, kinetin, and 2,4-D have been used in these media. Best growth of this tissue has been obtained on a medium containing MS salts and vitamins plus (per litre) 20 μM BAP and 2 μM 2,4-D. Over 6 to 12 weeks, these cultures produced compact nodular masses of tissue, (Figure 3). A major limiting factor to the growth of this tissue was the production of a black phenolic exudate which often prevented growth after a few weeks. A number of additives have been used in an attempt to overcome this problem. Best results have been obtained with citric acid (75 mg/l) and ascorbic acid (50 mg/l), PVP (0.01%) and activated charcoal (0.5%); however, only a partial reduction of exudate has been achieved. Further reductions of exudate have been achieved when the tissue has been emersed in stationary liquid culture medium, and when the cultures have been incubated in darkness.

Small green nodules which subsequently developed into shoots have been formed on this tissue when placed on a roller drum at 4 rpm in solution containing MS salts and vitamins and 20 g/l sucrose. Rapid initiation and growth of roots has occurred in these cultures with shoots when 0.5% activated carbon has been added to the solution.

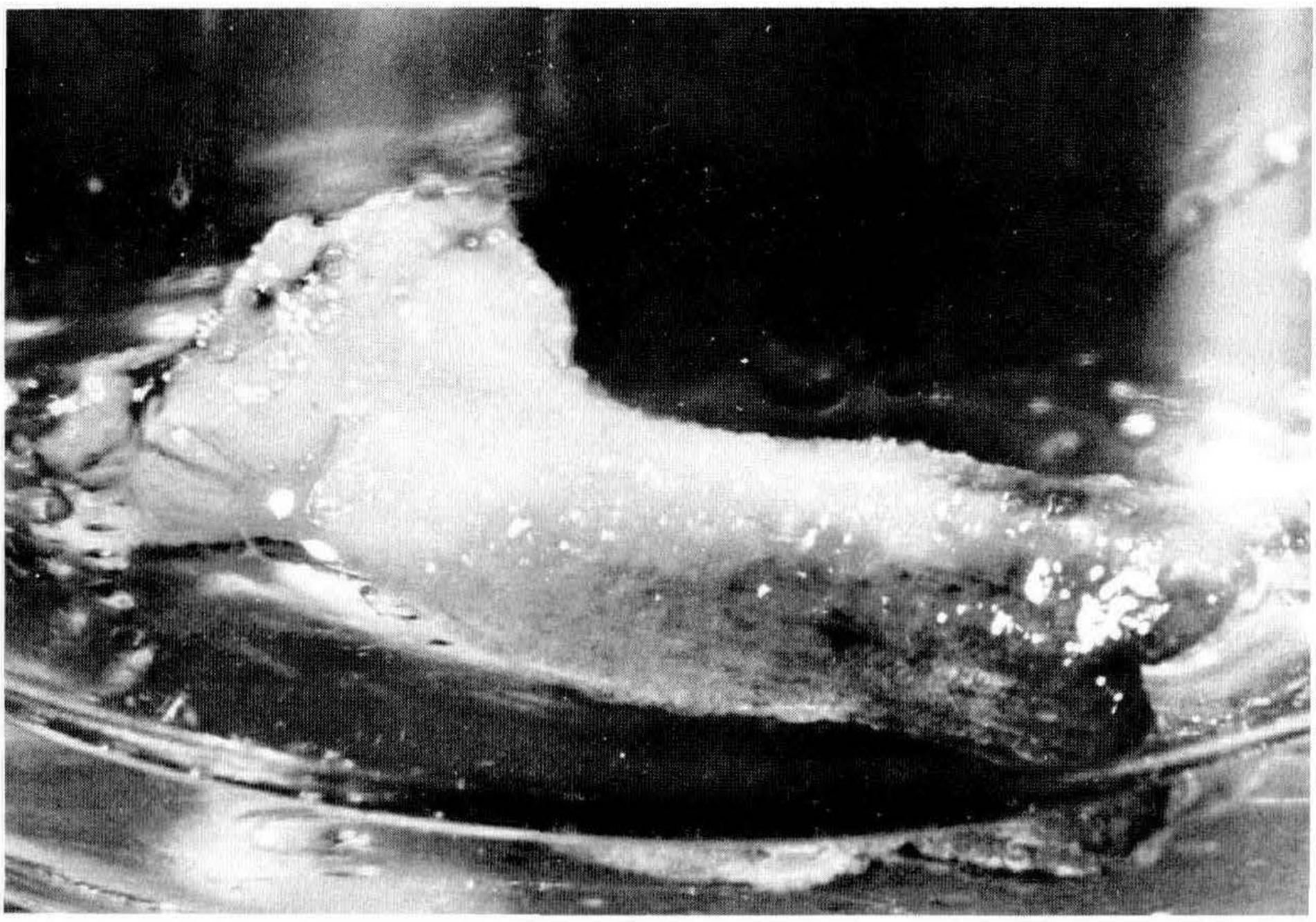

Figure 2. Callused leaf of 'New Guinea Cavendish' produced when 2μM 2,4-D was added to the multiplication medium.

Figure 3. Compact nodular masses of tissue on medium containing M.S. salts and vitamins plus (per litre) 2μM 2,4-D and 20μM BAP.

The Use of Culture Filtrates and Gamma Radiation. *Fusarium oxysporum* f. sp *cubense* was cultured on liquid medium and its metabolites (principally fusaric acid) used *in vitro* to select for resistance to these toxins. The supernatant from fungal filtrates was passed through a millipore filter and was then incorporated in or used to flood the multiplication medium. Surviving plants were grown for three generations on the toxin-amended multiplication medium prior to being tested in the glasshouse and field. More than 95% of adventitious buds which were developed from a 'Williams' plantlet, died when cultured on this medium. Although we do not have any evidence that *Fusarium* overcomes host resistance through the actions of these toxins on host tissue, and very weak evidence that toxins contribute to the fusarium wilt syndrome, we are hopeful that surviving plants will be resistant to the wilt pathogen.

Multiplying shoot cultures have been treated with low dose gamma radiation in an attempt to produce useful off-types.

Screening Techniques. In banana, *F. oxysporum* f. sp *cubense* gains entry into the xylem elements of the adventitious roots. It then spreads into the rhizome stele and invades the elements of the pseudostem. In resistant banana cultivars the infection is checked within the roots or rootlets or at the root bases. With tissue-culture plantlets the juvenile roots are unable to preclude the fungus from the rhizome stele and any defence reaction has to take place in the rhizome. This may not occur if undifferentiated vascular elements are present in the rhizome. Therefore, with these plantlets inoculum density greatly influences symptom development. Theoretically these plantlets should be able to express resistance if a very low inoculum density is used. In our experiments we have been using a density of 300,000 conidia per ml, but we plan to experiment with a series of inoculum dilutions. Research workers in other countries believe that Panama disease resistance testing can be done only in the field and that glasshouse testing does not give a true indication. In field screening, a susceptible cultivar is usually grown for a full growth cycle on the trial site as a means of building up the inoculum level in the soil, to fully test plants for resistance. Thus we intend to use a disease nursery to field test any plants which survive initial screening in the glasshouse.

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PROPAGATION OF ORNAMENTAL RAINFOREST PLANTS

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Wavell Heights, Queensland 4012

Any discussion about rainforest plants generally leads to some disagreement about which plants are truly rainforest species and which are not. The distinction is not as clear as one might imagine because some species, for instance *Lophostemon confertus* (better known as *Tristania conferta*), are prominent in some rainforests and can be equally prominent in some eucalypt forests.

The "Language of Botany" defines rainforest as "a closed community dominated by trees which form a two or more layered dense canopy in which lianes and epiphytes are usually conspicuous with a lower sparse assemblage of small trees, shrubs and herbs, including ferns".

Other definitions also include orchids, palms, wide-leaved forbs such as philodendron relatives, ginger relatives and bananas, special plant modifications such as trunk buttresses and leaf drip tips, and an absence of grasses, annual herbs, eucalypts, and acacias.

Rainforests are widespread in tropical and sub-tropical lands or parts of those lands which receive a fairly continuous and high rainfall. Rainfall is more important to the development of rainforest than soil type or soil fertility, although good soil drainage is usually an important factor. Provided topogra-

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Rainforests are widespread in tropical and sub-tropical lands or parts of those lands which receive a fairly continuous and high rainfall. Rainfall is more important to the development of rainforest than soil type or soil fertility, although good soil drainage is usually an important factor. Provided topogra-

phy is favourable, areas receiving an annual rainfall of 1,275 to 1,500 mm or more (50 to 60 inches or more), develop rainforests, irrespective of whether the soil is basalt, andesite, granite, phyllite, slate, or beach sand.

At lower rainfalls, down to about 900 mm (36 inches), soil fertility is more important and dry softwood or vine scrub, which is a depauperate type of rainforest, develops on richer soils. Topography is important though, and patches of rainforest are usually developed where some geological feature helps to trap moist air.

The rainforests comprise an incredible diversity of plant life, not only in numbers of species but also in plant form. There are upper canopy trees and lower canopy trees; there are small trees and shrubs that do not enter into the competition for light but grow well as understory plants in low light. Some climbing plants scramble up to light in the same way as some epiphytes grow on the upper part of trees in strong light. Others of both groups grow on the lower trunks or rock faces.

The soil carries large-leaved forbs such as *Alocasia*, *Alpinia* or native banana. In addition there is a tremendous variety of ferns, from the most delicate and tiny filmy ferns to giants such as *Angiopteris evecta* which may have fronds up to 9 or 10 metres long, and from the soil and rock dwelling ferns to the epiphytic species in the tops of the trees.

In each of these categories of plant form there are many species with attractive flowers, fruit, or foliage — species with the potential to become valuable additions to the already immense array of commercial ornamental plants. I propose now to illustrate some examples of these various plant forms.

While many rainforest trees have inconspicuous flowers, others are quite spectacular. Outstanding flowering trees include *Baklya syringifolia*, *Brachychiton discolor*, *Buckinghamia celsissima*, *Darlingia ferruginea*, *Deplanchea tetraphylla*, *Doryphora sassafrassa*, *Elaeocarpus bancroftii*, *Oreocallis wickhamii*, *Sloanea australis* and *Xanthostemon chrysanthus*.

Smaller flowering trees and large shrubs are *Backhousia anisata*, *Cerbera manghas*, *Dillenia alata*, *Phaleria clerodendron*, *Pilidiostigma glabra*, *Pithecellobium grandiflorum*, *Quintinia sieberi*, *Turraea brownii* and *Zanthoxylum brachyacanthum*.

Other trees are notable for their fruit and include *Cupaniopsis serrata*, *Diploglottis cunninghamii*, *Dysoxylum fraseranum*, *Hicksbeachia pinnatifida*, *Ochrosia elliptica*, *Podocarpus elatus*, *Syzygium hodgkinsoniae*, but there are many more. The foliage of others is attractive, particularly in the juvenile

stages; *Geissois biagiana* and *Macaranga tanarius* are examples.

The understory trees and shrubs include some with remarkable foliage or unusual flowers or fruit. Besides having potential for shaded gardens some may also prove useful indoors. They include *Alyxia ilicifolia*, *Anopterus macleayanus* foliage and flowers, *Eupomatia bennettii*, *Fagraea racemosa*, *Fissistigma stenopetala*, *Pavetta australis*, *Randia chartaceae*, *Randia hirsuta* and *Triunia youngiana*.

Light-seeking climbers include: *Agapetes meiniana*, *Aphanopetalum resinosum*, *Faradaya splendida*, *Hoya macgillivrayi*, *Millettia megasperma*, and *Tylophora grandiflora*. Shade-loving climbers include *Capparis sarmentosa*, *Elaeagnus latifolia*, *Fieldia australis*, *Freycinetia excelsa*, and we have several *Raphidophora* such as *R. australasius* and *R. pachyphylla*.

The large-leafed herbs or forbs are represented by *Alocasia macrorrhiza*, *Alpinia caerulea*, *Cordyline canniaefolia*, *Dracaena angustifolia*, *Orthothylax glaberrimus* and *Tapeinocheilos queenslandiae*. Other plants growing in the same situation are *Bowenia serrulata* and *Lepidozamia hopei*.

Ground and rock covering plants include *Boea hygroscopica*, *Drymophila moorei*, *Kreyssigia multiflora* and *Peperomia* spp.

Ferns are many and varied — from the *Platycerium* spp. to the tassel ferns and tree ferns.

The rainforest is not a particularly good place to look at rainforest trees if you have cultivation in mind. You will be impressed by the tall trunks and more than impressed by the height of the trees. From a cultural point of view the most interesting place to see rainforest plants is in regrowth country where regeneration is taking place. Most rainforest trees when grown in the open are shorter with spreading crowns and flower more regularly and profusely.

The cultivation of rainforest trees is by no means a new concept and, in fact, many species were collected and distributed during the very early settlement of Moreton Bay. Some of these specimens are still growing in southern capitals and in overseas gardens because rainforest plants are the easiest to grow and most adaptable section of our native Australian flora.

Much is said at times about developing our rainforest plants as indoor plants. However, to gain acceptance in this well-supplied area our natives will have to be just a little better than or distinctly different from the established exotics because, in general, they lack leaf colours other than green

and they have long internodes.

Australian rainforest plants may be propagated by the same general methods as for other plants, namely from seeds or by vegetative means such as cuttings, grafting, and by tissue culture. There are a few with viviparous habits such as *Lomandra spicata* which, besides producing seeds, may also produce plantlets on the flower spikes. The rainforest *Pandanus monticola* may drop small aerial rooting shoots and *Remusatia vivipara* produces small burr-like bulbils on sterile stems. The seeds of some plants such as *Cordyline* may germinate on the plant.

Seeds of most rainforest plants are short-lived although some are remarkably slow in germinating. They do not dry-store but need to be kept moist in plastic where they will germinate.

Some seeds are light and windblown such as those of *Doryphora, Calducluvia,* and *Alstonia.* Many species have fleshy fruit and relatively large seeds that are eaten by cassowaries and wild pigs. The cassowaries pass the seeds and are important distributors as well as efficient collectors of seeds.

The slow germination of some large seeds is an interesting phenomenon. They need to be planted fairly quickly to retain viability but take up to 4 years to germinate. In my limited experience these include *Aceratium ferrugineum,* some of the Lauraceae, and possibly *Syzygium gustavioides.*

Other rainforest seeds have a strong tendency to rot if buried in the normal manner of planting seeds. They germinate on a moist surface, and, in nature, would be amongst a mulch of fallen leaves. These include *Bowenia, Lepidozamia,* and possibly the slow-germinating species mentioned earlier. Some growers have best success in germinating seeds of these species in plastic bags with slightly moist peatmoss.

Cutting propagation utilizes the standard tip and stem cutting methods and use of rooting hormones. Rainforest plants are high humidity plants and the best methods should be used to maintain high humidity over cuttings. Old, thicker stems seem to be most successful for *Tecomanthe hillii* and *Pandorea baileyana*; basal trunk suckers should be tried for species such as *Aceratium ferrugineum.*

Root cuttings are successful for *Pentaceras australis,* the *Austromyrtus acmenioides* and *A. bidwillii.* Surface roots of pencil to finger thickness, cut to 15 to 25 cm lengths are laid down horizontally in propagation mix. When the suckers that arise produce their own roots they can be potted individually.

Tissue culture has been successful with some native

plants and I am sure it could be used just as successfully with rainforest species.

A large number of rainforest plants have the potential to become important ornamentals. Propagation should not present any serious problems. The main limitations are in knowledge of the species and availability of propagation material.

COMMERCIAL PRODUCTION OF KANGAROO PAWS

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Department of Agronomy and Horticultural Science
University of Sydney
Sydney, New South Wales 2006

INTRODUCTION

There has been a rapid expansion of interest in the development and production of Australian native plants. One genus which has received a great deal of attention is *Anigozanthos* (kangaroo paws). Kangaroo paws blooms, originally all bush-picked, are currently available from commercial plantings. Now, the potential of kangaroo paws as "potted colour" is about to be realised.

Extensive work has already been done with *Anigozanthos* in areas such as taxonomy, ecology, evolution, hybridisation, plant selection, micropropagation, field cultivation, pathology, and flower production. However, much of the horticultural information has been published for the gardening fraternity or as a result of scientific investigations into the biology of the genus. With the introduction of kangaroo paws as cultivated cutflowers, information relevant to field production has been gathered by workers in Western Australia. Other information is less easily available as it originates from the experience and observations of gardening enthusiasts, plant breeding experts, and unpublished research work.

At the University of Sydney, work is aimed at the production and utilisation of new hybrids of *Anigozanthos* as containerised plants.

PLANT IMPROVEMENT

Many species of *Anigozanthos* are not well-suited to field cropping or nursery production methods. *Anigozanthos flavidus* is the most vigorous, reliable, and long-lived of the species but produces flower stems which are up to three metres in height and are generally unspectacular. *A. manglesii*, the red

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and green kangaroo paw, Western Australia's floral emblem, produces stunning single terminal inflorescences but is highly susceptible to two major fungal diseases — rust (*Puccinia haemodori*) and ink disease (leaf blackening). Other species such as *A. rufus*, *A. humilis*, *A. preissii*, and *A. onycis* produce magnificent flower colour and form, with a dwarf habit, but are relatively short-lived.

Considerable effort has been put into the hybridisation and selection of new cultivars of the popular kangaroo paws. The work by S. Hopper and K. Oliver in Western Australia, and M. Turner in Victoria is particularly noteworthy. Hopper (9) undertook studies on the evolution, ecology, and natural hybridisation of *Anigozanthos* species in Western Australia and produced many F_1 interspecific hybrids, four of which found their way into the nursery industry. These were *A. preissii* × *A. flavidus*, *A. onycis* × *A. flavidus*, *A. rufus* × *A. flavidus* and *A. manglesii* × *A. flavidus*. Selections from the first three are now widely known as 'Regal Claw', 'Dwarf Delight', and 'Red Cross', respectively. These studies provide valuable information on reproductive biology, pollination, seed set, germination rates and phenotypic heritability (10,11,12,13).

Oliver (18) initiated breeding and selection work aimed at synthesising new hybrids of significant horticultural value and has succeeded in producing a range of selections of complex parentages, over several ploidy levels, which are currently being released commercially. Turner has established an extensive and systematic breeding programme aimed at drawing on the full potential of the genus for floral characteristics, growth habit, and disease resistance. His selections for cut flower production have drawn considerable attention to the crop in the U.S.A. (19). Other cultivars are aimed at the containerised plant market (Turner, pers. comm.).

The University of Sydney has been involved in the hybridisation of kangaroo paws since 1981. Cross-pollination of selected species has resulted in a range of exciting new hybrids which are proof of the great potential of kangaroo paws as a flowering pot plant crop. However, with the impending release of these and other new cultivars for nursery production, research is concentrating on the means by which flowering can be manipulated to ensure the ability to produce a flowering crop to meet market demands.

PROPAGATION

The first area of concern is the method by which this crop can be produced in sufficient quantity for commercial production. Seed supplies are often scarce, particularly for the more

unusual species (26). Germination rates of available seed are usually low and variable for many species, although slightly improved with hot water and chemical pre-treatments. Some hybrids are sterile and do not set seed at all (10). Development of the seedling to flowering is slow, taking nine to eighteen months (10), and variability in flower quality and productivity is well-established (3). Rhizome division has been an alternative method of propagation but the rate of multiplication of material still remains low, as well as unreliable. It cannot realistically be considered for large-scale production.

The most effective means of commercial propagation of kangaroo paws is through the use of tissue culture techniques. Establishment of *A. flavidus* in culture media was first documented at Canberra Botanic Gardens (17). Ellyard (2) successfully induced the formation of multiple shoots of *A. manglesii*, *A. flavidus*, and *Macropidia fuliginosa*, and successfully re-established plantlets in soil. McComb and Newton (16) reported surprisingly high survival rates of tissue-cultured plants re-established in potting mix, and they recorded flowering in less than four months after removal from 5 cm tubes.

In recent years, micropropagation of kangaroo paws has moved from the scientific research laboratory to commercial tissue culture establishments. New plant selections can now be established in culture and rapidly multiplied to large numbers. Experience with nutrient media, culture conditions, and transplantation procedures for kangaroo paws exists in the commercial sector because of the large-scale production of the Hopper hybrids *in vitro*. This, in fact, has been a major contributing factor to the wide distribution of these hybrids as representatives of *Anigozanthos* in retail nurseries and provides evidence for the potential of this method of propagation. Despite risks of induced phenotypic variation and latent microbial contamination, of major concern to research and commercial laboratories alike, micropropagation offers the best method for the rapid multiplication of kangaroo paws.

GROWTH REQUIREMENTS

Transplantation from Tissue Culture. Little is known of the optimum conditions for growth in the early stages of crop development of kangaroo paws from tissue culture. Kangaroo paws is relatively easy to re-establish in soil in comparison to some species, for example *Grevillea* cv. Robyn Gordon (15). Survival rates of 80% were obtained by McComb and Newton (16) and increased to 95% when an anti-transpirant spray of Acropol® 1% (v/v) was applied to plantlets.

Rapid adaptation of tissue-cultured plantlets to the exter-

nal environment demands the initiation of photoautotrophic growth and development of functional roots after transplantation. Initiation of root primordia using indole-3-butyric acid (IBA) in the final stage of subculturing enhances rooting on transfer from culture to potting media (16). It is the author's experience that rooting of individual shoots in culture leads to reliable plant survival, early establishment, and uniform crop growth after transplantation. Material can also be transferred directly from multiplication media into soil but an effective means of initiating roots soon after removal from culture is essential. Hughes (14) found that 250 ppm IBA applied as a quick-dip — with mist — promoted early root initiation and development.

High humidity is an important environmental factor used to maintain plant turgidity until growth begins. However, care must be taken to ensure that over-wet conditions do not develop. Excessive wetting of the leaves and waterlogging of the growing media can cause black leaf spots, poor growth, and/or survival. It is recommended that newly transplanted material be placed in a protected environment designed to maintain high relative humidity until growth is apparent.

The growing medium should provide good drainage and aeration for young plants. A mixture used successfully at the University of Sydney is 1:1, peat:sand, moistened and drained prior to planting. This mixture retains adequate soil moisture under a humidity tent for initial root development. The nutrient requirements of newly transplanted kangaroo paws have yet to be investigated.

Even, moderate temperatures between 20°C and 27°C are generally recommended when transplanting tissue-cultured plants (1). Exposure of *A. manglesii* seedlings to low temperatures, 12° to 15°C, early in development has been reported to favour plant growth and floral initiation (7, 24). However, the vegetative growth of *A. manglesii* and *A. flavidus* plantlets from culture was found to be optimal at 24°C (day) and 19°C (night) (14).

The survival and subsequent growth of transplants may be enhanced by the initial use of low light and the gradual introduction of high light intensities. However, a 50% reduction in light showed no beneficial effect on the growth of *A. manglesii* and *A. flavidus* (14).

Growing on Potted Plants. It has been found that kangaroo paws will not tolerate very wet or alkaline soil conditions, which induce iron deficiency. They do best in well-drained, moderately acidic, sandy soils, in full sun (25,26). At the University of Sydney, mixtures of German peat and coarse quarry

sand provide adequate growing media for potted plants. However, the identification of a better mixture to decrease net weight, while maintaining good drainage, would certainly be beneficial to commercial growers.

Favourable growth responses of Kangaroo paws to high nutrient levels have been reported. In pot trials, *A. flavidus* showed increased plant height and lateral shoot production with high levels of phosphorus, potassium, and nitrogen (4). Growth of a range of *Anigozanthos* species and hybrids, under hydroponic conditions at Knoxfield in Victoria, was found to be very vigorous, and plants flowered outside their normal season (8).

Watering has been found to be critical when flower buds are developing. The combination of a limited medium volume, rapid root growth, good drainage, and warm temperatures may lead to the wilting of young flower stems. Older flower stems tend to retain their rigidity better under water stress. It is desirable to keep the foliage as dry as possible since constant wetting by overhead irrigation increases plant susceptibility to foliar fungal diseases.

CONTROL OF FLOWERING

Temperature is the single most important environmental factor affecting flower production in *Anigozanthos*. Grieve and Marchant (6) reported the work of Went (1956) in which temperatures of 17°C (day) and 11.5°C (night) were said to produce the best growth and flower colour in *A. manglesii*. No details of the experiment are available. The conclusion was drawn that flowers in this species only form under low temperatures and that this is the reason for spring flowering after flower formation in winter. This conclusion has been investigated in recent studies at the University of Sydney.

Van de Krogt and Noordegraaf (24) showed that temperatures of 15°C (day) and 12°C (night) resulted in a greater number of flower stems in the first flowering season than other temperature regimes. However, in a subsequent study (22), higher temperatures were found to induce a high flower yield in the second flowering season. These results suggest that cold temperatures favour floral initiation but that flower evocation is hastened by higher temperatures.

Hagiladi (7) found that pre-cooling *A. manglesii* seedlings at 10°C enhanced growth at 25°C and hence, lateral shoot production and flower yield were increased. The best growth of seedlings was obtained at 20°C (day) and 12°C (night). It is suggested that vegetative growth is initiated when night temperatures are 12°C to 15°C and that maximum lateral shoot

production should be obtained before night temperatures are lowered to 10°C. At this temperature, floral initiation is said to take place. Floral evocation is reported to be directly related to temperature. With increased temperatures, more flowers appear.

Work at the University of Sydney has investigated the pattern of flower development under natural conditions. It is found that floral initiation in field-grown kangaroo paws occurs in the autumn, flower bud development is slow through the winter months, and as temperatures increase in spring, the flower stems appear (Motum and Goodwin, unpub.). Thus floral initiation occurs earlier than previously suggested by Grieve and Marchant (6).

The use of micropropagation is a new strategy in kangaroo paw production. However, interesting effects have been observed. Flowering of plants from seed occurs in 9 to 18 months (10). McComb and Newton (16) reported flowering of plants from tissue culture in less than 4 months after removal from tubes. Current studies on tissue-cultured plants of *A. humilis* × *A. flavidus* at 21°/16°C indicate that floral initiation is evident soon after deflasking. The control of floral induction, synchronisation, and uniformity of flower production within a crop is now a major area of research.

Studies so far have revealed that, although transplantation from tissue culture is best done under controlled conditions, complete plant development under glasshouse conditions may prove problematic. Temperature studies indicate that high temperatures encourage flower induction but flower colour tends to fade. Temperatures of 30°/25°C produced stunted and aborted flowers without pigmentation (Motum and Goodwin, unpub.). Low temperatures maintain strong flower colour but slow flower induction (Motum and Goodwin, unpub.). Flower colour is associated with anthocyanins present in the branched hairs covering the racemes. The intensity and shade of colour of the flowers may vary with changes in pH due to their ionic character (5). Flower colour of kangaroo paws under controlled conditions may be manipulated with the use of acid or alkaline solutions, but techniques have yet to be investigated.

Photoperiodic studies suggest that responses to long and short days may be variable in Kangaroo paws. Van de Krogt (24) and Hagiladi (7) reported little or no effect of day length on flower formation. However, long days (16 hrs day/8 hrs night) have been reported to hasten flowering in *A. flavidus*, while short days (8 hrs day/16 hrs night) encourage flowering in *A. manglesii* and *A. rufus* (Motum and Goodwin, unpub.). The degree of response may depend on the species or cultivar

receiving attention.

DISEASES

The most serious problem of kangaroo paws is disease control. Kangaroo paws have been found to be susceptible to two major fungal diseases. Ink spot disease, or leaf blackening, has always been associated with field cultivated Kangaroo paws, but is particularly significant in the production of perfectly formed potted plants. It is reported to be caused by *Alternaria alternata* (21). However, the plants themselves also produce chemicals which are seen as a blue/black ink in tissue culture media and show blackening with tip senescence, even in sterile conditions, suggesting that the situation may be more complex. Harsh chemical sprays can also be instrumental in causing leaf blackening.

The second foliar disease is rust, caused by *Puccinia haemodori* (20). Until recently, this disease had only been recorded on Kangaroo paws in Western Australia. It is now known that this disease may be a threat in the eastern states. Moist conditions favour these diseases although some measure of control has been reported with the fungicide Mancozeb® (3,26). Breeding and selection of Kangaroo paws looks to be the most effective means of limiting these problems at present. Work at the University of Sydney has been undertaken to collect further information on these problems.

CONCLUSIONS

It is evident that kangaroo paws have been the subject of extensive study. In addition to their use as cut flowers, they will soon be available as containerised plants. With exciting new cultivars being produced by plant breeders, further information on propagation, growth requirements, control of flowering, and disease problems of *Anigozanthos* will be needed by commercial growers.

Micropropagation offers the most effective means of rapid multiplication of new plant selections. Problems associated with tissue culture production remain the subject of ongoing research. As Kangaroo paws is new to cultivation as containerised plants, information on optimum growth requirements in this context is limited. However, knowledge is expanding. The control of flowering remains a problem, although a practical approach to programming flowering pot plant production is being developed at the University of Sydney. The basis for the successful production of Kangaroo paws as a commercial crop is the effort put into plant improvement and selection for disease resistance. Further research is now needed in critical

areas of commercial production to do justice to these new selections.

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PROBLEMS AND OPPORTUNITIES IN TROPICAL FRUIT TREE PROPAGATION

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INTRODUCTION

Tropical fruit tree propagation as referred to in this paper is largely confined to those species of tropical or subtropical origin which are not major industries in northern Australia. However a few more established crops (e.g. mango and lychee) are included in the context of developments and problems associated with plant quarantine introduction and propagation.

There has been little innovative research in propagation of the "emerging" tropical tree fruits in terms of support from government institutions in Australia. This is perhaps justified in the order of research priorities. However, as varietal screening and market development proceed, the few fruits with sustained market prospects will be identified.

Developments in propagation techniques to date have largely arisen from the initiatives of individual nurserymen, and trial and error in quarantine facilities where problems in establishing importations have arisen.

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For most species, relevant propagation techniques have been developed overseas (particularly in Asia). However, in Australia problems have arisen due to climatic differences, shortage of parent stock (stock and scions), and operation costs. We have nursery stock costs which, at the purchaser level, are currently limiting industry development. *In-vitro* culture and juvenile stock propagation are desirable prospects for the future despite the fact that for most species such development appears difficult at this stage.

HISTORICAL ASPECTS OF NORTHERN AUSTRALIA TREE FRUIT INTRODUCTION

Queensland already has an enormous diversity of deciduous, subtropical, and tropical fruit tree species. Efforts to increase the range have been prompted by collectors (South America and Asia in particular), exotic fruit study groups (e.g. R.F.C.), and grower interest in supplying domestic, ethnic, and export markets.

In the 1890's Kamerunga was established as the State's tropical crop introduction station. In addition to sugarcane, rubber, coffee, cocoa, palm oil, and most standard tropical fruits, the introductions also included mangosteen, rambutan, lychee, longan, wampi, etc. Many of the tropical exotics did not thrive due to inadequate irrigation and lack of management understanding. Further, all material was of seedling origin and resultant crops were often of poor quality.

In the early 1970's renewed interest in tropical fruit species arose and importation of clonal material of tropical fruit tree species started in earnest. The Horticulture branch of the Queensland Department of Primary Industries has been a major importer. Importation through quarantine reached a peak between 1978 and 1982 and has now tapered off due to the shortage of new cultivars.

Table 1 summarises the species and number of cultivars successfully brought through Kamerunga since 1970, and, the grafting techniques used both in quarantine and nurseries.

PRINCIPAL GRAFTING TECHNIQUES

Side Veneer. Of all techniques this has been the most useful in quarantine. This is probably due to the capacity to handle material which has been in transit for a long period, or has been collected in an indifferent condition at source.

Scions should preferably be pre-cinctured — although unnecessary for carambola and casimiroa. Mamey sapote, on the other hand, requires a 2 to 3 month cincture period for best

Table 1. Clonal introduction through Kamerunga Research Station and grafting techniques found successful.

	IN	% G	S.V.	We/M.We	F.B.	A.L.	B.G.
Artocarpus heterophyllus (jackfruit)	3	–	+	(+)	+	–	+
A. polyphema (chempedak)	1	–	+	(+)	+	–	+
A. heteropyllus × *A. polythema* (hybrid jackfruit)	1	–	+	+	+	–	+
Averrhoa carambola (carambola)	25	100	(+)	(+)	+	–	
Bouea macrophylla (maprang)	4	–				+	+
Casimiroa edulis (casimiroa)	29	100	(+)	(+)			
Chrysophyllum cainito (caimito)	4	50	(+)	+		+	
Clausena lansium (wampee)	2	–	(+)	+	(+)		
Diospyros digyna (black persimmon)	2	–	+	(+)			
D. discolor (mabolo)	1	–	+	+			
Durio zibethinus (durian)	16	80	(+)	(+)	+		+
Euphoria longan (longan)	15	70	+	(+)	(+)	(+)	
Lansium domesticum (langsat.duku)	16	70	(+)	(+)	+	–+	
Litchi chinensis (lychee)	30	40	+	+	+	(+)	
Mammea americana (mammea)	1	100	+	+			
Mangifera indica (mango)	75	90	+	(+)	+	+	
Manilkara zapota (sapodilla)	22	85	(+)	(+)	+	+	
Matisia cordata (matisia)	5	100	+	+			
Myrciaria cauliflora (jaboticaba)	1	100	+				
Nephelium lappaceum (rambutan)	52	85			(+)		
N. mutabile (pulasan)	6	65			(+)		
Pouteria campechiana (canistel)	4	50	(+)	+			
P. sapota (mamey sapote)	5	80	(+)	+			
Sandoricum koetjape (santol)	3	80	(+)	+			
Syzygium cumini (jambolan)	1	–	+				
S. malaccense (Malay apple)	3	–	+	(+)			
S. samarangense (wax jambu)	3	–	+	(+)			
Tamarindus indica (tamarind)	7	–		(+)			+
Ziziphus jujuba (Chinese jujube)	2	–	+				
Z. mauritiana (Indian jujube)	2	–	+				+

Key

IN = Number of cultivars imported through Kamerunga.
% G = Percentage grafted in quarantine (balance introduced as rooted trees).

Grafting Techniques Used Successfully

S.V. = Side veneer graft
We/M.We = Wedge or modified wedge graft.
F.B. = Modified Forkert bud graft.
A.L. = Air layer
B.G. = Bottle graft

\+ = graft successful
(+) = grafts most commonly used commercially
– = not feasible

No annotation = either uncommonly used, or low percentage success.

results. All grafts are either PVC taped, bagged following graft tying, or placed in high humidity chambers.

Wedge or Modified Wedge. Stocks must be extremely vigorous and scions preferably terminal in a "hard", near-to-bud-

burst condition. The Fitzroy technique has been particularly successful, even for *Artocarpus* species (which have troubled most northern nurserymen). The criteria are "hard" scions, with all leaves or at least 50% of leaves (cut) retained. Stocks must be young, vigorous, and the graft made high so as to retain at least 50% of original leaf area on the stock. The scion match should be nodal — and with near equal diameter for stock and scion. The leaf on the stock nodal joint should preferably be left intact. The critical factor in the Fitzroy technique is to enclose completed grafts in an environment with zero air movement. In practical application this requires PVC, glass, or mylar cabinets. Stock vigour is essential and may necessitate bottom heat for some species — even in north Queensland. Extremely hot, dry periods (October — December) should be avoided.

The modified wedge is a simple technique for "easier" species, such as mango, carambola, casimiroa, etc. Only one face of the wedge is cut on the scion and it is particularly useful for small diameter scion/large stock combinations since cambium match location is simplified.

Modified Forkert Budgraft. This technique was borrowed from Asia and is an essential method for propagating rambutan and pulasan. However, in Malaysia it is also used for a wide range of species — including carambola, durian, jackfruit, chempedak, sapodilla, etc. In practice it is a simple procedure but requires considerable experience.

The rootstock patch flap can be subtended from either top or bottom, but the flap must be cut so that it does not overlay the scion bud initial(s). Critical factors are: vigorous rootstock, and obtaining, scion sticks from vigorous, upright branches on the donor tree. On completion buds must be tightly, but not heavily, taped. Good light exposure is essential. Taking of budwood and budding is best attempted only on bright, sunny days.

In addition, the modified forkert bud technique has been valuable in quarantine for difficult species, such as lychee and longan, and for other species when graftwood is extremely limited.

Chip Budding. This is seldom used on tropical species since in all except a few, e.g. casimiroa, wampi, it is not as reliable as the aforementioned techniques. The same comment applies to T-budding.

Punch Budding. There has been very little research with this technique for tropical exotic fruit trees. Whilst it does work for rambutan it is generally not as reliable as the modified forkert. It appears that success is most likely with species

which have a relatively thick cortex and show a good carbohydrate build-up after cincturing.

Cuttings. Garner, *et al.* devote considerable discussion and tabling of trial data to point out the merits of cutting propagation. In practical application, however, there is very little use of it in nursery production of tropical fruit species. The problems are essentially reliability and the length of time required. For most sapotaceous species it is even necessary to remove initial callus formation in order to stimulate rooting. However, for some of the tropicals, e.g. durian, rambutan, there has been little definitive research — particularly that concerned with comparison in variation of juvenility, nutrient status, carbohydrate induced accumulation, controlled bed temperature, hormonal stimulation, misting, incident light exposure, etiolation, and orientation of the cutting in the medium.

With low cost reliable propagation as the ideal (assuming eventual tree growth and longevity satisfactory) cutting research is warranted.

Approach Grafting. Whilst relatively common in Asia this technique is not used significantly in Queensland principally because of the shortage of stock trees. It is, however, very reliable for any species if the prescribed procedures are followed. These are: vigorous stock and scion branches, grafting with semi-mature (green/brown) stem combinations, and proper attention to the scion weaning process are adhered to.

The technique has been particularly useful in quarantine for ensuring the survival of cultivars which have established poorly from rooted tree introductions — and, for multiplication of single survivals to a level of security. For field grafting on stock trees the grafting period is best restricted to the wet season.

Bottle Graft. The Thais have developed this technique with remarkable success, particularly for mango, durian, tamarind, and artocarpus species. Seed are bed-sown and seedlings pulled when 3 to 4 months old, then transferred into small, clear poly bags with the roots balled in coconut fibre. The seedlings are then decapitated, tied up to an appropriate branch of the scion tree and approach grafted (side veneer graft) into a suitable shoot. After 4 to 6 weeks the scion branch is cut at a level near the roots of the seedling. Following potting, the scion base usually develops roots and a double root system is provided. The technique works best during the summer monsoon season and whilst not practised widely in north Queensland it is a practical technique for more difficult species, such as durian and jackfruit. Table 2 lists a summary of propagation techniques for selected fruit tree species in

Table 2. Summary of propagation techniques for selected species in north Queensland.

		Rootstock			Scion	
Mango	Grafting Best mths. 1 - 12	Min. R'stock Ht. (mm)	Stock age (mths)	Pre-cincture weeks before	Defoliate+ weeks before	Special notes
We./M.We	10 - 3	500 - 1000	6 - 24	N/N	2 - 4 +	Selection of plump buds is
S.V.	11 - 3	500 - 1000	6 - 24	N/N	2 - 4	critical for good "takes".
F.B.	10 - 3	300 - 1000	9 - 24	N/A	N/A	
Sapodilla						
S.V.	8 - 11	500 - 800	15 - 24	3 - 5	3 - 5	After 4 to 6 weeks remove
&	4 - 5					callus from cuttings base.
We/M.We	8 - 11	500 - 800	15 - 24	3 - 5	3 - 5	Cuttings very slow to root.
A.L.	9 - 3	N/A	large branch	N/A	N/A	
F.B.	9 - 12	400 - 800	12 - 24	N/A	3 - 5	
C	4 - 9	N/A		3 - 5	N/A	
Carambola						
S.V.	8 - 12	1000	5 - 12	N/N*	1 - 3 +	Air layers and cuttings very
&	4 - 6					difficult.
We/M.We	8 - 12	1000	5 - 12	N/N*	1 - 3 +	
F.B.	9 - 12	1000	5 - 12	N/A	1 - 3 +	
Rambutan						
F.B.	10 - 12	1000	12 - 24	N/A	only lower	Air layers not reliable.
&	4 - 5				leaves 1-2	Average only 50% survival.
Wedge and side veneer grafts are possible but much less reliable.						
A.L.	10 - 4	N/A	N/A			
Durian						
S.V.	9 - 1	700 plus	12 - 18	2 - 3	N/A	Use of scions with protruding
We/M/We	9 - 1	200 - 800	3 - 18	2 - 3	N/A	undamaged buds essential for
F.B.	9 - 12	700 plus	12 - 18	N/A	N/A	Forkert method.
A.L.	9 - 3	N/A	N/A	N/A	N/A	

Lychee and Longan						
S.V.	8 - 11	500 - 1000	12 - 20	3 - 4	N/A	Side veneer preferred for
We/M.We	8 - 11	500 - 1000	12 - 30	3 - 4	N/A	lychee.-growth slow for
F.B.	10 - 12	500 - 1000	12 - 20	N/A	only lower leaves 2 - 3	cuttings.
A.L.	9 - 3	N/A	N/A	N/A	N/A	A.L. the normal commercial
C	4 - 8	N/A	N/A	2 - 4	N/A	method.

N.B.

1. Preferred graft methods at top of each list.
2. For mango and sapodilla, terminal scions preferred for wedge, modified wedge and side veneer.
3. S.V. = side veneer; We = wedge graft; M.We. = modified wedge graft; F.B. = modified Forkert bud; A.L. = airlayer; C = cuttings; N/N = not necessary; N/N* = not necessary if use scion from drooping branches.
4. Bottom heat preferred for all cuttings with best results during winter.
5. Some nurserymen prefer leaving 6 to 8 terminal leaves (often cut in half) on the scion when grafting.
6. Approach grafting not listed — but can use for any species with good success.
7. + defoliate — but prefer to leave 6 to 8 terminal leaves intact.

north Queensland.

Rootstock Compatability and Tree Performance Uniformity in tree growth of the emerging tropical exotics has been compromised due to the "anything and all" approach by nurserymen in regard to access to numbers of rootstocks. Unfortunately, the same approach is often adopted in Asia and thus there are few guides to rootstock selection.

We have witnessed overgrowth of rambutan scions on some rootstock cultivars, incompatability with some lychee cultivars (particularly Amboina and Kwai May Red) on Tai So seedling rootstocks, and poor performance of Thai longan cultivars grown on Chinese cultivar rootstocks (and vice versa). Whilst some of these problems have been overcome (for example using Wai Chee or Bengal seedling rootstocks for lychee cultivars), obviously many more will arise particularly because there are varying incompatabilities at the cultivar level within species.

The Future Whilst there has been little organised and documented "emerging" tree fruit species propagation research in northern Australia, there has been a considerable body of knowledge built up (and is still being developed) by a number of innovative nurserymen.

What is essentially lacking is a coordinated approach to the gleaning of trial and error information right through to the field planting and cropping stage. Of major concern for the various crops is that rootstock (or own roots) choice be such as to achieve and maintain maximum productivity.

Tissue culture research should be pursued for the most promising of the exotics. Success in this area has been largely complicated by contamination and the difficulty in formulating the callus medium. Once achieved we still require field research on long term growth of own-rooted trees.

BUDDING OF EUROPEAN (SPANISH) CHESTNUT (*CASTANEA SATIVA* MILL.)

HENRY HILTON
Nightingale Orchards
Stanley, Victoria 3747

The European (Spanish) chestnut is a relatively new tree fruit crop in Australia, especially for production in commercial orchards. The trees are grown for the shiny brown nuts which are produced in prickly seed cases or burrs. The starchy,

north Queensland.

Rootstock Compatability and Tree Performance Uniformity in tree growth of the emerging tropical exotics has been compromised due to the "anything and all" approach by nurserymen in regard to access to numbers of rootstocks. Unfortunately, the same approach is often adopted in Asia and thus there are few guides to rootstock selection.

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edible nuts are very popular in parts of Europe and it is from these connections that a substantial market has developed in Australia. Chestnuts (*Castanea*), oak (*Quercus*) and beech (*Fagus*) are all genera in the family FAGACEAE — the cup-bearing trees. Chestnut burrs are vegetative structures with a similar function to the cups which carry oak acorns.

Thirteen species of chestnut are now listed and the most important one in Australia at the present time is the European or Spanish chestnut, *C. sativa* Mill. The name indicates that this species is a native of southern Europe and it is also widely distributed in the Asia Minor countries. The European or Spanish chestnut is similar to the American chestnut, *C. dentata* (Marsh.) Borkh. with both species having long leaves with coarsely toothed margins. However, the leaves of the American chestnut are wedge-shaped at the base and do not have hairs on the undersurface. Shoot growth of the European or Spanish chestnut is stouter and the buds are larger than other chestnut species.

Little has been done with the selection and development of chestnut cultivars and, at present, nurserymen select propagation materials from the better strains from within their own areas. In northeastern Victoria there are probably some 12 different strains. The best ones have the following characteristics:

- large, dark brown, shiny nuts.
- easy release of nuts from the burr.
- moderate to heavy and regular (annual) cropping.
- burrs full of nuts. (Some strains develop only one nut out of a possible three.)

All non-cultivated chestnut trees have developed from seed and, therefore, there is a tremendous amount of variability. Care must be taken from the very start with the commercial production of chestnut trees. I have not read any research findings on the subject but, in my experience, less incompatability occurs when chestnut wood is grafted onto seedlings produced from the same tree. This may not be totally desirable, of course, since the rootstocks may need to be selected for characteristics which are different from those of the scion, e.g. tolerance to root diseases, vigour, etc. The same incompatability has not been experienced with chip-budded stocks so this method of chestnut propagation seems to allow the normal range of stock and scion selection criteria to be used.

Throughout the world where European or Spanish chestnuts are grown for nut production most nursery stock is grafted. In northeastern Victoria I have found chip budding to be just as successful as nursery grafting and quite a lot better

than T-budding. It is thought that budding of chestnuts is not widely practised because the wood is fluted, or grooved, and the cambial layers of the bud and stock do not join uniformly.

Budding in northeastern Victoria is carried out in late summer (first 2 weeks of February) when, in a normal growing season with rainfall supplemented by irrigation, the rootstocks should be in ideal condition. The highest summer temperatures should have abated, daylight hours shortened, and humidity increased as a result of "dewy" nights starting to occur. Budding in early February allows sufficient time for callusing to take place before temperatures fall further and growth ceases. Once callusing has occurred it is possible to remove the bud ties before winter.

Selection of bud sticks. This is of great importance due to the nature of the wood. The current season's growth should be selected and should be firm, mature, and bearing healthy buds. With chestnut many of the basal buds on the current season's growth tend to be missing and this should be taken into account when deciding how much budwood to collect. The diameter of the bud sticks should be similar to or slightly less than that of the stock.

Preparing bud sticks. All leaves should be removed as soon as the bud sticks are cut from the parent tree. For chip budding the leaf petiole should be cut as close to the bud as possible. Once the leaves have been removed it is essential to prevent the bud sticks from drying out by wrapping them in a damp towel or some other material. Remember the importance of labelling all material, especially when bud sticks are collected from more than one source.

The budding operation. Remove leaves from the rootstock up to a height of 300 mm from the ground. The first cut is made downwards into the side of the stock at an angle of about 20°. Ensure that the knife is held horizontally to leave the base of the cut level (Fig 1A). A second cut is then made downwards to meet the first (Fig 1B). The piece of stock is removed and thrown away. A similar operation is performed on the bud stick to produce a chip bud (C) which fits into the prepared stock. The bud conveniently sits on the downward-sloping bottom cut until it can be tied in place (D). Chip budding is easier if the rootstock and bud stick are the same thickness so that a perfect match can be made (E). Chip buds which are slightly smaller than the prepared cut should be placed centrally. Sometimes budwood may be in such short supply that very thin material must be used. Chip buds from this material are small and must be placed on one side of the cut to ensure good cambial contact (F).

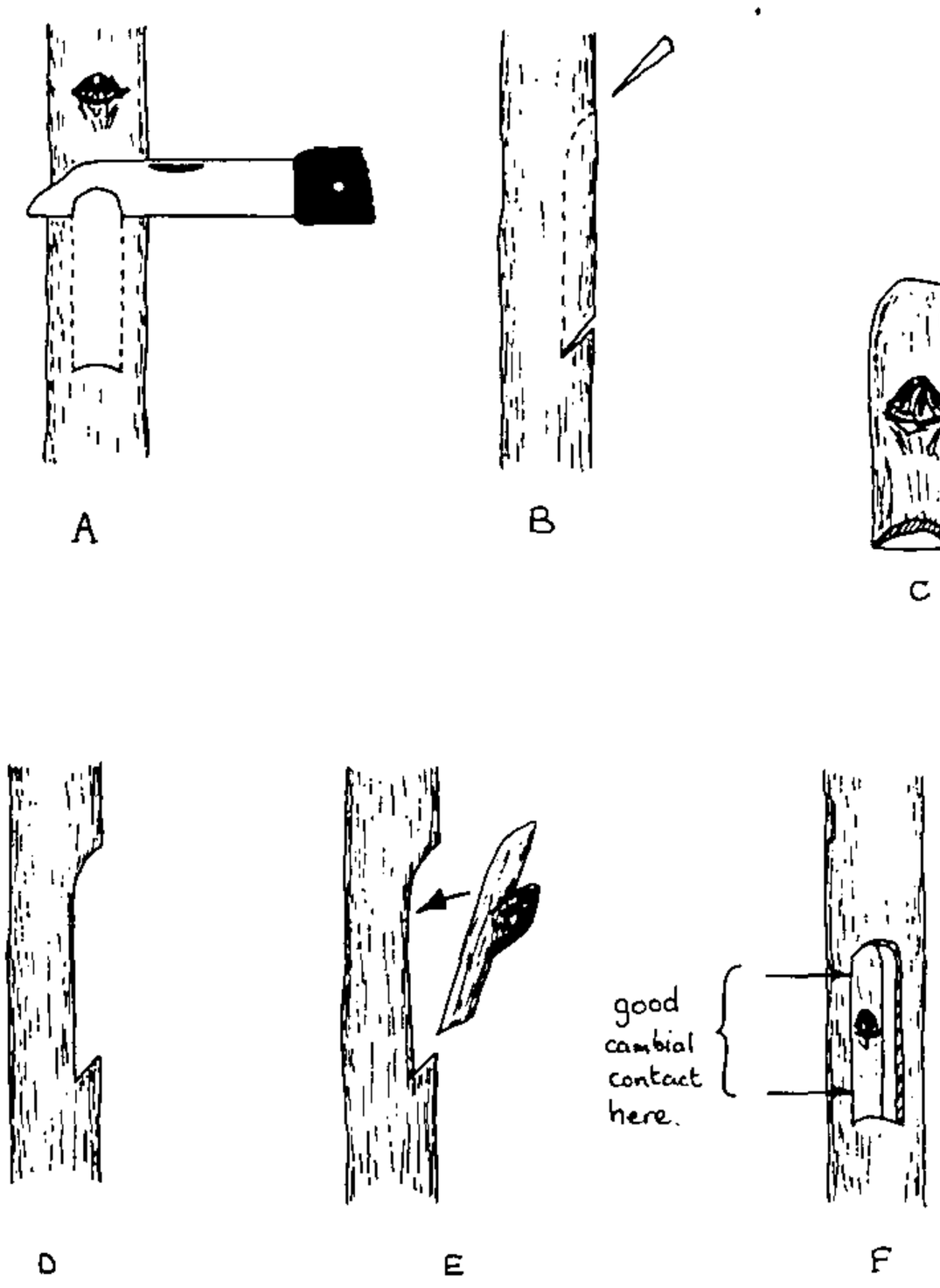

Figure 1. The chip budding operation.

It is then important to tie the chip firmly in place with plastic tape. The whole bud is covered over to prevent any drying out or insect damage. Within 14 days the tape can be removed to allow inspection of the bud. Should the bud have not taken then, providing the conditions are still suitable, another attempt can be made. The stock should not be cut back until the following spring when growth recommences.

Comparing chip budding with traditional T-budding, my results have shown that the chip budding method for chestnut produces a consistent 96% "take", whereas T-budding is much less reliable with takes ranging from 50 to 85%. I believe the single most important factor in the success of chip budding for chestnuts is a relatively large area of direct cambial contact. Chip budding also succeeds under conditions which are not quite perfect due to the fact that callus growth does not have to be as prolific as with T-budding.

The results of budding chestnuts in Australia are better than those observed in North America or Europe. Possible reasons for this are:

- more days of consistent warmer temperatures, enhancing callus growth.
- variation between night and day temperatures are not as great.

- during February (Southern Hemisphere) we have more sunlight hours than are usually recorded in August in the Northern Hemisphere.

Chip budding chestnuts onto selected seedling rootstocks allows growers to produce uniform, desirable trees. Orchards, or groves, of such trees should provide the grower with early, substantial yields of high quality nuts.

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1984 — A YEAR OF PROBLEMS FOR TREE FERNS — SOME GENERAL OBSERVATIONS

A. G. SONTER

Sonter's Fern Nurseries
240 Singles Ridge Road
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Out nursery has been producing the tree fern, *Sphaeropteris cooperi* [syn. *Cyathea cooperii*], from spores for more than ten years.

Quite suddenly in 1984, although the spores germinated as usual, the prothalli degenerated and production dropped to almost zero. The same phenomenon occurred simultaneously in nurseries in Perth and Sydney.

About the same time, enquiries began to flood in from tree fern growers around Australia whose production from spores had failed. Within a period of two months growers had contacted us from Darwin, Cairns, Brisbane, Adelaide, Melbourne, and a host of other areas all around Australia, all with the same story — their spore production had failed. Buyers informed us there was an Australia-wide shortage of tree ferns.

Over the next four months we increased our spore sowing tenfold and for the next three months I spent my time trying to solve the production problems.

The following things were tried:

1. Spores were collected from many remote areas around Australia from natural tree fern populations — from Bedford

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The following things were tried:

1. Spores were collected from many remote areas around Australia from natural tree fern populations — from Bedford

in Western Australia to Atherton in Queensland.

2. Spores were sterilized.

3. A wide range of sowing media were tried, including peat moss, sawdust, pine bark, perlite, vermiculite, and a range of combinations of these.

4. The pH was varied from 4.0 to 8.0

5. The daylength was varied from 8 to 24 hours.

6. The humidity was varied.

7. A wide variety of fungicides were tried.

Results were no better — the crop still failed.

Numerous samples of prothalli were tested by laboratories around Australia who constantly diagnosed: "no diseases or no pests — it must be an environmental problem".

Suddenly at the end of 1984 most of the prothalli in our trials stopped degenerating and grew beautifully, irrespective of media, light, temperature, etc. The only failures were in the widest ranges of the trials.

It should be noted that prior to 1984 we were producing over 100,000 tree ferns a month from spores, covering a range of about thirty different cultivars, and there were no problems of degenerating prothalli.

By the end of March, 1985, after three months of successful production, most of our grower customers had cancelled their orders because their own production was now "doing nicely". This is being written in May, 1985, and there are tree ferns everywhere.

Our nursery has produced many millions of ferns from spores and we have been very conscious that many cultivars can be destroyed by a single factor being out of line, at any time.

It is my considered opinion that the minute, delicate *Cyathea cooperi* spores which are responsive to the most minuscule of variations in the complex balance of environment, media, and nutrients have, during this period of 1984, been indicating to us in a very real way, a change in the earth's total environmental balance. We do not know what changed — perhaps radiation, atmospheric gases, or a host of factors, but we do know that something did happen, and the tree fern spores in their own way told us about it.

Incidentally, we have since sown more of each batch of spores collected around Australia in 1984, and they have all grown successfully, with only normal losses.

NEW PLANT GROWTH REGULATORS FOR CUTTINGS AND FOR TISSUE CULTURE

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INTRODUCTION and LITERATURE REVIEW

For centuries propagators have sought ways to enhance the rooting of cuttings that rooted with difficulty, to cause non-rooting cuttings to root, to hasten healing of grafts and, in general, to cause ease and speed of propagability to be improved. In the early 1930's, a marvelous breakthrough occurred for cutting propagation when Thimann and Went (19) and their coworkers (18) discovered that a root-promoting substance, indoleacetic acid (IAA) was found in many higher plants. This substance, dubbed "*auxin*" or IAA, when applied to the base of cuttings could be used to hasten the rooting of cuttings of many species and cause rooting in others previously difficult or impossible to root. Even better rooting results were found for analogs of IAA, such as indolebutyric acid (IBA) and naphthaleneacetic acid (NAA). Today, these latter compounds are the active principles in numerous commercially available rooting compounds. Because IAA breaks down in light and IBA and NAA are essentially non-labile in light, IBA and NAA are more commonly included in such formulations.

Although much research was conducted in ensuing years, no additional economically feasible chemical treatments were found until recently. Hess' work with *rooting cofactors* is perhaps the most notable of such attempts to find additional root *stimulating compounds* (6). He successfully demonstrated that extracts of juvenile *Hedera helix* (English ivy) could interact synergistically with IAA to increase rooting in the mung bean rooting bioassay. However, no commercial applications utilizing rooting cofactors have taken place, although the principles demonstrated by the work of Hess and others should stimulate further investigations along this line of research.

Gibberellins, first discovered in 1939 in Japan, are now known to be a large group of naturally occurring compounds that cause internode elongation and numerous other plant responses. Their discovery led to a flurry of research with these compounds in the 1950's and later, including attempts to utilize them in improving propagation success. However, gibberellins had little effect on rooting of cuttings, or frequently were even inhibitory (1,13).

The work of Folke Skoog and associates in Wisconsin led

to the discovery of another important class of active plant growth regulating chemicals, the *cytokinins* (16). Cytokinins are involved in division, growth, and differentiation of plant cells. In tissue culture systems, such as callus derived from tobacco pith, it has been demonstrated that cytokinins function in balance with auxin to induce shoots or buds. This knowledge has greatly enhanced our ability to propagate numerous species through tissue culture (*micropropagation*). This subject will be addressed further in the discussion of the application of new compounds to *in vitro* culture.

Certain *fungicides* have also been demonstrated to enhance rooting of cuttings. In some cases, as reported for cuttings treated with captan, enhancement of rooting was in excess of the response expected if the fungicide had been merely controlling pathogens (20). Benomyl, another fungicide, has also been suggested as a possible enhancer of shoot multiplication in tissue culture systems, since it is reported to have cytokinin-like qualities.

Research in our laboratory in the 1960's and 1970's illustrated that compounds generally employed as *growth retardants*, notably daminozide (SADH, B-Nine) and chlormequat (CCC, Cycocel) can profoundly influence propagation success. Tuberous root formation in dahlia was greatly increased under normally non-inductive photoperiods (long-days) by whole-plant sprays of 2500 to 5000 ppm daminozide or 1000 to 2500 ppm of chlormequat (9). Cuttings taken from such daminozide-sprayed plants rooted more readily than did those from the control plants, but rooting was depressed for cuttings taken from plants sprayed with chlormequat. Cuttings of several herbaceous species were also found to root more quickly than non-treated cuttings when the cutting bases were dipped for short periods of time (15 to 60 seconds) in 1000 to 5000 ppm daminozide solutions (12). Such daminozide-induced rooting was consistent for chrysanthemum, carnation, dahlia, poinsettia, geranium (*Pelargonium*), and other herbaceous species (6,12,13). It was also effective for cuttings of several woody species, especially *Juniperus* spp.

Chlormequat, on the other hand, inhibited formation of adventitious roots to a level less than that produced by the non-treated cuttings. In spite of the observation by Read and Bryan (8) that daminozide sprays could alleviate chlorosis caused by chlormequat, stimulation of rooting by chlormequat treatment has been inconsistent, suggesting that further research is required.

A *controlled-release* method of delivery of growth regulators was explored in the early 1970's, in which a polymer-

encapsulated formulation of chlormequat was incorporated into the growing medium for height control and into the rooting medium for stimulation of early rooting (10,11). However, when geranium cuttings were rooted in a medium containing controlled-release chlormequat, subsequent root development was greatly retarded. Carpenter and Carlson (2) also noted poinsettia root stimulation when incorporating chlormequat in a potting medium for stock plants, but Shanks (15) experienced mixed results when rooting cuttings from stock plants that had been sprayed with ethephon (Ethrel).

From the foregoing research reports (and the work of numerous other researchers), it becomes readily apparent that opportunities abound for further research with new growth regulating chemicals and new approaches with known chemicals.

NEW CHEMICALS

Several new chemicals have been developed by chemical companies and research laboratories in recent years. This report will focus briefly on three of them: triacontenol, conjugated auxins, and substituted phenyl urea derivatives.

MATERIALS AND METHODS

Tissue cultures of hardy deciduous azaleas from the University of Minnesota woody ornamental breeding program (led by Dr. Harold Pellett), and *Typha glauca* callus cultures were employed as the test units. Methods for producing the azalea cultures (U. of Minnesota Accession 800112) were those described by Economou and Read (3) and Fellman (4), while the *Typha* callus method was described by Zimmermann (21). The tissues cultured by these methods were subsequently placed on the appropriate test media, in which the chemicals being evaluated had been incorporated at various levels.

RESULTS AND DISCUSSION

Triacontanol. Table 1 shows the mean number of shoots produced by a hybrid deciduous azalea cultured on Economou and Read medium containing various levels of triacontanol. In contrast to reports by Ries' group (14), no significant differences were found in shoot or root formation. However, as also found with two other experiments, there appeared to be a trend toward an increase in root production, but this increase was considerably less than one would anticipate had an auxin been used (e.g. NAA, IAA). It is apparent that further studies are required to clarify potential uses for triacontanol in propagation schemes.

Table 1. Effect of different triacontanol concentrations on root and shoot formation from azalea accession 800112 after 4 weeks culture *in vitro*.

Triacontanol concentration (mg/liter)	Mean number of: shoots	roots
0.001	0	0.67
0.01	0	1.67
0.05	0	1.35
0.1	0	1.33
1.0	0	2.01
Control (0 level)	0	1.20

IAA-Conjugates. IAA-conjugate (D,L-alanine)[1] was tested on a *Typha* callus bioassay, with the expectation that because it was in a conjugated form it would resist degradation and thus remain more active. However, the mean callus rating (Table 2) was similar to that for NAA, but inferior to the stronger auxin-like compounds: picloram and 2,4-D. Note that more roots were produced by NAA than by the IAA-conjugate, but no roots were produced by the best callus stimulating treatments. These preliminary findings are considered inconclusive at this time, but suggest a level of activity worthy of further investigation.

Table 2. Callus and root production on *Typha glauca* female spike segments cultured *in vitro* on media containing different growth regulating *chemicals*.

Plant growth regulator	Mean callus[z] rating	No. explants[y] producing roots
10 mg/l 2,4-D	1.65	0
10 mg/l picloram	1.91	0
10 mg/l NAA	1.00	16
10 mg/l IAA conjugate	1.00	4

[z] rated on a 4 point scale, where 1 = no callus, 4 = excellent callus.
[y] 23 explants per treatment.

Substituted Phenyl Ureas. Perhaps the most promising new group of chemicals for propagators to consider, N-(2-chloro-4-pyridyl)-N[1]-phenylurea derivatives (4PUs), have been reported to have cytokinin-like properties by Takahashi, *et al*, (16) when employed in the tobacco callus bioassay. They indicated that 4PU-30 (or 4PU-Cl), which has a chlorine in the 2-position of the pyridyl ring, had activity 100 times that of benzyladenine. Since little research had been reported on the effects of 4PU-Cl for propagation purposes, we decided to in-

[1] Supplied by Norman Good, Dept. of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan.

vestigate its shoot-forming potential, using *Typha* callus cultures and hardy deciduous azalea microcutting explants. In the *Typha* callus bioassays, 4PU-1080, which has two chlorine substituents on the pyridyl ring, was also tested.

Typha Callus Experiments. Rates of 100 mg/l of both 4PU-Cl and 4PU-1080 caused death of the explants. However, 1 mg/l 4PU-Cl caused prolific production of green roots by calli derived from a medium containing picloram. This was similar to the response caused by BA at 5 mg/l. However, 1 mg/l 4PU-1080 stimulated an even more prolific production of green roots than the other treatments. In no case were buds or shoots produced in the 8 week-duration of these experiments.

A much greater responsiveness to 4PU compounds was observed for the hardy deciduous azalea tissue cultures (4). Table 3 illustrates that relatively low concentrations of 4PU-Cl (0.05M) resulted in dramatic increases in shoot numbers. This response was consistent between trials involving media containing 0.6M IAA, or no auxin in the medium. In other experiments comparing the influence of different cytokinins on azalea shoot production *in vitro*, significantly greater shoot numbers were produced by azalea cultures with 0.05M 4PU-Cl than by cultures containing 0.05M zeatin or 2iP. Both zeatin and 2iP are commonly used for azalea shoot proliferation, but at higher concentrations. This would suggest that 4PU-Cl may have a stronger cytokinin-like activity than zeatin and 2iP. In addition, tiny bud-like protuberances appeared on the leaves of the microshoots produced on media containing 0.5M 4PU-Cl after 10 weeks in culture, further suggesting a strong cytokinin effect. Anatomical studies showed that these structures had a somewhat bud-like character and developed from trichomes situated over vascular tissue. Although they did not grow into shoots, they did acquire a meristematic dome-like structure and one or more leaf primordia.

Table 3. Production of shoots by azalea accession 800112 after culture for 10 weeks on media containing different 4PU-Cl concentrations. Means are for 20 cultures per treatment.

4PU-Cl Concentration (M)	Mean No. of Shoots per culture
0	1.0 ab[1]
0.0005	1.0 ab
0.005	1.4 b
0.05	2.3 b
0.5	5.1 c
5.0	0.2 a
50.0	0.1 a

[1] Values followed by the same letter are not significantly different at the 5% level.

Additional studies are required to determine optimum levels for 4PU derivatives used in tissue culture of azaleas and to stimulate and monitor development of the bud-like protuberances. Applications of these compounds for other species and other propagation methods (e.g. cuttings) should be investigated, since they are obviously extremely active plant growth regulating chemicals. As more is learned about the physiological effects of these and other compounds and how they interact with known growth regulators such as auxins, gibberellins, and cytokinins, additional strides in the world of plant propagation are highly probable.

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PROGRAMMING STOCK PLANTS FOR PROPAGATION SUCCESS

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Abstract. Our research has demonstrated that the stock plant (mother or source plant) has profound influence on subsequent success of explants cultured *in vitro*. Extremely different *in vitro* performance results from different levels of mineral nutrition, plant growth regulator applications, light quality, and photoperiod treatments of the stock plant. Cultivar differences have been demonstrated also, even for species which are easy to culture. Further, preculture treatments of the explant with cytokinins can increase microshoot yield equivalent to that produced by incorporating the same cytokinin into the medium. When established cultures are treated as stock material (microstocks), light intensity and light quality can be manipulated to improve number of microshoots produced and the subsequent rootability of such microshoots. Forcing solutions have also shown promise as a delivery system for incorporating plant growth regulators into softwood growth of forced deciduous woody species. Pertinent literature is reviewed and possible relationships to endogenous hormone levels are discussed.

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PROGRAMMING STOCK PLANTS FOR PROPAGATION SUCCESS

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Abstract. Our research has demonstrated that the stock plant (mother or source plant) has profound influence on subsequent success of explants cultured *in vitro*. Extremely different *in vitro* performance results from different levels of mineral nutrition, plant growth regulator applications, light quality, and photoperiod treatments of the stock plant. Cultivar differences have been demonstrated also, even for species which are easy to culture. Further, preculture treatments of the explant with cytokinins can increase microshoot yield equivalent to that produced by incorporating the same cytokinin into the medium. When established cultures are treated as stock material (microstocks), light intensity and light quality can be manipulated to improve number of microshoots produced and the subsequent rootability of such microshoots. Forcing solutions have also shown promise as a delivery system for incorporating plant growth regulators into softwood growth of forced deciduous woody species. Pertinent literature is reviewed and possible relationships to endogenous hormone levels are discussed.

Propagators and researchers have known for some time that treatments applied to the stock plant (mother plant, source plant), and to the environment under which the stock

plant is grown, have a profound effect on subsequent propagation. Such effects may include production of larger or more cuttings, and improved root regeneration by cuttings taken from such stock plants. Nutrition, light, temperature, genotype, plant growth regulator applications, physical manipulations, and season have all been reported to influence propagation efforts.

LITERATURE REVIEW

There are numerous references linking stock plant nutrition with rooting of cuttings. The classic work of Kraus and Kraybill (26) is a notable example in which they demonstrated that carbohydrate-nitrogen ratio affected rooting of tomato cuttings. Other nutrient levels including boron (41) have also been considered important factors in the rooting of cuttings.

Reduced light intensities have been reported to enhance rooting of *Forsythia* and *Weigela* (27) and *Dahlia* (4). Extreme light reduction leading to etiolation also has frequently been reported to improve rooting (14,25). Several workers have reported that reduced stock plant light intensities can lead to better rooting (1,24,30). An increased level of endogenous auxin is generally thought to occur under reduced light, thus enhancing rooting (29).

Whalley (42) has reviewed literature on photoperiod effects on rooting of various ornamentals. Bhella and Roberts (3) reported that rooting of Douglas fir cuttings was increased by long days (LD). Others have also shown an effect of stock plant photoperiod on rooting of cuttings (2, 21). Night interruption or day extension with supplemental lighting has been utilized to provide a continuous supply of cuttings and explants for culture *in vitro* (19,35,36). Light quality has also been shown to affect cutting production and rooting (19). Red light increased axillary bud activity while far-red caused better rooting, similar to reported effects for *in vitro* culture of petunia leaf segments (34). In the latter work, a 30-min. day extension with red light nearly tripled microshoot production. Stock plant temperature regime, growth retardant treatments, cultivar, and girdling have all been implicated as possible factors influencing subsequent rooting of cuttings (17,37,38).

A greater yield of haploid plants resulted from *in vitro* culture of anthers from tobacco plants grown under short days of high light intensity (9), but Hughes, *et al.* (23) produced high yields of protoplasts from barley plants grown under short days with low light intensities. Begonia leaf cultures were positively affected by long days applied to the stock plants (18), and Paterson and Rost (31) showed that jade plant (*Cras-*

sula argentea) leaves regenerated better if stock plants had been held in the dark or under short days. Cheng and Smith (6) for tobacco tissue cultures, and Read, *et al.* (34) for petunia leaf segment cultures, demonstrated dramatic differences in productivity among different genomes or cultivars.

Although the aforementioned reports and others exist in the literature, early literature on the influence of the stock plant on micropropagation is still somewhat limited. It seemed apparent that an organized approach to stock plant investigations was required, since the stock plant clearly has a profound influence on propagation success. For the past several years we have therefore concentrated our research on the stock plant as a means of modifying in vitro responses and increasing micropropagation success. This specialization may be grouped into four categories:

1. Treatments applied to the intact stock plant.
2. Treatments applied to the detached explant prior to culture.
3. Treatments applied to the tissue while subjected to continuous or repeated culture. This, in essence, treats the tissue as a miniature stock plant, or "microstock".
4. Treatments applied to cut deciduous branches in a "forcing solution".

Intact Stock Plant Treatments. Conventional greenhouse or growth chamber methods (13,15,36) were employed for growing the stock plants and *in vitro* culture techniques were those described by Read *et al.* (36), Gavinlertvatana *et al.* (16), and Economou and Read (13). Nutrition of the stock plant was shown to profoundly influence shoot proliferation in tomatoes (36). However, in *Salix* (15), little difference was seen in *in vitro* shoot production, even though macrocuttings were affected by levels of N, P, and K provided to the same stock plants as those used for in vitro tests. More strikingly different shoot multiplication *in vitro* was observed among the eleven *Salix* clones tested. This was consistent with observations with *Petunia* (34), *Alnus* (35), and azalea (10) in which shoot production varied greatly among cultivars and clones.

Treatment of the stock plant with growth regulating chemicals can also strongly affect shoot and callus formation *in vitro*. Chlormequat sprays applied to tomato stock plants led to greater shoot numbers produced by culture of leaf segments taken from such stock plants (36). This is consistent with results of de Lange and de Bruijne (7). Increases in callus production of *Dahlia* resulted when leaf segments from plants sprayed with daminozide were cultured *in vitro* (16). An inter-

action with stock plant photoperiod was also observed, with short day treatments combining with daminozide to cause greater callus formation and ethylene production in the flask atmosphere. More recently we have found that 2000 ppm daminozide sprays applied to *Petunia* stock plants 8 days prior to leaf segment culture resulted in greater shoot proliferation than for leaf segments from water-sprayed stock plants. Further research with this approach is required, since rates of application and time elapsed after chemical application can modify explant response. As with cuttings, physiological stage can also have an effect on *in vitro* performance, since shoot proliferation is less from leaf explants taken from plants in the flowering stage than those in an actively growing vegetative state (36).

Explant Pre-culture Treatments. A practical method of applying "stock plant" treatments is by utilizing the explant as the subject to be treated rather than the intact stock plant. *Petunia* leaf segments have been treated with cytokinins prior to culture on a cytokinin-free medium, resulting in shoot proliferation similar to that achieved when the cytokinin is incorporated into the medium (12,13,36). Dipping the entire leaf or the leaf segment for 3 minutes in 400 ppm benzyladenine (BA) was most effective. Further research in which *in vitro*-derived microshoots were dipped in $N^6(\triangle^2$-isopentenyl)-adenine (2iP) or N-(2-chloro-4-pyridyl)-N^1-phenylurea (4PU-Cl) caused shoot proliferation similar to that reported with 2iP incorporated in the proliferation medium (10,11). This method of growth regulator treatment offers promise for further gains in micropropagation efficiency. Rates and timing require further study, as well as consideration of this method for utilizing compounds which are expensive or difficult to readily incorporate into the medium. It is also feasible to employ this technique as a means of micronutrient, growth substance, or other chemical pulsing to briefly stimulate the tissue. These approaches are currently under investigation in our laboratory.

Treatments Applied to the Culture Tissue (Microstock). Hughes (22) has reviewed the exogenous factors affecting growth and morphogenesis in plant tissue culture systems, but little emphasis has been placed on treating the culture tissue as a miniature stock plant, or microstock. However, because of the efficiencies of space utilization, study of this approach is deemed useful, since the elimination of large stock plant inventories would be possible and light intensity, photoperiod, light quality, and temperature can be readily manipulated. These factors can often be easily modified to improve micropropagation success, as well as to enable studies of their physiological effects.

Low light intensities (10 or 30 Em^{-2} sec^{-1}) applied to microstock cultures of azalea increased number of cuttings produced *in vitro* and improved their rootability when compared with microstocks cultured under higher light intensities (10,32). A possible reason for the improved root formation of cuttings from low light may be related to the presence of a greater level of root-promoting substances, such as indoleacetic acid (IAA), since IAA is known to be reduced under high light levels (29). Rooting of microcuttings was also promoted when microstocks were cultured for 2 weeks under red (R) light following 2 weeks of far-red (FR) prior to placing the microcuttings in a rooting medium (10,32). Photoperiodic effects have also been studied in our laboratory, but no consistent relationships have been established, in spite of the earlier mentioned reports (9,23,31). Similarly, no distinct temperature influences have been delineated, although like Heide (18), we have seen an apparent interaction of temperature with other culture environmental factors.

Another area of concern in the study of microstocks is the problems inherent in the typical culture environment, particularly as they influence leaf anatomy and subsequent plantlet establishment. Sutter and Langhans (39) and others (5,8) have indicated that epicuticular wax formation is lacking or greatly reduced, and that leaf anatomy and stomatal behavior are abnormal. These factors result in difficulty in acclimating plantlets to ambient conditions of low humidity and high light normally encountered in the greenhouse or field. Methods usually suggested for circumventing this difficulty most often involve gradually reducing relative humidity and providing heavy shade at first to keep light levels low. These can then be gradually increased by sequentially reducing the amount of shading material used. However, our work (33) illustrates that a greatly reduced light level is not requisite for successful direct rooting of microcuttings in a controlled environment rooting facility (CERF) in the greenhouse. The CERF provided high relative humidity, but much higher light levels than in the systems usually employed for direct rooting or acclimation. This higher light intensity probably contributed to the fact that growth rate of hardy deciduous azalea (*Rhododendron* spp.) microcuttings was superior to microcuttings rooted in more conventional low light systems. Also, acclimation to greenhouse conditions was achieved up to 2 weeks faster. Such rapid acclimation is highly desirable and argues for further study to determine optimum combinations of humidity and light for the most acceptable rooting and acclimation of *in vitro*-derived plants.

Forcing Solution Treatments. Research with numerous de-

ciduous tree and shrub species has demonstrated that new softwood growth can be "forced" from buds of quiescent stems (after "dormancy" or cold requirement has been met). Such softwood growth can sometimes be rooted as softwood cuttings, but it is more frequently an excellent source of clean explant material for tissue culture use. The optimum forcing solution for chestnut (*Castanea* spp.) and several other woody species is similar to those used as floral preservatives, i.e. it contains 200 ppm 8-hydroxyquinoline citrate and 2% sucrose. We have subsequently demonstrated that such forcing solutions can be effectively used as "delivery systems" for plant growth regulating chemicals such as gibberellins and cytokinins. GA_3 applied in this fashion has been used to stimulate extension or elongation of the softwood shoots, although it may later lead to retardation of *in vitro* development. Conversely, cytokinins such as benzyladenine can be metered into the tissues via the "forcing solution" and subsequently may increase shoot production *in vitro*.

DISCUSSION/FUTURE RESEARCH

Changes in endogenous hormone levels resulting from stock plant treatments need to be further documented. Limited studies with leaf segment culture of *Petunia* stock plant treatments of R and FR light from germination to explant excision have indicated a correlation between endogenous hormone levels and such light treatments (36). It is therefore logical that further investigation of endogenous hormonal changes resulting from stock plant treatments is required. Repeated culture of azaleas *in vitro* has led to a state of "habituation" with improved microshoot production and rooting (11), but recent work with *Alnus* has shown opposite results if cytokinin is discontinued as a culture medium constituent (28). In addition, recent work with leatherleaf fern (*Rumohra adiantiformis*) suggests that anatomical studies may lead to a better understanding of *in vitro* responses to stock plant treatments. From these initial studies, it seems clear that stock plants offer a convenient vehicle to expand our knowledge and effectiveness in propagation, as well as facilitating more effective physiological research.

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VIRUS-TESTED PROPAGATING MATERIAL AND THE FRUIT VARIETY FOUNDATION

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INTRODUCTION

Research in Australia and overseas has confirmed that the quality of planting material used in orchard establishment has far-reaching effects on subsequent plant vigour, fruit production and quality, and other crop characteristics.

Of prime importance in determining the potential productivity of planting material in many fruit crops is freedom from harmful virus diseases. These viruses may result in reduced vigour, yield, fruit quality, and orchard life. A list of some deleterious virus diseases of fruit crops is given in Table 1.

Table 1. Some deleterious Viruses of Fruit Crops

CITRUS	
Exocortis	Xyloporosis
Tristeza	Citrus stubborn
Psorosis	Citrus greening
STONE FRUITS	
Prunus necrotic ringspot	Plum pox
Prune dwarf	Western X
Peach yellow bud mosaic	Peach yellow bud mosaic
APPLES	
Apple mosaic	Apple ringspot
Apple proliferation	Apple russet ring
Apple green crinkle	Spy epinasty and decline
GRAPES	
Leafroll	Fanleaf
Yellow speckle	Asteroid mosaic
Corky bark	
AVOCADO	
Sunblotch	

Most orchard crops are propagated vegetatively, either by budding or grafting, and these techniques allow the transmission of viruses from generation to generation. Most viruses are not seed-borne and therefore a similar virus transfer does not normally occur in crops propagated by seed.

Techniques such as meristem culture and heat treatment are available to remove viruses from vegetative material. Horticulturists, plant pathologists, and virologists are, therefore,

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able to work together to produce fruit crop vegetative propagating material free of known deleterious viruses. The material is then termed virus-tested rather than virus-free because it is only checked to ensure that harmful viruses have been removed and it is possible that other relatively unimportant viruses are still present.

Once virus-tested propagating material has been produced, it is important to maintain a nucleus of clean stock, to test it for horticultural trueness, and to develop multiplication systems which will allow the industry to take advantage of its improved vigour and cropping potential.

THE AUSTRALIAN FRUIT VARIETY FOUNDATION (fvf)

The Fruit Variety Foundation (fvf) was brought into being by a decision of the Australian Agricultural Council in 1971. The responsibilities of fvf chiefly relate to the maintenance of virus-tested mother stock of a range of fruit cultivars in special foundation plantings. However the influence of fvf is far wider; for example, it assists in the coordination of the importation of new fruit cultivars into Australia and, at the other end of the system, provides coordination and assistance to State budwood multiplication schemes.

Finance for the development and maintenance of the foundation plantings is provided on a 50:50 Commonwealth/State Government basis with States contributing in proportion to their number of producing orchard trees of the crops involved. A total of four professional staff are employed by fvf in Victoria, New South Wales, and Tasmania to manage the foundation plantings and conduct related activities.

The foundation plantings are administered on a day to day basis by the local State Department of Agriculture, but a coordinating committee meets annually to review the functions and operations of the scheme. The committee contains a representative from each State Department of Agriculture, one from CSIRO Division of Horticulture, and one from the Commonwealth Department of Primary Industries (Plant Quarantine). It is comprised of both horticulturists and virologists and is the chief guiding hand of fvf.

The foundation plantings are principally in fenced blocks on Government research stations, but in crops where viruses can be pollen transmitted from one tree to another, the virus-tested mother plants are maintained in glasshouses. A listing of the crops currently in fvf and the location of the foundation plantings are shown in Table 2.

The mother stock maintained in the foundation plantings is regularly reindexed by professional staff to ensure that the

Table 1. Crops in fvf and Location of Foundation Plantings.

CROP	FOUNDATION PLANTING SITE
Apples	Gove, Tasmania
Pears	Gove, Tasmania
Avocados	Somersby, New South Wales
Cherries	Rydalmere, New South Wales
Almonds	Rydalmere, New South Wales
Prunes	Rydalmere, New South Wales
Citrus	Dareton, New South Wales
Grapevines	Irymple, Victoria
Peaches	Burnley, Victoria
Nectarines	Burnley, Victoria
Apricot	Burnley, Victoria

material remains free from deleterious viruses.

SUBMISSION OF FRUIT CULTIVARS TO FOUNDATION PLANTINGS

It is the responsibility of the State Department of Agriculture and CSIRO Division of Horticulture to clean-up virus-infected material of important fruit cultivars and to propose them for incorporation in the foundation plantings. The fvf committee controls the entry of new cultivars to the foundation plantings and regularly reviews the need to maintain existing cultivars. Candidates for submission must be justified on horticultural importance to the fruit industries as well as having freedom from deleterious viruses.

HORTICULTURAL MERIT OF CULTIVARS IN fvf

It is a firm policy of fvf that the foundation plantings are not genetic resource collections. Cultivars which do not have continued commercial relevance to the horticultural industries of Australia are removed. This is to keep the size of the foundation plantings manageable and to control the costs of running the scheme. However, new overseas fruit cultivars with good prospects for industry use may be incorporated.

To ensure that the virus-tested cultivars maintained in the fvf foundation plantings are horticulturally true-to-type, horticulturists check the cultivars from time to time and provide descriptions of cultivar characteristics.

This is a difficult area with stone fruit because the mother plants are maintained in glasshouses and are not allowed to flower or fruit. As previously explained, this is because in these crops some deleterious viruses are pollen-transmitted from tree to tree. In these cases special virus-tested trees need to be planted and grown to determine horticultural characteristics. Alternatively, observations are made in existing trials or plantings on research stations which have used the virus-tested budwood.

ROOTSTOCK/SCION CONSIDERATIONS

It would obviously be unwise to graft virus-tested budwood onto virus-infected stock. For this reason fvf maintains virus-tested material of both stock and scion cultivars. Where seed is used to produce rootstocks, then virus-tested trees are maintained of these cultivars.

STATE MULTIPLICATION SCHEMES

It is the responsibility of the State Departments of Agriculture to arrange multiplication and distribution schemes to ensure that virus-tested budwood is available for industry use.

The first stage in the development of a virus-tested budwood scheme is the establishment of nuclear plantings. These are established with budwood (or seed as appropriate) obtained directly from the professional officer in charge of the relevant foundation planting. Nuclear plantings are usually located on State Government research stations. They act as a local source of budwood for the establishment of multiplication blocks to supply the quantity of budwood required by industry. In some cases there is no need for a nuclear planting and multiplication blocks are established directly. In other situations where only relatively small quantities of budwood are required, the nuclear planting may also serve as the multiplication block.

It is obviously vital that the State Multiplication Schemes are so organized and managed that re-infection with harmful viruses does not occur. To this end nuclear areas are usually fenced and grown in some isolation, stone fruit trees are deblossomed to prevent infection with pollen-borne viruses, and trees are reindexed from time to time to ensure continued freedom from harmful viruses.

In the production of peach seed for rootstocks the trees must obviously be allowed to flower and fruit, and to ensure against re-contamination with pollen-borne viruses the trees are grown in isolation and re-indexed at regular intervals.

The distribution of budwood to industry is often controlled by grower organized committees with technical support from State Departments.

Queensland currently has fvf multiplication schemes for apples, stone fruit, grapes, citrus, and avocados.

THE FUTURE OF fvf

Governments have continued to support the need for the fvf scheme. However a comprehensive review of the scheme is currently in progress and some changes may occur.

Australia with its fvf scheme, together with the Interregional Research Project (IR-2) scheme of USA, and the EMLA scheme of the United Kingdom, has been at the forefront in establishing germplasm banks of virus-tested, horticulturally important fruit cultivars. Interchange of material between these schemes allows for much faster introduction of new fruit cultivars through quarantine and speeds up their incorporation into virus-tested foundation plantings.

The benefits of the scheme are now becoming increasingly apparent in the Australian fruit industries. Continued close surveillance of all facets of the scheme should ensure that these Australian fruit industries have the benefits of virus-tested fvf propagating material.

AN HISTORICAL REVIEW OF GRAFTING TECHNIQUES

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Grafting is the implanting of a piece of tissue from one plant into another in such a manner that they will maintain a permanent bond. It is one of the oldest arts of plantcraft.

Natural grafting has been around at least as long as plants have had cambium layers to unite, and this natural grafting probably stimulated the early practitioners by way of approach grafting.

References are available to show that grafting techniques were used by the Chinese 3000 years ago (9). At approximately 2000 years ago Aristotle (9) (384 to 322 B.C.), Virgil (4) in his "Georgics" or "The Art of Husbandry" (30 B.C.) and Pliny the Elder (4), in his "Historia Naturalis Volume II" (77 A.D.) all discussed grafting with considerable understanding. Paul the Apostle (9), in his Epistle to the Romans (Chapter XI, Verses 17 to 24) "And if some of the branches be broken off, and thou, being a wild olive tree, wert graffed in among them, and with them partakest of the root . . .", appears to show that at that time the possibility of a reaction between stock and scion (cion, cyon, sion) was recognized.

Columella (2,6), who was regarded as one of the most learned writers on practical agriculture in Rome at the time of the birth of Christ, and who wrote 12 books on gardening (De Re Rustica) and related subjects, together with a supplementary treatise on trees, mentioned the bark and cleft grafts and the patch bud.

Australia with its fvf scheme, together with the Interregional Research Project (IR-2) scheme of USA, and the EMLA scheme of the United Kingdom, has been at the forefront in establishing germplasm banks of virus-tested, horticulturally important fruit cultivars. Interchange of material between these schemes allows for much faster introduction of new fruit cultivars through quarantine and speeds up their incorporation into virus-tested foundation plantings.

The benefits of the scheme are now becoming increasingly apparent in the Australian fruit industries. Continued close surveillance of all facets of the scheme should ensure that these Australian fruit industries have the benefits of virus-tested fvf propagating material.

AN HISTORICAL REVIEW OF GRAFTING TECHNIQUES

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Grafting is the implanting of a piece of tissue from one plant into another in such a manner that they will maintain a permanent bond. It is one of the oldest arts of plantcraft.

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Furuta (7) quotes Theophrastus (370 to 286 B.C.) as writing in his "De Causis Planitarium" that the period of the Dog Star (autumn and spring) was the optimum for grafting. He also quotes Cato Major (about 160 B.C.), writing on the grafting of the olive using a bark graft with Greek willow ties and a sticky mass of clay with sand and cattle dung to seal the work.

While in these early times references are available discussing the aims of grafting and listing some types of grafting, the art was regarded as a professional secret by many over the ages. Indeed from time to time there has been agitation against grafting as being contrary to the nature of plants by being injurious and devitalising.

Some of the early writers, e.g. Virgil, seem to have had only the vaguest idea of the possibilities and limitations of the work, and even today it is not uncommon to hear reports of various rather unlikely combinations which, when followed up, are not true grafts.

Pliny, according to Bailey (4) describes a cleft graft. He gives several precautions: the stock must be that of a tree suitable for the purpose, and the graft must be taken from one that is proper for grafting; the incision or cleft must not be made in a knot; the graft must be from a tree that is a good bearer and from a young shoot; the graft must not be sharpened or pointed while the wind is blowing; a graft should not be used that is too full of sap, not more than one that is dry and parched, and finally it is a point most religiously observed to insert the graft during the moon's increase.

Many propagators today find more than a modicum of truth in some of the above statements and many of the small and maybe sometimes large losses which occur result from the neglect of basic rules elucidated some 2000 years ago.

Very little more appears to have been heard on the subject of grafting until the Renaissance (1300 to 1500 A.D.) when, as Hartmann and Kester (9) write, a resurgence of interest occurred as large numbers of new plants were imported into European gardens and were perpetuated by grafting.

During this period cleft and whip grafts were in wide use and it was realised that cambium layers must be matched, although the nature of the tissues was not understood. Most trees in English orchards were being grafted at this time. Leonard Mascall (12) in 1572 penned a delightful treatise on the joys of "planting and graffing, the which not only we may see with our eyes, but also feele with our handes in the secret workes of nature", and reviewed the English experience to that time.

In 1672 Drope (8) wrote in his book, "A Short and Sure

Guide in the Practice of Raising and Ordering of Fruit Trees", that oranges should be budded with an inverted "T" incision and discoursed on leaving the wood in the bud, using dormant scions for grafting, and on the mechanics of union.

Also in 1672 Sharrock (4) in his "History of the Propagation and Improvement of Vegetables" under the heading "Insitions" describes various types of grafts (and buds) with a rather interesting illustration of the various types of cuts. Sharrock also reiterates much of the early advice of Pliny.

Hartmann and Kester (9) write of the work of Stephen Hales who approach-grafted three plants and found that the centre one stayed alive when severed from its roots, and also of Duhamel who, at about the same time, studied wound healing and the graft union.

During the 19th century several writers discussed various aspects of the art. Thouin (9) described 119 kinds of grafts and classified grafting under three headings —

1. Bud grafting or budding (inoculation)
2. Scion grafting or what has been referred to as grafting proper
3. Grafting by approach, sometimes called inarching.

Thouin also discussed changes in growth habit due to grafting. The Gardeners' Chronicle (1) of 1851 showed woodcuts depicting details of various grafting cuts.

Burke (5) writing in "Australian Horticulture" of March, 1983, records the grafting of *Lechenaultia* in France in 1846 as the earliest known graft of an Australian native plant and states that more Australian native plants were grafted in Britain later in that Century. Hartmann and Kester (9) also note that Vochting in the late 19th century continued Duhamel's work on the anatomy of the graft union. Garner (8) quotes Knight's work on the use of raffia to temporarily cincture buds during the "taking" period.

With the coming of the 20th century, advancements in communication and research tools and the increase in the number of research workers, a great amount of information has become freely available. It would not be possible for me to completely detail the advances in this period, so I will confine my remarks to two areas of interest, i.e. tying and sealing, and mechanization.

The earliest tying materials appear to have been plant fibres, particularly the bast fibres of trees such as the bass wood (*Tilia* spp.), willow (*Salix*, spp.) and *Hibiscus tiliaceus* L. By the early 1900's other materials such as raffia and yarn were being used, followed by the use of waxed cloth, thread,

manila paper, and nursery tape. With the introduction of plastic (polyvinyl chloride [P.V.C.], etc.) ties in the 1950's some of the problems of both fixing and sealing were solved, although the new material was not without its problems, such as sunburn.

P.V.C. did not take over completely and we still see rubber strips in use in field grafting, and other materials such as crepe rubber, Parafilm®, florists tape, and plumber's tape being used in "bench" type situations. For top working and tree repair work it has been common for tacks (brads, bootmakers tingles, or flathead nails) to be used with or without other tying aids.

In some situations a special sealing material has not been necessary. Probably the first sealant was "pug", this being a mixture of clay, dung (horse or cow manure generally), chopped hay, or hair. With raffia, the common practice and the more hygienic one, was to cover the work with molten wax, but some workers heaped sandy soil up over the graft and this provided a good situation for callusing and, after two to three weeks, the raffia was decomposed sufficiently to avoid the need to cut it off.

Paraffin wax and other manufactured low melting point waxes (candle wax) have been used but grafting waxes (cold or hand) and brushing waxes (hard or hot) made to a range of formulae have been devised. Some of the materials used are listed: —

Basic wax: beeswax, resin, tallow.

Additives: raw linseed oil, mineral turpentine, alcohol, paraffin wax, lamp black, honey, talcum (chalk), fish glue, powdered charcoal (for visibility and heat absorption), venetian red, Kieselguhr (diatomaceous earth).

One pre-1900 French recipe contained black pitch, Burgundy pitch, yellow wax, tallow, and sifted ash (6).

Waxes are still used but the following is a list of some of the alternative materials that have been used to seal over the wound: —

Asphalt emulsion (Colgraft®)
Aerosol asphalt (wound dressing)
Petroleum jelly or mastics from similar sources
Petroleum jelly impregnated bandages (Densotape®)
Lanolin
Colloidal vulcanised rubber

Colas (cold bitumen) starch mixture
Wallpaper paste
Latex base pastes and paints (Goldseal®)
Plastic (P.V.A.) and acrylic paints
Wax impregnated plastic (Parafilm®)
Babies' bottle teats.

In Queensland, with deciduous fruit tree top working, waxed calico was used but did not encourage callus formation and encouraged ants to build under it. As a result of this, after the graft (strap or cleft) was completed and sealed with a minimum of mastic, a cylinder of paper was formed around the scion and filled with sand. This was successfully used until replaced by plastic (PVC) sheets. Plastic sheets may have to be shaded to prevent sunburn.

Various forms of hot callusing have recently been used over grafts without the need for a great deal of sealing, although as Hellriegel (10) says, Shippy used this technique over 50 years ago with apples. Plant growth substances, such as auxins (IBA, IAA, etc.) and gibberellins, anti-oxidants such as hydroquinone, and fungicides such as Mildothane® have been used mixed with the sealant to hopefully improve the results.

In the past, grafting was often just part of the general nursery and orchard practice and the proprietor did the carpentry part of the work with semi-skilled workers to tie and seal, etc. With the ever increasing need to produce much larger numbers of more specialised trees at a lower cost there has been, as one would expect, many changes. Most of the changes have taken place in the nursery as this has been the area of need.

We might start with the field grafting operation where probably the only changes are in the use of degradable ties, reusable budding clamps, and field transit machines.

In the grafting shed we have progressed from the original bench grafting for deciduous material to the use of containerised stock and to "cutting-grafts", and micro-grafting. With controlled conditions it has been possible in some situations to prepare the material mechanically using semi-skilled labour. Grafts, such as the chip bud, have been reintroduced to extend the grafting period. The plant growth cycles have been readjusted to facilitate these practices.

In 1957 Alley (3) introduced a modified version of Jacob's circular saw type grafting machine at the University of California, Davis. With Alley's machine it was claimed that three reasonably skilled persons could make 700 to 1000 grafts per hour with grapes. Alley also mentions a modified hand saw which could be used with his machine to cut the rootstocks

for top working grafts in the field. At this time (1957) grafting shears or secateurs were also available. Modern machines are based on the earlier ones.

In recent times budding guns capable of budding 500 plus stocks per hour have become available. However highly skilled manual budders are also capable of working large numbers of rootstocks under assembly line conditions. It must also be remembered that there has to be requirements for these enormous numbers of plants, a supply of suitable uniform rootstocks and scions, and that a high level of management skills in the nursery needs to be available.

As already stated, a tremendous fund of knowledge has been amassed over the centuries. It would be a great step forward if the Data Bases discussed by Wren (13) could be made more readily accessable to plant propagators, possibly through the auspices of the IPPS.

In conclusion, I can do no better than to follow R.J. Garner and others, and say that the modern grafter would do well to become imbued with some of the ancients' inquisitiveness, enthusiasm, and the observance of the IPPS motto, "To Seek and to Share".

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CHIP BUDDING — A POSSIBILITY FOR PAWPAWS (PAPAYAS)

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REVIEW OF LITERATURE

The common pawpaw or papaya (*Carica papaya*) has been cultivated in Australia for many years but has not become of much commercial importance. Part of the reason behind this has been the problems involved with maintaining good lines and the inability to take advantage of a chance superior type(s) which may appear in mass populations.

Similarly, dioecious lines present horticultural difficulties which result in inefficiency of the cropping system.

Asexual or vegetative propagation offers an opportunity to overcome these problems (3,6). Cuttings have been successful in South Africa (1) and Australia, and side grafts have been used in Australia (4), Papua New Guinea and Asian countries (2). These do not make the best use of available scion (such as could be obtained from a chance seedling), so other methods need to be investigated.

The vegetative propagation of pawpaws has met with varied success and tissue culture techniques similarly have not been finalised as yet (2,5).

The use of chip budding could offer a possible alternative method in which the number of plants from scarce budwood can be maximised.

MATERIALS AND METHODS

Pawpaw seeds were germinated and grown in seedling trays, in a peat/vermiculite mix. The seedling trays were placed in a fibreglass-covered screen house (this mix is not suitable for outside use as it is easily moved by heavy rain and leaches quickly). Seedlings were thinned to 1 plant/container after germination and then given weekly applications of Aquasol®.

Seedlings were vigorous but tended to crowd after 30 cm. in height. Stem basal thickness varied from 5 to 12 mm. This range of material was considered to be suitable for budding close to the base of the stem.

To produce small budwood pieces approximately the same thickness as the stock seedlings, the apical point of the scion

stock plants was removed. This forced the production of side shoots.

The usual chip budding technique was used; however, in this case both the rootstock and scion stock plants were maintained in an active state of growth. Normally, this technique requires either or both the rootstock or scion wood to be dormant (3). Parafilm (or florist tape) was used to bind the buds.

RESULTS

Preliminary trials on poor quality stocks indicate that the soft, vigorous seedlings will give the best results. A batch of 50 seedlings done under these conditions resulted in an 80% success of buds pushing out. However, 50 seedlings which were left a further three weeks in the same size trays and using older, harder scion material, resulted in only a 58% success rate which would be too low for commercial operation. A further trial of 200 seedlings was largely destroyed by cyclone Gretel and cannot be presented here.

DISCUSSION AND CONCLUSIONS

It is thought that the rootstock seedlings would have benefitted from potting on into a larger container, eg. 1 to 1½ litre plastic bag using U.C. type mix before crowding occurs. This should allow for a more uniform size plant and make budding easier, as budding in the trays can become awkward.

The ideal size of the pawpaw seedlings has yet to be determined and is dependent on the size of budwood available, although 30 to 40 cm is considered the maximum.

As the stock plants age, they lose a clearly defined cambial layer producing a matted fibrous type of tissue under the bark region. Initial work suggests that this type of stock is not very useful as it is difficult to match cambial areas and has not given good results.

Buds (forced by removing the apical point of the plant) tended not to be as symmetrical as the stocks, being irregular and usually curving upwards towards the light. It was difficult to get many shoots of appropriate size for budding. However, this could be overcome by using budded plants. Once the initial buds have taken and grown out to useable size, these can be used as budwood, leaving a few shoots at the base to regrow. The shoots from the chip buds tend to be more symmetrical and are easier to use for a bud source.

Some problems were encountered with the thickness of the bark on the stock plants in relation to the thickness of the bark on the budwood, as well as the "take" of the chip piece on the bottom or heel of the chip. The bark at the base of the

stock plants, even when quite young, can be quite thick and can lead to some matching problems. To overcome this problem insert chip buds higher on the stock plants if budwood size permits. The second problem was that the buds sometimes did not take from the bottom or heel of the chip, although, the bud took on the back. The buds tended to die from the bottom up. It seems that this is the critical area of the bud. Some shrinkage has been observed to occur on the stock heel and it may be necessary to sit the bud slightly below the level normally correct for chip budding. This would fit with the difference in bark thickness to afford a better match.

Mother stocks can be maintained in pots for many months but tend to lose vigour. This results in poor quality scion material which would result in lower success rates. It is felt that a continual turnover of these to ensure vigour of the scion would be desirable. Similarly, a good supply of vigorous seedlings from which to select is required.

By using vigorous seedlings and young, vigourous, well-matched scions, chip budding of papaws can be successful. The freshness of budwood is very important as it desiccates quickly. It is also important to maintain vigorous growth of the budded plants to avoid stunting.

Whilst it would take some practice to perfect the technique, it is easy to learn and requires no special facilities or abilities. An example of this was that a work-experience student was able to obtain a 68% success rate without previously having used this technique.

This technique should also be of use for researchers and plant breeders to maintain lines and carry out agronomic trials. Further refinement of the technique is possible. A full yield trial to compare yields etc. is necessary to justify the use of this technique on a commercial scale.

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GETTING TO THE ROOTS OF THE PROBLEM

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INTRODUCTION

A well formed root system is an essential prerequisite for the growth and development of a vigorous tree and the achievement of a full life-span (5). There has been a long history of concern about the malformation of root systems by propagation and planting (or transplanting) techniques (7). Distortions of the root system may be so severe that poor growth, toppling or even death may result (4).

Harris (5) identifies two types of root defects:

1) kinked roots in which the major roots are bent, and
2) circling or girdled roots in which the roots circle around the stem or other roots.

The degree of root deformation is affected by nursery practice, container design, planting method and the site (6). Such factors can cause the development of abnormal root systems in container-grown plants. Indeed the root system of container-grown plants may never develop the same structure as the "normal" system of direct sown plants.

The root formation of plants grown from cuttings is rarely the same as the same plants grown as seedlings. Similarly, nursery production techniques usually cause malformation (3). After planting, the distortions of the root system may persist for many years (2), although the degree of distortion may decrease with time (6). Although distortions usually reduce growth and may kill the plant, it is surprising that a relatively small proportion of free roots may be sufficient to sustain the plant (5).

In this study, field observations of planted trees toppling over have led to a review of planting and propagation practices. Subsequent experiments examined the relationship between the root and shoot development and the size of the container in which the plants were grown. There are implications for the growing of native plants, especially when the situations in which the trees are to be planted, are considered.

MATERIALS AND METHODS

The first part of this study simply consisted of observations on the toppling of 8-year-old *Eucalyptus regnans* trees growing at Toolangi, Victoria. Some 1317 trees have been

planted in this Victorian Forest Commission experimental plantation. These trees were approximately 20 to 25m tall with a diameter at breast height of about 25 to 35cm. The root systems of 10 recently fallen or loose trees were excavated and the structures of the root systems determined. Later, sections of the root system were photographed.

In the second part of the study, random samples were taken of the seedlings growing in the production nursery at the V.C.A.H. — Burnley. The seedlings were removed from their pots and the roots examined. Deformities in the root systems were identified and the causes determined where possible. The proportion of "normal" to deformed root systems among the seedlings was also recorded.

The third aspect of this work involved the raising of *Eucalyptus camaldulensis* from seed; 100 seedlings were grown in 5cm pots, 40 in 7.5cm pots, and 30 in 15cm pots. Each week, from week 4 to week 9 after germination, seedlings were transferred from the 5cm pots to the 15cm pots. At the end of the 10 week experimental period, the height, leaf number, fresh weight, and dry weight of the seedlings were recorded. Each week the progress of roots in the 5cm pots was investigated by removing the seedlings, and observing how far the roots had grown into the pots.

RESULTS

Results from the first phase of the study showed (Table 1) that the proportion of fallen trees in the plantation was increasing. Examinations of trees that had fallen in 1982, 1983, and 1984 revealed that in every case root systems were seriously deformed (Figure 1). The deformities in each tree were responsible for a weakening of the trunk, at or below the soil surface (Figure 2), which caused the plant to fall.

Table 1. Fallen trees at Toolangi, Victoria. (The plantation was established with 1317 trees in 1976).

Year	Fallen Trees
1976	0
1979	32
1984	77

In the second part of the study samples taken at random from the container-grown seedlings revealed that several different causes of root deformity could be identified (Table 2). These correlated with different phases of the plant production process. The number of plants with deformed root systems was unexpectedly high (Table 3).

Figure 1. Deformed root system on a fallen tree at Toolangi.

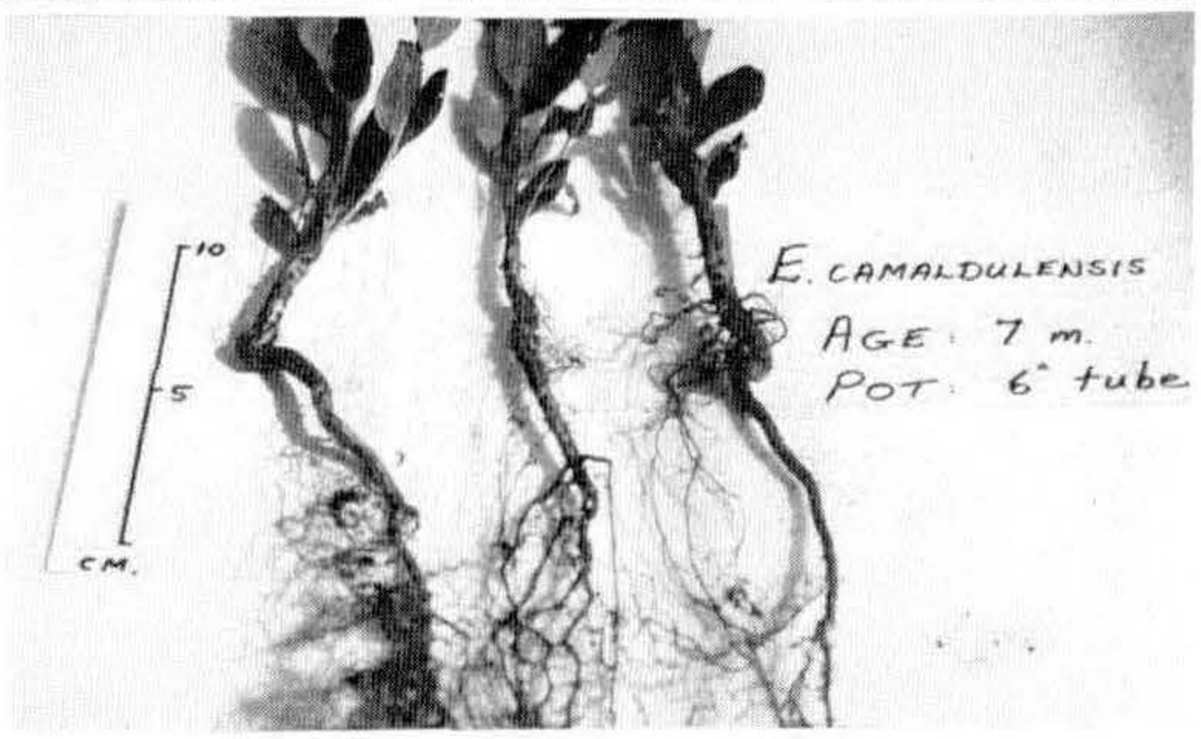

Figure 2. Examples of deformed root systems. *Above*: From a fallen tree at Toolangi. *Below*: From container-grown seedlings.

Table 2. Causes of root deformity due to propagation and planting procedures.

Procedure	Aspect of Procedure Causing Deformity	Kinking	Circling
Propagation	1. Depth of Germination Tray	✓	
	2. Pot (a) shape		✓
	(b) diameter		✓
	(c) depth	✓	✓
	3. Pricking out	✓	
	4. Potting on	✓	✓
Planting	1. Hole (a) shape		✓
	(b) diameter		✓
	(c) depth	✓	✓
	2. Twisting as planting		✓
	3. Depth of planting	✓	

Table 3. Deformities in the root systems of seedling samples, taken at random, at the VCAH nursery.

Species	Sample size	Roots % Normal	Roots % Deformed	Major cause of Deformity	Size of pots
Eucalyptus camaldulensis	20	10	90	Pricking Out	15cm tube
	5	20	80	Pricking Out	7cm pot
E. maculata	10	20	80	Pricking Out	15cm pot
E. melliodora	10	30	70	Pot shape	7cm pot
E. pauciflora	5	0	100	Pricking/Pot shape	15cm pot
E. leucoxylon	5	0	100	Pricking/pot shape	7cm pot
Melaleuca ericifolia	5	60	40	Pricking/Tray	15cm tube
	5	0	100	Pot size & shape	7cm pot
Leptospermum phylicoides	5	40	60	Pricking Out	7cm pot
Bursaria spinosa	5	100	0	—	7cm pot

The final part of the study revealed that plants which were grown in larger containers grew more rapidly (Figure 3). The increases were real in that plant dry weights increased substantially (Figure 4). Transplanting of seedlings from small pots into larger ones improved growth, but growth was still significantly less than for seedlings sown directly into large containers.

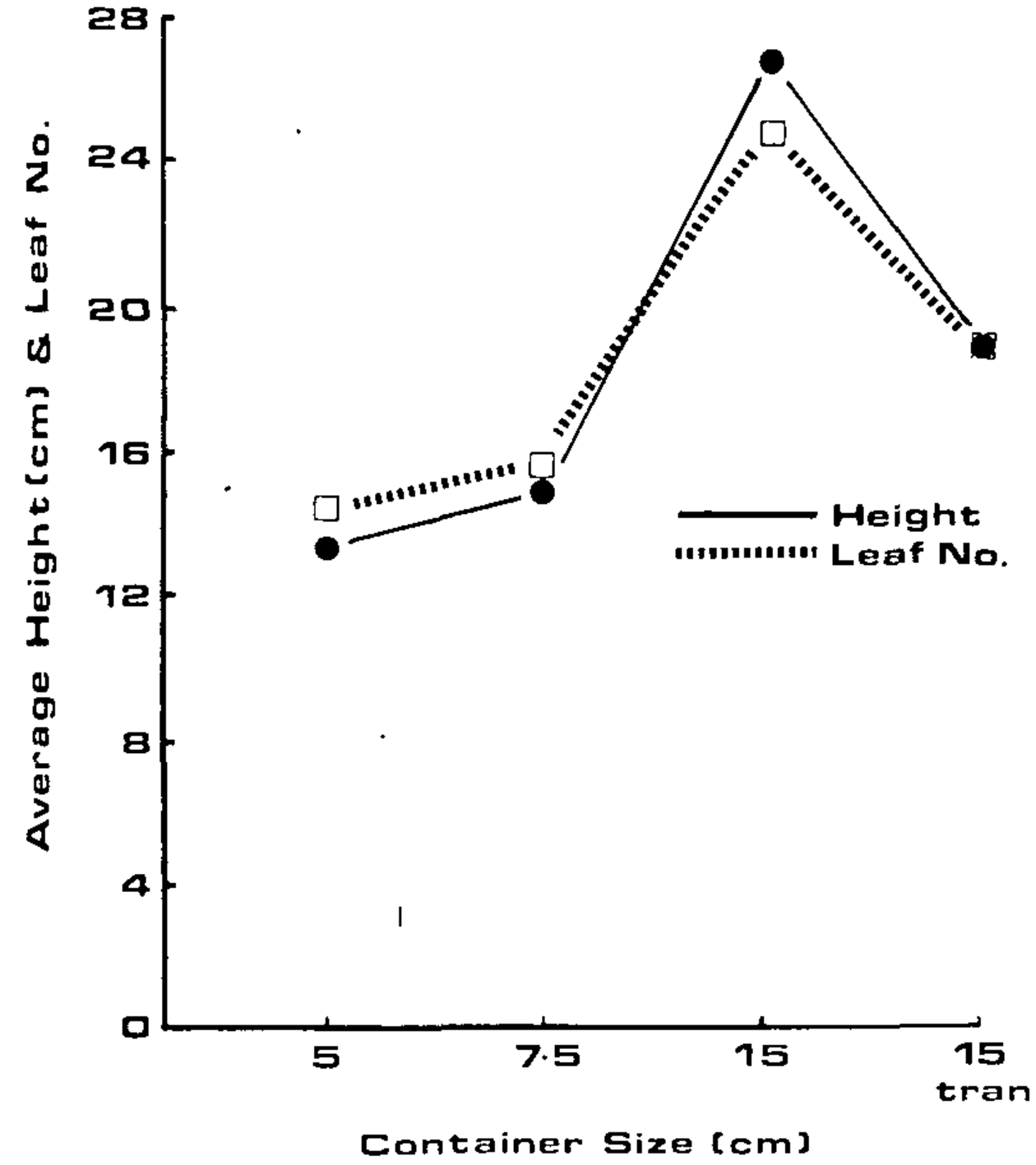

Figure 3. Average height and leaf number vs. container size.

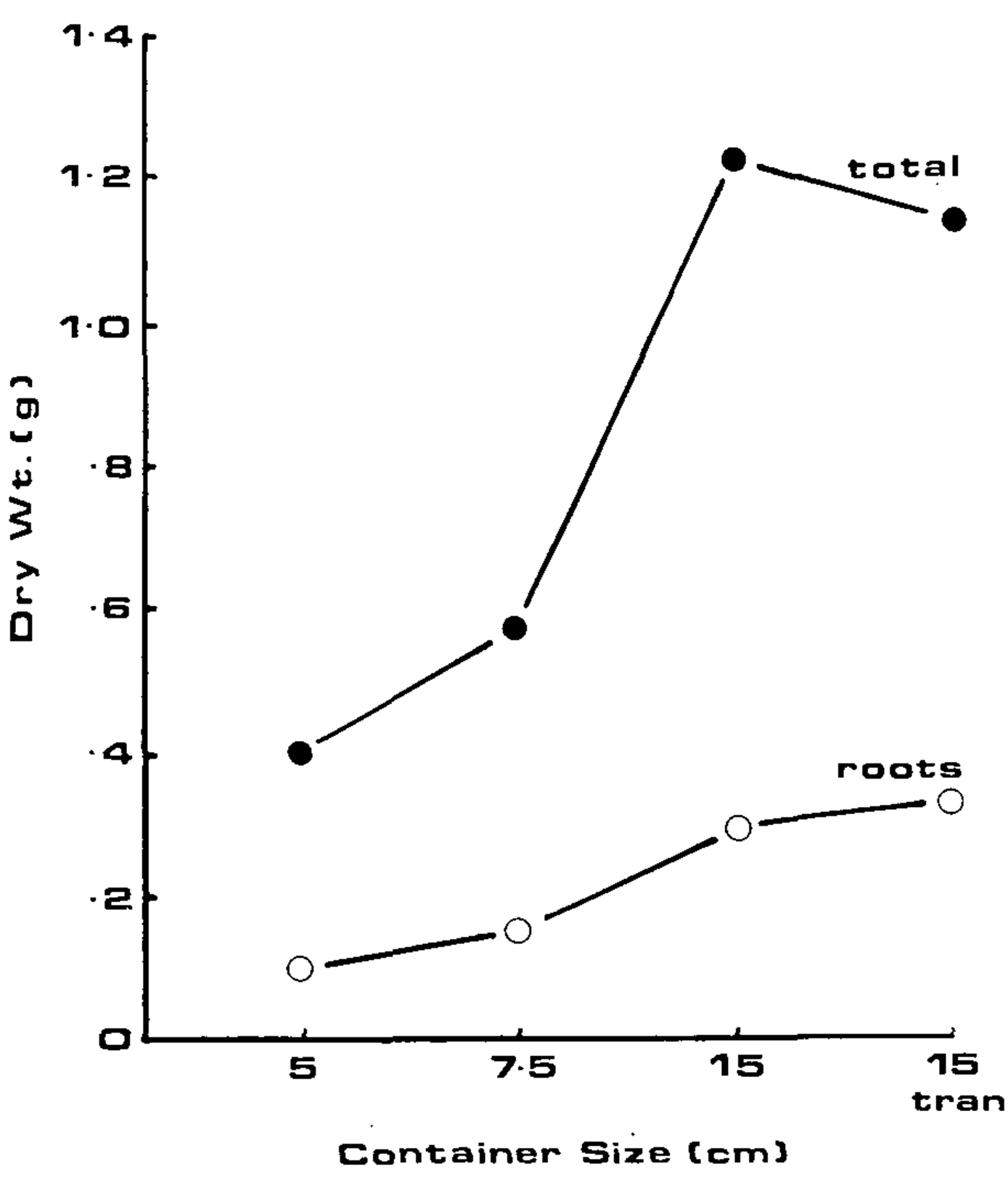

Figure 4. Average dry weight of whole seedlings and of root systems vs. container size.

DISCUSSION

It is comparatively rare that the demise of trees can be traced back with any certainty to poor plant propagation or planting technique. This can be done at Toolangi, however, where the circling of roots has either girdled the plants own stem or caused the development of major lateral roots on one side only. The causes of these problems may be two-fold:

1) The use of pot-bound seedlings where the root systems were already circling within the pot. The seedlings were planted without any correction of these problems.
2) The planting of seedlings with larger roots which, as they were placed in the holes, the plants were twisted so that all the roots could be accommodated in the small holes.

The 8-year-old trees at Toolangi were substantial plants, and the high incidence of fallen trees represents a dangerous situation. The root systems of some standing trees were so weak that the trees could be shaken by hand. It is likely that the proportion of fallen trees in the plantation will continue to increase in the next few years.

It is also worth noting that trees with deformed root systems, especially those which are circling, may actually grow better than "normal" trees in the initial years of growth. This is because the roots are starved, partially or totally of photosynthate, and so the foliage, and stems, above ground may be healthier and bigger in appearance. Eventually, however, as the restrictions become more severe the health and vigour of an affected tree decline (8).

Growth of plants of native genera in containers has always given some cause for concern. This has been especially true for eucalypts, which have very long tap roots as seedlings. The tap root may be four times as long as the stem in this early seedling stage. The tap roots are important for the establishment of the young seedlings although they may be lost after 8 to 10 years as the tree matures (1). This means that there are likely to be problems when seedlings are germinated in flat trays, which have a depth of about 5 cm, or when seedlings are "pricked out". Accordingly plants should not be left in trays for long after germination and should be planted into the largest pot practicable.

The choice of propagation strategies is not easy. Large pots take more space and space is costly. This extra cost, however, may be more than offset by greatly reduced handling and growing times. In this study, saleable eucalypts were produced within three months. It would seem that greater attention to the relationship between plant and pot size may pay divi-

dends. Furthermore, the use of container-grown stock may be inappropriate for some situations. The use of direct-seeding techniques might be better in forests or salt-affected rural areas where deep-rooted trees are required.

Propagation which involves "pricking out" or re-potting every few weeks would appear to increase the risks of root deformity, especially "kinking". This necessitates great care by operators and some pruning of the root system to reduce the risk of deformity would seem wise (3). As far as the development of a healthy root system is concerned it would seem that the less the interference the better the system. This means larger pots and fewer re-pottings. The economics of this sort of system are not simple — there are both gains and losses.

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DEVELOPMENTS IN PLANT PROTECTION PRACTICES IN THE NURSERY INDUSTRY

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INTRODUCTION

Plant protection is the management of insects, diseases, weeds, and other organisms which interfere with plant growth — and it experiences its own set of difficulties within the nursery industry. These embrace the high standard of cosmetic appearance demanded of the industry's products, the diversity of species cultivated and production environments utilized, and the need for workers to enter agrochemically-treated areas and handle treated plants daily. Other factors which complicate the day-to-day decision making associated with plant protection in plant nurseries include the lack of applied research information on the cultivar(s) and pests, and the interactions between the nursery environment and the pesticides used.

PESTS AND THEIR DEVELOPMENT

A pest is any living organism which interferes with the growth or cosmetic appearance of a plant. Thus, PEST is a collective term for organisms such as aphids, grubs, mites, fungi, weeds, mice, nematodes, and bacteria. The presence of pests in a nursery results in either reduced value of plants in the market place or increased production costs which are associated with producing a plant suitable for sale. The rate and scale of pest development and subsequently the damage inflicted are strongly related to the environment. The environments used by nurseries are diverse, ranging from rigid glass through poly-tunnels, shade cloths, and semi-protected to open environments, as well as computerized environment control houses. The rate of pest development, the population dynamics of the pest, and the level of damage incurred will all vary in the different environments. To manage pests adequately it is necessary to integrate a knowledge of the pest and cultivar and their environmental interactions as well as various control measures available, into a plant protection programme compatible with the management goals of the nursery.

FOUNDATION FOR PEST CONTROL

Next to a sound knowledge of the growth requirements of the cultivar(s) under production, hygiene is the foundation for pest control in nurseries. Whilst this fact has been recognized

for years, the majority of nurseries pay limited attention to this practice. Greater attention to the many aspects of hygiene will be necessary for commercial survival. Prevention of pest problems is the cheapest form of control. Attention to the choice of pest-free propagating material, the storage and cleanliness of containers, cleanliness of media preparation and storage areas, media sterilization or pasteurization, the cleaning down of benches, beds, pathways before new stock is set in place, and the prevention of weed seeding in and around the nursery are some examples of hygienic practices.

More nurseries are increasing basic hygiene practices such as media sterilization and on-site chlorination of their water supply. From surveys conducted in Victoria by Sutton (7) and Curtis (2), the percentage of nurseries sterilizing or pasteurizing their media has increased from 32% in 1978 to 76% in 1984. Of the 76% of nurseries treating media, 33% used methyl bromide and 43% used heat treatments (Table 1), and while 38% have practised media treatment for more than 10 years, 28% have done so for 6 to 10 years and 10% for only 1 to 5 years.

Table 1. The proportion of nurseries, methods used, and the history of sterilization/pasteurization practices in the nurseries surveyed.*

DO sterilize/pasteurize			DO NOT sterilize/pasteurize
76%			24%
Methyl bromide	Steam	Air-steam	
33%	24%	19%	24%
History of treatment			
1-5 years	6-10 years	>10 years	
10%	28%	38%	24%

* Curtis (2).

CHEMICAL WELFARE — CHANGING STRATEGIES

Pesticides are widely used by nurserymen even though little information is available about their use for specific nursery cultivars, pests, or environments. Most nurseries have a vast array of chemicals which are badly stored and poorly applied — often with scant regard for the safety of the applicator or the nursery hands working in production. The choice of an appropriate pesticide, its strategy of use, pest resistance, timing, and type of application equipment needed, plus public health and environmental issues are some aspects which require consideration when developing a plant protection programme.

(a) **Improvements in New Pesticides:** Over the years since synthetic agrochemicals have been available there have been great improvements in the rate of application and selectivity,

and knowledge of the potential for environmental distribution and accumulation and potential residue situations (3).

The rate of application of pesticides has steadily declined from the 1.5 kg per hectare for DDT in 1950 to the 100 g per hectare and even 20 g per hectare with the recent introductions of synthetic pyrethroids (Figure 1).

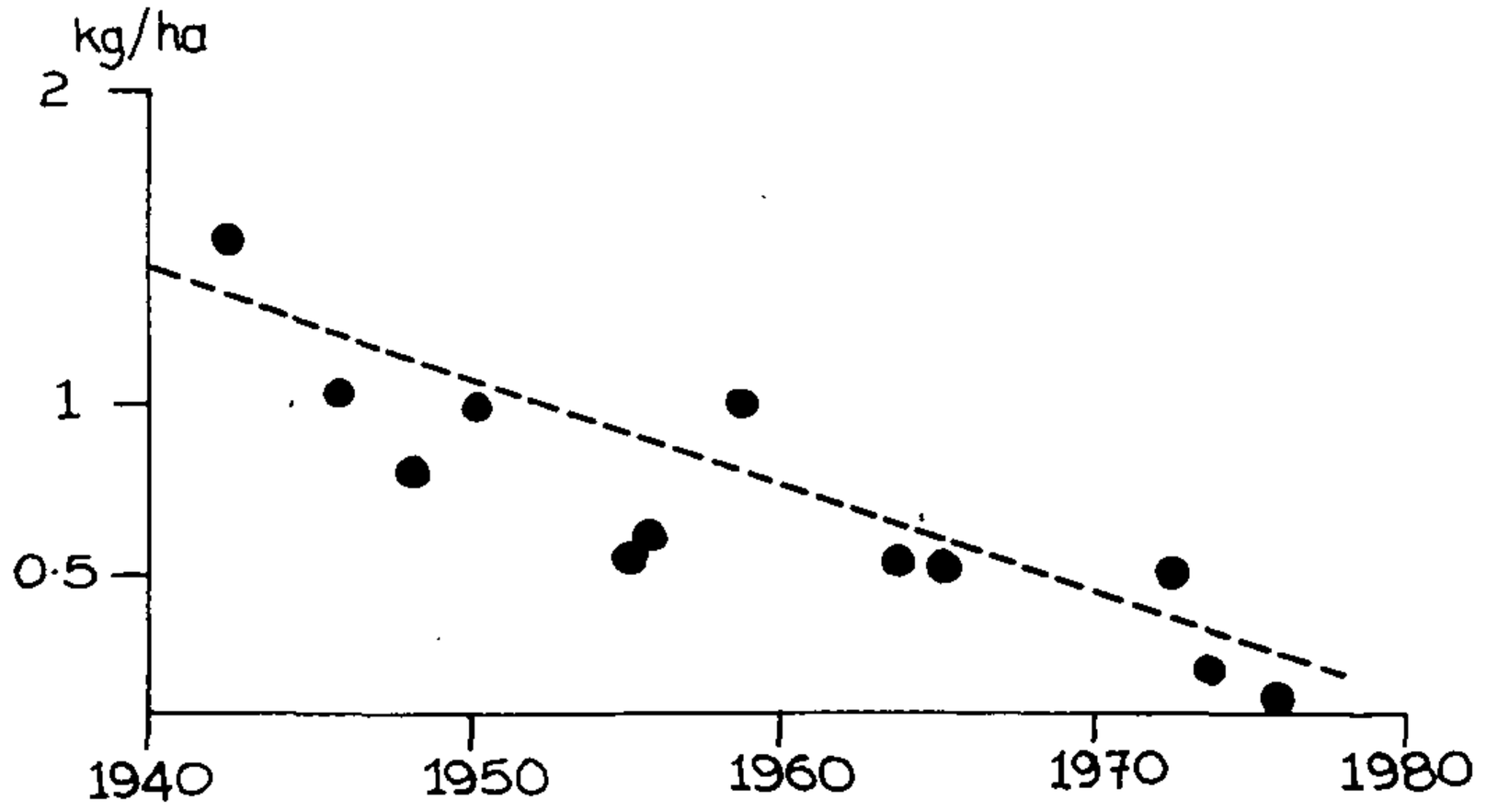

Figure 1. Evolution of rate of application of insecticides. Graph based on DDT (1942), parathion (1946), dieldrin (1948), diazinon (1951), azinphos-methyl (1955), dimethoate (1956), carbaryl (1958), chlordimeform (1963), monocrotophos (1965), diflubenzuron (1972), permethrin (1973), decamethrin (1975).

The potential of a chemical to be distributed and accumulated in the environment is determined by a number of physiochemical factors. The volatility and the ability of living organisms to gain access to and to accumulate it increases this potential. This potential is reduced by lower rates of application, by the more rapid degradation of the compound, and by its ability to be adsorbed onto soil particles. Water solubility may increase or decrease dispersal, depending on conditions. Figure 2 presents the above properties for a number of major insecticides. The decline of dispersal potential is demonstrated by a reduction of bar size and a shift of the bars towards the bottom half of the graph.

(b) **Application of Pesticides:** The pesticides available to the nurseryman have become more specific and selective in their activity. This in turn has demanded improved application techniques and the correct timing of chemical applications in relation to the stage of cultivar growth and pest activity if adequate pest control is to be achieved. Regular maintenance of equipment, operation of equipment in accordance with manufacturer's recommendations, and regular calibration of equipment are all necessary to ensure that the correct dose rate reaches the target.

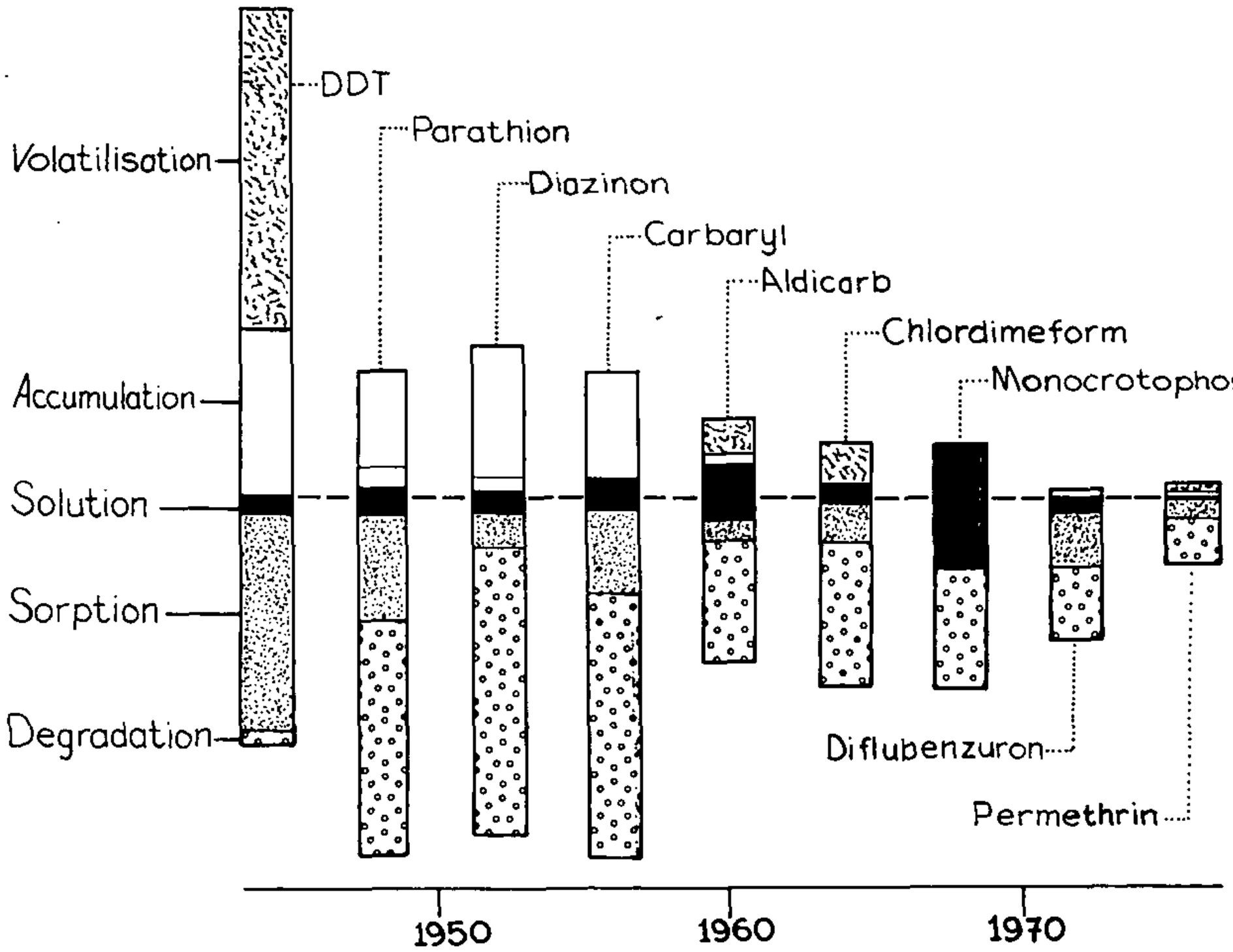

Figure 2. Evolution of the potential of insecticides to be distributed and cumulated in the environment. Compounds arranged according to time of introduction. The potential of a pesticide to be distributed and cumulated in the environment is reduced by a decreased rate of application (indicated by bar size), by the degradability of the pesticide and by its ability to be adsorbed on soil particles (sorption). Water solubility (solution) has a neutral position; it increases dispersal or degradation, depending on conditions. Thus the potential of the insecticides to be distributed and cumulated in the environment diminishes with decreasing size of the composite bars and with a shift of the bars toward the bottom half of the graph (3).

(c) Strategy of Chemical Usage: Strategies of use must aim to minimize the pressure on pests to develop resistance and to prolong the useful life of the pesticide. Better strategic use of such pesticides as the fungicides benomyl (Benlate) and metalaxyl (Ridomil) and the synthetic pyrethroid insecticides would have delayed the development of pest resistance to these useful and very active chemicals.

Major efforts must be directed at developing strategies to prevent or delay the build up of resistance, and such strategies must be implemented early in the commercial life of the chemical (6). Similarly, Bonar (1) has shown that nursery pests can develop resistance to pesticides very quickly, particularly under glass and with an over-dependence on chemicals for their control.

(d) Anti-Pesticide Pressure Group: Nurseries are industries in urban areas and draw their staff from such areas. In general terms urban societies do not favour the use of agricultural chemicals. The recent warehouse fires in Brisbane, Gatton, and Melbourne — all containing some agricultural chemicals — have only hardened the attitude of the anti-chemical groups. The community has the right to be concerned and demand protection from the indiscriminate use and sometimes blatant misuse of hazardous chemicals. The nursery industry does not have a clean record in this regard.

The real concern is that unless the hazard record of the manufacture, storage, distribution, and use of agrochemicals is improved then political pressure will result in restrictive legislation. This will mean fewer pesticides and greater restrictions on their availability and use. The anti-chemical lobby is well organized and has greater political clout than the nursery industry and farming associations.

There is support among research personnel to see the availability of the more hazardous pesticides restricted, and perhaps for some form of licensing of people at the point of recommendation, sale, and application.

(e) Alternatives to Synthetic Pesticides: Alternatives which appear to have the greatest potential in the short term are products based on insect diseases such as *Bacillus thuringiensis* (DIPEL), nuclear polyhedrosis virus (ELCAR) and, in the United Kingdom, *Verticillium lecanii* (a disease of aphids). Researchers are working towards more virulent strains and a broader spectrum of insect activity as a result of genetic manipulation (4).

Insect pheremones are finding use both in mating confusion and population monitoring in cotton budworm and pink bollworm, codling moth of apples, and the carnation tortrix, a nursery pest in the United Kingdom (8). The use of pheremones and insect diseases increases the complexity of plant protection programmes and broadens the control measures available in the nurseryman.

(f) Biological Control: This technique utilizes a beneficial organism to control pests by predation or parasitism. A limited range of beneficial organisms are available in Australia for use by the nursery, citrus, deciduous fruit, and vegetable industries.

The predatory mite, *Phytoseiulus persimilis*, has afforded control of outbreaks of two-spotted mite in nurseries, and parasites for mealy bug control should be available in late 1985. The nursery production system with its diversity of cultivars should favour the development and maintenance of a

plant protection programme integrating pesticides compatible with the biological components. Nurserymen must learn how to manage such an integration without any reduction in cosmetic quality of the cultivars produced.

(g) Pest Monitoring: This involves the regular monitoring of susceptible cultivars for the presence, numbers, and stages of pests and beneficial species. These counts are related to the stage of growth of the crop, the environmental conditions, the life cycles of the pests and beneficial insects, and the nearness of the market. Pesticides are only chosen for a specific need and applications are only made when pest pressures demand treatment.

Monitoring techniques which take into account specific nursery pests and cultivars will need to be developed to continue to meet the cosmetic demands on the industry's products. Any resultant reduction in the number of sprays and release of labor for more productive activities can mean the difference between a profit or loss on a particular commodity.

PLANT PROTECTION PROGRAMMES

The development of plant protection programmes will be based on sound growing conditions for the cultivar(s) and the broad principles of hygiene. They will incorporate the use of biological control with the application of compatible pesticides based on the monitoring of pest and beneficial populations. The success of an integrated plant protection programme is dependent upon regular monitoring and the strategic application of compatible pesticides. Some extracts from such a programme for the integrated control of pests on ayr chrysanthemums in the United Kingdom are presented in Table 2 (5).

Table 2. Extracts from action sheet used in conjunction with weekly monitoring data of integrated pest control programme for ayr chrysanthemums for cutting.

Weeks after planting out	Pests to be observed	Pest threshold requiring action	Action if threshold exceeded
1	Leaf miner spots or miners	More than 5% plants affected	Diazinon spray
	Aphids in growing points	1 aphid per 2 plants	Spray of pirimicarb, nicotine or pyrethrum resmethrin
3	Thrips in growing points	1 adult per 50 plants	Spray nicotine
	Thrips in growing points	1 adult per 50 plants	Spray nicotine

Table 2. Continued

5	White and healthy aphids (check beneath leaves)	Any live aphid	Give second spray of *V. lecanii* to isolated patches if rest of bed showing white bodies, otherwise spray nicotine
	Thrips in growing points	1 adult per 50 plants 1 adult per 10 plants	Spray nicotine Spray diazinon
	Leaf miner Get parasitism checked by ADAS	If less than 95% parasitism and more than 5% plants attacked	Introduce 10 parasites 1,000 plants or spray diazinon
	Caterpillar holes or tatters in leaves	Any damage	Spray *B. thuringiensis* this week in preference to next
7	White and healthy aphids (beware immigrations)	Any live aphid	Spray pirimicarb for shiny brown aphid, nicotine for other aphids, diazinon if thrips present
	Thrips in buds	Any live thrips	Spray diazinon
	Leaf miner spots or mines	As for 5th week	As for 5th week
	Caterpillars	Any increase in damage	Fog *B. thuringiensis* and include the disease with all future *V. lecanii* sprays
	Red spider mite and predator	1 to 5 mites per infested leaf	There should be 1 predator every 5th infested leaf, purchase extra predator if there is a presence but below threshold

PROFESSIONAL PLANT PROTECTIONISTS

To operate a plant protection programme based on pest monitoring, a biological component and compatible agrichemicals will require special technical input.

YES! A major chance in pest control in the nursery industry will be a move to the integration of control practices plus the employment of professionals — people qualified in pest biology and population dynamics, agricultural chemicals and pesticide application, who also have an understanding of public health and the environmental constraints on pest control. You will contract this professional to monitor pest and beneficial insect activity at frequent intervals depending on the season, the pest, and the stage of growth of the cultivar(s).

NO! You will not lose control of your operation. You will receive a written report containing details of pest and beneficial insect populations, predicted changes in the populations, current level of damage, advice on compatible pesticides, and recommendations of what, when, where and how to spray. The decision is still yours.

The plant protection consultant will work closely with the manager or owner and will develop and fine-tune techniques for the monitoring of populations and damage and the provision of advice on the-timing and placement of chemical applications. Consultants will not have your knowledge of the cultural requirements of your cultivars but will add detailed knowledge on your pests, co-operate in developing techniques, warnings, and advice to your benefit.

CONCLUSIONS

The last ten years have seen rapid change in the nursery industry — the development of large retail garden centres, the development of new propagation and production techniques, and a more intensive and sophisticated level of production and management. Experienced marketers are employed and export markets are being sought. To keep pace with the changing management and the demands of new markets the nursery industry need to upgrade its approach to pest control and reduce its dependence on regular scheduled applications of pesticides by the adoption of integrated plant protection programs and the employment of professional plant protectionists.

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THE ROD TALLIS MEMORIAL AWARD

This award was set up in memory of the late Rod Tallis, a young Sydney nurseryman who had been very active in IPPS.

The award is offered each year to persons under 25 in the State where the Conference is being held. Young people in nurseries, educational institutions, and government departments, who have an interest in plant propagation, are invited to apply.

The applicants, who need not be members of IPPS must outline why they should be given the chance to attend the IPPS Conference. They also need to present a biography and to outline their interest in horticulture and plant propagation.

The winner of the award attends the Conference as a guest of the Society and must prepare a paper for presentation at the Conference. The winner also receives a book award.

In 1985 Peter J. Lewis, a recent graduate in horticulture from the Queensland Agricultural College won this year's award and presented the following paper:

THE POTENTIAL FOR GRAFTING IN THE PROPAGATION OF AUSTRALIAN NATIVES

PETER J. LEWIS
37 Sorbiston Street,
Wellers Hill, Brisbane
Queensland 4121

INTRODUCTION

Australia is the custodian of an amazing diversity of native plants. This diversity is linked with the widely varying

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environments that cover Australia. From the tropics of the north, the deserts in the centre and the west, and the alpine areas of the south, the natural environment is constantly changing.

As a native plant collector, I would like to be able to collect selected natives from these environments and successfully grow them together in one place. By achieving this I can share with other people the beauty and distinctive habits of species such as *Eremophila maculata* from Western Queensland, *Prostanthera magnifica* and *Banksia coccinea* from Western Australia. If these species from vastly differing environments are to be grown together however nature alone cannot be relied on and it becomes necessary to lend a helping hand. One method that has proven effective is the ancient art of grafting.

The greatest value of grafting lies in the propagation and production of disease resistant plants. The root rot fungus, *Phytophthora cinnamomi*, has long been the scourge of the horticultural industry, particularly in the nursery and cut flower industries. Now native plant nurserymen and enthusiasts of Southeastern Queensland have been able to enjoy the spectacular displays of *Grevillea dryandri*, *G. longistyla*, and *G. wickhamii* simply by grafting these tropical and inland species onto the phytophthora tolerant rootstock, *G. robusta*.

Western Australian banksias have long been noted for their attractive foliage and inflorescences, but most of the desirable species are susceptible to the root rot fungus, *P. cinnamomi*. Researchers are now starting to obtain results from grafting projects however, as highly desirable species such as *Banksia occidentalis* and *B. speciosa* have been successfully grafted onto the tolerant east coast species, *B. integrifolia*. This is good news for the cut flower industry (3).

The cut flower industry could also benefit from other initial grafting experiments. *Chamelaucium uncinatum* (Geraldton wax flower) a popular cut flower in Southeast Queensland has it cultivation problems, notably longevity of shrub life after two years. However, it has been successfully grafted onto the tolerant local species, *Baeckea virgata*. This also indicates that some native plant species can be successfully grafted onto closely related genera.

Intergeneric grafting could prove to be a large plus for the native plant nurserymen who are continually seeking plants that are showy, unusual, and easy to grow. Two largely unexplored genera of native plants that fit this category are the eremophilas and prostantheras. For example, an *Eremophila* sp. from the McDonnell ranges grows to 0.5 x 1 m, and has

masses of dark blue flowers for most of the year; this is an ideal specimen for a rockery. This species has performed remarkably well in the sub-tropical conditions of Brisbane when grafted onto *Myoporum insulare* rootstock. *Prostanthera magnifica*, the species with the largest flowers of the genus is growing beautifully in similar conditions after being grafted onto a hardy local species, *Westringea fruticosa*. These are only two possibilities, out of many different species.

For nurserymen, the weeping standard, *Grevillea* 'Poorinda Royal Mantle' grafted onto 2 metre *G. robusta* rootstock is increasing in popularity every year, even though it is a high priced nursery item. They are reaping the rewards of work done on grafting native plants at the Australian National Botanic Gardens in Canberra in 1971.

Grafting can also be used for the preservation of rare and endangered species, such as Western Australian banksias. It can also be used for new plant hybrids or variants that are difficult to grow using normal macro and micro propagation procedures.

GRAFTING TECHNIQUES

Many of the different grafting techniques have worked successfully on Australian plants. The most popular techniques being the simple approach graft and the top wedge graft.

(i) Approach Grafting. Approach grafting is the safest grafting method and the best to use on species that have been collected from their natural environments. The plants are transplanted into large nursery containers in such a way that root disturbance is minimized. In this state they can be transported to the nursery and maintained. A suitable rootstock is then introduced into the container and the approach carried out.

Approach grafting is a slow process taking approximately 8 weeks to complete under favourable conditions. After the scion has been cut away from its own rootstock, the grafted plant can be removed and planted in favourable local conditions. Most of the Central Australian and Western Queensland eremophilas and prostantheras have been introduced into Brisbane in this manner. This technique has given the best success for their introduction into the new environment. In their natural environment there is not the quality of material required for other grafting techniques. For example, *Prostanthera megacalyx* has been successfully approach grafted but not top wedge grafted. The plants we are using are original plants from their natural environment.

(ii) Top Wedge Grafting. Top wedge grafting is chiefly used to increase numbers of the species that have adapted and thrived in their new environment. The technique is very simple and straight-forward, though a word of warning is required for two steps. The matching of the scion and rootstock is vitally important. Without cambium alignment on both sides, grafting success is notably lessened. The scion and rootstock must have approximately the same stem diameter.

The ideal scion has only 2 to 3 dormant buds, with the top bud at the bud break stage. Trim all leaves off the scion so as to minimize transpiration loss.

For tying the graft, the use of Parafilm®, a biodegradable paraffin tape, is preferred over the conventional grafting tape. It is waterproof, gives a tight bind around the graft, and breaks down over time thus eliminating the need to cut the binding away from the graft. Two other grafting techniques as described by Burke (1) which could be applied to natives, are the top cleft cutting-graft and side cleft cutting-graft. These methods have been used extensively with camellias and hibiscus and have brought about a significant labour reduction in the mass production of grafted plants.

The grafting of the Geraldton wax was a special case. The best success was achieved when a large cutting of Geraldton wax was approach grafted onto the *Baeckea virgata* rootstock. The cutting was simply pushed in beside the rootstock with minimum foliage removal and grafted. With this graft technique a success rate of 90% has been achieved.

PROBLEMS

(i) Time of Year. For grafting to be economical, the graft success rate should be as close to 100% as possible. Each species has its peculiarities and it is only by regular grafting attempts and careful monitoring that the best time and appropriate techniques will be found. To give an example, *Grevillea dryandri* is difficult to graft while it is budding and flowering. This usually occurs in late autumn in Queensland.

(ii) Incompatibility. Incompatibility is beginning to show as a problem, especially when grafting different genera together.

Symptoms of incompatibility include;

a) marked differences in growth rate or vigour of scion and rootstock.

b) failure to form a successful graft in a high percentage of cases.

c) overgrowths at, above, or below the graft union. (2)

The last symptom is becoming noticeable in the grafted *Eremophila maculata.* (2 year old) forms onto *Myoporum insulare.* The scion is approximately twice the diameter of the rootstock, so effectively the plant is becoming top heavy with the graft being the weak spot. The plants need to be staked in exposed areas to prevent graft breakage. We must now look for other compatible local rootstocks that will overcome this problem.

(iii) Rootstock Selection. We must select rootstocks that best suit our future cultural requirements. Where possible, choose a local species that has performed reliably in the intended environment. For Brisbane environments, *Grevillea robusta* is ideally suited as a rootstock for Grevilleas in home garden situations. It has displayed tolerance of high phosphorus levels, the fungus *Phytophthora cinnamomi*, has shown no noticeable incompatibility problems after 8 years, and grows well in the poor soil conditions of the typical suburban garden.

(iv) Scion Selection. Some species, even though grafted, still do not perform well. We must only select the species that grow well in their new environment. Continuing with poorly adapted species will only lead to a poor representation of it and disappointment. For a local example, the Western Australia *Eucalyptus ficifolia* is susceptible to leaf pests and diseases in Southeast Queensland even though they are grafted.

CONCLUSION

The ultimate potential of grafting Australian native plants has not been fully realized at present. A co-ordinated effort is required from research personnel and concerned industries on this conventional propagation technique. The potential benefits have been illustrated by the results achieved in the temperate and exotic tropical fruit industry, both in varietal and monetary terms.

Researchers in Western Australia (3) and many other individuals have shown initiative.

Acknowledgements. The author wishes to thank Mr. Harvey Shaw for his invaluable advice and assistance.

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THE HYDROVAC THEORY: WILL IT WORK TO ROOT CUTTINGS?

ALAN SUBRITZKY

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INTRODUCTION

About four years ago a South Auckland nurseryman began investigating the use of some kind of controlled environment for the transfer of tissue culture material. This led to attempts to alter the air pressure inside the cabinet. This often resulted in the cabinet blowing up or collapsing inwards. Several cabinets were constructed and discarded, until finally two units, one constructed of steel, the other of aluminum, were considered to be satisfactory. Aluminum was tried because of its light weight. The aluminum cabinet weighed 240 kg compared to the steel unit which weighed 360 kg.

In February 1985 Hortex was approached by the inventor to trial this unit, which he believed would revolutionize propagation methods as we know them today.

Hortex agreed to trial the invention and this paper outlines the machine, its principles and the trials carried out in it.

This cabinet differs from other controlled environmental cabinets in that it is completely sealed, and the pressure inside it can be varied from 0 to minus 14.7 KPA.

DESCRIPTION OF THE HYDROVAC UNIT

The cabinet trialed was the steel unit and it was coated with enamel. It was 2 metres long, 1 metre wide, and 1.9 metres high. It had four shelves which held up to 2500 cuttings in trays. (Figure 1).

The vacuum is controlled by a time clock and is applied by a suction pump with four non-return valves evenly spaced up one side of the cabinet. The vacuum is adjustable between 0 and minus 14.7 KPA.

The cuttings in their trays are flooded by a nutrient solution which is pumped into the support trays by a submersible pump from a 200 litre nutrient tank at the base of the cabinet. The solution drains back to the tank by gravity. This nutrient solution kept the humidity high and there was no need for mist.

Light was provided by two fluorescent tubes above each shelf. These were on a time clock which allowed the day length to be varied as required.

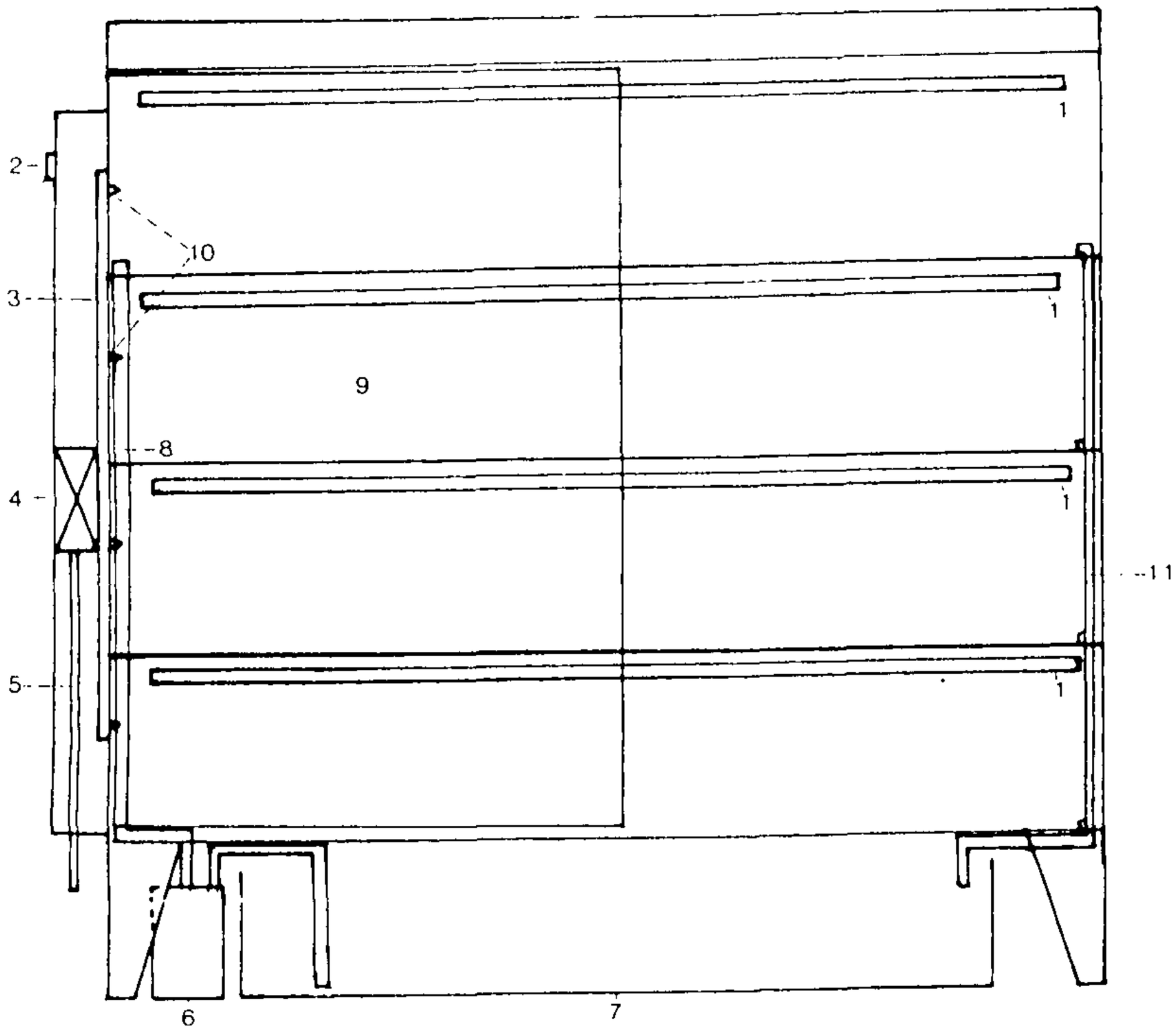

Figure 1. Key:

1 Lights	7 Nutrient tank, 200 ltr capacity
2 Controls	8 Flow pipe
3 Vacuum pipe	9 Door
4 Vacuum pump	10 Non-return valve
5 Exhaust	11 Drain pipe for returning solution
6 Pump	

CUTTING TRIAL

Only one trial has been carried out to date and this was set up on 11 March, 1985, and was run for 21 days; 1600 cuttings were used, and all had a 5 sec. quick-dip in a 3000 ppm IBA solution.

The plant material used was:

500 *Actinidia chinensis* 'Hayward' (kiwifruit)

500 *Feijoa sellowiana* 'Mammoth' (feijoa)

500 *F. sellowiana* 'Triumph' (feijoa)

100 *Daphne odora* 'Rubra'

Half of the cuttings of each cultivar of kiwifruit and feijoa were set into 54 flix propagation trays in a medium consisting of 9 parts pumice and 1 part peat moss. The other half were set in Growool slabs.

The daphne cuttings had been set for four weeks before the trial commenced. They were in trays in 9 parts pumice and 1 part peat moss. Only two trays were placed in the cabinet and these were compared to two trays left in the propagation house.

The cuttings received one nutrient flow every 24 hours at 8:30 a.m. They received a 15-hr. day with the light being on from 5 p.m. till 8 a.m.

The vacuum was on for 75 min., off for 15 min. and then on and off at 15 min. intervals for the next 75 min. This cycle was repeated on a 24 hr. cycle. The door was removed after 3 days and the cuttings inspected. The trial was completed on 1st April after 21 days.

RESULTS

After 21 days the cuttings were not in good condition. The results were not encouraging. All but a few of the feijoas had dropped their leaves as had approximately half the kiwifruit cuttings. The daphne cuttings, however, were in good condition.

Most of the feijoas were decaying at the base. Some had started to swell and form a callus but only one had produced a root. With the kiwifruit the results were better. There was a 41% strike in the pumice and peat media and a 28% strike in the Growool. The cuttings were left in the shadehouse for 7 days before they were tubed.

Of the daphne cuttings, 84% had rooted in the cabinet after 21 days, compared to only 46% of the control in the conventional propagation house.

DISCUSSION

The 41% strike of the kiwifruit cuttings was poor when compared to the 90% usually obtained in conventional propagation houses. These results, however, were obtained in four weeks compared to the usual 10 to 12 weeks.

There was a problem with the shelves buckling under vacuum and causing ponding. When this occurred basal decay of the cuttings was much worse.

It was thought that the light intensity of the fluorescent tubes may have been too high and this may have caused degeneration of the cuttings and led to leaf drop.

Although the feijoas gave a very poor result one cutting rooted in three weeks. For anyone who has propagated feijoas they will realise that this is a very short time. Also the amount of swelling on the base of the feijoa cuttings indicates that the

healing process of the wound may have started immediately. The end result may have been quite different if decay had not set in.

CONCLUSIONS

The hydrovac being only a prototype needs many modifications before the vacuum theory can be proved one way or the other.

A dimmer switch may be needed to reduce light levels, which possibly would reduce leaf drop.

The shelves need to be reinforced to prevent buckling under vacuum which caused ponding of the nutrient solution and led to root decay.

A glass panel is required in the door so the cuttings can be observed at any time.

The door needs to be modified, as it is attached by 6 wingnuts making it awkward to replace and obtain an effective seal. This may be achieved by something similar to a coolroom door for ease of operation.

The limited results from the first trial are not a fair indication of whether the vacuum does encourage root initiation or not. What is clear is that roots were produced much quicker in the hydrovac, than in conventional propagation houses. There is sufficient encouragement from these preliminary results to continue testing the vacuum theory.

PROPAGATION OF *PIERIS JAPONICA*

ED AND GWEN ARTLETT

Taihoa Nursery
Mt. Wilson, New South Wales 2785

We have a small, cold climate nursery about 820 metres above sea level. We have developed a method of producing a reliable crop of *Pieris japonica* which has proved to be very successful.

It is essential to have healthy stock plants, as the percentage strike falls if the stock plants are neglected. Cuttings are taken in late summer or early fall (February and March and even in April), but the percentage strike falls if the outside temperature drops below 20°C.

Tip cuttings are collected in the early morning. Cuttings of a uniform length are taken for each cultivar (an abundance of stock material is required to do this). The cuttings are treated

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Tip cuttings are collected in the early morning. Cuttings of a uniform length are taken for each cultivar (an abundance of stock material is required to do this). The cuttings are treated

with a basal dip of liquid IBA at 5000 ppm for 5 sec. Cuttings are not wounded and only sufficient basal leaves are removed to allow the cuttings to be inserted into the propagating medium.

The cuttings are placed in Growool propagating sheets, size PB 25-40. Three sheets are placed in a standard punnet tray holding 108 cuttings. The trays of cuttings are placed on a sand bed in the polyhouse. The trays have large square holes and this allows good capillary contact with the Growool, which is essential, as well as providing good drainage.

No mist is used and bottom heat is used only when the temperature falls below 25°C. Roots appear in about four weeks. The bottom heat is kept on until there is good root development. In mid-winter (mid-June to early July), the bottom heat is turned off, and the cuttings are hardened off. They are moved to a bushhouse, still keeping the trays on a sand bed to enable good contact with the Growool.

In early spring (September) the cuttings are potted up into 125 mm pots and are ready for sale by autumn (March) of the following year. Plants in 200 mm pots take about 2 years.

The potting mix used is a sand/peat mix with Nutricote 40-day slow-release fertiliser, dolomite lime, and FTE 36 fertilisers added. Liquid fertiliser is also used.

Table 1. Percentage strike achieved for six *Pieris* cultivars using Growool as a rooting medium.

Pieris japonica	85%
P. j. 'Christmas Cheer'	95
P. j. 'Variegatia Nana'	95
P. j. 'Foresti'	80
P. j. 'Bert Chandler'	90
P. j. 'Florabunda'	90

Results have improved dramatically since we began to use Growool. Its use has cut production costs, because previously cuttings were struck in community trays, time was taken to break out the roots, and plants were very much slower to pot up. Growool is much quicker on the potting machine and transplant shock has been reduced.

PROPAGATION OF TROPICAL AND SUBTROPICAL GREVILLEAS

ROBERT L. DAWSON

Utingu Native Plant Nursery
37 Sorbiston Street
Wellers Hill, Queensland 4121

The plants grown at our nursery have been collected from a wide variety of sources. These include plants from enthusiastic native plant collectors, from members of the Society for Growing Australian Plants, other nurseries and, more recently, from hybrids, which have occurred naturally in most cases in gardens.

Grevillea's generally hybridize very readily and seedlings that have come up in gardens in and around Brisbane are the source of many of the hybrids in cultivation.

The majority of the tropical grevillea's are grown from cuttings, which appear to be superior to seedlings. They flower much younger than seedlings, usually in the same season, and have uniformity in flower colour and growth habit.

Evaluating new plants for use in our production is done in several ways. Plants are grown in large shrub tubs, and in the ground in display gardens at the nursery. Plants that show any new and interesting features, for example, reliability, free flowering, new and interesting flower colour, interesting foliage, and pest and disease resistance are used as mother stock. Cuttings are taken and hopefully rooted to establish stock of mother plants to begin building up sufficient numbers for release to the trade.

MOTHER STOCK

Tropical and sub-tropical grevilleas show varying degrees of difficulty when propagated from cuttings. The most important thing in propagating these plants is to have good, healthy, fresh cutting material. To achieve this, hygiene and management of mother stock is essential.

The mother stock plants are grown in large shrub tubs or in the ground. Cuttings are also taken from young plants growing in the nursery for sale. This method promotes bushy growth in the young plants and also provides good, fresh, propagation material and helps build up the numbers of new plants more quickly.

The mother stock plants are pruned heavily from the time they are potted. After pruning, a high nitrogen fertilizer is applied to keep the plants growing vigorously, thereby maintaining good supply of fresh vigorous cutting material, relative-

ly free from leaf and stem diseases. Mother stock plants are disposed of after 18 to 24 months and replaced with fresh young plants.

It cannot be emphasized too strongly the importance of good hygiene in every stage of the propagation of grevilleas. Sanitation procedures used are: tubes and trays are soaked in a solution of sodium hypochlorite; benches and tools are sterilized daily; heated benches are drenched regularly; a foot bath is placed at the propagation house door to help prevent pathogens being brought into the propagation house via workers boots; and propagation media is steam pasturized. Every precaution is taken in all steps in the propagation process to minimize the infection of cuttings.

The cuttings are taken from stock plants throughout the whole year. Fresh growth is taken — usually in the morning — and kept cool and moist while being transported to the preparation room. Here the material is cut into two to four node cuttings with the bottom leaves being removed and, in most cases, the remaining leaves are trimmed to about half their original size. This helps reduce transpiration and overcrowding in the tray of tubes. The ends of the cuttings are then dipped in a hormone rooting solution of varying strengths to suit the type of material and plant being propagated. After the hormone treatment the cuttings are inserted into individual 50 mm plastic tubes and placed on heated benches in a warm, humid, misted — but well ventilated — greenhouse. After being placed on the bench the cuttings and tubes are drenched with a fungicide. The cutting rooting mixture used is perlite (60%) and peatmoss (40%). After pasturisation a slow release fertilizer is mixed in at about one-tenth the recommended rate. This gives the cutting some nutrition once struck. After the cuttings have struck they are moved to a poly-covered igloo and are irrigated daily until new growth is evident. From the igloo they are moved to a 50% shadehouse until they are ready for potting on.

The potting medium used is a mixture of sand 40%, hardwood aged sawdust 40%, and pinebark flakes 20%. To this, Nutricote — a slow release fertilizer — is added at the recommended rate. Extra care is needed with grevillea's when potting to avoid root damage. After potting, the plants are put out in the full sun and an application of Ronstar® (oxadiazon 2%) pre-emergent herbicide is applied to the top of the pots.

The popularity of all types of sub-tropical and tropical grevilleas is increasing because they are some of the fastest growing and most spectacular, free flowering Australian native plants. One in particular, *Grevillea* 'Robyn Gordon' has been

one of the most popular native plants to be grown in recent years, because of its rapid growth, all year flowering, and proven reliability in a wide range of climatic conditions.

The native nectar-feeding birds are welcome visitors to any garden and the sub-tropical and tropical grevilleas, such as *G.* 'Misty Pink', *G.* 'Pink Surprise', *G.* 'Sandra Gordon', *G. banksii*, *G. pteridiifolia*, *G.* 'Honey Gem', *G.* 'Starfire, *G.* 'Pink Parfait', *G.* 'Ned Kelly', etc., are excellent plants for attracting these birds. The hybrids with their showy, vividly coloured flowers, are very good for use in floral displays and arrangements. The flowers last at least as well as most common cut flowers and, because they flower for most of the year, there is never any shortage of fresh flowers.

Their use in parks and public gardens, in private gardens, and as roadside planting would result in an abundance of colour and nectar-feeding birds and animals.

With such a wide range of flower colours and growth habits there is a tropical and sub-tropical grevillea, or hybrid, for every garden and landscape.

HIBISCUS PROPAGATION IN COOL CLIMATES

WELLS A. EDEN[1]

Charman Road Nurseries Pty. Ltd.
1/19 Taylor Street
Parkdale, Victoria 3195

In earlier years, Melbourne nurserymen usually propagated *Hibiscus rosa-sinensis* cultivars in late winter to early spring from hardwood cuttings taken from established garden plants. Results were quite often variable and unreliable, particularly with less hardy cultivars, due to frosty conditions affecting the parent plants.

When the struck cuttings were potted into 125 mm pots they generally did not attain saleable size until early summer, thus missing out on late spring sales.

With experimental batches of cuttings taken during summer and autumn, I found that success rates with soft tip and vigorous stem cuttings were much better and more predictable.

A strike rate of 90% to 95% was achieved consistently with soft tip cuttings approximately 100 to 125 mm long. An

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IBA in talc (0.5%) cutting powder was used over a range of both common and Hawaiian cultivars.

Table. 1 *Hibiscus rosa-sinensis* cultivars used in the trial.

Hibiscus rosa-sinensis cultivars:		
'Mrs George Davies'	'General Courteges'	'Agnes Galt'
'D. J. O'Brien'	'Cameo Queen'	'Wilders White'
'Mrs Tomkins'	'Sabrina'	'Wrightii'
'Andersonii'	'Copper Queen'	'Johnsonii'
H. rosa-sinensis Hawaii cultivars:		
'Surfrider'	'White Kalakua'	'Covakanic'
'Catavki'	'Miss Veno'	'Mary Forbes'

To obtain sufficient suitable cutting material, a quantity of selected plants from the spring crop were potted into 200 mm pots in early summer (early December) and grown inside a polythene igloo, which had been coated with Parasolene® glasshouse paint on three separate occasions. The igloo was well ventilated on sunny days to prevent overheating, and the plants were liquid fertilised to maintain rapid growth. Cuttings were harvested from mid-summer to mid-autumn (late January to the end of April).

Prior to preparation, the cutting material was immersed for 30 to 40 sec. in a solution of Aliette® fungicide (fosetyl 74%) at the rate of 10 grams of product to 10 litres of water. After preparation, the cuttings were dipped in a 0.5% IBA in talc, and then placed in plastic trays in a steam sterilised medium of 4 parts coarse river sand to 1 part German peat moss.

The propagation house was a conventional glasshouse with thermostatically controlled ventilation, and heated benches 65 cms above the floor. The 200 mm deep sand propagating beds were heated by basal hot water pipes at 100 mm centres and bench temperature was thermostatically maintained at 22°C. The mist system was controlled by an artificial leaf and pivoting balance arm. Benches for establishing stock after tubing were constructed of asbestos cement sheet over thermostatically controlled heating pipes, without misting sprinklers.

Healthy root development occurred after 4 to 5 weeks during summer and early autumn but took longer as daylight hours grew shorter and sunlight intensity decreased in late April and May. Strong, vigorous cuttings with good root development were potted into 75 mm tubes, whilst smaller cuttings were potted into 50 mm tubes; both sizes were placed on the heated bench without mist and kept in the glasshouse for a further two to three weeks until well established in the tubes.

Subsequently they were transferred to a polythene igloo and placed on wire mesh benches 100 to 150 mm above the floor. This procedure maintained hygiene, promoted air pruning of root systems, and insulated them from the cold ground temperature over winter.

Electric fan heaters within the igloos maintained a minimum air temperature of 10°C during winter, enabling the plants to carry through in good condition ready for potting on into 150 mm pots in August. Igloos were of double skin construction giving extra protection from extreme cold conditions.

After potting on, the plants were grown on in the igloos and by early October some of the better developed plants were suitable for moving on into 200 mm pots. The remainder of the crop was ready for sale in late October to early November and the 200 mm pot size saleable by December. Regular fortnightly sprayings for fungal control was carried out during winter and spring with alternate applications of Rovral® (iprodione) and Aliette®.

Hibiscus require high nitrogen levels during spring and summer to attain maximum growth, therefore a weekly or fortnightly liquid feeding programme was essential.

This method of propagation has enabled *H. rosa-sinensis* to be propagated during autumn and winter ready for sale in spring, with a high degree of success.

VEGETATIVE PROPAGATION OF HYACINTH

JOHN H. COLWELL

Little Acre Wholesale Nursery
11 St. Georges Avenue
Montrose, Victoria 3765

The hyacinth *(Hyacinthus orientalis)* is a member of the Liliaceae family and is a native of the Mediterranean and Asia Minor. It is called the Dutch hyacinth and is a true bulb. Bulbs are highly modified underground structures which are made up of swollen leaf bases. These tissues hold food reserves which are used for the growth of the plant.

Except for the specialist bulb producers, few people have any knowledge of hyacinth propagation. Only a few books on propagation carry any reference to them, and their morphology is not well understood.

The main areas of bulb production in Australia are Victoria, New South Wales, and South Australia. Hyacinths are produced for use as pot plants and for the home garden.

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The main areas of bulb production in Australia are Victoria, New South Wales, and South Australia. Hyacinths are produced for use as pot plants and for the home garden.

In Australia they bloom in late winter and early spring (August to September), but this period may be extended by cold storage treatment. The range of colours is white, yellow, orange, red, pink, mauve, and blue. Flowering height is about 20 cm.

Harvest. Hyacinth bulbs are harvested when the foliage turns yellow. They are dried rapidly after harvest to ensure that losses from fungi do not occur.

Storage. Bulbs are best stored at 23 to 30°C. Storage below this leads to a stunting of flowers.

In New South Wales and South Australia producers prefer natural drying but in Victoria, where climatic conditions are usually more humid, artificial drying methods are used.

Propagation. Only the very best quality bulbs should be used for propagation. Bulbs 17 to 19 cm in circumference are used, as smaller bulbs produce stunted plants.

Hygiene, as with all propagation, is of prime importance. Bulbs are surface-treated with sodium hypochlorite, using 150 mls of 13% solution to 50 litres of water. The bulbs are dipped in this solution for two minutes. All tools and surfaces are also cleaned and surfaces sterilised with methylated spirits. The floors and trays are washed with Biogram®, using a 1% solution.

If a nematode treatment is necessary the hot water treatment used can cause much physical damage to the flowers, so it is much better to carry out this treatment at propagation time, as discussed later.

Two methods are used for the propagation of hyacinth. One involves cutting or scooping out of the basal plate with a curved blade or a blade type drill set in the bench. When using the latter, great care should be taken when placing the bulbs over the blades. The aim of this method is to expose the scale leaves so that adventitious bulblets may develop.

The second and most used method, is called scoring. This is done by making three deep cuts into the basal plate of the bulb so as to cut the growing point and so stop the flower from developing. For this method a block of wood with a three-bladed tool set into it is used. This allows for a greater output, but again care must be taken when pushing the bulb down onto the blades.

Some propagators cut "V" sections instead of straight cuts. This leads to somewhat larger bulblets forming than with the straight cuts.

With both of these methods the aftercare is the same, although the number of bulblets produced is different.

Scooped bulbs may get 50 to 70 bulblets but they will take 4 to 5 years to produce a flowering sized bulb. This method is usually only used for the production of a new cultivar.

Scored bulbs give 20 to 30 bulblets which only take three years to produce flower-sized bulbs. Using this method, bulbs are into production more quickly.

After cutting, bulbs are placed in slatted trays in a dark room, which has been sterilised for the common pathogens. The temperature is kept at 21°C for one week and then gradually increased to 30°C over a few weeks. Humidity is important and is maintained between 80 and 85%. These conditions are maintained for a period of 10 weeks while the bulblets form.

The humidity is then gradually lowered to 50% over the next week in readiness for planting out.

Planting out. The bulbs are ready for planting out in late autumn (early May). The soil used is a good, friable well-drained type which has been enriched with 50 to 80 M^3 of chicken manure per hectre or 3 tonnes of blood and bone meal per hectare.

Newly propagated bulbs are planted at a depth of 12 cm in rows or using a block system.

All bulbs are lifted each year and graded. In the second year they are treated for nematodes.

Large bulbs are planted 15 to the metre, and small bulbs up to 60 to the metre run. Large bulbs should be planted by hand and must be planted upright at a depth of 12 to 15 cm, or flower quality is affected.

Diseases and pests. Hyacinth, like many other plants, have a range of diseases and pests that can cause losses in production. The following affect production in Australia.

Yellow Disease. This is a bacterial rot — *Xanthomonas hyacinthi* — and causes a yellow ooze to form and the bulbs decay. If the bulbs are infected before planting they produce no plant above the ground. When the bulbs are cut open the yellow ooze exudes from the centre. Infected plants will have yellow and brown stripes on the stem and flowers.

This disease is spread by wet conditions. Staff should never be allowed to work on the crop when the foliage is wet.

To control Yellow Rot, rogue very carefully and spray affected areas with formalin. Heat treatment is very precise and dangerous. Bulbs are treated at 37.5 to 38°C for four weeks to kill the bacteria in the bulbs.

Soft Rot. This is a bacterial disease (*Erwinia carotovora*). It

was first noted on carrots but is found in many ornamentals with large or modified stems or tubers. Wet conditions and high nitrogen levels are responsible for the build up of this disease. The visual symptoms are stunted growth at flowering time, followed by yellowing and drying of the leaf tips. Bulbs decay, and the organism spreads rapidly causing the collapse of the scale leaves into a dirty white smelly mass. The odor can be detected by those working the bulb store.

Only stored bulbs should be saved. These should be treated with mercuric chloride after harvesting of the bulbs. If the disease is found when working on propagating material in the dark room, the infected bulbs can be removed and placed in high light areas. Chloroplasts are produced and when the bulbs are in this condition the disease is retarded, so the bulblets can continue to develop. When these are planted there is no sign of the disease on the bulb.

Other minor diseases have been found on Hyacinth bulbs; these include; *Sclerotinia*; *Botrytis*; *Penicillium* bulb rot; and *Pythium*.

Nematodes. Nematodes are responsible for losses in bulbs and cause the problem known as Ring disease. They feed on the scale leaves and this can be seen when an infected bulb is cut open. Foliage and flowers become distorted. Nematodes can be controlled by a hot water treatment using water at 43 to 44°C for four hours, followed by rapid cooling and drying. This treatment also rids the bulbs of eelworm.

GRAFTING OF *EUCALYPTUS FICIFOLIA*

FRED VAN ALLMEN

Fitzroy Nurseries
GPO Box 126
Rockhampton, Queensland

When horticulturists from the East Coast of Australia saw the brilliant red flowers of the Western Australia *Eucalyptus ficifolia* they had to take this tree back with them, only to find that *Phytophthora cinnamomi* attacked the roots. Because of the desirable flowers, horticulturists have patiently tried various methods of propagating this difficult plant.

The flowers on mature trees grown from seed vary widely in colour from white to deep red. Selections of good red flower colour variants have been made and grafted onto *E. ficifolia* rootstock, but these have proved unsuccessful as these low-rainfall trees die in the heavier soils and high rainfall of the East Coast.

was first noted on carrots but is found in many ornamentals with large or modified stems or tubers. Wet conditions and high nitrogen levels are responsible for the build up of this disease. The visual symptoms are stunted growth at flowering time, followed by yellowing and drying of the leaf tips. Bulbs decay, and the organism spreads rapidly causing the collapse of the scale leaves into a dirty white smelly mass. The odor can be detected by those working the bulb store.

Only stored bulbs should be saved. These should be treated with mercuric chloride after harvesting of the bulbs. If the disease is found when working on propagating material in the dark room, the infected bulbs can be removed and placed in high light areas. Chloroplasts are produced and when the bulbs are in this condition the disease is retarded, so the bulblets can continue to develop. When these are planted there is no sign of the disease on the bulb.

Other minor diseases have been found on Hyacinth bulbs; these include; *Sclerotinia*; *Botrytis*; *Penicillium* bulb rot; and *Pythium*.

Nematodes. Nematodes are responsible for losses in bulbs and cause the problem known as Ring disease. They feed on the scale leaves and this can be seen when an infected bulb is cut open. Foliage and flowers become distorted. Nematodes can be controlled by a hot water treatment using water at 43 to 44°C for four hours, followed by rapid cooling and drying. This treatment also rids the bulbs of eelworm.

GRAFTING OF *EUCALYPTUS FICIFOLIA*

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When horticulturists from the East Coast of Australia saw the brilliant red flowers of the Western Australia *Eucalyptus ficifolia* they had to take this tree back with them, only to find that *Phytophthora cinnamomi* attacked the roots. Because of the desirable flowers, horticulturists have patiently tried various methods of propagating this difficult plant.

The flowers on mature trees grown from seed vary widely in colour from white to deep red. Selections of good red flower colour variants have been made and grafted onto *E. ficifolia* rootstock, but these have proved unsuccessful as these low-rainfall trees die in the heavier soils and high rainfall of the East Coast.

Eucalypts do not allow easy scion to rootstock combinations, even though their botanical and physical characteristics are often close. There have been many cases of graft rejection after periods of up to 8 years of seemingly compatible growth.

This brings us to the selection of rootstocks, taking into consideration compatibility, percentage of graft successes, and incidence of delayed graft incompatibility. There is a variation in the rainfall along the East Coast and different rootstocks will have to be experimented with for different areas. We have experimented with various rootstocks for *E. ficifolia* which may prove suitable for the central Queensland coastal area.

Using "A Key to the Eucalypts" by W. F. Blakely three possible rootstocks that were closely linked with *E. ficifolioa* and from areas of similar rainfall were selected, namely *E. calophylla*, *E. gummifera* and *E. intermedia*. All four species (including *E. ficifolia*) are in the Series Corymbosae — Peltatae and sub-series Neocorymbosae.

E. ficifolia is a small spreading tree from Western Australia having an irregular form with flame coloured to fiery red flowers. *E. calophylla* is a large tree with white or pink flowers, also from Western Australia. *E. gummifera* is a medium to large tree which occurs on the East Coast of Australia. *E. intermedia* is similar to *E. gummifera* in growth habit and distribution but grows in areas of much higher rainfall.

Grafting Method. Healthy young seedlings growing in 100 mm (or larger) pots are selected for rootstocks. The scion material is obtained when it is growing in a primary mature flush. This mature scion material must have the buds just ready to burst. The leaves on the rootstock have to be left on, as this greatly assists the graft. A top wedge graft is used and it is held in place with small clothes pegs. We find this is a most cost effective method.

When the grafts are made they are placed in a high humidity tank. This is comprised of a water tank with a layer of sawdust in the bottom. The top of the tank is covered with clear plastic to retain moisture. The tank provides a high humidity environment which favours good growth and prevents the grafts from drying out. This method is being used with the three rootstocks currently on trial.

With *E. gummifera* there have been problems with callus formation above the ground which induces suckers. These suckers rapaidly outgrow the graft if not checked. Observation suggests there is genetic variation in some of the rootstocks as they are not consistant in their performance, often developing a "bottle tree" effect due to incompatibility.

E. intermedia looks more promising as a rootstock. There is less suckering from the base and better uniformity in the grafts than with *E. gummifera*; it is also a suitable rootstock for the central Queensland area.

E. calophylla 'Rosea' also looks good but trials with this rootstock have only been going for 12 months.

In summary, we are in our second year of trialing *E. intermedia* and *E. gummifera* and problems with suckering and genetic variability have been encountered. *E. calophylla* has only been under trial for one year but early results look promising. All will take time but no definite success can be claimed until a significant number of grafts have reached at least 8 years of age.

THE NEW ZEALAND EXPERIENCE IN EXPORT OF NURSERY STOCK

BARRIE L. McKENZIE

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Box 20-165, Glen Eden
Auckland, New Zealand

Horticulture in New Zealand is broadly spread across both the North and South Islands, which offers a diverse range of climate from subtropical in the Bay of Islands to a cold climate in Southland. The native flora is extensive as is the range of plant material being grown.

The New Zealand nursery industry is very fortunate to have a strong research base which is both Government and University funded. This gives support to the private nurseryman and to the industry as a whole.

Regardless of climate, soil, and the range of flora available the market demand in New Zealand is limited due to the small broadly spread population. Because of this, several New Zealand nurseries have sought markets overseas.

Traditionally New Zealand is a trading country recognized for its primary industry, and over the past 20 years considerable emphasis has been placed on horticulture. A great deal of this has been the result of the rapid growth of the kiwifruit industry and the international acceptance of this product as a valued fruit.

With the export of the fruit came the demand for kiwifruit plants. It was from this plant that the industry diversified and moved into the export of ornamentals, opening markets in the United Kingdom, U.S.A., and Japan.

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During the oil shock of the early 1970's the cost of heating for overwintering in the northern hemisphere became high. This allowed the New Zealand nursery industry to take advantage of the hemisphere difference to air freight stock, from an early winter, into the United Kingdom spring, landing it there as an advanced line ready for potting on.

A rapid growth of this practice resulted, and today large quantities are sent by sea and air to Europe. Credit must be given to companies such as Duncan and Davies who did the footwork for many years prior to large consignments being successful.

The question can be asked "Why export"? The determination of New Zealand growers to find new plants for production has resulted in considerable interest overseas, and together with the limited home market, has resulted in the development of the export industry.

Because New Zealand is an island isolated from any large land mass, and has a high standard of nursery stock, quarantine officials worldwide allow growers to enter markets which would otherwise by prohibited.

Research and stock improvement plays an important part in nursery stock production. This has resulted in the elimination of virus diseases from such plants as daphne and nandina, and enabled growers to offer a product superior to that currently on the market.

Following a disease problem in the United Kingdom the New Zealand exporters and the New Zealand Ministry of Agriculture implemented new quality assurance procedures as a joint effort. Strict growing standards were set and all exporters are required to abide by the recommendation laid down. These producers are reviewed each year to ensure that they conform to changing quarantine standards around the world.

Most production is carried out in soiless media, and liner material is produced in 5 and 10 cm containers. Traditionally air freight has been the main method of shipment but with new facilities and improved environmental control, container shipping by sea has proved successful. This has allowed larger volumes to be moved, and the opportunity to ship fully grown specimens.

Much has been written about the future of horticulture in New Zealand and only time and results will prove if the statistics are correct. There is no doubt, however, that we have a wide range of stock to offer, that will be accepted if the quality and hygiene is consistent, and the New Zealand growers continue to accept the challenge of export markets.

TRAINING PLANT PROPAGATORS AND NURSERY WORKERS

HOWARD C. BROWN[1]

California Polytechnic State University
San Luis Obispo, California 93407

During the 1950's an extensive study of higher education in California was made, resulting in passage of the Donahoe Act which delineated responsibilities. The University of California, with 9 campuses, has the responsibility for research, extension, and teaching to the Ph.D. level; the California State University, with 19 campuses, has teaching responsibility at the bachelor's and master's level; and the 104 community colleges in California provide a two-year education geared primarily to local community needs.

Cal Poly is one of the four state universities with an agriculture program. Our teaching program has a practical orientation with lots of "hands on" experience and our graduates go mainly into agricultural production or supporting industries. We claim that we are preparing them for middle-management positions but we also are giving them the skills and experiences that will enable them to climb to the top.

Our long-time president, Julian A. McPhee, took charge of Cal Poly during the depression years in the 1930's. Having been a high school agriculture teacher, he was concerned that, in the traditional college, students would take two years of general education before declaring a major. If they discovered in the third year that they were in the wrong major, several years of course work could be lost. And so he introduced what he called the upside-down system in which students began their major classes from the first day. If for some reason the student had to leave school at the end of one or two years, at least he had some marketable skills. If the student found that he was in the wrong major he could change to another at an early stage. The upside-down system was criticized and condemned by many educators, but over the years it was copied by many colleges and universities.

In talking with employers, President McPhee heard the criticism that, in general, college graduates had a weakness in writing reports. This led to the requirement when Cal Poly was authorized to award the B.S. degree in 1941 that every student would write a thesis before graduating. We are probably the only university in the United States that requires a thesis for a bachelor's degree. The students complain about the

[1] Professor Emeritus

requirement and frequently put it off until the last hour. However, when I visit graduates on the job they often comment that it was a most valuable experience.

In California we try to establish an interest in horticulture at an early age. We have a strong vocational agriculture program in many of our high schools, partially funded by the Federal Government. In 1963 the U.S. Congress passed a Vocational Education Act that provided federal funds to expand existing high school programs in agriculture; the typical program was heavily animal-oriented but was in an area that became urbanized. As a result, land was limited and, since the livestock industry had moved away, jobs were likewise limited. Many of the agriculture teachers could see ornamental horticulture as a means of continuing a strong agriculture program, meeting community needs and training students for immediate exployment. The teachers as a group asked for help in expanding into horticulture. Our faculty travelled all over the state working with the schools on curriculum, facilities, and teaching skills. Each summer we offer workshops for over 100 teachers involving horticultural skills.

As greenhouses and other facilities blossomed on the high school campuses, Ornamental Horticulture became part of the judging program for the Future Farmers of America. This brought a respectability to the field that had not existed previously — and when girls were admitted into the FFA program in the 1970's it doubled the potential enrollment.

Our program in Ornamental Horticulture is very closely allied with the nursery, floriculture, and landscape industries of California. For the past 37 years the California Association of Nurserymen has held its annual Refresher Course on our campus. Our students are greatly involved in its operation, offering them an opportunity to meet and talk with potential employers. Our program in Floral Design was established at the request of the California State Florist's Association over 25 years ago when they realized that no young people were going into their business. With this as background let us take a look at our teaching program in Ornamental Horticulture. How would a young person acquire the skills and knowledge that would prepare him for a career as a propagator or nurseryman?

Our courses are set up on a quarter system of four 11-week quarters per year. The traditional student would start in the autumn quarter and continue through the spring with summer off to work or travel.

The first quarter the student would take at least two major courses:

(1) Orientation, which looks at the field of horticulture, career opportunities, how to use the library, and how to write reports, including an autobiography for his departmental file.

(2) Nursery Practices, where soil mixing, sanitation practices, seed propagation, transplanting, potting, canning, and greenhouse operations are studied.

Hopefully the student would live on campus the first year and be an active member of the O.H. Club. The student would be encouraged to take a part-time job at the Ornamental Horticulture Department or at a local wholesale nursery and should work closely with the advisor on scheduling classes and balancing the school work with co-curricular activities.

During the second year this student would take the Plant Propagation class to learn about cuttings, rooting aids, budding, layering, and tissue culture and would be encouraged to become involved in the Agricultural Enterprise Program in which a crop would be researched. Then, financed by the Cal Poly Foundation, the student would produce and market the crop, receiving ⅔ of the net profits for his efforts. The student would be encouraged to apply for the summer training program at Monrovia or Hines Nursery.

During the third year this student would take the Advanced Plant Propagation course which emphasizes grafting, dormancy in seeds, and winter propagation. By then the student would have completed chemistry, entomology, plant pathology, and a host of horticulture courses. At this stage students are encouraged to apply for an internship in the propagation or nursery production field and they might also take a special problems course, dealing with some phase of propagation.

In the final year our student will sign up for a senior project (thesis) course. The subject, approved by the advisor, will be researched in the library. Treatment plots will be established and, hopefully, results will be obtained for early spring write-up. In the senior Seminar class public speaking skills can be polished, and an employment resume is prepared, as well as exploring the latest developments in the major field. Having established career goals the student will interview both on and off campus.

If the scenario follows through the student will graduate in June of the fourth year with the proud parents at the ceremonies, then proceed to a job as a plant propagator or nursery employee.

Cal Poly has the largest enrollment in Ornamental Horticulture of any university in the United States. We traditionally

graduate 150 to 200 students a year and most of them go into the ornamental horticulture industries of California.

While we claim to be educating students for middle managemnt positions, it is rewarding to see them climb the ladder of success. Many of them become owners or managers of businesses. They are active in their trade associations as is evidenced by the number of our graduates who have been presidents of the California Association of Nurserymen. We also have an active alumni association. A new graduate taking a job in the industry can be sure that there are O.H. graduates in the area to give him a helping hand. Suport for our program is evidenced by the fact that our students receive $35,000 to $40,000 a year in scholarships.

A number of alumni have remarked to me that it was interest in plant propagation that took them the college route but it was the support courses such as accounting, business law, labor relations, computer science, and public speaking that enabled them to advance in the business world.

SEED GERMINATION STUDIES WITH KENTIA PALMS *(HOWEA FORSTERANA)*

G. P. LAMONT

New South Wales Department of Agriculture

Gosford, New South Wales, 2250

Abstract. Seed of the kentia palm (*Howea forsterana*) was subjected to presowing treatents before planting in peat:perlite (50:50) at incubation temperatures in the range 20 to 40°C. Four percent of freshly harvested seed was found to be non-viable. Air drying the seed at 20 to 25°C for two weeks prior to sowing hastened decomposition of the outer husk. After 12 months there was nil germination of dried seed incubated at 20°C compared with 1.3, 5.4, 7.9, and 11.0 percent at temperatures of 25°, 30°, 35°, and 40°C, respectively. None of the undried seed had germinated after 12 months irrespective of substrate temperature. Chipping of part of the outer husk resulted in 6% germination compared with nil for unchipped seed, while soaking chipped seed in gibberellic acid (250 to 1000 mg L^{-1}) further improved germination. Gibberellic acid at greater than 250 mg L^{-1} produced no increase in germination and, at 750 mg L^{-1} germination was inexplicably decreased. A relationship between substrate temperature and seed decay appeared to exist for dried seed with maximum decay (ca.20%) occurring at 35°C. Fungi have been isolated from decayed seed and their pathogenicity and control are currently being investigated. Seed stored at 5°C for periods of up to 24 weeks had not germinated after 12 months.

REVIEW OF LITERATURE

The kentia palm, *Howea forsterana* (previously *H. forsteriana*), is one of the most familiar and widely grown ornamental palms in the world. For more than a century this elegant slow-

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REVIEW OF LITERATURE

The kentia palm, *Howea forsterana* (previously *H. forsteriana*), is one of the most familiar and widely grown ornamental palms in the world. For more than a century this elegant slow-

growing palm has adorned the hallways and drawing rooms of wealthy Europeans (5). There is currently a strong world demand for kentia palms as indoor plants.

Kentia palms are endemic to the lowlands of Lord Howe, Island, a small island off the coast of New South Wales. The island climate is temperate with a mean annual temperature of 19°C (maximum and minimum recorded temepratures are 31.5°C and 6.0°C, respectively) with a winter dominant rainfall averaging 1676 mm annually (7). The harvesting and sale of seed from the natural stands of kentia palm has been an important source of income to Lord Howe Island for more than 100 years. Recently a nursery has been established on the island where seed is germinated and the young sprouts are exported to mainland Australia and to other parts of the world.

Most palms possess a single meristem hence the principal means of propagation is from seed. Some palms produce suckers and thus may also be propagated vegetatively by division or aerial layering (5). More recently, *in vitro* methods of propagation have been developed (9). For economically significant palms, such as the oil palm (*Elaeis guineensis*), extensive studies have identified the optimum conditions for seed germination (4, 8). For the majority of palms, however, these conditions are unknown. The time required for the germination of palm seed varies greatly and may take several days for some species or up to 3 years for others (5, 10).

There is a dearth of information on the optimum conditions for the germination of kentia palm seed. This paper describes experiments investigating the effects of pre-sowing seed treatments and substrate temperature of the germination of kentia palm.

MATERIALS AND METHODS

Seed for all experiments was harvested on 30 March, 1984, from a single, mature palm growing in a well-watered garden on Lord Howe Island. The seed was plump and of a light green/yellow colour. Seed was planted in a medium of German peat moss and perlite (50:50) in shallow trays and placed on gravel over electric heating cables. Planting medium was maintained in a moist but not wet state at all times. In all experiments counts of germinated and decayed seed were made after 12 months.

Prior to conducting the germination experiments a sample of 100 seeds were cut open and examined for healthy embryos.

Experiment 1: The effects of air drying seed prior to sowing and of substrate temperature on germination.

Samples of 150 seeds were either planted fresh or air-dried in a greenhouse at 20 to 25°C for two weeks prior to planting. The planting media were maintained at temperatures of 20, 25, 35 and 40°C.

Experiment 2: The effect on germination of chipping the outer husk of the seed and soaking in gibberellic acid.

The outer seed husk was removed from the embryo end of the seed using secateurs. Samples of 100 seeds were then soaked for 48 hours in aqueous solutions containing 0, 250, 500, 750, and 1000 mg L^{-1} GA_3. Seed was planted and maintained at 25°C.

Experiment 3: The effect of low temperature storage on germination.

Samples of 200 seeds were stored in moist peat:perlite (50:50) at 5°C for 0, 2 weeks, 4 weeks, 8 weeks and 24 weeks. Seeds were then planted and maintained at 25°C.

RESULTS

Four percent of the fresh seed examined soon after harvest was found to have a dead embryo.

Experiment 1: Within two months of planting, the outer husk of dried seed had decomposed sufficiently to separate from the seed. By contrast the outer husk of undried seed did not reach this stage of decomposition until 6 to 8 months after planting.

None of the undried seed had germinated after 12 months irrespective of substrate temperature. Germination of dried seed showed a linear increase with increasing temperature ($P < 0.05$, $r_2 = 0.98$). At 20°C no seed germinated compared with 11% at 40°C (Table 1). For dried seed there appeared to be a relationship between substrate temperature and the percentage of decayed seed, with a peak occurring at 35°C (Table 1). For undried seed there was no trend except that the highest percentage of decayed seed also occurred at 35°C.

Table 1. The effects of substrate temperature and seed drying on germination and decay of kentia palm seed 12 months after sowing.

Substrate Temperature °C	No. Seeds	Undried Seed		Dried Seed	
		% germ.	% decayed	% germ.	% decayed
20	150	0	4.8	0	<1
25	150	0	2.6	1.3	3.3
30	150	0	1.4	5.4	5.3
35	150	0	18.9	7.9	19.9
40	150	0	2.0	11.0	8.8

Experiment 2: Chipping and soaking the seed in gibberel-

lic acid improved germination (Table 2). After 12 months an average of 13% of seed chipped and soaked in GA_3 (250-1000 mg L^{-1}) had germinated compared with 6% for the chipped control, and 0% for the unchipped control. A higher percentage of chipped seed decayed compared with unchipped seed.

Table 2. The effects of chipping the outer husk and gibberellic acid concentration on the germination and decay of kentia palm seed 12 months after sowing. Substrate temperature 25°C.

Treatment	No. Seeds	% Germinated Seed	Percent Decayed
Unchipped	100	0	3
Chipped (C) + O mg $L^{-1}GA_3$	100	6	10
C + 250 mg $L^{-1}GA_3$	100	18	14
C + 500 mg $L^{-1}GA_3$	100	15	13
C + 750 mg $L^{-1}GA_3$	100	3	8
C + 1000 mg $L^{-1}GA_3$	100	17	17

Experiment 3: None of the seed stored for varying periods at 5°C had germinated after 12 months (Table 3).

Table 3. The effects of storage at 5°C on germination and decay of kentia palm seed.

Period of Low Temperature Storage	No. Seeds	Percent Germinated Seed[1]	Percent Decayed Seed
2 weeks	200	0	6.9
4 weeks	200	0	10.8
8 weeks	200	0	16.1
24 weeks	200	0	4.5

[1] 12 months after the commencement of storage. Substrate temperature 25°C

DISCUSSION

The germination of kentia palm seed is reported to take 6 months to 3 years (5). The observations reported here were made 12 months after sowing and thus must be interpreted as provisional.

Air drying of the seed hastened decomposition of the outer husk and, at 25°C or higher, improved germination compared with undried seed. Jones (5) reported that the viability of seed of many tropical palm species was reduced if seed was allowed to dry. The kentia palm, however, is from a temperate climate and, in native stands, mature seed would fall and undergo natural drying on the soil surface at a mean temperature of approximately 20°C and relative humidity of about 70% (7). In Experiment 1 seed was dried for two weeks under similar conditions.

In both dried and undried seed the percentage of decayed seed increased with increasing temperature, reaching a maxi-

mum at 35° C. Fungi have been isolated from these decaying seeds and their pathogenicity and control is currently being investigated. It is possible that 35°C is the optimum temperature for such organisms.

The increased germination at higher temperatures recorded in this experiment confirms findings for other palm seeds. The optimum seed germination temperature for the tropical oil palm (*Elaeis guineensis*), for example, was found to be 42.0°C dry heat for 60 days (8). A temperature of 44.5°C was however, found to be fatal. The optimum temperature for germination of kentia palm seed has not been reported in the literature, but commercial growers in Australia provide a bottom heat of 25°C in germination beds.

Chipping of the outer husk of palm seed has been reported to hasten germination of some species (3). Experiment 2 confirmed this with kentia palm and the soaking of chipped seed in gibberellic acid further enhanced germination. The reason for the low percentage germination for seed soaked in 750 mg $L^{-1}GA_3$ compared with the other concentrations is not known. Gibberellic acid has been reported to stimulate germination of seeds which are physiologically dormant (1, 2). Nicholls (6), however, found that excised embryos of *Howea forsterana* seed germinated rapidly *in vitro* and concluded that the embryo was not physiologically dormant.

The effects of low temperature storage on germination of kentia palm are not yet apparent. Sixteen percent of seed stored for 8 weeks subsequently decayed. Only 4.5% of seed stored for 24 weeks decayed but detection was difficult because the outer husk had not fully decomposed. Low temperature may cause embryo death in some species of palm (5).

The overall seed germination percentage after 12 months was surprisingly low. Data gathered from the Lord Howe Island Board nursery for undried seed collected and sown in April, 1984, showed an average 15 to 20% germination after 12 months (C. Weale, pers. comm.). Such seed was collected from many trees and planted in a friable medium with no temperature control (year-round temperature in the range of 15 to 30°C). In the experiments reported here none of the undried seed had germinated after 12 months. The reason for this discrepancy is unknown but may be a genetic effect.

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TAXUS PRODUCTION IN THE U.S.A.

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The genus *Taxus* is probably one of the finest narrow-leaved evergreens for use in the landscape. The literature tells us that *Taxus* fossils have been found between layers of sandstone and shale originating about 150,000 years ago. (1) The genus has long been associated with religion and most of the Christian churches were built in yew groves throughout England. In the United States, the genus appeared in horticulture in the mid-1800's and much of the early popularity was due to the work of T. D. Hatfield, who was the head gardener at the Hunnewell Estate at Wellesley, Massachusetts (2).

There has been quite a bit of controversy as to exactly how many species of *Taxus* truly do exist. There are at least 3 species relatively universally accepted - *Taxus baccata* (English yew), *T. canadensis* (Canadian yew), *T. cuspidata* (Japanese yew). In the United States the English yew is only hardy in certain areas of the country. This species is not hardy in my state of Michigan.

The Canadian yew is a native species ranging from Virginia to the Great Lake Forests in the U.S.A. This plant, unfortunately, only thrives well in the shade and cannot tolerate full

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The Canadian yew is a native species ranging from Virginia to the Great Lake Forests in the U.S.A. This plant, unfortunately, only thrives well in the shade and cannot tolerate full

sun. To my knowledge, the only hybrid being grown in the United States today is *Taxus* × *hunnewelliana*. Apparently, this hybrid is a chance cross between *T. canadensis* and *cuspidata*.

The Japanese yew was brought into the United States from Japan in the late 1860's and has been crossed with *T. baccata* to give the *Taxus* × *media* forms. The majority of the *Taxus* grown in the United States are *T.* × *media* cultivars. *T. cuspidata* 'Capitata' is also widely grown and is generally propagated sexually, which will be discussed later.

The major area of *Taxus* production in the U.S.A. is from the East coast to about the Mississippi river. The largest single producer of *Taxus* is Zelenka Evergreen Nursery, located at Grand Haven, Michigan, which is made possible by the very favourable microclimate of Lake Michigan. This nursery has approximately 1,000 acres of field production plants, approximately 5,000,000 plants in liner beds and is sticking approximately 2,000,000 cuttings annually. In addition to the cutting propagation, 350 lbs of *T. cuspidata* 'Capitata' seed are sown annually.

In addition to Western Michigan, there are sizeable *Taxus* production in Southern and Western Illinois and in the northeast corner of Missouri. Only a relatively small amount of production occurs west of the Mississippi river and below the Mason-Dixon line (along the southern border of Pennsylvania) and virtually no production in the Southern or Southwestern states, due to extreme summer heat and the fact that plants in this genus do not grow well in excessively warm soil temperatures.

The propagation techniques used at Zelenka Nurseries, are outlined below:

SEXUAL PROPAGATION

The sexual propagation of *T. cuspidata* 'Capitata' is handled differently than in most U.S.A. nurseries. All of the seed of this cultivar comes from Japan and is received in March or early April. It is stratified in sand boxes, outside, for a minimum of 12 months. Seed of this cultivar must have 12 months stratification; if it does not receive the full 12 months, the seed will lie for an extra year after sowing before germinating.

After the 12 month stratification period the seed is removed from stratification boxes and the sand is washed from the seed, which are then sown in wooden flats at the rate of 1,000 seeds per flat. Germination ranges from 30 to 35 percent, depending on viability; the flats are maintained in poly covered houses for two years. After germination, the polyhouses

are covered with shade cloth during the summer and held in houses with no heat. At the end of the second year, seedlings are removed from the flats and transplanted to a liner bed using a 10 row planter. These beds are in large lathhouses, 2,000 feet by 200 feet. The plants are held for three years before planting in the field.

ASEXUAL PROPAGATION

1. **Taking cuttings.** *Taxus* cuttings are taken in the fall after they have been subjected to several hard, killing frosts. In western Michigan, this is late October to early November. Cuttings are harvested either by machine or by hand. The bulk of the cuttings are harvested with a modified pull type combine which has a cloth belt. This combine will accommodate two field rows, or one liner bed of ten rows. This technique has reduced the harvest cost of cuttings considerably, since two people can harvest the equivalent of 200,000 cuttings in four hours, where in the past it took a crew of 16 to 20 people eight hours to accomplish the same number.

2. **Preparation of cuttings**. Cuttings are handled at Zelenka's both stripped and unstripped. The majority of the 2,000,000 cuttings stuck annually are not stripped. It is our belief that wounding a *Taxus* cutting is not necessary and the labor saving is considerable. The fear of decayed needles in the medium, eventually causing basal decay of the cutting, is unfounded. The cultivars that are hand cut are normally those plants that do not accommodate the machine, or plants that are going to be saleable the following spring, so great care is taken when taking cuttings from those plants.

All benches are labeled for cultivar, the farm these cuttings come from, as well as the usual other data — stripped/unstripped, hormone, etc.

3. **Sticking.** The cuttings are stuck in raised sand benches with bottom heat and minimal top heat. The bottom heat starts at 70°F (21°C) and as rooting progresses, the bottom heat is reduced to 60°F (15°C). The cuttings are stuck by using a board and knife, slitting through the sand, and two people stick, facing each other, starting in the center of the bench working towards the aisle. The sticking rates are 2,000 cuttings per hour, per person, and these crews work a 9 hour day. All *Taxus* cuttings are hormone-treated. Zelenka uses Wood's Rooting Hormone as well as Chloromone. The strengths of both of these liquid hormone products varies with the cultivar and condition of the wood.

4. **Culture.** After the plants are stuck in the benches, the watering is either by hand, or by manually operating the mist controls. It is important to create high humidity with a mini-

mal amount of water in the medium. This is one genus of plants that "does not like it's feet wet". Preventative spray programs are used primarily for fungus gnat problems and any other insect that might appear during the life of the crop. After rooting, which normally is in late February or early March, a liquid fertilizer program is employed through the mist lines.

5. **Harvest.** The cuttings are lifted from the benches in early to mid-May. They are well-rooted to this point, with both primary and secondary roots, but the fear of planting out and encountering a late spring freeze in late May is always a concern. If benches are needed for early softwood crops, the cuttings can be pulled, packed in wax lined boxes, and stored at 35°F (2°C). This has been done for several years and cuttings have been stored for 60 to 70 days with perfect survival after planting. After cutting removal, the benches are cleaned, and prior to sticking the next crop, they are cleaned with a Clorox bleach (1:10) to the point of run-off through the drain holes in the benches. There are some trial benches of perlite/sand combinations which are being used for the 1984-1985 crop.

LINER FARM PLANTING

Prior to planting at the liner farm the beds are prepared and the final treatment is a tank mix of Treflan and Lindane which is roto-tilled into the beds. The rooted cuttings are planted with a 10 row planter, and a crew of 12 people will plant 90,000 rooted cuttings in a 10 hour day. After planting, only a preventative spray program and minimal herbicide applications are carried out. The plants are fertilized annually, using a fertilizer formulation to allow 100 lbs of actual N per acre per year.

The top pruning is carried out with the combine, described previously for harvesting cuttings. Root pruning at the end of the second year is done using a Swiss made machine, "Fobro", which has a vertical root pruner attachment as well as the horizontal root pruning blade. Tunnels are fixed to a draw bar and cover the plants to avoid damage. The harvest is at the end of the third growing season and we do not fall-harvest these plants. We try to coordinate our liner farm harvesting in the spring to coincide with the field planting. Plants are harvested with the "Fobro" multi-row lifter shaker and the root pruning blade allows mechanical pruning rather than hand pruning prior to field planting.

FIELD PLANTING

As the plants are planted in field rows, the ground preparation is very similar to that at the liner farm, also using a pretreatment of Lindane and Treflan. The planting is done

using a two-row planter, with the rows 40 in. apart, and a three-row planter which allows the harvest of 8 to 10 in. and 10 to 12 in. plants. Field culture consists of cultivating frequently; the fertilizer treatments are based on soil analysis, but are usually about 100 lbs of actual N per acre per year. The herbicide application is primarily Princep which is applied by air in both spring and fall. The insecticide/pesticide spray program is again primarily preventative; the Fletcher scale is the most serious insect problem encountered.

The field harvest is unique in that Zelenka Nurseries uses a technique known as ball and pot rather than ball and burlap. The plants are balled out of the soil and then placed in a plastic container for sale. The nursery will harvest quite a few units in the fall and these are stored in unheated polyhouses for shipments in February and March. We normally can get into the field around the middle of March for the spring-dug plants. Plants are brought in from the field on 4-steer wagons after being run under a water rack and then placed in holding areas by cultivar and size. As the orders are gathered for loading, the order gatherers pick up the amount, cultivar, and size required for the order and take them to the loading docks. Most of the orders that leave the nursery are on shelves, using aluminum racks and boards. We rarely "tier-stack" orders. The nursery has the capability of loading 49 semi-trailer trucks daily from three shipping docks. A total of 1,026 semi-trailers were shippped in April, 1985.

SUMMARY

It is obvious that the climatic conditions of lower Western Michigan are extremely favourable for *Taxus* production. The combination of the microclimate from Lake Michigan, the light sandy loam soil, and favourable weather conditions all are very important attributes. This area of Michigan normally receives 100 inches of snow during the winter and the normal ranges in temperature are -5°F in winter to 90°F in summer.

The genus *Taxus*, has an extremely high landscape value. "The high quality appearance and maintenance-free aspect result in *Taxus* being classed as the best shrubby needle-type evergreen for landscape use" (3). I would most certainly have to echo these comments. The attributes of this plant cannot be over-emphasized.

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DOMESTICATION OF THE AUSTRALIAN TROPICAL PROTEACEAE

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The sub-tropical and tropical representatives of the important Proteaceae family contain some of Australia's most spectacular flowering and foliage ornamental trees and shrubs. There is considerable horticultural interest in their economic importance both in Australia and abroad as their attributes become better known.

This family has also given Australia and the world a popular and delicious nut crop. The macadamia, is now of considerable economic importance, especially in Hawaii. This is one of the few Australian plants used for food purposes on any scale. Several other lesser known rainforest species produce edible nuts which could have future potential.

Most of the tree species produce beautiful coloured and grained and very sought after cabinet timbers. These timbers, usually marketed as various forms of silky oak come from shrinking virgin stands of forests, and another 20 years will see the end of this resource. No replanting has been done using these trees despite the fact that they are tough and fast growing, and have few pests or diseases. They can thrive on poor soils and in most cases make excellent windbreaks.

New species are still being discovered and named in the fast disappearing and ravaged rainforests of North Queensland. Let us work and hope that all of these species can be introduced into cultivation before their habitat is alienated forever. National Parks are no guarantee that they are all safe because National Parks only consist of a disjointed series of logged mountains and an occasional beach; the diversity and variability of these forests means that each local area, creek or mountain, often has its own unique and endemic species. This family's members are rarely found in pure stands. They mingle and are found scattered through the forests and grasslands. They contribute to the total ecology of a forest, an important aspect of its health. Only they have the ability to breakdown inorganic and insoluble phosphates locked in the phosphate-poor Australian soils, by a combination of their special root systems — in conjunction with mycorrhiza — into organic and soluble phosphates at the soil surface where it is eventually available to other plants as well.

Hence, in combination with legumes, they can be impor-

tant colonisers of ravaged areas or depleted soils and are able to convert poor, very acidic soils into something which will support other plants as well.

Their importance is obvious, judged by any set of values. They improve forest health, and provide food for fauna. No other plant group produces as much nectar from their flowers. They also provide food for humans. Aesthetically they have attractive foliage with beautiful and often highly perfumed flowers. Large numbers of birds, including parrots, are attracted to these plants. They are also used for windbreaks and will grow well in poor soils where nothing else will thrive.

There are hundreds of species plus an increasing number of hybrids from man's combinations of these in the tropical Proteaceae. These will ensure that they will always show us the ability of the ancient God, Proteus — that their family was named after — that of diversity of form and the ability to change shape at the God's (substitute 20th century man's) will.

Proteaceae occupy two broad ecological niches in the tropics.

(a) *Rainforest*. They are mainly small to large trees and sometimes understory shrubs around the edges of the forest.

(b) *Open forest and heathlands*. Here they vary from ground covers, to shrubs, to small trees in open country. Many grow in the full tropical sun.

PROPAGATION

Four main methods of propagation have been successfully used to grow tropical Proteaceae.

1. **Seed**. Seed is difficult to obtain for many species, particularly the rain forest trees. Seed is often easier to obtain from the shrubs and open forest species. Their habit of shedding their seed erratically, often means that it is difficult to collect large quantities and seeds may therefore be quite expensive, as time and patience is required to collect them.

Seed viability is often short — from a few months for rainforest species to a year or two for grevilleas and others. Seed from rainforest species is generally winged and has a thin papery shell.

For germination the seeds need to be fresh, placed in a sterile well-drained low phosphorus medium, and only lightly covered. The pH should be about 6 and best results are with bottom heat and about 50% shade.

The hard-coated seeds also need to be fresh for best results. They can be germinated using a similar method but can be covered a little more, and can tolerate more sun.

The seed from cultivated plants is easier to harvest, but there is always the danger of hybridsation when species from different areas are grown together in a garden. Hybrids should be grown to assess their horticultural potential. The form of some species varies in cultivation; for example, some rainforest trees which are tall, slender, and have only small crowns naturally form neat rounded and shorter trees when grown in the open. They often flower spectacularly and seed collection is usually much easier from these trees.

2. Grafting and Budding. Grafting and budding has been used as a propagation technique for tropical Proteaceae.

Macadamia plants propagated for commercial plantings are produced by grafting or budding onto seedling rootstocks.

Grevillea "standards" are being produced by approach grafting ground cover species onto *Grevillea robusta* (silky oak) rootstocks. By this technique a weeping habit is obtained, or with others, simply a reliable rootstock which allows that species to survive in a different environment. Commercially the "standard" using the prostrate *Grevillea* 'Royal Mantle' grafted onto 1.5 to 2 m high *G. robusta* rootstock has been quite successful.

G. dryandri, a "touchy" tropical grevillea has been successfully grafted onto *G. robusta* rootstock and this has improved its reliability and reduced its susceptibility to *Phytophthora cinnamoni*.

Telopea speciosissima, the New South Wales waratah has recently been successfully budded onto some species rootstocks so as to get earlier flowering and to keep improved cultivars, including the white form, of this outstanding plant.

There is a future for these techniques in propagation as more species, and unusual forms for specialist effects, are required by a public which is becoming more sophisticated in its plant needs.

3. Tissue Culture. Tissue culture is newer on the scene than the traditional forms of propagation but has already proved successful with several grevillea species. This method will become more widespread as problems of overcallusing, transplanting, and hardening off are overcome. To date, tissue culture has not been used on tropical Proteaceae to my knowledge, but no doubt it is possible.

4. Cuttings. This is probably the best method of propagating the tropical Proteaceae. We have developed techniques over the last decade to propagate all the grevillea hybrids and several of the most spectacular rainforest trees from cuttings, although not all of these are commercial propositions at this

stage.

Only material from cutting-grown cultivated specimens is commercially useful, where it can be kept clean of insects and fungi by a regular spray program, and where the plants nutrient levels are kept at an optimum. The state and quality of the cutting material is of crucial importance for a good result.

The cutting material is kept as clean as possible, and when the cuttings are made they are placed in a sterile medium under mist. (We use an electronic sensor system). The house has automatic ventilation, good light, and a bottom heat temperature of 27 to 30°C is maintained.

Initially at Lakkari Nursery we only used cutting material from the pots with an occasional pruning of the garden plants. Pruning the pots, while giving the plants shape, dramatically slows down nursery turnover whilst waiting for them to grow back. Results were reasonable, however, and commercial enough to get by. Since we have been obtaining bulk cutting material from our Farm Nursery Gardens however, results have been much better. This is because cutting material taken from well-maintained in-ground stock plants is superior. The results were 10 to 20% better and produced more vigorous plants without the need to hold nursery stock in pots, thereby increasing turnover.

There was a problem caused by ethylene damage, causing leaf burn and overheating in the sealed boxes used to transport the cuttings the 120 kilometers from the farm to the production nursery. Ethasorb was used and this has solved the problem.

It has not been necessary to use refrigeration for the transport of cuttings; material can be sent quite long distances by road or air transport using the above method.

The propagation of *Oreocallis wickhamii* from cuttings has advantages over seed propagation as seeds are often hard to find and must be fresh. Seedlings are also slow to develop in the early stage. They also take 6 to 8 years to flower.

Cuttings of the rainforest species, such as *Oreocallis* spp. and *Athertonia* spp., are fairly slow to strike — to 12 to 16 weeks compared to 6 to 8 weeks for grevilleas. Once struck they are slow to establish in the tubes, or when potted on, they are slow to develop a good root system. Extra iron and a good supply of nitrogen is essential for good growth, and for this reason, *Oreocallis spp. has only been marketed in 175 mm* or 200 mm pots.

The rainforest species have proven very hardy and amenable to cultivation particularly when grown by cuttings as they

maintain a compact form and flower prolifically when young. They are much hardier than their origin would have one believe. The high altitude species can handle mild frost and have been grown and flowered as far south as Melbourne in some cases. They do well in the sub-tropics and in warm to cool temperature climates. They can survive in dry or wet conditions once established. One outstanding member of the rainforest Proteaceae is *Oreocallis wickhamii* (Queensland tree waratah). This tree is probably the most spectacular flowering tree in Australia when in full bloom. It was formerly known as *Embothrium wickhamii* and is a small rainforest tree occurring naturally on the deep red soils of the Atherton Tableland and similar high altitude rainforests in North Queensland. It occurs usually at altitudes of 1000 m or more, where the climate is wet most of the time, cool in winter (down to 0° or less, in fact it snowed recently) and hot for the rest of the year, with occasional dry spells.

Most of the tree's former geographical range has now been cleared for grazing. Though small by rainforest standards, it is still sought by foresters because of its beautifully grained, pink shiny timber. Never common, it is now rare in the wild due to forestry and clearing for farming. No replanting has ever been done and it could soon join the ever-growing list of endangered species. *O. wickhamii's* future in the wild depends on habitats being protected in National parks, but its future in cultivation is assured now that it can be reliably and continuously propagated from cuttings. *O. wickhamii* in cultivation is a small tree, growing to 6 to 7 m x 3 m. New growth is a furry, light lime green, and older leaves are a bright green, making a very dense and attractive canopy. The flowers are this tree's most eye-catching feature, covering the whole canopy with hundreds of 20 to 30 cm bright scarlet clusters of "Waratah" — like blooms from September to November. They will last well on the tree provided the many parrots and honeyeaters attracted to the nectar-dipping flowers do not get to them first.

Athertonia diversifolia is one of the most beautifully foliaged of the Australian rainforest Proteaceae. It has giant oak-like leaves up to 60 cm long. The new growth is a shiny bright red changing to a rust-tinged dark green. The flowers occur in 30 cm long racemes similar to macadamia flowers, and are a creamy honey colour. The seed pods are large and bright blue enclosing a large almond-shaped nut, reputedly sweeter than a macadamia and just as palatable.

This highland tropical rainforest from the Atherton tablelands (hence its name) was formerly called *Helicia diversifolia*. Seed is difficult to obtain from this species.

Two seedlings were obtained 6 years ago and planted on deep red former rainforest soil on our farm in northern New South Wales. They have survived a severe drought and minimum temperatures of −4°C, and are currently 5 metres high and are magnificent.

Cutting material is taken from stems which are 1 to 2 cm thick and covered with a red furry down. These cuttings are quite difficult to strike but some success has been achieved.

This spectacular plant is rare in the wild and therefore warrants attention to bring it into cultivation to ensure its continuing survival.

Grevillea hilliana is an endangered species in the wild. It has been grown from seed in the past but this is not always easy to obtain. Plants from seedlings take many years to flower. Plants grown from cuttings have produced a bushy plant that has flowered in two years. Mature leaves are large and shiny green with a silvery reverse side. The flowers are spectacular with many clusters of lemon flowers 30 to 40 mm long all over the whole tree.

Its habitat in northern New South Wales and Queensland rainforest is dwindling. It produces an excellent timber and makes a tough and showy ornamental.

I have only described a few species of the rarest and most spectacular of the tropical Proteaceae.

Most of this group are spectacular and are amenable to cultivation. Their diversity is such that new species are still being discovered and new hybrids continue to appear.

This group of species occurs in our own backyard and its domestication for use in home gardens, landscaping, re-vegetation, and medicinal purposes is a worthwhile challenge.

The continued survival of many of our most beautiful nectar-feeding birds, parrots, bats and possums, are inextricably bound up with the continued survival of the tropical Proteaceae.

RESPONSE OF VEGETATIVE GROWTH TO LIGHT AND TEMPERATURE IN *ANIGOZANTHOS*

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The aim of this experiment was to study the response of the vegetative growth of two commercially important *Anigozanthos* species (Kangaroo paws) to varying temperature and light conditions under short-day glasshouse conditions.

MATERIALS AND METHODS

A glasshouse trial using *A. flavidus* and *A. manglesii* was conducted at the University of Sydney's Darlington glasshouse complex between July and September, 1981.

Seed of *A. manglesii* was pretreated by soaking in hot water (60°C) for 2 hours before sowing. Seed was sown in a mix of 1 part perlite: 1 part sand on 18 April, 1981 and germination was complete by 18 May 1981. Seedlings were pricked out into a sand/peat growing medium and grown on in a propagation glasshouse for 3 weeks. On 7 June, 1981, 240 plants of each species were selected for uniformity and transferred to the temperature controlled glasshouses. Water was applied by hand when required and humidity varied with temperature and frequency of watering.

Six day/night temperature ranges were employed, namely: 15°/10°C; 18°/13°C; 21°/16°C; 24°/19°C; 27°/22°C; and 30°/25°C. The two light levels were: full sun and 50% shade, using cloth suspended 60 cm above the plants.

The treatment design within each temperature was a split plot in time with the two species and two light levels as the main plots and four harvest times as the subplots. The experimental design was an incomplete block design (4) with whole plots arranged completely at random. Twenty plants were allocated to each whole plot using random number tables. Plants were subsequently re-randomised every 3 weeks. Temperature treatments were not replicated due to the unavailability of replicated environment rooms. Hence differences between temperatures cannot be tested statistically and a graphical presentation is used.

Assessment involved the random selection of 3 plants from each main plot every 7 days between 18 August, 1981 and 7 September, 1981, totalling 12 plants per treatment. Parameters measured were leaf area using a Paton Electronic Planimeter (CSIRO) with an accuracy of 0.5mm^2, oven-dry top weight, oven-dry root weight, (plants had not developed rhizomes) and total plant height measured from the soil surface to the tip of the longest leaf. Qualitative data on morphological differences were also recorded.

RESULTS AND DISCUSSION

Previous researchers (2,5) have suggested that the most favourable temperature range for the vegetative growth of kangaroo paws is between 15°C and 20°C.. These findings have not been substantiated by the results obtained in this experiment. These results indicate that both species will respond with increased vegetative growth to temperatures higher than previously recommended.

Plant Height, Leaf Area, Shoot Weight and Root Weight. At 3 months the effect of temperature on growth in plant height was clear, height increasing with temperature up to 27°/22°C (Figure 1). Significant height differences between species were only apparent at temperatures above 21°/16°C, (Table 1)

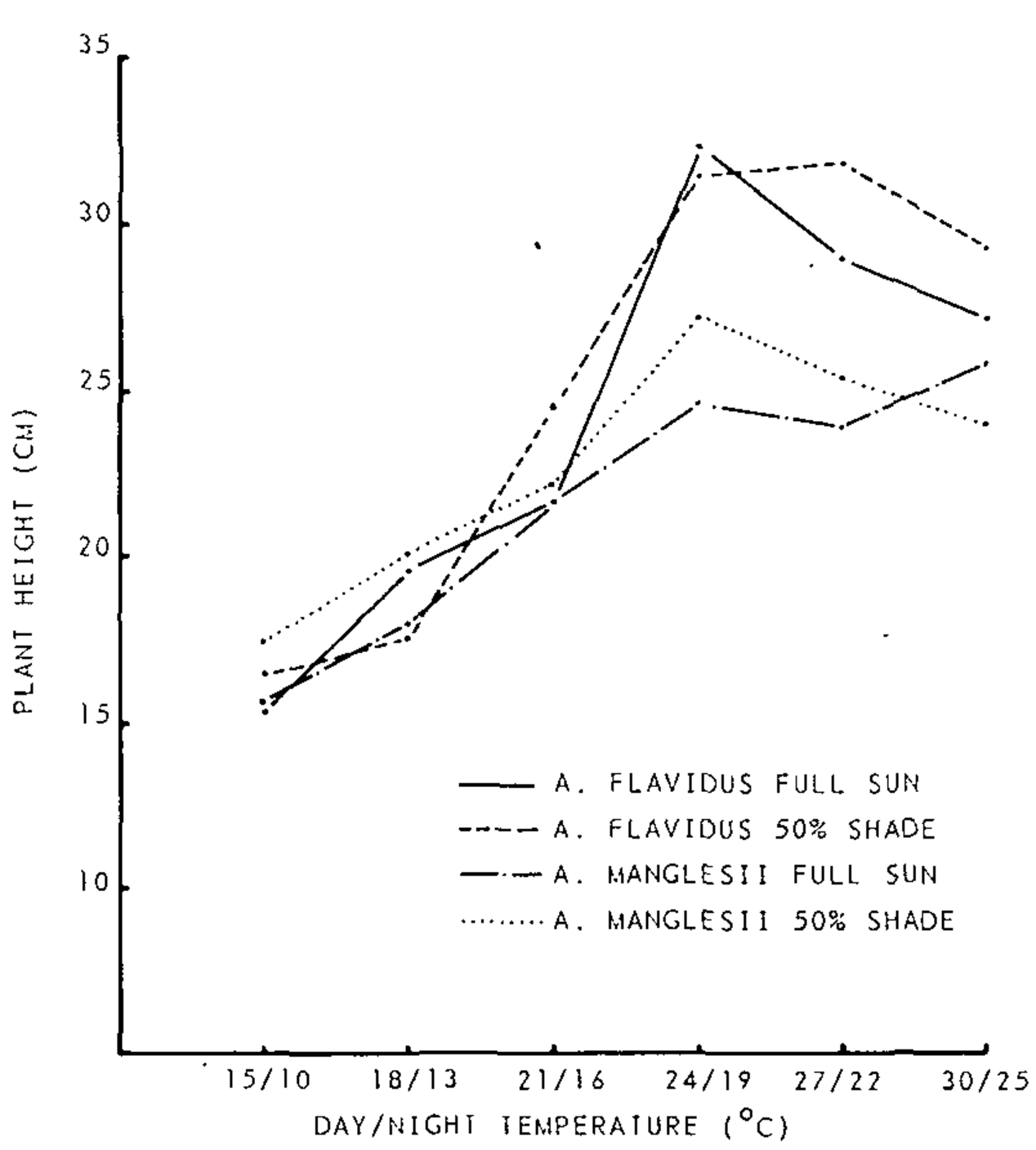

Figure 1. Plant height response of *A. flavidus* and *A. manglesii* to temperature and light after 12 weeks growth.

In most cases, plants subjected to 50% shade reached their maximum height at a higher temperature than those exposed to direct sun. The light level had no significant effect on the height of either species within any of the 6 temperature ranges (Table 1).

The response of leaf area to increasing temperature was, as might be expected, similar to the pattern for height growth (Figure 2). Both species attained maximum leaf areas at 24°/19°C, (full sun) and at 27°/22°C (shaded).

Leaf area decreased markedly in all cases above 27°/22°C and only at temperatures above 21°/16°C did the leaf area of *A. flavidus* significantly exceed that of *A. manglesii*. Light level had no significant effect on the leaf area of either species within the temperatures tested, (Table 1).

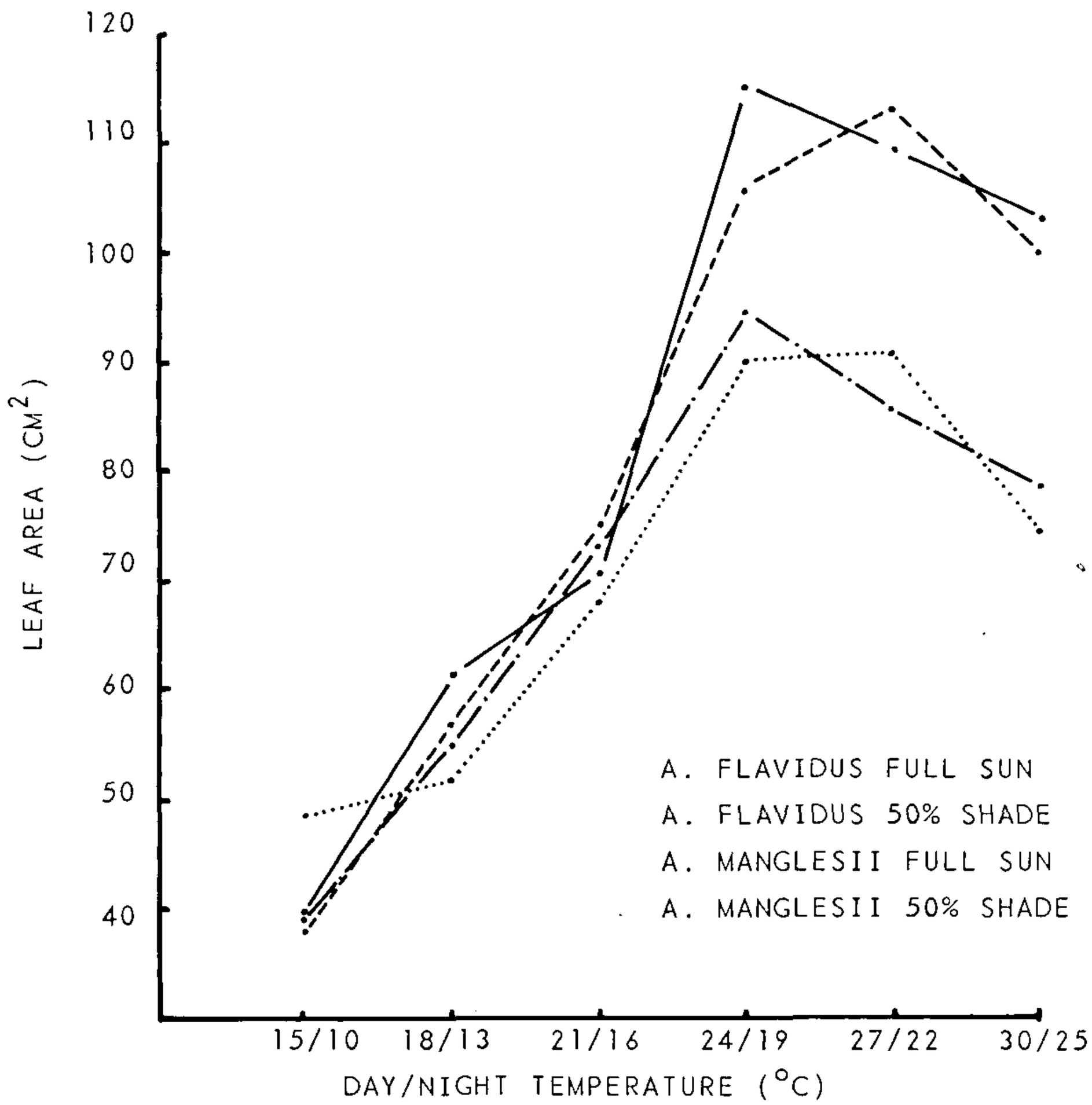

Figure 2. Effect of temperature and light on the leaf area of *A. flavidus* and *A. manglesii*.

Table 1. Variance ratios (F) and significance levels[1] (P) for the influence of light intensity and species type on leaf area, shoot dry weight, root dry weight and plant height at different day/night temperatures.

Comparison	15/10°C		18/13°C		21/16°C		24/19°C		27/22°C		30/25°C	
	F	P	F	P	F	P	F	P	F	P	F	P
Leaf Area												
Between species	<1	N.S.	<1	N.S.	0.57	N.S.	7.11	*	10.36	*	13.13	**
Light level within A.f.$_{(2)}$	<1	N.S.	<1	N.S.	0.12	N.S.	1.46	N.S.	<1	N.S.	<1	N.S.
Light level within A.m.$_{(3)}$	<1	N.S.	<1	N.S.	<1.25	N.S.	<1	N.S.	<1	N.S.	<1	N.S.
Shoot Weight												
Between species	<1	N.S.	3.81	N.S.	7.23	*	3.56	N.S.	8.78	*	41.8	***
Light level within A.f.	2.99	N.S.	3.14	N.S.	2.99	N.S.	2.74	N.S.	1.57	N.S.	4.22	N.S.
Light level within A.m.	3.36	N.S.	7.49	*	1.92	N.S.	6.00	*	1.62	N.S.	49.86	***
Root Weight												
Between species	3.86	N.S.	11.58	**	22.46	***	11.26	**	6.02	*	51.73	***
Light level within A.f.	7.20	*	3.83	N.S.	14.41	**	5.42	*	6.90	*	3.57	N.S.
Light level within A.m.	6.17	*	12.15	**	11.87	**	1.21	N.S.	10.85	*	35.45	***
Plant Height												
Between species	<1	N.S.	<1	N.S.	1.17	N.S.	36.69	***	23.23	***	9.57	*
Light level within A.f.	<1	N.S.	<1	N.S.	1.96	N.S.	<1	N.S.	5.25	N.S.	<1	N.S.
Light level within A.m.	2.18	N.S.	1.21	N.S.	<1	N.S.	3.17	N.S.	1.31	N.S.	1.61	N.S.

(1) : * = $P < 0.05$
: ** = $P < 0.01$
: *** = $P < 0.005$
: at ⅛ degrees of freedom
(2) *A. flavidus*
(3) *A. manglesii*

Mean values for shoot and root dry weight are shown in Figures 3 and 4. Both species showed maximum shoot weight at 27°/22°C, dropping sharply at 30°/25°C particularly in *A. manglesii* under 50% shade.

Shoot weight of *A. flavidus* was significantly higher than that of *A. manglesii* at these two temperatures. Shading had no significant effect on the shoot weight of *A. flavidus* and little effect on *A. manglesii* except at 30°/25°C where the suppression of shoot weight was highly significant.

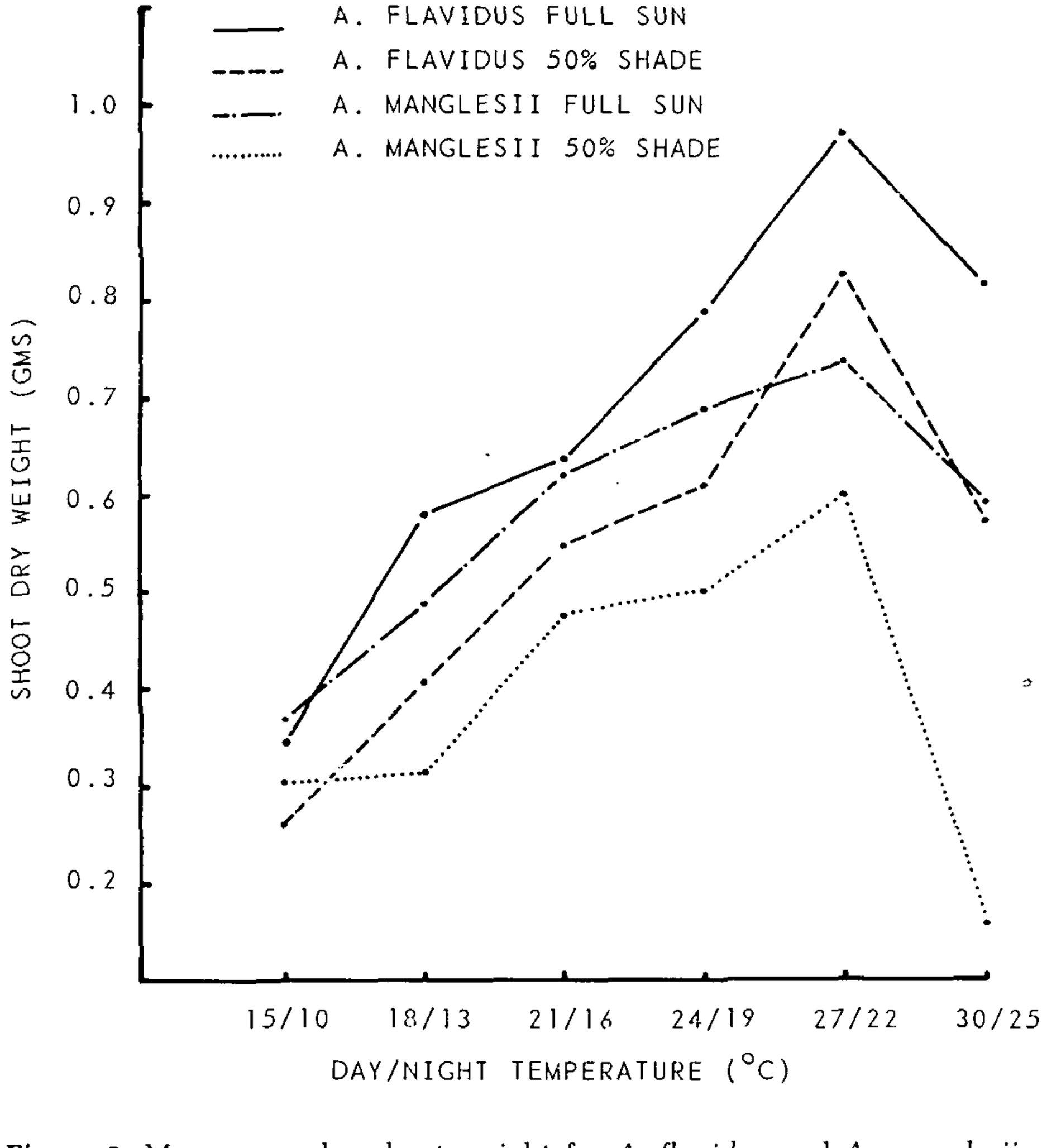

Figure 3. Mean oven dry shoot weight for *A. flavidus* and *A. manglesii* vs temperature at two light levels.

Results obtained for plant height, leaf area, and shoot weight indicate that the critical day/night temperature range for both species lies somewhere between 24°/19°C and 27°/22°C beyond which plants are increasingly stressed. The de-

crease in growth above these temperatures and the morphological aberrations observed, namely twisted, drooping leaves and dead root tips, may be due to metabolic disturbances associated with high respiration rates and a decline in net photosynthesis resulting in the loss of carbohydrates which otherwise would be available for growth. Water stress may also have affected growth. High temperatures associated with low relative humidity could have led to rapid depletion of the available water, followed by stomatal closure and decreased photosynthesis. The blue spotting on the leaves and blue staining of the roots of *A. manglesii* suggests that this species was particularly stressed at 30°/25°C. The production of blue phenolic substances is a well known response of plants in this genus to physiological stress.

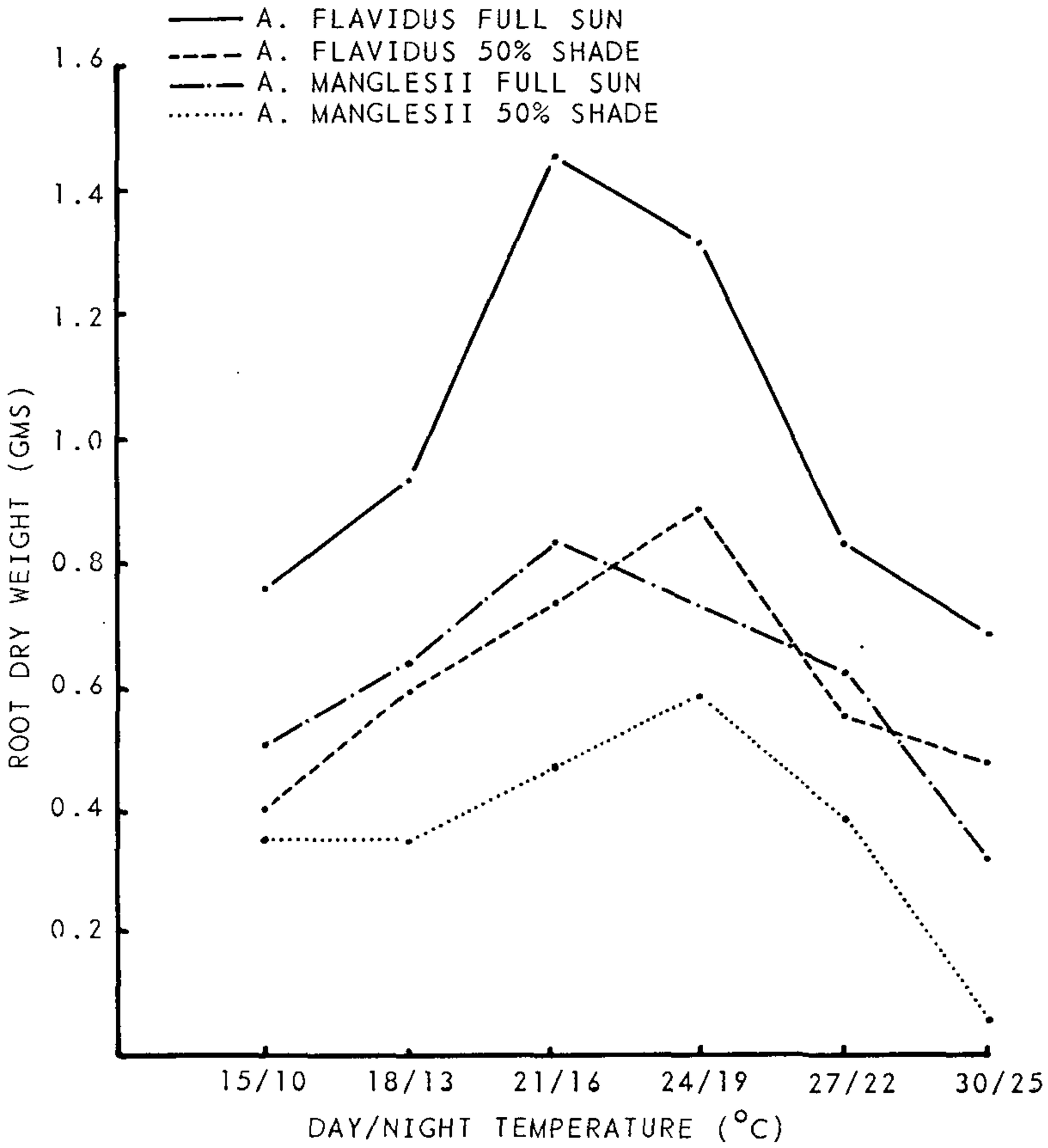

Figure 4. Mean oven dry root weight for *A. flavidus* and *A. manglesii* vs temperature at two light levels.

Root weight differed from shoot weight in its response to temperature, showing maximum development at 21°/19°C in full sun and 24°/19°C in 50% shade. This may be an adaptation to the natural environment in which plants of this genus grow where deep sandy soils provided a cool run for the plants. The fact that the maximum root weights for shaded plants occurred at a higher temperature than for plants in full sun is probably due to the lower pot temperatures experienced by the roots under shade as a result of more moist soil conditions.

Root and shoot weight was found to be significantly reduced by shading at higher temperatures. It is well documented (6) that an increase in temperature beyond a certain minimum will not produce a corresponding increase in photosynthesis even though respiration continues to rise, and that the effect of high temperatures on photosynthesis is more marked under low light conditions.

Root/Shoot Ratio. The root/shoot ratios of both species decreased with temperature above 24°/19°C (Fig 5). Characteristic root/shoot ratios for kangaroo paws grown in the field have not yet been established and are not available for comparison with these results. At most temperatures shading also reduced the root/shoot ratio. In a discussion on this subject Kramer and Kozlowski (3) suggested that shading decreased root growth as a result of a reduction in photosynthesis and a diversion of carbohydrates to leaf production. As pointed out

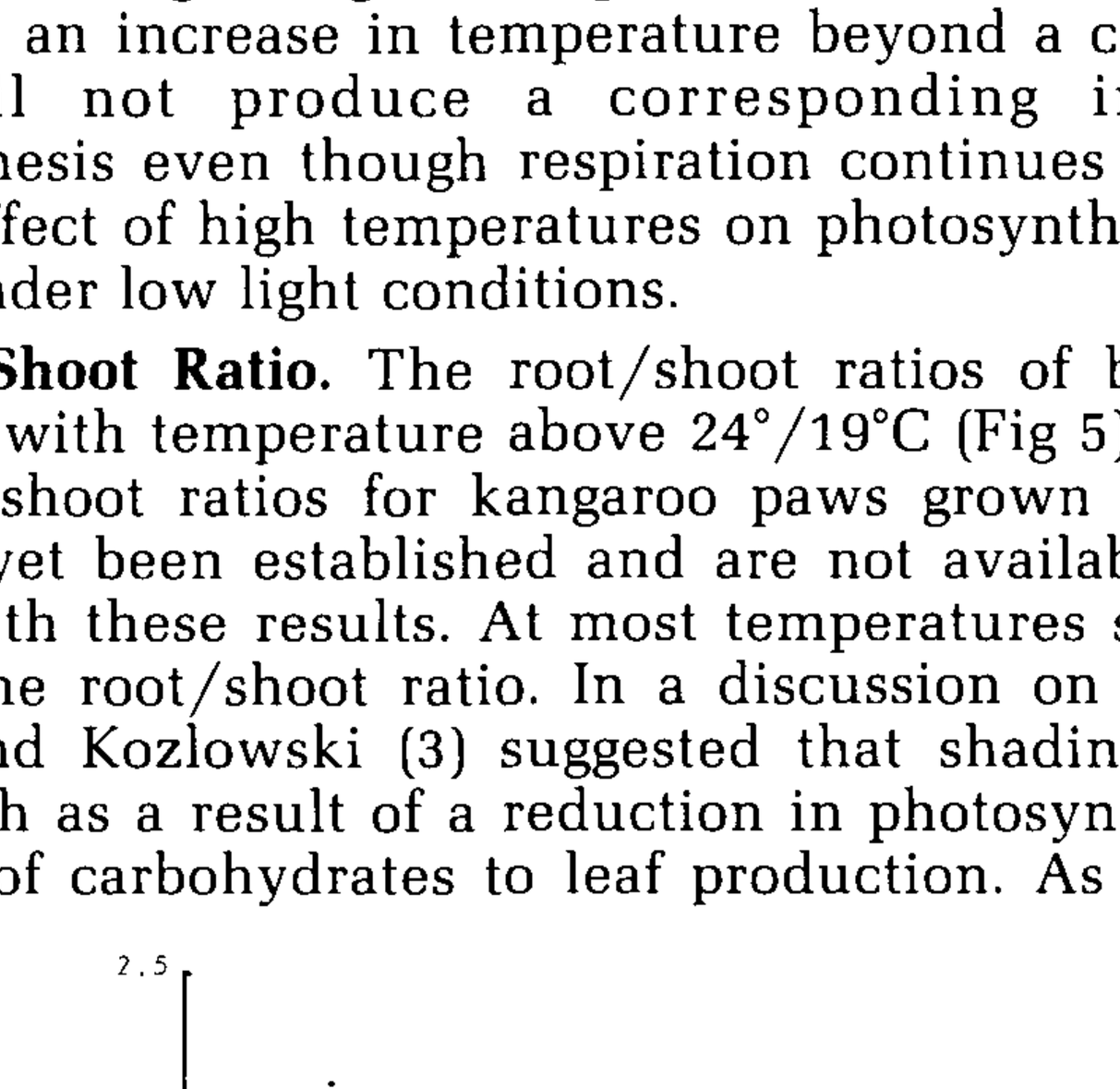

Figure 5. Mean root/shoot ratios for *A. flavidus* and *A. manglesii* vs temperature at two light levels.

by Brouwer (1) this reduction in the root/shoot ratio has adaptive value. A decrease in the ratio at low light intensities guarantees favourable light interception.

CONCLUSIONS

In view of the results obtained, the optimum conditions for vegetative growth of *A. flavidus* and *A. manglesii* under glasshouse conditions would appear to be a 24°/19°C day/night temperature range.

The high root/shoot ratio obtained at this temperature gave these plants superior adaption to transplanting into the field, compared to plants grown at higher temperatures. Shading was found to have no beneficial effect on growth.

Acknowledgements. The technical assistance of Mr. A. Stewart and Ms. K. Baghurst is gratefully acknowledged.

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PROPAGATION FACILITIES — PAST AND PRESENT

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During the last few decades the ingenuity and innovation of both the nursery propagator and research worker has resulted in the improvement of the traditional facilities and the development of entirely new propagation concepts. The objective of this paper is to briefly review these developments in propagation facilities.

During the early days of nursery production the open ground was normally the only facility available. Raising plants by seed, layering, grafting, and hardwood cuttings were the dominant methods used. Today, open-ground methods are still very important and they have been made much more efficient through mechanization, herbicides, and knowledge of correct timing for carrying out each operation. Examples which illustrate this include techniques to overcome seed dormancy, development of specialized machinery for mounding up stool beds of apple rootstocks, and the use of herbicides to reduce labour costs and improve crop quality of species raised from hardwood cuttings.

Many of the greatest advances have been realized in protected propagation facilities. Bell-jars were one of the first facilities used by the nursery propagator. They were made of glass and were round at the base varying in height up to approximately 60 to 70 cm (1 to 2½ ft.). They could be handled by one person and were placed over individual small quantities of cuttings or grafts. Ventilation was provided by placing a small block of wood to tilt the bell-jar. During spring and summer the jars were shaded except on the north side. These bell-jars essentially provided a miniature greenhouse environment where there was some control over light, temperature, and humidity. One traditional facility which is still successfully used today was evolved by the Canadian nursery propagator, Leslie Hancock of Woodland Nurseries, Mississagua, Ontario, in the 1920's following a visit he made to China. It was referred to as the "burlap-cloud" — whereby softwood cuttings were stuck in raised beds filled with sifted soil. A humid and cool environment was provided around the cuttings by regular handwatering over the burlap to keep it moist.

Cold frames are a traditional facility which, although labour-intensive, still provide low cost-effective methods for plant propagation. The traditional cold frame is a wooden or

brick rectangular framework around and over an unheated soil base. Uses for cold frames include:

(i) Breaking seed dormancy by cold-moist stratification.
(ii) Germinating seeds of broadleaf trees, shrubs, and conifers, for rootstocks or ornamentals.
(iii) Rooting softwood, semi-ripewood, evergreen hardwood, and deciduous hardwood cuttings.
(iv) Hardening-off flats of cuttings and bench grafts, bedding out rooted cuttings for liner production, and providing space for pot-grown liners and rootstocks.

Modifications in the design of cold frames have taken place. They include the implementation of the smaller Dutch light, making it easier for the lights to be handled by one person. Also, the provision of basal heat through hot water pipes or electric wiring in order to raise the soil temperature. In order to give greater control over temperature and humidity, an inner layer of glass was placed between the cuttings and the outer light. These modified cold frames were referred to as double-glass frames. The improved control over the environment, providing there was sufficient extra shading, meant that besides winter hardwood cuttings, both semi-ripewood and softwood cuttings could be successfully rooted. Today, instead of the inner glass light, polyethylene is sometimes substituted.

The development of the greenhouse provided the nursery propagator with a facility which provided the opportunity to control the environment far more effectively. Innovations in greenhouse design, cladding (covering) materials, equipment, heating systems, and energy saving methods, now provide the propagator with many alternatives from which to choose for the small and large scale nursery. The last decade has demonstrated how consideration to effective bench and floor area layout for the integration of materials handling systems has been an important contributory factor to increased financial nursery profits — particularly for operators who undertake direct sticking procedures.

Research in both Europe and North America has shown many ingenious and effective ways for saving energy. These include the use of a fan for blowing air between two layers of polyethylene used for cladding a greenhouse, thermal screens and thermal covers, installation of electronic equipment for controlling the air and base temperature, the provision of basal heat by day or night only, and insulating the benches or beds with 2.5 cm (1 in.) or 5.0 cm (2 in.) sheets of expanded polystyrene (Styrofoam®).

Today the propagator has a number of different propagation systems from which to choose. The choice will be dependent upon locality, available capital, size of nursery, and the types and quantities of species to be grown. These systems can conveniently be grouped as follows:

CLOSED CASE

The traditional closed case (utilizing polyethylene) is a brick or wooden cold frame structure located within a greenhouse. Basal heat is provided through hot water pipes or electric cables. Besides being very effective for rooting cuttings, they provide an excellent environment for callusing bench grafts, hence the alternative name — grafting cases — is sometimes referred to. To provide more flexibility in use one, or occasionally two, layers of polyethylene are now normally used instead of glass.

Polyethylene film allows some movement of gases, such as oxygen and carbon dioxide, but inhibits the movement of water vapor, so encouraging an increase of humidity to keep the cuttings turgid. For closed case propagation to be successful, the propagator must appreciate that it is necessary to create a correct balance between air temperature, leaf temperature of the cutting, humidity levels, and shade. Up to 80% shade is necessary during the summer months to avoid stress to the cuttings or grafts.

Until recently there has been little fundamental research related to the environment of cuttings being rooted under polyethylene. Research by K. Loach at the Glasshouse Crops Research Institute, Littlehampton, Sussex, England, has now provided the propagator with a greater appreciation of the physiology involved — particularly in comparison with mist propagation.

The nursery industry in Holland has been effectively using polyethylene over cuttings and grafts for many years and this experience was no doubt a major factor for its implementation in many other countries. For rooting conifers and broad-leaved evergreens during the winter months some nurserymen in temperate climates have been experiencing problems with mist propagation. The advantages in rooting cuttings under polyethylene include:

(i) Minimal leaching of nutrients and subsequent leaf drop induced by frequent overhead misting.
(ii) Less stress from excess water being retained in the rooting medium — particularly where a high peat ratio mix is used for broad-leaved evergreens.
(iii) Less energy is required to heat the rooting medium because there is no overhead mist removing heat.

There are essentially three methods for rooting cuttings under polyethylene film:

1. **Contact.** A continuous layer of polyethylene film is layed directly on the cuttings, and then tucked in around the edges of the bed or bench to ensure it is in direct contact with the upper leaf surfaces. Condensation droplets will quickly form on the underside of the polyethylene ensuring a humid environment is maintained.

2. **Supported.** Here the polyethylene is supported by a wooden or metal framework to leave an air space between the cuttings and layer of film. Some propagators prefer this system as it is easier to inspect the cuttings as it provides greater air circulation which, in turn, may help to reduce disease incidence. However, with lower humidity levels occurring, greater care must be given to correct shading values.

Supported polyethylene to provide a series of tunnels provides an excellent system for rooting broadleaved evergreens in the winter, and then for the summer months, a mist line can be easily installed within the tunnels for softwood propagation.

3. **Drape.** Polyethylene drapes are used to increase the air space around the cuttings by securing it down the inside of the greenhouse roof and allowing it to hang down along the side of the propagative bench or floor bed. In wider span greenhouses a false ceiling can be created by supporting the film on tight wires and allowing it to drape down on all four sides to create a tent. Mist lines or foggers can be installed if required.

MIST PROPAGATION

Since the Tennessee nurseryman, H. Templeton, in 1953 devised and implemented the concept of intermittent mist (controlled bursts of mist), mist propagation has developed worldwide as a standard and effective system for rooting cuttings. (The physiology, equipment, and various adaptions have been well-documented in the IPPS Proceedings and in plant propagation textbooks). The overhead application of small water droplets keeps the cuttings turgid by reducing transpiration and respiration while the cell tissues are kept cool by the evaporation of the film of water which had formed on the upper surfaces of the leaves. Today mist propagation facilities are sited outdoors (in warm climates), and in cold frames, tunnels, shade houses, and greenhouses.

Engineering technology has improved the effectiveness of mist propagation, particularly in relation to nozzle design and control equipment for regulating misting frequency and retain-

ing accurate control of basal heat. Traditionally, in a greenhouse a mist propagation system was sited on a bench, but the need for reducing costs and implementing effective materials handling has meant that today most systems are constructed at floor level.

Management of mist propagation systems can be a problem with some propagators — particularly in temperate climates. Sometimes this is due to ineffective maintenance and disease control procedures. Experience has shown problems can be due to cutting stress caused by excess water application from the nozzles. Mist propagation should not be considered as a system which is "problem-free", because it is not. This is one reason why propagators today are installing fogging and closed case facilities with polyethylene film covers as an alternative.

LOW POLYETHYLENE TUNNELS (SUN TUNNELS)

Low polyethylene tunnels are essentially an extension of mist propagation but have been classified in this paper as a separate system as they provide the propagators with a temporary or permanent low cost facility. They are constructed to provide a continuous tunnel 1.0 m (3¼ ft.) high and 0.9 to 1.2m (3 to 4 ft.) wide supported by a metal or wooden framework. Following sticking of the cuttings and fungicidal drench the tunnels are covered with milky (opaque) polyethylene. The tunnels as originally designed in Denmark do not contain an internal misting line while those in North America and many other European countries do. Providing that the incoming light intensity is reduced by at least 50%, high temperature and high humidity are allowed to develop without causing undue stress to the cuttings.

Low polyethylene tunnels are particularly useful for softwood cuttings in that they save utilizing valuable greenhouse space for large quantities of easy-to-root cuttings. Also they are a useful facility for a new nursery business where capital expenditure is limited.

FOGGING

The concept of fogging is not new but during the last five years the nursery propagator has found that in certain situations it has many advantages over other systems. For example, significantly less water is required than a mist system resulting in reduced waterlogging of the rooting medium and less stress to the cuttings. Larger cuttings may be successfully rooted — particularly those with large, soft leaf laminas. Fogging systems are particularly useful for establishing new plants from the micropropagation laboratories to wean them to a more normal regime.

With fogging there is a distribution of very small water droplets to create a constant high humidity level. These airborne droplets, down to 10 microns or less, increase the humidity level of the atmosphere until there is an excess of water droplets suspended in the air. True fogging essentially gives the propagator an environment similar to a sea mist. Mist propagation creates droplets with a considerable size range, most of which are larger than 50 microns, so they quickly fall and are unable to create the suspension effect.

During the 1950's and 1960's the main fogging equipment for propagation was the Swiss manufactured Defensor® units. Today we have a considerable wider selection of more sophisticated equipment some of which was initially developed for industrial use. Essentially equipment now available can be placed in three categories:

1. High pressure fogging whereby a series of atomizing nozzles are embedded in 1.3 cm (½ in.) pipes with the filtered water particles distributed upwards as a "symmetrical cone"; e.g. Mee Industires Fog System®.

2. Ultrasonic humidifier nozzle (siphon nozzle) whereby very fine droplets are produced by water being accelerated by compressed air; e.g. Sonicore® system.

3. Ventilated high humidity whereby self-contained units are sited within the greenhouse to generate fine water particles that are then, in turn, forced by a fan and mixed into a stream of cool air for distribution within the greenhouse; e.g., Agritech® system.

In conclusion, the choice of the propagation facility will largely be determined by available financial capital, the crops to be grown, and the geographical location of the nursery. It is important that today's facility is designed so that it can be easily modified to future market demands and innovations. Before making the final choice it is very important to seek advice from fellow nursery propagators, extension officers and, where applicable, specialist private consultants.

ROOTING HARD-TO-ROOT CONIFERS

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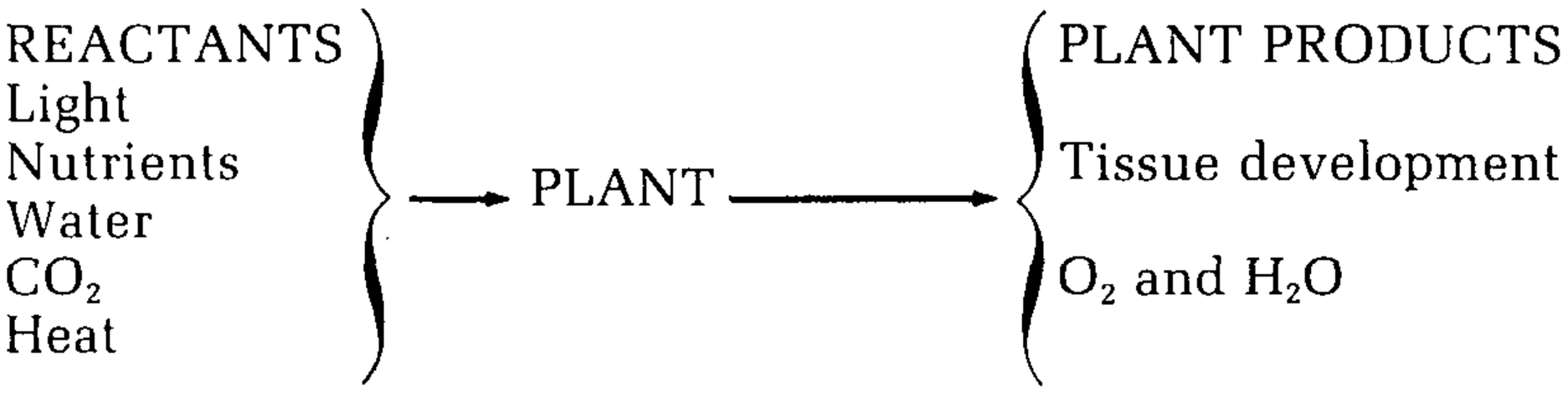
In October, 1971, the Western Region, IPPS, held its 12th annual meeting in Santa Barbara, California. One of the presentations (1) that year made a lasting impression on me. Robert W. King of the California Propagation Co., Sepulveda, California, spoke on "The Balance of Light, Humidity, and Temperature As Related To Cutting Leaf Drop". The "bottom line" of his experiments was that rooting percentages of *Pittosporum tobira* and other cuttings could be increased by about 30% if bottom heat was reduced an average of 10°F. on cloudy days. He noted that rooting time was, however, increased by more than 10%. My question of Mr. King after his presentation was — "had he considered turning the bottom heat even lower to see if he could get increased benefits." He answered in no uncertain terms that he was in the business to make money and that time was money — since bench space was very costly. Both my question and his answer have continued to haunt me over the years.

My presentation today takes up where Mr. King's left off nearly 14 years ago. In his very clear introduction, Mr. King summed up plant development and growth as follows:



Simply stated: a warm, well-fed, well-watered and well-lighted plant will grow vigorously. Conversely, a poorly fed and poorly watered plant in a cool, poorly-lighted area will produce tissue growth much more slowly. Plant propagators know that it is the proper balance of these reactants that is the key to successful propagation and production. We know that the plants more difficult to propagate from cutting are those in which the proper balance of these reactants is very critical. Most of us have lost crops both from too much light and heat and from too little water, as well as from too little light and too much water. The conifer propagator must not only be able to maintain this optimum balance of heat, light, and water, and nutrients but he must be able to maintain it over a very

long period of time during which there are often considerable weather changes in the seasons. He must, of course, be able to do all this in a cost effective manner.

Over the years we have worked out a less traditional method for achieving this balance of heat, light, and water which has enabled us to root conifers using much less energy, fewer chemicals, less water, and less labor — but requiring more time.

In the early 1970's, and at the time I heard Mr. King's talk, we were getting the approximate rooting results that we are today. We were doing this using fiberglass covered "A"-Frame greenhouses dug into the hillside, electric bench heat; and PYE mist control units controlling Monarch mist heads, together with Acme convection-tube fan systems and polypropylite shade cloth. In short, we had state-of-the-art structures for the time. I do not need to dwell on the construction and operation costs of such units today. By 1983 we were confidently rooting our same line of conifers, mostly dwarf and ornamental spruces, with some firs and hemlocks outside under a canopy of deciduous and evergreen trees without a structure, without an automatic watering system, without bottom heat, and without the use of fungicides. The trade off: it now takes up to 1½ years to produce a well-established rooted conifer cutting outside as opposed to 6 to 8 months in the greenhouse. For us the savings in dollars, labor, and materials have much more than offset the cost of holding the cuttings the extra time.

The theory behind our strategy is really just an extension of Mr. King's findings: Reduced bottom heat temperatures, although slowing tissue growth, greatly reduces the growth of pathogens. In addition, if light is kept to the low levels of only a few hundred foot candles, the water requirements are greatly reduced both from transpiration and evaporation. In fact, the water needs are reduced to the point that our cuttings need no water other than rain from January through June and no more than 2 or 3 waterings per week during the hot summer months. Cuttings receiving such low amounts of water and no bottom heat have a greatly reduced chance of decay, so much less so that our outside cuttings have fungicide treatments only when they are initially stuck (one in 1½ years) as opposed to weekly applications for those cuttings in the greenhouses.

I would like to encourage more of you to experiment with propagating conifers outside in high shade without bottom heat. Our nursery is located 30 miles east of Portland, Oregon, at the western end of the Columbia River Gorge, at an elevation of 1000 ft. Our yearly temperature is several degrees

cooler than that of Portland, Oregon, and ranges from about 0° to 90°F. Our annual rainfall is about 60 in. per year.

LITERATURE CITED

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CONTROLLING THE ENVIRONMENT FROM CUTTINGS TO FIELD

JAMES F. McCONNELL

Bailey Nurseries, Inc.
Yamhill, Oregon

At Bailey Nurseries, a significant quantity of softwood cuttings are rooted and successfully planted bareroot to the field within the same growing season. These plants normally remain in the field throughout the summer and through another full growing season producing what is referred to as a "year and a half" plant. The objective of this practice is to provide the nursery trade with a medium sized, highly vigorous bareroot plant in as short a time as possible. This plant is unattainable by other nursery practices. Certain environmental conditions must be created and maintained in order to produce healthy, vigorous rooted cuttings with good survivability.

Controlling the environment for propagation begins with healthy vigorous stock plants from which to take cuttings. The stock plants should have optimal water and nutrition, and be free of all diseases and pests. Without these essential factors, the propagator is at a distinct disadvantage. Actively growing field stock will normally provide excellent cuttings; however, in some cases stock plants must be maintained.

Once it has been determined that the cuttings are at the proper stage for propagation, they must be given a healthy environment in which to exist after being separated from the parent plant. A sharp knife or pruning shears are used to make a good clean cut. Small bundles of cuttings (25 to 50) are laid in the cool shade of the stock rows until they are picked up and placed in a basket. Cuttings are picked up within a few minutes after they have been taken from the stock plant. Baskets of cuttings are immediately drenched with cool, clean water.

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Transporation of the cuttings to a refrigerated cooler is done as soon as possible. Moistened burlap creates an excellent cooling effect when placed directly over the cuttings. A refrigerated cooler maintained at approximately 40°F. (8°C) provides good storage of cuttings until they can be dipped in rooting hormones and planted in a rooting medium.

The rooting medium is a very important environment that must be created. A well-drained rooting medium is essential, consisting of 50 to 80% pumice with the remainder being washed builder's sand. A coarse, well-aerated soil mix requires attention to prevent drying out, but it is hardly ever waterlogged. Drain tiles below the ground beds ensure excellent drainage of the media.

Misting of cuttings is possibly the most critical environment to be created. At Bailey's the majority of our cuttings are rooted under a Growing Systems Traveling Irrigator. It is simply a motorized spray boom traveling on tracks that are suspended from the superstructure of the quonset style greenhouse. The irrigator has a dual clock system that allows a great deal of flexibility in determining the number of times that the boom travels through the greenhouse each hour. Nozzle size and speed of travel, as well as the number of passes through the greenhouse in a given amount of time determines the amount of mist applied to the cuttings. An excellent filtration system eliminates the worry of plugged nozzles. The application of mist is totally uniform and the results are frequently spectacular. The minimum amount of water that will keep the plants from wilting provides the most desirable misting pattern. Creating this environment requires very close supervision.

Mechanical ventilation of our greenhouses is not necessary since both ends of the greenhouse are open. Wind currents moving through the greenhouse can, however, cause rapid drying of mist from the cuttings. To avoid this problem, plastic wind barriers are used to cover the lower portion of the doors. The upper portion of the door is always open to prevent heat buildup and air stagnation. In the evenings, the wind barriers are removed to allow the cool night air to circulate through the cuttings. Allowing the cuttings to dry in the evening and early morning dramatically reduces the incidence of disease.

A piece of 47% shade cloth is normally placed over the greenhouse while the cuttings are being stuck. This shade cloth is left in place for 3 or 4 days to reduce the stress due to the sun. Some cuttings will tolerate full sun after the shade cloth is removed while others must be protected by a light coating of liquid shading over the top of the greenhouse.

As soon as the cuttings have enough roots to survive on their own, the mist is removed and fertilization begins. Liquid fertilizer (20-10-20) is applied through the traveling irrigator at a rate of 200 to 300 ppm. The fertilization continues on a weekly basis and is stopped at least one week prior to field planting.

Three to five days before planting, a portion of the new terminal growth is trimmed from the rooted cuttings. This procedure hardens the cuttings and ensures less stress when the plants are in the field. The day before the cuttings are dug, they are thoroughly watered.

The digging process begins early on the day before the scheduled planting date and is normally completed by 10:00 a.m. The rooted cuttings are carefully dug with forks to save as many roots as possible. They are packed in large wooden boxes and thoroughly drenched prior to being placed in the cooler. Several hours at 40° F causes the cuttings to be very turgid.

The field planting operations also begin early in the morning. A wagon is loaded with the boxes of rooted cuttings at 3:00 or 4:00 a.m. The wagon is kept tarped throughout the day so the cuttings will remain as cool and fresh as possible. Planting begins at 5:00 a.m. to take full advantage of the cool morning conditions.

It is essential to prepare a mellow soil for the planting operation. This begins months in advance. A plow down crop of spring oats is planted in the spring as soon as the ground can be worked. This crop of oats is used only to create organic matter, therefore, it is fertilized heavily (100 lbs. actual N per acre) to promote vigorous straw growth. The oat straw is chopped before the seed heads mature. The ground is then plowed. The soil pH is tested and adjusted with agricultural lime. Preplant fertilizer is also applied at this time after the fertility levels have been determined by soil testing. Soil-borne insects, such as symphylans, are eliminated by an application of a soil insecticide.

The actual soil conditioning for the planting operation consists of preparing a good loose seed bed with adequate moisture to make the soil slightly moist. A tractor draws trenching blades through the moist ground, creating furrows into which the rooted cuttings are placed. The actual planting is done by hand. Once the cuttings are in the furrow, they are packed by the pressure of the planter's foot. The surface of the ground is immediately leveled with a small field cultivator and a band of herbicide (usually Devrinol) is applied directly over the cuttings. It should be noted that this practice is not

recommended by the chemical manufacturer and a great deal of caution should be exercised. Slight foliar burning has been observed on certain barberry and hydrangea species.

Planting and watering-in go hand in hand. As soon as the planting crew has worked past the reach of one irrigation line, the irrigation water is turned on and the cuttings are watered in for two to three hours. Planting continues and new irrigation lines are laid down and turned on as needed until the planting is finished and all cuttings are watered in. An irrigation crew member is assigned to keep the cuttings moist and cool by periodically turning the water on and off as needed for the next week to 10 days. This operation closely resembles a propagation misting program. This is another situation where the soil should not be waterlogged. The cuttings are monitored daily for new root growth. As soon as new roots are observed, the periodic watering is stopped and the newly planted cuttings are included in the regular field watering program.

Plants that are routinely summer-planted as rooted leafy cuttings are: *Hydrangea arborescens*, *H. arborescens*, 'Annabelle', *Spiraea* × *bumalda* 'Anthony Waterer', *S.* × *bumalda* 'Coccinea', *S. albiflora*, *Prunus* × *cistena*, *P. glandulosa*, *P. triloba*, *Ligustrum vulgare* 'Lodense', *L. ovalifolium*, *Rosa rugosa* cultivars, *Weigela florida* cultivars, *Aronia arbutifolia*, *Berberis thunbergii* '*Atropurpurea*' and *Ilex verticillata*. Summer planting normally ends by the third week in August to allow the plants enough time to establish in the field before the winter rains begin. Typically, 100,000 to 125,000 rooted cuttings are field planted by a crew of 20 to 25 people in 8 hours. One person coordinates this entire planting operation.

It is strict attention to detail and leaving nothing to chance that encourages the best results. Every step of the process must be carefully monitored. When a program such as this is first initiated, it is best to start small and work up to larger quantities. This will provide valuable experience, show where improvements can be made, and bring out limitations that are peculiar to your operations.

SYSTEM OF DIRECT STICK PROPAGATION

ROSS MERKER

Briggs Nursery, Inc.
4407 Henderson Blvd.,
Olympia, Washington 98501

Propagation techniques vary from complex micropropagation and grafting procedures to simple seed sowing and stem cutting systems. One system used by Briggs Nursery, Olympia, Washington, for the rooting of cuttings of easily propagated plants is "direct stick." The term "direct stick" is used to describe the rooting of cuttings directly in the container in which the plants are to be sold. Transplanting of cuttings is avoided by the direct stick process, and growing and labor time is reduced. This propagation technique lends itself to volume propagation of easily-rooted plants that can be marketed in a smaller container such as a one gallon. Several requirements are necessary for good success with this system.

A source of healthy stock plants is needed, as well as a plastic propagation structure. Briggs Nursery uses single 14 x 100 ft. quonset houses. Misting of the cuttings is done by a Phytotronics mist controller with individual house controls. Direct stick at our nursery is done in May, June, and July; timing depends on cutting readiness; the cooler months are avoided to eliminate the need for bottom heat. Leafy, softwood cuttings in May, June, and July root very quickly and uniformly. A clean water source is important to avoid disease and algae growth. Briggs Nursery chlorinates their water supply.

The use of multiple cuttings per container greatly increases the fullness of the finished product and speeds up marketing time, so large amounts of cuttings are required. Routine pruning of growing container blocks can provide this large amount of uniform cuttings. The finished product is most attractive when the cuttings are placed near the center of the container at the 12, 4, and 8 o'clock positions.

Some easy-to-root cuttings such as cotoneaster, potentilla and euonymus require almost no preparation other than basal leaf stripping. Others require a hormone, such as Dip & Grow, and mechanical wounding of the stems. (See Table 1).

Shade is required on quonset houses to prevent burning from the sun. Paint or shade cloth can be used. Careful monitoring of mist is mandatory due to cultivar differences and weather changes. It is important that plants with variable rooting times are not mixed in the same house, since the first rooted cultivar will receive too much water. One cultivar per house is optional. Reducing the water as soon as rooting takes

place is imperative, or stem decay will occur. Mist heads generally provide better foliar wetting than irrigation heads, although Briggs Nursery currently is successful with an irrigation type sprinkler. The sprinkler currently used is the Olson SR7-0505.

Windblown liverwort spores cause some growth of liverwort; this pest can be killed by drenching with 4.4 ounces of Captan and 4 ounces of Wex per gallon.

Direct stick propagation can result in a marketable gallon container as quickly as 3 months from the sticking date. Less than 90% rooting would indicate that the cuttings should be done under a more controlled environment than a quonset house, but easy-to-root plants can be very successfully rooted with this system in simple quonset houses.

Table 1. Sticking date of leafy softwood cuttings, rooting time, and hormone requirement for a range of easily-rooted species.

Plant	Direct stick date	Ninety percent or more rooted & off mist	Hormone required
Berberis thunbergii 'Atropurpurea'	June 5	46 days	none
B. thunbergii 'Atropurpurea Nana' [syn. *B. thunbergiaea* 'Crimson Pygmy']	June 5	46 days	none
B. thunbergii 'Rose Glow'	June 5	46 days	none
Cotoneaster apiculatus	May 16	41 days	none
C. dammeri	July 2	15 days	none
C. d. 'Coral Beauty'	July 2	15 days	none
C. d. 'Lowfast'	June 21	21 days	none
C. horizontalis	May 16	41 days	none
C. microphyllus 'Cochleatus'	July 9	30 days	none
C. salicifolius 'Repens'	July 8	50 days	none
Escallonia 'Apple Blossom'	July 25	37 days	none
Euonymus alata 'Compacta'	July 12	50 days	1-10 Dip & Grow
E. fortunei 'Sunspot'	May 29	35 days	none
E. fortunei 'Emerald Gaiety'	May 17	46 days	none
Ilex crenata 'Convexa'	July 24	45 days	1-10 Dip & Grow
Leucothoe axillaris	June 21	71 days	1-10 Dip & Grow
Parthenocissus henryana - 2 cultivars -	July 8	9 days	none
Photinia × *fraseri*	June 1	60 days	1-10 Dip & Grow
Pieris japonica 'Mountain Fire'	July 17	60 days	1-10 Dip & Grow
Potentilla fruticosa - 7 cultivars -	June 25-July 11	15-19 days	none
Prunus laurocerasus (syn. *P. officinalis*)	July 26	45 days	none
P. laurocerasus 'Otto Luyken'	July 17	45 days	none
Viburnum opulus 'Nana'	July 24	21 days	1-10 Dip & Grow

RAY MALEIKE: At Briggs Nursery do you use any kind of fertilizer in your "direct stick" rooting method?

ROSS MERKER: Yes, we use a little Osmocote in the mix, then we run fertilizer through the irrigation system.

BEV. GREENWELL: Roger, what dwarf conifers are you rooting in the open — under high shade?

ROGER MACKANESS: Ornamental spruces, *Chamaecyparis obtusa* 'Nana', a few true firs, dwarf firs, *Picea pungens* 'Koster', and dwarf Douglas fir. *Abie balsamea* 'Nana' roots very easily.

DON DILLON: Ross, in your slide pictures, cuttings sometimes died at the base but rooted above — did this occur when you were not using a rooting hormone? What do you think causes this?

ROSS MERKER: I think the cause of rotting and rooting above is from too much water in the medium, particularly in a bark-sawdust mix. We ordinarily do not use a rooting hormone — only for the hard-to-root items.

ALBERT NEWCOMB: Roger, do you have any problems with fungi, when you are rooting your cuttings in the open — out under the pine trees?

ROGER MACKANESS: It is amazing to us how few disease problems we have in the open. We just fungicide drench to start and that is all. In the greenhouse we are continually spraying.

ANNE KYTE: Jim, you mentioned that you had no problems with your nozzles clogging. How is this accomplished?

JIM McCONNELL: The boom system that we use has a 100 mesh strainer in the line. Behind each nozzle we have another 100 mesh screen. It works very well. We have never had to unplug one.

PHIL BARKER: Roger, you are trading longer rooting time for greater rooting success. Is that right?

ROGER MACKANESS: No, the rooting time is the same. We are trading longer rooting time for lower labor and handling costs.

DICK SNYDER: Jim, when you use Devrinol right over the tops of your plants, do you find any injury or root inhibition?

JIM McDONNELL: It is a radical thing to do and is not recommended by the manufacturer. We have noticed some leaf burning on barberry and hydrangea, but on the vast majority of our plants we take care of a lot of weeds with just one operation. We have not seen any problems with subsequent crops on the same land.

VOICE: What is the rate of Captan application for liverwort control?

ROSS MERKER: We use 4.4 oz Captan + 4 oz of a spreader-sticker (Wex) per gal., and drenching with that — put on with a back-pack sprayer.

VOICE: What about the snow-load on your A-frame greenhouses; and what are the dimensions?

ROGER MACKANESS: We get lots of snow, up to 6-ft., where we are, at 1000 ft., and at the mouth of the Columbia River Gorge. The A-frames are equilateral triangles, 10x10x10 ft. Quonset hut greenhouses will collapse under the snow but the A-frames will hold. In the houses we walk in a trench in the middle, with the 3 ft. benches on the ground on either side. There is very little cubic feet of space in the houses to heat in winter or cool in summer.

VOICE: Ross, do you need to use any bottom heat in your direct sticking method?

ROSS MERKER: None whatsoever; we stick the cuttings in May, June, and July. One of the purposes of this method is to get away from the heat bill.

PROPAGATION OF FRUIT TREES AT VAN WELL NURSERY

RICHARD G. VAN WELL
Van Well Nursery, Inc.
Wenatchee, Washington

Fruit tree production numbers are difficult to ascertain as most nurseries do not readily divulge the number of trees grown and sold.

We can figure out that fruit trees in the Pacific Northwest are a big business. Based on the 1% certification fee, there appears to be 2,500,000 fruit trees sold by nurseries in the State of Washington each year. Many people do not realize what it takes to grow a saleable tree. My plan is to give you a quick overview of this process.

Based on our production, apple trees are the most popular trees grown, followed by pears, cherries, peaches and the rest of the stone fruits. Apples are, by far, the species grown in the largest numbers. I would suspect that all nurseries in the Pacific Northwest would have somewhat the same ratios.

The rootstocks for all fruit trees are started from seed, or are produced by clonal propagation. Limited number of seedlings and clones are being reproduced through tissue culture.

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We have planted some tissue-cultured seedlings in the past and will continue to use them on an experimental basis to see what develops. One big problem is the cost.

At the present time most pome fruit nursery trees take three years to develop from seed while most stone fruit trees take two years to develop a tree. The seeds to start the seedlings are planted in either the spring or fall. In the case of pome fruits, seeds are planted in seed beds and grown one year and then transplanted into the nursery row for propagation. With stone fruits the seeds are planted directly in the nursery row and budded in the row without being transplanted. The exception is cherry seedlings which are handled as the pome fruits.

Starting about the end of July and going to the first of September nurseries do their budding. This is an active time in the nursery and a time that requires much care in order to produce the correct selections of cultivars that are true-to-name and meet the standards of the Fruit Tree Certification program of the state.

All nurseries maintain cultivar blocks called scion orchards. These blocks are inspected by the state and also indexed to insure that the trees are clean of known viruses. Washington certification rules include a 5% tolerance for indexed and certified stock.

Budding is the main propagation process used by nurseries in the state. We use the "T" budding method, although some nurseries use "chip" budding. We have experimented with "chip" budding for the last five years and have not seen any improvement over "T" budding. In "T" budding we expect 60 to 85% stands on stone fruits and 90 to 95% stands with pome fruits.

In the following spring all seedlings are cut back to the bud and the bud is developed into a nursery tree by constant suckering and limbing.

During the fall of the second year we are ready to dig our trees. This occurs about the first week of November. Before we can dig, all leaves must be removed. If the leaves were brought into storage mold would develop that would be harmful to the trees when stored.

Some nurseries remove leaves by using chemicals. We do not — all of our leaves are removed by hand. Leaf removal usually starts about the last week of October. Dr. Fenton Larsen, of Washington State University, has published a research paper showing that early removal of leaves may stop or delay the tree from going into dormancy.

The trees are dug in the fall before the ground freezes and put into storage where they are protected from winter weather. In storage the humidity is kept high to keep the trees from drying out.

During the winter months — December through February — the trees are graded according to specific standards set forth by the State of Washington Department of Agriculture, and by the American Association of Nurserymen.

Following the grading and warehousing of the trees, comes the sales and shipping season. During the month of April over 50% of the trees we have in storage are shipped or delivered. Shipping and storing the trees is another important link in the chain from the seed to the planting of the tree in the orchard.

All of the different steps of production and delivery of fruit trees requires careful and organized effort by all who are involved in the fruit tree nursery business.

BUDDING HEIGHT AND ORCHARD PLANTING DEPTH FOR MALLING APPLE ROOTSTOCKS

CARL PERLEBERG

Columbia Basin Nursery

Quincy, Washington

The budding height on the dwarfing Malling apple rootstocks are presently 6 in above ground level, but budding height for apple seedlings are still at about 2 inches above the soil line. Let us describe the history of the Malling budding heights and how and why it changed.

In the 1950's when the dwarfing Malling rootstocks were first used in the United States many of the nurseries budded these new rootstocks at the same height as the seedlings — two inches. It was discovered soon in orchard plantings that these low-budded, high-planted Malling trees tended to lean badly. The budding height was increased in the 1960's to a maximum of 10 to 12 in. so that the plants could be planted at least 6 in. deeper at the orchard site thereby, hopefully, stabilizing the tree and always keeping the bud union out of the ground 4 to 6 in. to prevent scion rooting.

In the last 10 years the budding height has been lowered back down to 6 or 7 in. above the ground. This height of budding works very well with either a sled type mechanical planter or a 24 in. augered hole. Most mechanical planters travel at a 15 in. depth. The total vertical length of the root-

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In the last 10 years the budding height has been lowered back down to 6 or 7 in. above the ground. This height of budding works very well with either a sled type mechanical planter or a 24 in. augered hole. Most mechanical planters travel at a 15 in. depth. The total vertical length of the root-

stock and shank is about 16 in. — 8 in. for the nursery planting depth, 2 in. for a nursery cultivator hill and a bud union at 6 in. height. So, if the new fruit tree is planted to the bottom of the trench the bud union will remain 1 in. out of the soil.

The advantages to this planting depth are:

1. The nursery-grown root system is planted in the top soil and not too deep.

2. The orchard tree's anchorage is improved by planting at a 5 in. deeper depth than in the nursery row.

3. No danger from rootstock aerial rooting or burr knot growth.

4. A little greater fruit tree vigor.

5. Greater tree uniformity in the orchard.

6. Greater bud union winter protection by being planted only 1 in. out of the ground.

7. Some allowance for soil erosion in the tree rows caused by heavy rain storms or sprinkler irrigation washing the herbicide-treated bare soil away from the tree trunks.

The budding height of the seedling-rooted trees is still about 2 in. in the Pacific Northwest. In California the budding height on seedlings has been observed to be 5 or 6 in. I feel that this greater height of 5 inches fosters the additional problem of root or trunk suckering and seedling burr knot growth. Also, for our northern apple growing areas the bud union area would definitely be more winter-tender if planted several inches above ground level. I personally plant all seedling-rooted trees with the bud union about 3 in. below the ground.

I would like to mention that there is a continuing trend in the Pacific Northwest toward the 12 ft. high orchard tree. This medium-small sized, heavy bearing tree is a realistic compromise between the big, high tree spaced too far apart and the small, spring frost-susceptible tree. Whatever rootstock is used, it must have the capacity to fill up the allotted tree space quickly and to produce a healthy, very productive orchard tree. With the growth controlling chemicals and scoring technology available today, a progressive plantsman can steer the growth intensity and productiveness throughout the fruit tree's life. Incidentally, this year our orchard operation, Royal Crest Orchards and Columbia Basin Nursery, scored apple and pear trees to induce branching, stunting, blossoming, and early fruit ripening. These desired responses require timeliness and precision. This year we scored 600 acres with a tree age of 2 to 18 years, beginning 8 weeks before apple blossom and ending 10

weeks later. The precision scoring crew of 15 to 18 people worked at 4 distinct times — a total of 5 weeks.

If you are ever in the Quincy, Washington area please drop in for a tour of our nursery and orchard operations.

FINGERPRINTING APPLES: A CHEMICAL METHOD OF IDENTIFYING CULTIVARS

FENTON E. LARSEN, RICARDO A. MENENDEZ, and ROBERT FRITTS, JR.

Department of Horticulture and Landscape Architecture
Washington State University
Pullman, Washington 99164-6414

Abstract: To identify apple, *Malus pumila* Mill. [syn. M. *domestica* Borkh], cultivars, electrophoretic separation of proteins and isozyme patterns from shoot bark extracts was investigated. Cross-examination of enzyme banding patterns allowed the identification of 33 clonal apple rootstocks. Virus-tested rootstocks were distinguishable from the original contaminated material, and selections of 2 rootstocks propagated by tissue culture expressed rather broad isozymic differences compared with their respective original stocks. Of 57 clonal apple scion cultivars and sports, all cultivars were identified. Sports within each cultivar, however, were indistinguishable, with the exception of 'Wijcik', a natural compact mutant of 'McIntosh'. Isozymic patterns of scion cultivars showed no apparent effect of sample timing, rootstock, growing location, or age of the wood where the sample was taken.

A precise method of identification of tree fruit cultivars is needed, especially during the early vegetative growth phases and during dormancy when many morphological criteria cannot be used. Tree fruit nurseries are especially interested in an identification method to help correct labeling errors or losses and to assist in patenting or with patenting infringement. Growers need a technique to positively identify suspected scion and rootstock errors in their own plantings or to establish true identities where orchard purchases have been made or are anticipated. A chemical identification method has the potential to be more precise than the usual morphological approaches to identification.

Chemical taxonomy, that is, the classification of plants based on chemical differences, is not a new method. It has been used to help establish taxa, genera, species, and ecotypes and is an invaluable aid in evolutionary studies (3). Many chemicals have been used as so-called genetic markers, i.e. oils in citrus, resins in conifers, and phenolic compounds in many plants. More recently, extensive work has been done with proteins, and more specifically enzymes. Proteins provide

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some advantages over other compounds since the techniques may be less involved, faster, more economical and more positive, and proteins are less affected by environmental conditions (1). Proteins are stable and reliable for identification purposes, but the same type of tissue should be compared for identification, and the sample should preferably by taken at the same stage of growth.

A physico-chemical process called electrophoresis can separate proteins in a plant extract on the basis of their electric charge and/or size. The protein extract can be made from leaf, stem, or root tissue. After the proteins are separated in a gel matrix, proper staining will reveal the position of the proteins in the form of bands in the gel. The results can either be recorded photographically or by densitometric scanning.

In order for a fingerprinting technique to be useful, it must satisfy several requirements:

- It must be based on constant markers; the constancy of the markers must hold for samples taken from different growing areas and at different times of the year.
- The methodology should be reproducible; different laboratories should be able to follow the procedures and obtain identical results.
- It should be able to identify clones at a time when morphological or horticultural characteristics are not observable (i.e. young trees, dormant season, interstems where no leaves are present, etc.)

In working with proteins, it is more useful to look at specific enzymes in their different forms (isozymes). Specific staining techniques are available for many enzymes (2). In apple clones, we have found several enzymes extracted from shoot bark tissue, that contain many forms, or isozymes, and these are very useful for identification of many differences found among cultivars (Figure 1). Because clones are asexually propagated, a difference in banding patterns for a given enzyme between two cultivars is proof of genetic dissimiliarity. Two cultivars differing in one or more enzyme banding patterns can be readily separated. Not all enzymes have a different pattern in every cultivar. For many, the patterns are common. It is the cross-examination of different patterns for several enzyme systems which gives fingerprints for each clone.

By repeated cross-examination we have been able to differentiate among 33 clonal rootstocks (Table 1). In Table 1 different banding patterns are identified by numbers within each enzyme/electrophoretic condition. Therefore, rootstocks with the same number, within a column, cannot be differenti-

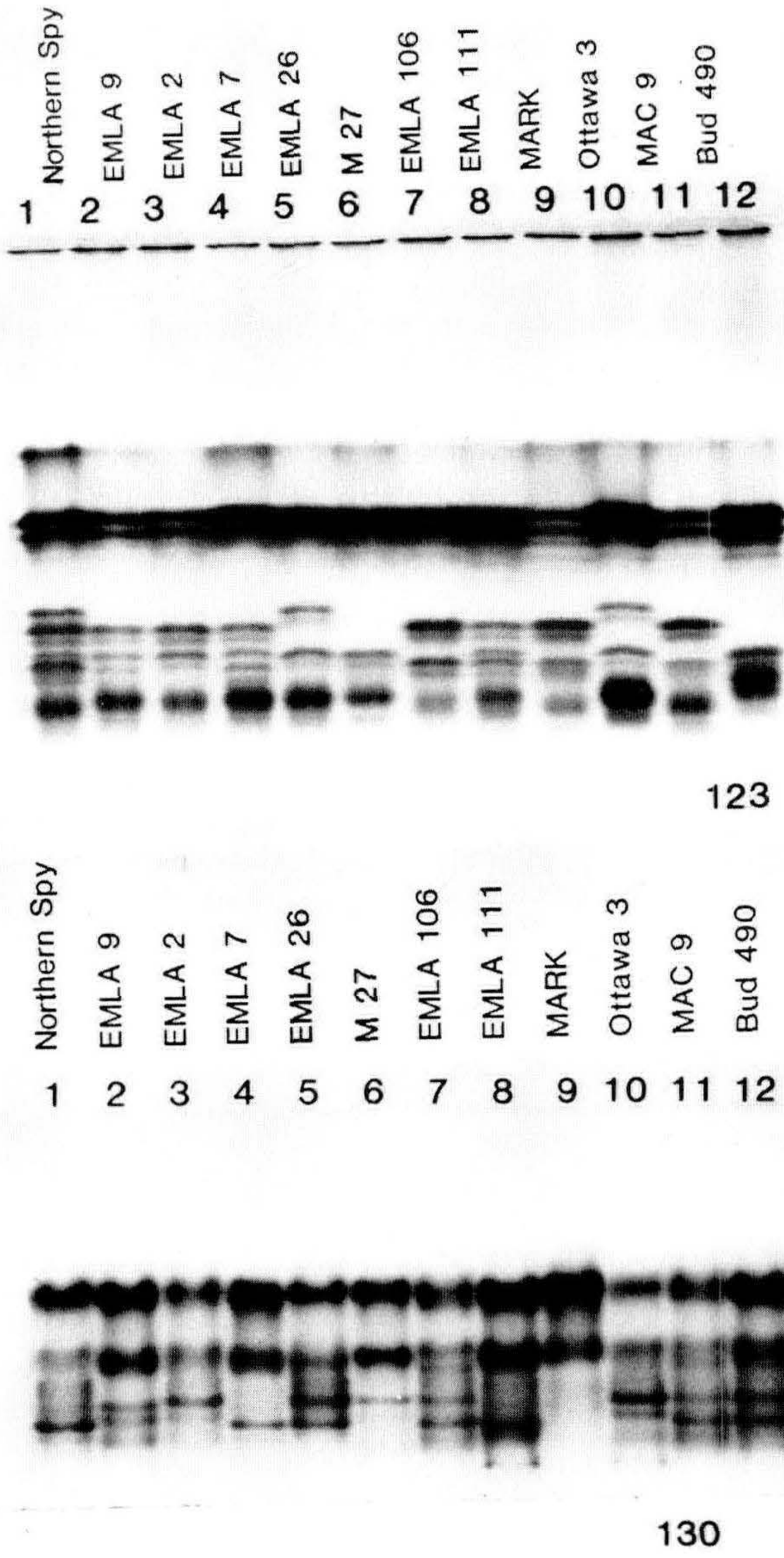

Figure 1. Polyacrylamide gels showing the banding patterns of 11 apple rootstocks. Each gel was stained for a different enzyme. The relative position of the bands, in the vertical direction under each rootstock, represents the fingerprint for that enzyme. Note how two rootstocks may have the same pattern in one gel, but can be distinguished by different patterns in the other gel (enzyme system). For example: EMLA 2 and EMLA 7 are the same in gel #123, but in gel #130 are easily differentiated.

ated by that enzyme system. For example, under enzyme "a", rootstock #2 (M 4), and rootstock #3 (M 9) each share banding pattern 2. Budagovsky 490, rootstock #28, is represented by banding pattern 6, which is a unique pattern for that rootstock within the "a" system. No differences in banding patterns were observed due to growing conditions, or when sampling was done at different times throughout the year.

The large number of banding patterns obtained for each enzyme indicates the great genetic diversity of clonal apple rootstocks, and suggests that several genes may be involved in the coding of so many different variants. Even clones with very close morphological traits, or those genetically related, possess very few isozymic similarities; for example, M 26, M 27, MAC 9, P 2 (Polish series), P 22, and Ottawa 3 all have M 9 as one parent, and yet, none of them share more than 3 patterns with M 9.

Virus-tested clones were distinguishable from the original contaminated material, and virus-tested clones from different programs (East Malling-Long Ashton and Washington Certified IR2 Project) expressed some isozymic differences. MAC 9 (Michigan series) and MARK (virus-tested MAC 9) were also very similar but distinguishable. The horticultural differences sometimes observed between the virus-tested material and their original stocks might be explained by genetic differences (possibly originating in the eradication or selection process) or by the inherent effects of the presence of viruses.

The tissue culture propagated selections of M 7 and MAC 9 expressed significant deviations from the mother clones, distinguishable by 7 of the 9 enzyme systems. These selections are indeed new clones, and their horticultural value should be carefully tested.

Table 2 lists all the scion cultivars and sports tested in this study. All cultivars included were positively identified by the cross-examination of the isozyme banding patterns of 4 enzymes. Sports within the same cultivar, however, appeared identical and were, therefore, indistinguishable. The only exception was 'Wijcik', a natural compact mutant of 'McIntosh', which could be distinguished from the latter but appeared indistinguishable from 'Spartan'. The banding patterns for each enzyme and scion cultivar are summarized in Table 3.

As with the clonal apple rootstocks, identification of apple scion cultivars was feasible by using their isozymic diversity. It was evident that each enzyme produced fewer patterns than found for the clonal rootstocks, indicating a more narrow genetic base.

Table 1. Isozyme patterns[z] produced by enzyme systems used to distinguish several clonal apple rootstocks. Northern Spy was used as a comparative standard.

Rootstocks	ENZYME SYSTEMS								
	a	b	c	d	e	f	g	h	i
1. Northern Spy	1	1	1	1	1	1	1	1	1
2. M 4	2	2	12	12	7	9	3	12	5
3. M 9	2	13	10	17	2	2	3	14	3
4. M 26	3	14	16	19	2	2	3	5	8
5. M 27	4	4	5	5	4	5	1	5	17
6. MM 106	5	17	6	22	3	14	7	4	6
7. MM 111	2	15	6	13	5	15	3	4	1
8. EMLA 2	2	2	3	2	13	3	1	2	16
9. EMLA 7	2	2	2	3	3	4	2	3	5
10. EMLA 9	2	2	2	2	2	2	2	2	15
11. EMLA 26	3	3	4	4	2	2	3	4	8
12. EMLA 104	5	12	19	16	11	6	3	3	14
13. EMLA 106	5	2	6	6	3	6	1	6	6
14. EMLA 111	2	2	6	7	5	1	4	8	1
15. M 9 WC IR2[y]	2	13	10	20	2	2	3	14	3
16. M 26 WC IR2[y]	3	6	10	11	2	2	3	3	8
17. MM 106 WC IR2[y]	5	17	6	21	3	14	7	4	6
18. MM 111 WC IR2[y]	2	15	6	1	5	15	3	4	1
19. M 7 TC[x]	2	13	4	13	12	2	3	13	5
20. MARK	5	2	7	8	2	14	1	7	18
21. MAC (Michigan series) 1	9	2	15	16	6	12	2	10	13
22. MAC 9	5	2	7	8	2	14	1	6	19
23. MAC 10	1	1	6	10	6	1	3	9	9
24. MAC 46	4	4	19	14	9	11	5	8	13
25. MAC 9 TC[x]	5	12	18	18	2	5	3	15	4
26. Ottawa 3	3	3	8	9	4	7	1	12	4
27. Budagovsky 118	9	16	17	17	2	2	1	14	7
28. Budagovsky 490	6	5	9	10	2	7	1	6	3
29. Budagovsky 491	5	10	14	13	2	10	1	4	12
30. Antonovka 306	2	9	5	14	8	1	1	4	11
31. Antonovka 313	3	11	4	2	10	13	6	11	11
32. Polish series 2	7	7	11	11	2	8	3	10	4
33. Polish series 22	10	6	16	4	12	2	3	13	2
34. Cornell-Geneva 10	8	8	13	15	2	2	1	3	11

[z] Rootstocks within a column with the same pattern number are not distinguishable by that enzyme.
[y] Washington State certified virus free
[x] Tissue culture propagated selections of the original

Table 2. Apple scion and sport cultivars identified by isozyme analysis.

Delicious and sports	Miscellaneous cultivars
Starking Delicious	Imperial McIntosh
Wellspur	Roger's McIntosh
Red Chief	Wijcik
Hi-Early	Jonagold
Ace	Jonamac
Apex	Nured Winesap
Red King	Winesap
Oregon Spur II	Winter Banana
BM-62 (sport of Oregon Spur II)	Spur Winter Banana
Sharp Red	Law Spur Rome
Scarlett	Spartan
Atwood	Empire
Early Red One	Idared
Bisbee	Lodi
Ryan Red Improved	Cox's Orange Pippin
Spur Ryan Red	Mitsu
Early Brite	Priscilla
Cascade	Granny Smith
Brite And Early	Spur Granny Smith
Silver Spur	Rhode Island Greening
Classic	Tydeman's Red
Red Spur	Gravenstein
Top Spur	Cortland
Top Red	Golden Delicious
Real McCoy	Gold Spur
Starkrimson	Sundale Golden Delicious spur
Aomori	Criterion
	Firmgold
	Earligold

One desirable objective, identification of sports within cultivars, could not be achieved by these methods. Even though some commercially named sports may in fact be genetically identical, the technique failed to distinguish between spur and non-spur types as well as between very early coloring 'Delicious' sports and the original 'Starking Delicious'. The chimeral nature of most sports apparently did not affect the genetic base of the enzymes most commonly used for cultivar fingerprinting.

With the exception of distinguishing between sports within cultivars, the methods for fingerprinting apples described here can be used by the nursery or fruit industry whenever the identity of a lot of trees is questioned. The procedure can be applied to young budded trees and can be used at any time of the year (during the growing season or when nursery trees are in storage after digging). A method of identification of sports or strains within a cultivar remains to be developed.

This report was based on work done by Ricardo Menéndez to fulfill the requirements for a Ph.D. degree at Washington

Table 3. Banding patterns[z] produced by enzyme systems used to distinguish apple scion cultivars. Northern Spy was used as a comparative standard.

	Enzyme Systems			
Cultivar	a	c	f	g
Northern Spy	1	1	1	1
Delicious	2	2	2	1
Golden Delicious	3	3	3	2
Jonagold	4	4	3	1
Priscilla	4	2	3	1
Jonamac	4	5	3	1
Mutsu	4	4	4	3
Spartan, Wijcik	2	6	4	2
McIntosh	2	6	4	1
Empire	2	7	4	1
Idared	5	5	2	1
Winesap	2	8	2	1
Lodi	6	9	2	1
Granny Smith	7	10	1	3
Rhode Island Greening	1	10	1	1
Tydeman's Red	8	2	2	1
Gravenstein	8	2	1	2
Cortland	1	9	2	1
Winter Banana	4	7	2	1
Law Spur Rome	8	9	2	1
Cox's Orange Pippin	1	9	1	1

[z] Cultivars within a column with the same pattern number are not distinguishable by that enzyme.

State University. Partial financial support was given by central Washington tree fruit nurserymen, Washington State Nursery Association, the Horticultural Research Institute, Oregon Rootstock, Inc., and the International Dwarf Fruit Tree Association.

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VOICE: Question for Jim Will. What fraction of Armstrong's rose production is currently micropropagated? And could you give us some idea of the economics of micropropagation vs. field grafting of roses?

JIM WILL: We are now producing about 7½% of our roses by micropropagation. The cost of micropropagating roses is about twice that of field production. But we have many cultivars that cannot be produced by field-budding techniques. In the future these will be produced by micropropagation. Those, such as 'Mr. Lincoln' and 'Queen Elizabeth', which are easily field-produced, will not be micropropagated.

PHIL BARKER: In propagating different cultivars by micropropagation do you find distinct differences in the root system of these cultivars?

JIM WILL: We have more significant differences in shoot development in cultivar variation. With roses there is no particular difference in root development.

PHIL BAKER: Are the root systems in micropropagation different that what they are in conventional propagation — using the same cultivar?

JIM WILL: There is very little difference in the root system between a micropropagated and a seedling-grown rose.

BRUCE BRIGGS: In rhododendrons, the root system of a tissue-culture propagated plants is usually much heavier than a cutting-propagated plant, because of the way the tissue-culture plant develops — somewhat similar to a seedling grown plant, more of a mass of roots.

CHARLES TUBESING: A question for Jim Will. Do you encounter any viruses in your rose stocks?

JIM WILL: We use only stocks that have been heat-treated and viruses-indexed at the University of California, Davis, for propagation in tissue culture. Viruses have been one of the significant problems in greenhouse roses throughout the industry. Virus expression will appear in tissue-cultured material if clean stock is not used.

OPTIMIZATION OF TISSUE CULTURE MEDIA

CAROLYN ALBRECHT

Microplant Nurseries, Inc.

Gervais, Oregon 97026

When Murashige and Skoog developed their medium for plant tissue culture over 20 years ago, it was seen to be a great breakthrough in *in vitro* plant propagation. By varying the concentrations of various plant growth regulators, researchers found they could grow a wide range of herbaceous plant species, plus some woody species.

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A breakthrough for those interested in the tissue culture of ericaceous plants arrived with Anderson's medium for rhododendron. Further improvements in the tissue culture of woody plants came with McCown and Lloyd's Woody Plant Medium.

The traditional approach to starting a new plant species or cultivar into tissue culture is to try one of the three media mentioned above with various levels of cytokinin and auxin. Some cultivars, especially of woody species, refuse to respond to this method, or even to other media, such as Boxus's or de Fossard's. Other cultivars, although they can be grown in tissue culture, give less than satisfactory results economically, or yield poor quality plants.

We at Microplant Nurseries have faced this problem time and again, in that we mainly grow clones of woody species which have not previously been cultured *in vitro*. In response to this challenge, we have followed the lead of John Driver in developing a systematic approach to optimizing plant tissue culture media.

To begin this process for a particular plant, we search the literature for any reports of tissue culture of this or a related plant. This may only give us a starting point, as successful culture in research does not always translate into success at the commercial level. If no published report is available, or if the results of such reports are unsatisfactory, we will start the plant on three or four different media, such as Murashige-Skoog (MS), Woody Plant Medium (WPM), or Boxus (LB). Another approach, as with a new apple clone, may be to try three or four different media previously developed for different apple clones. After two or three cycles on these media (about two to three months), we visually evaluate the plant's growth on each medium and pick the best one. This may be all that is necessary to achieve eventual production of the clone.

If there are still problems with the plant, we will try to improve, or customize, the medium. We start the customizing process by dividing the chemical components of the medium into their inorganic groups, namely the nitrate group, the sulfate group, the phosphate group, iron EDTA, and calcium chloride, or the halide group. Each group will then be scanned separately. Scanning a chemical or chemical group is done by placing shoot tips on a series of media containing three to five different levels of the particular chemical or chemical group. We use 6 to 12 replicates per treatment, depending on how much material is available. Each week, the heights of the shoot tips are measured and the number of leaves are counted. The shoot tips are transferred every week to fresh medium of the same composition. At the end of three weeks, the results

are analyzed. The optimum level is determined by the amount of growth. At this stage we may also compare different formulations, such as MS nitrates compared to WPM nitrates.

Determining the optimal level of each group may sufficiently define the medium for commercial production. If there are still problems that prevent production, or if plant quality is poor, further refinements will be tried. This is done by dividing each inorganic group into its constituent parts, such as ammonium nitrate and potassium or calcium nitrate for the nitrate group, and scanning each one separately. This does greatly increase the length of time necessary to optimize the medium, but for some plants the extra steps are worth the effort.

In order to determine the optimum value for a given medium component, it is necessary to plot a curve based on the growth data and pick the high point on the curve. There are computer programs available which will do this. We use one obtained from John Driver that computes a polynomial regression analysis. At times, no bell-shaped curve results from the data. This is due either to being in the wrong concentration range or to an interaction between chemicals in the medium. Either the experiment is repeated, with a higher or lower range of concentrations, or else we move on to the next component and repeat the experiment later.

This system is useful for determining the optimum level of other ingredients of the medium, such as vitamins, sucrose, or growth regulators. Using this method of optimizing media has led us to some interesting observations on the differences between cultivars of the same species. For example, one crabapple cultivar we grow requires sorbitol for growth and will not grow on a sucrose-based medium. Another crabapple cultivar will not grow at all on sorbitol, and its growth suffers if any sucrose is replaced by sorbitol. These reactions are straightforward and the effects can be observed visually. Yet a third crabapple benefits from the presence of both sucrose and sorbitol, an effect not readily observed without careful measurement.

With modifications, this system can also be used to optimize rooting media. We are currently trying to optimize rooting media for one apple clone which grows well in multiplication and also roots well, but the tips turn brown and stop growing in the rooting medium. In another case, we are trying this method in an attempt to increase the rooting percentage of a maple clone.

Optimizing the medium may sound slow and painstaking, but the results have been worth the effort. By using this

system we have achieved improved rooting percentages and/or improved plant quality in apples, maples, blueberries, and other plants. Although optimizing plant media is not the answer to all our problems, it is a very important tool for us at Microplant Nurseries.

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LONG-TERM STORAGE TECHNIQUES FOR IN VITRO PLANT GERMPLASM[1]

JEANNE GUNNING[2] and H.B. LAGERSTEDT[3]

National Clonal Germplasm Repository
33447 Peoria Rd., Corvallis, Oregon 97330

The United States Department of Agriculture has established a National system of Plant Germplasm Repositories whose goals are to collect, maintain, evaluate, and distribute plant material of economically important crops. These crops are stored as seeds or as living plants. The Corvallis Repository is a clonal repository responsible for the maintenance of pears, filberts, mint, hops, and all the small fruit crops. Plant

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[1] Contribution of the Oregon Agricultural Experiment Station in cooperation with the U.S. Department of Agriculture, Agricultural Research Service. Technical paper No. 7762 of the former.

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material maintained includes genetically important foreign and domestic cultivars, and undeveloped species germplasm collected from around the world. At each clonal repository a tissue culture program aids in the maintenance, distribution, and health improvement of the germplasm collection.

The tissue culture lab's most important function is to maintain a back-up collection of all germplasm stored in the repository. This collection provides replacement plants for screenhouse and field collections. Eventually, the *in vitro* back-up collection could replace the labor-intensive, costly, screenhouse collection (3). To do this, ways must be found to retard *in vitro* plant growth and reduce the labor involved in long term storage. The subject of this paper is the different methods currently being investigated by the Corvallis Repository tissue culture lab to extend the storage life of *in vitro* germplasm collections.

STORAGE IN GROWTH ROOM CONDITIONS

Standard growth room conditions for cultures reported in this paper were 23°C and a light level of 25 $\mu Em^{-2}sec^{-1}$ for 16 hr/day. Cultures were grown in 13×100mm tubes, with 3.5 ml medium unless otherwise indicated, using 10 tubes per treatment.

When left on the shelf in a standard growth room, some *in vitro* shoots and plantlets maintain themselves until the culture medium is depleted. Under standard growth room conditions, four *Mentha* species survived from 6 to 13 months, depending upon their growth rate before medium depletion. *Rubus spectabilis* lasted 12 to 15 months, and 'Merton Thornless' blackberry lasted 13 to 16 months. *Vaccinium ovatum* was viable for 17 months. Moisture loss was occasionally hastened by having too thin a film of wax around the cap, or by perforation of the film seal. Use of self-sealing caps that allow gas exchange, but not water vapor exchange, eliminated this problem.

In an attempt to extend shelf life by suppressing growth, clones of six genera were grown with and without plant growth regulators (PGRs). 'Merton Thornless' blackberry cultures without PGRs were slightly stockier and darker green than those with PGRs and, after 8 months, were ranked in better overall condition. *Mentha* × *dumetorum* without PGRs had growth similar to cultures with PGRs, while mint(USDA 10467) without PGR exhibited slightly more vigorous growth than those with PGRs. All mint cultures remained viable until the medium was depleted, which occurred sometime after 8 months. Strawberry cultures of 'Bounty' and 'Dabreak' with PGRs proliferated shoots to the point of overcrowding, which

caused browning of the medium, tissue browning, and death within 3 months. Cultures without PGRs had only one or two shoots and thicker, longer petioles; cultures were viable for 5 months, at which time the medium was about depleted. Survival of strawberries 'Midway', 'Morioka 17' and 'Climax' was extended by 1.5, 2.0 and 3.5 months, respectively, where PGRs were not included in the medium.

Vaccinium ovatum cultures with PGRs were in excellent condition after 9 months, while those without had shorter shoots, more basal callus, and were slightly chlorotic after 6 months (experiment in progress). Cultures of *V. uliginosum* showed opposite results: PGR cultures began to decline after 6 months, while those lacking PGRs were in excellent health at 7 months (experiment in progress).

Cultures of *Ribes* (ORUS-11) with PGRs were crowded, and the medium brown, after 2 months. The medium was depleted during the 7th month. Cultures without PGRs died the first month. In other experiments with *Ribes* (ORUS-11), browning of the culture media containing PGRs was reduced by increasing the initial pH of the medium to pH 7.0 or pH 8.0 (initial pH of controls: pH 5.7), or by increasing agar content to 8 g/l or 10 g/l (controls: 6 g/l agar).

These results illustrate that elimination of PGRs cannot be used as a standard method for growth suppression, and that clonal response differences are apparent. In some clones, elimination of PGRs resulted in decreased vigor or death, while in other clones it resulted in improved plant vigor and/or culture longevity.

Another attempt to slow shoot growth involved increasing agar content from 6g/l (control) to 8 and 10 g/l (experiment in progress). The increased agar content resulted in healthier cultures for 'Merton Thornless' blackberry, mint (USDA 10487), *Mentha* × *dumetorum*, and *Vaccinium ovatum* when evaluated after 8 months. Control cultures of *Vaccinium uliginosum* died by the 6th month, while high agar cultures were still viable at 8 months. Cultures of *Humulus lupulus* in a treatment using 12 g/l agar were ranked in even better condition after 8 months than cultures grown in 8 or 10 g/l agar, although all were in viable condition. However, increased agar content had no observable effect on longevity of *Ribes* (ORUS-11) or 'Bounty' and 'Dabreak' strawberries. Increased agar content of the medium retards the rate of medium depletion in several genera. This may contribute to increasing culture longevity.

Another method of suppressing growth is to increase the osmotic potential of the medium by increasing the sugar content. *Mentha* cultures evaluated after 8 months (experiment in

progress), are being grown in 0.088M sucrose as the control, 0.222M sucrose and 0.222M glucose. Shoots of *Mentha aquatica* growing in 0.222M sucrose had smaller leaves and less height than controls, with heavy purpling of stems and leaf veins; their average time to death was 8 months. In the 0.222M glucose cultures, *M. aquatica* had small dense clumps of shoots and were very dark green for the first three months; thereafter, growth resulted in depletion and browning of the medium, similar to sucrose controls. In both the sucrose controls and 0.222M glucose treatments, 9 of 10 cultures were viable in the 8th month. In contrast to *M. aquatica*, *M. arvensis* showed only small differences between treatments for the first 2 months, and ultimately all treatments depleted the medium in an average of 6 months. Thus, increased sugar content did affect growth during the first few months, but did not always result in an extended shelf-life.

Decreasing the sugar content of the medium reduces the carbon source, forcing a reliance on photosynthetic products for new shoot growth. Media were prepared with 8g/l agar, glucose at 0, 0.03, 0.06, and 0.09 M concentrations, and no PGRs. Each tube contained approximately 5 ml medium per tube. *Mentha aquatica* had similar vigor at all 4 glucose levels, with leaves becoming darker and slightly smaller as the glucose level increased. Evaluated at 5 months, cultures were in good condition. Strawberry 'Dabreak' also grew very well in all 4 concentrations of glucose. Cultures in 0.09M glucose rooted, but died by the 4th month following browning of shoots and media. In a similar way, all of the 0.06M cultures and half of the 0.03M cultures were dead by the 5th month. Seven of 10 cultures grown without glucose were in good health when evaluated at 5 months. These results show that growth rate in strawberry cultures can be slowed by decreasing the glucose level.

The sugar-alcohols, mannitol and sorbitol, have been added to media to retard shoot growth. Codaccioni studied the effects of mannitol and glucose on *Mentha spicata* [syn. *M. viridis*] cultures.(1) Some of her findings were: 1) mannitol delays rooting, but ultimately results in more roots; 2) mannitol breaks apical dominance and stimulate lateral branching; and, 3) without the addition of a metabolizable sugar, mannitol is unable to support plant growth. Repository experiments with *Mentha* and mannitol supported the first two findings, but not completely the third. Experiments with *Mentha aquatica* and *M. arvensis*, using 0.028, 0.056 and 0.111M concentrations of mannitol combined with 0.111M glucose, revealed an inverse relationship between mannitol concentration and shoot height. When mannitol and glucose were increased, multiple branching and shortening of internodes occurred. Vitrification

(translucent tissue) also increased. Higher levels of 0.222M glucose + 0.222M mannitol were extremely injurious to mint, blackberry, gooseberry, strawberry, hops, and blueberry. Of two clones of *Mentha* grown in 0.028 and 0.111M mannitol without glucose, *Mentha arvensis* did not grow, while *M. aquatica* did. In 0.111M mannitol, *Mentha aquatica* was very stunted, highly branched, dark green and intensely vitrified, yet half of the cultures were viable in the 7th month. At the 0.028M level, there was no vitrification, less branching, slight chlorosis, and healthy shoots; 9 of 10 cultures were viable when evaluated in the 8th month. Only 6 of 10 control cultures in 0.111M glucose were viable. The same two mint clones were grown in 0.028M and 0.111M sorbitol, without glucose. In the lower concentration, sorbitol slowed growth without producing the great morphological changes seen with mannitol. When evaluated at 8 months, 50% of the *M. arvensis* and 100% of the *M. aquatica* cultures were viable. Growth of *M. arvensis* in the high sorbitol concentration was similar to growth in the low concentration, and viability was the same. Growth of *M. aquatica* in the high concentration was extremely branched and vitrified, yet all 10 cultures were dark green and vigorous at 8 months. In general, sorbitol appeared to effectively retard growth, while causing less severe symptoms as compared to mannitol.

Another attempt to suppress plant growth and extend storage life was by adding a growth retardant to the standard media.(2) Three concentrations of Cycocel [11.8% (2-chloroethyl) trimethylammonium chloride], 10, 20, and 30 mM, were tested on several genera. All concentrations were lethal to *Ribes* (ORUS-11) and *Vaccinium uliginosum*. With *V. ovatum*, leaves stayed green for 6 and 8 months in the 10 and 20mM treatments, respectively, but no new growth appeared. In 'Merton Thornless' blackberry, 20 and 30 mM levels led to severe stunting and death. The 10mM cultures grew well developed, dense clumps of shoots with very short internodes. After 8 months the pressure of the shoot mass against the culture tube prevented the mass from descending in the tube with the medium, resulting in a separation of shoot mass from medium. In *Humulus lupulus*, the 20 and 30 mM treatments were injurious, whereas the 10mM cultures were all viable, with growth similar to the controls, when evaluated at 7 months. Cultures of strawberries 'Dabreak' and 'Bounty' were more chlorotic as the Cycocel level increased. In all 3 treatments, shoot proliferation caused overcrowding and browning of the medium, just as in the controls. Half of the cultures in all treatments were dead by the 4th month. In contrast to the gooseberry, bluebery, blackberry, hop and strawberry cultures, mint cultures grew in all Cycocel concentrations. The higher

concentrations caused shortening of internodes, thickening of leaf blades and stems, and a deeper green color. In *Mentha dumetorum*, the 3 Cycocel treatments and the controls had a 50% death rate by the 8th month. Mint (USDA 10487) treated with 30mM Cycocel also had a 50% death rate by the 8th month, yet the control, 10 and 20mM Cycocel treatments had only a 10% death rate. Tolerance to Cycocel appears to be highly specific. Further experiments should clarify its usefulness in germplasm preservation.

STORAGE IN COLD TEMPERATURES

A commonly used cold storage temperature for *in vitro* cultures is 4°C. Mullin stored 50 *Fragaria* clones for 6 years at this temperature, in the dark. However, under these conditions regular replenishment of the liquid medium was necessary.(4) *In vitro* germplasm collections at the Corvallis Repository have been held for varying lengths of time at 5°C, in darkness. The following general response was observed for *Fragaria*, *Mentha*, *Rubus*, and *Vaccinium* cultures during a year of storage: etiolation, root growth, gradual depletion of medium, and gradual browning of medium. Contaminations occurred as endogenous bacteria or surface spore multiplied to visually observable levels. In some cases of older *Rubus*, *Fragaria* and *Vaccinium* cultures, development of new basal shoots occurred as the primary shoot-tip died. *Rubus spectabilis* cultures placed in 5°C storage were green and healthy at 4 months. At 6 months the shoots had brown leaves and stems, which appeared dead, but were actually dormant. Transfer to the growth room resulted in 39 of 40 cultures developing shoots from axillary buds. In single cultures of 27 cultivars of *Pyrus*, stored more than 8 months, the original leaves blackened and abscissed. This was followed by new, but etiolated, growth from the shoot tip. Germplasm storage at 5°C does retard growth, but is accompanied by gradual decline of tissues and browning of media.

Results of germplasm stored at −1°C have ranged from poor to excellent, depending on the genus and sometimes the clone. Three hundred clones of *Mentha*, stored for a year, exhibited no growth and no tissue breakdown; when placed in the growth room for 1 week, growth was vigorous. However, this new tender growth succumbed when cultures were returned to −1°C storage. Cultures of *Mentha spicata* [syn. *M. cordifolia*], *M. longifolia*, and *M.* × *dumetorum* survived 2½ yrs of uninterrupted −1°C storage in good condition. *Fragaria chiloensis* and 'Midway', evaluated after 17 months of storage at −1°C, were in good condition. In another experiment (in progress), the strawberries 'Climax', 'Morioka 17' and 'Midway' were grown with and without PGRs at temperatures of 1°C,

5°C and 23°C. After 11 months of storage the healthiest cultures emerged from 5°C.

Stock cultures of *Ribes* (ORUS-11) and *R. diacanthum*, as well as cultures of a dozen other *Ribes* clones, stored well for 1 yr at −1°C whereas cultures began dying after several months at 5°C. Storage of several hundred *Rubus* clones showed mixed results, suggesting broad genetic variation in tolerance to cold storage.

These experiments, and others not reported here, show that *in vitro* germplasm storage at −1°C and 5°C is highly promising. Where clones are sufficiently cold tolerant, −1°C storage is preferable, as it seems to suspend plant growth. Suspension of plant growth reduces or eliminates problems of medium depletion, etiolation, and delayed contamination during storage.

POSSIBILITIES FOR FUTURE RESEARCH

Currently under investigation at the Corvallis Repository is a preservation method suggested by Boxus, where defoliated stems are submersed in the culture medium and placed into cold storage. (Seminar, Oregon State University, 1983) *Pyrus* shoots 1.5 to 2.0cm long were submerged and placed in 23°, 5° and −1°C storage. After 4 months, the shoot tips remained green and were somewhat swollen. As yet it is too early to determine the value of this technique.

Of the methods for prolonging storage life and suppressing growth outlined in this paper, cold storage at 5°C and −1°C have been the best. Much more work needs to be done with altered and amended media. The use of various types and concentrations of growth retardants needs to be expanded. Cold-hardening treatments could be tried as pretreatments for long-term cold storage. Combinations of media amendments plus cold storage should be very promising. The research on prolonging storage life of *in vitro* cultures is in its infancy. For germplasm repositories, this research will be of long duration due to the tremendous genetic variability encountered in large, diverse plant collections.

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TISSUE CULTURE OF CONIFERS

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Abstract. Three separate micropopagation systems are described: i) the establishment of multiple shoot and single shoot cultures with axilliary and lateral bud development using mature Douglas fir tissue; ii) the development of mature white spruce cultures exhibiting single shoots and shoot elongation with lateral bud development; iiia) enhancement of shoot growth exhibiting juvenile characteristics from mature yellow cedar tissue; iiib) the tissue and subsequent subcultures of secondary shoots.

Essential factors beneficial to enhancement of multiple shoots in Douglas fir and mature yellow cedar are: origin of source material, time of year for collection of source material, proximity of source material in relation to bole and crown of tree.

Proliferation of shoots in juvenile yellow cedar tissue trial resulted from pulse treatments involving a hormone enriched nutrient medium to one devoid of hormones. Primary rooting trials have been successful in transplanting juvenile yellow cedar plantlets, pre-rooted in-vitro, into soil in a greenhouse environment.

INTRODUCTION

Most mass plantings of forest trees are made from seedlings. The necessary seed is usually obtained through cone collection from selected stands. Most forest trees are grown from seed obtained as a product of open pollination and exhibit continuous variation of many characters. Desirable attributes due to non-additive gene effects are not preserved from one sexual generation to another, but could be maintained if it were possible to propagate individual trees vegetatively at a sufficient rate to produce clones for widespread re-forestation programs.

In practice, this conceivably means propagating mature trees, because superior growth of timber characteristics are often recognizable only after a prolonged period of growth. Because selection could be based upon small clones of trees rather than individuals, vegetative propagation of conifers would allow for a higher degree of genetic advancement in comparison with today's current breeding programs.

In vitro techniques clearly have the potential to provide ways of vegetatively propagating conifer species on a large scale.

The primary benefit from utilizing tissue culture is to have the ability to mass produce commercially valuable spe-

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cies that are genetic duplicates of trees with superior traits. With this capability one is able to realize increases in forest productivity through increased growth rates, better plantation survival, and increased resistance to disease and insects. In addition to benefits from genetic duplication there exists realizations of increases in wood supply available for harvesting, enhancement to existing tree improvement projects and reforestation programs, plus economic benefits to the forest industry. Through the use of micropropagation, seasonal weather restrictions, and seed and cone collection will no longer be of major concern.

From seeds or seedlings it is quite readily possible to initiate tissue cultures, but due to the fact most kinds of trees are heterozygous, this does not allow for individual trees to be cloned. Therefore, before *in-vitro* techniques can be used to produce large numbers of genotypes selected on phenotypic characteristics evident after several years of growth, methods must be found to obtain morphogenesis from tissues originating from mature trees. It is upon this statement that the following research has been based and its concurrent results herein presented.

For cultivation of the conifer tissue cultures three major British Columbian forest species; *Pseudotsuga menziesii* (Douglas fir), *Picea glauca* (white spruce), and *Chamaecyparis nootkatensis* (yellow cedar) were selected. All research work has been carried out at the laboratory facility of Les Clay and Son Limited.

METHODS AND MATERIALS

Douglas Fir and White Spruce Source of Explant Material. Terminal, subterminal, and lateral vegetative buds were collected from mature stands, at elevations from 1200 to 1400 meters. In the collection of the explant source material it was found that the proximity of the buds in relation to the crown and bole of the tree was of significant importance. Those buds gathered from the top and middle crown regions of the tree generated the highest degree of growth response within culture.

Time of year for bud collection was also crucial; just before spring flush when bud swelling is quite visible and overall bud size is approximately 1 to 2 cm. Stem sections 4 to 6 cm in length, with needles removed, exposed the buds for surface disinfestation. Meristematic bud tissue was excised from the surrounding bud scales following a quick-dip of the encapsulated buds directly into isopropyl alcohol. Ensuant to the above procedure the bud scales were removed with a sterile forcep and scalpel.

Since contaminants may not only come from the surface origin of the tissue, but from internal contamination from organisms trapped on the internal bud scales or due to diseased or necrotic tissue; it is thus important that upon excision of the explant the interior of the bud be exposed to a sterile surface where the bud and or bud scales have not previously touched.

This particular method of surface sterilization has minimized losses through bacterial and fungal contamination to 10 to 15% of a given test trial.

Source of Explants for Yellow Cedar. Along with vegetative shoot tips 1 to 3 cm in length gathered from mature tree stands, the implementation of juvenile shoot tip tissue 1 to 3 cm in length collected from yellow cedar seedlings (greenhouse grown) have been the primary sources for experimental trials. With regard to mature yellow cedar, collection of new spring growth material at elevations of 900 to 1000 meters generated more positive responses within culture than summer growth collections.

Yellow cedar explants undergo a more intense surface disinfestation procedure than either Douglas fir or white spruce. It begins with a 4-hr. soap bath with the addition of Tween 80 (soap water changed every ½ hr), followed by a 2-hr wash in a Benlate (fungicide) solution, then a 30-min 10% sodium hypochlorite bath, ending by rinsing 4-5× with sterile water. Each vegetative shoot tip has a small brown portion of basal tissue removed before inoculation.

Basic Culture Media and Environment. The basal salt nutrient medium for all experimental trials was agar solidified by the addition of 5.6 g. per litre Sigma brand agar and pH adjusted to 5.6 with NaOH and HCl. This was dispensed 15 ml per 25 × 150 mm culture tube unless otherwise noted. Many of the media formulas presented in this paper are proprietary to Les Clay and Son Ltd. (Table 1).

Douglas fir

Initiation of culture start material follows two pathways:

i) inoculation of explant onto a modified Murashige and Skoog basal medium with a 75% reduction in nitrate levels with organic constituents and concentrations labelled as Zr. Hormonal levels were high, ranging between 20 to 30 mg per litre 6-benzylaminopurine (BAP). Subsequent subculturing was onto Z1-1 medium devoid of phytohormones to allow for shoot elongation and proliferation.

ii) the second pathway followed an unusual methodology that proved very successful. The explant was placed onto two shoot initiation media, ZL-1 and FRBNH, FRBNH being a vari-

ation of MS medium. Both ZL-1 and FRBNH, respectively, were devoid of hormones. Test trials branched into two directions: i) initial trials were started on ZL-1 basal medium and continually subcultured onto the same; ii) additional set of experiments conducted saw the initiation of cultures onto FRBNH and subsequent subcultures onto ZL-1.

Table 1. A listing of proprietary media classification developed at Les Clay and Son Ltd.

	MEDIA CLASSIFICATIONS		
SPECIES	Shoot Initiation	Shoot Proliferation and/or elongation	Subcultures
Douglas fir	Zr,Z1-1 FRBNH	ZL-1,FRBNH	Z1-1
White spruce	SH,SH-1, SHNH	SHNH	SHNH
Yellow cedar (mature)	1/2MSP, 1/2MSP1	1/2 MSPNH	1/2MSP1, 1/2MSP, 1/2MSPNH
Yellow cedar (juvenile)	LMB,WPM-1' 1/2MSP, 1/2MSP1	WPMNH, 1/2MSPNH	WPMNH, 1/2MSPNH, LMB

White spruce

Initial inoculations of explant were placed upright with the basal portion pushed down into agar solidified media. The nutrient medium under primary investigation was that of Schenk and Hildebrandt (6). Various supplements were added including vitamins, amino acids, sucrose, and hormones. Final levels of additives were sub-categorized under formulas: SH, SHNH, SH-1. Although culture explants were inoculated onto all three SH modifications, it was found that those experimental trials that followed up with subculturing onto SHNH medium (no hormones) generated high degrees of growth response.

Yellow cedar (Mature and Juvenile)

On those test trials designed to run comparative studies on growth response between juvenile and mature tissue, identical media formulations were implemented for primary tissue inoculations. Modified MS basal nutrient medium at ½ strength salt concentration (½ MSP and ½ MSP1) supplemented with vitamins, amino acids, and a lower sucrose level were used. Inclusive was the addition of only auxins at low levels. Subsequent subculturing of explant for shoot initiation and proliferation took place on ½MSPNH medium without hormes.

Trials conducted to generate multiple shoots from juvenile yellow cedar explants included the implementation of Litvays medium (2) supplemented with a low level of BAP, written as LMB medium and continued subculturing onto Woody Plant

Medium (3) and 1/2MSPNH medium both containing no hormones.

The standard culture conditions were 2000 lux cool white fluorescent light, 18-hr, photoperiod at constant 20°C. Standard passage time between subculturing was every 3 to 4 weeks unless otherwise noted.

RESULTS AND DISCUSSION

Douglas Fir

Primary Shoot Formation. As was previously described, the guidelines set by pathway (i) found to induce multiple shoots, (Figure 1, left), in more than 35% of trial lots. This has been achieved by initiating pulse treatments for the first six weeks after explant inoculation from Zr medium, supplemented with an ever-decreasing level of cytokinin over the six week time period, to ZL-1 medium devoid of phytohormones.

Aside from cultures exhibiting multiple adventitious shoots, single shoot cultures were also attained. If exposure to cytokinins was prolonged over the initial six week period, the cultures exhibited signs of oxidation that led to eventual death of tissue. Rate of growth from time of inoculation to a growth plateau for both those cultures with noted shoot proliferations and cultures with only single shoots was just under four months with heights obtained up to 5 cm. In comparison, it was primarily suggested by McComb and Bennett (4) that explants from mature parts of trees may not start to multiply until they have been in culture for 6 to 10 months.

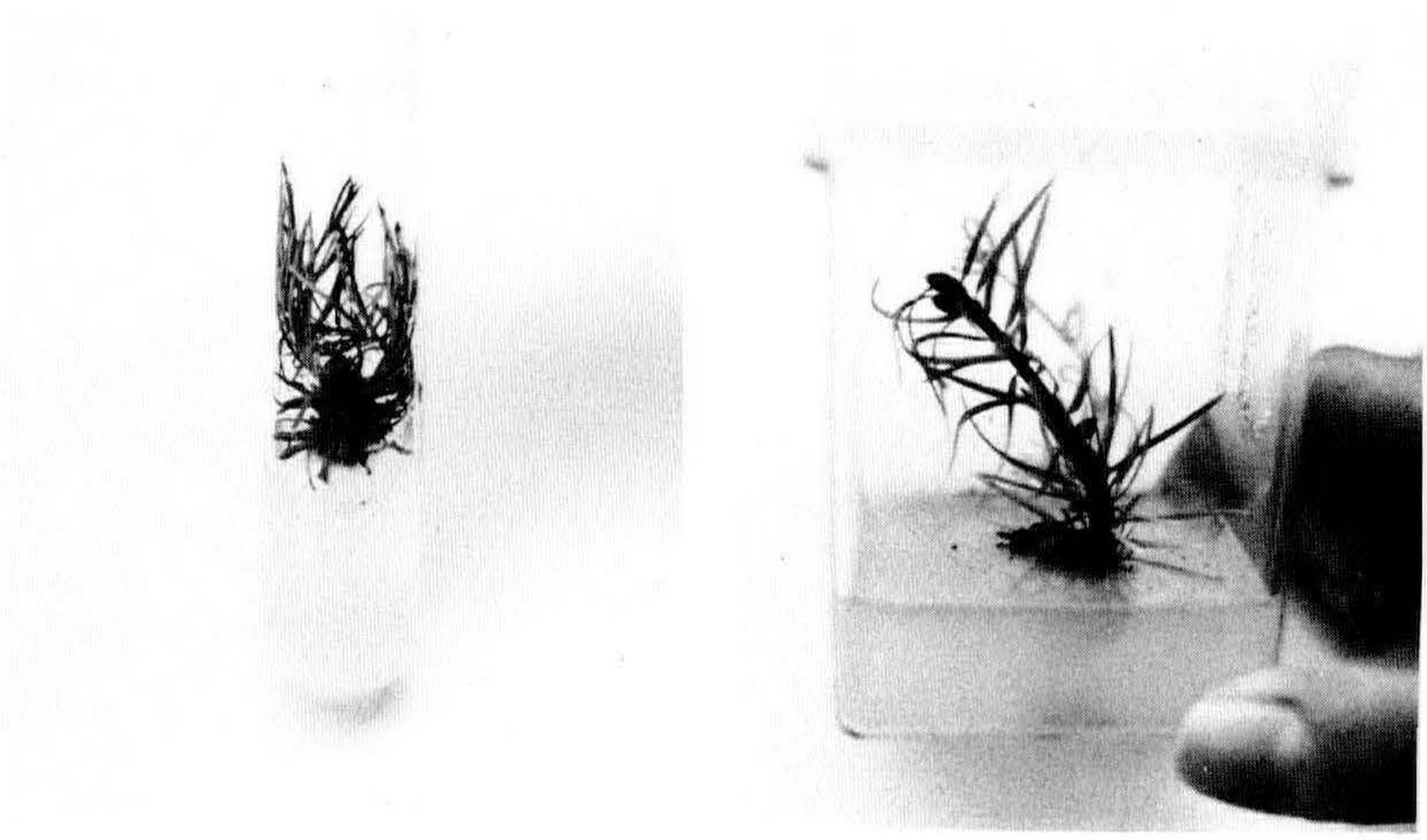

Figure 1. *(Left)*: Mature Douglas fir culture exhibiting multiple shoots. *(Right)*: Single shoot culture of mature Douglas fir with lateral and apical bud development.

Following pathway (ii), similar results were generated with a marked improvement of cultures exhibiting multiple shoots (50 to 60%). There was also a noted increase in growth rates.

Those trials initiated on ZL-1 medium and continually subcultured every 3 to 4 weeks onto the same medium, generated multiple shoots from the original explant within three months. All shoots displayed normal growth and needle development. Each new shoot, in turn, developed both axillary and lateral buds; apical bud formation was also noted.

Experiments conducted where FRBNH medium was the starting culture medium and subsequent transfers of explant onto ZL-1 medium followed, a slight increase in initial growth rate was observed. Here again, within three months proliferation of tissue had occurred with the development of multiple shoots. Better than 50% of test trials were indicative of these results.

Regardless of which pathway was taken, the end results were similar. By all rights inoculating and subculturing onto hormone-free media should, in fact, have hindered shoot proliferation, but instead it seemed to enhance multiple shoot development. A probable explanation may lie within the physiology of the plant itself or perhaps in the consistent nutrient supply made available to the tissue. Certainly the time of year for bud source material collection has proven to be critical. All conditions being equal, the types of responses just mentioned, are not obtained if the meristematic bud tissue is not at least 2 to 3 cm in size and in the final stages before flushing.

Secondary Shoot Development. Division of plantlets in those cultures showing a proliferation of tissue did not perpetuate continued multiple shoots. Instead, each excised plantlet grew only as a single shoot. Transfer to GA-3 culture vessels (from Magenta Corp.) became necessary as shoots outgrew the dimensions of the culture tube.

Removal of the shoot apex induced small, light-colored lateral and axillary buds that underwent typical development growth. Buds flushed and new shoots and lateral branching with continued bud development occurred.

Retention of the apical portion of the shoot also allowed growth, but larger, darker brown buds were produced that took a longer time to flush than the aforementioned smaller, lighter-colored buds (Figure 1, right). Here again both axillary and lateral bud development was present.

Shoot size and growth reached a plateau approximately 120 days after initial explant inoculation. Throughout early

spring and summer buds swelled and flushed and shoot growth was visible. Average height of plantlets at the end of 120 days growth period was 5 to 8 cm. Cultures exhibited good growth and tissue color. During the winter months, some signs of dormancy within the cultures became evident. There was a slight reduction in active growth accompanied by some browning of the basal needles. An increase in photoperiod to 18 hrs seemed to offset any tendency toward dormancy.

White Spruce

Primary Shoot Development. Initially several mineral salt formulations were selected for experimentation. Nutrient media included Murashige and Skoog salts (5), Woody Plant Medium salts, and B5 (1). All of the above were unsuccessful in generating growth responses and lead to eventual oxidation of the tissue.

Implementation of SH and SH-1 media for culture material proved very positive. Explant inoculation onto SH media, supplemented with various hormone levels, allowed for main shoot axis development. No adventitious shoots have been developed to date either through pulse treatments or repeated exposure to hormone-free nutrient media.

One to two week exposures of explants to hormone enriched SH medium (both SH and SH-1) were found to be optimum and the continued subculturing every 3 to 4 weeks onto hormone-free SHNH basal medium enhanced shoot elongation and lateral bud development along main axes (Figure 2, left). Problems of tissue vitrification were overcome by the incorporation of L-cysteine hydrochloride at 10 mg per litre into the nutrient medium.

Two very distinct types of shoot growth were observed in the white spruce cultures: (1) long, very slender, upright development, up to 4 to 5 cm in height with lateral bud production along main stem, and (2) short, bushy growth up to 2 cm in height with little to no lateral buds, only apical bud formation. (Figure 2, right). One explanation for the variance in shoot growth encountered in the white spruce cultures could be the variability in regional collection of source bud material. Bud development and growth is currently being monitored; to date none of the buds have flushed.

Yellow Cedar — Juvenile Tissue

Primary Shoot Development. The first set of experiments involved the inoculation of vegetative shoot tips 2 to 3 cm in length onto Litvay's medium with hormones. Pulse treatments alternating between a hormone-free medium (1/2MSPNH) to hormone-enriched media (WPM-1′ and LMB) were initiated at two-week intervals. This was essential for the first 4 weeks.

Forty-two days after initial inoculations, adventitious shoots were observed arising from the basal portion of the explant. (Figure 3, left). Slight basal callus formation was also noted. Postliminary subcultures repeated the initial pulse treatments and were able to continue generating multiple shoots.

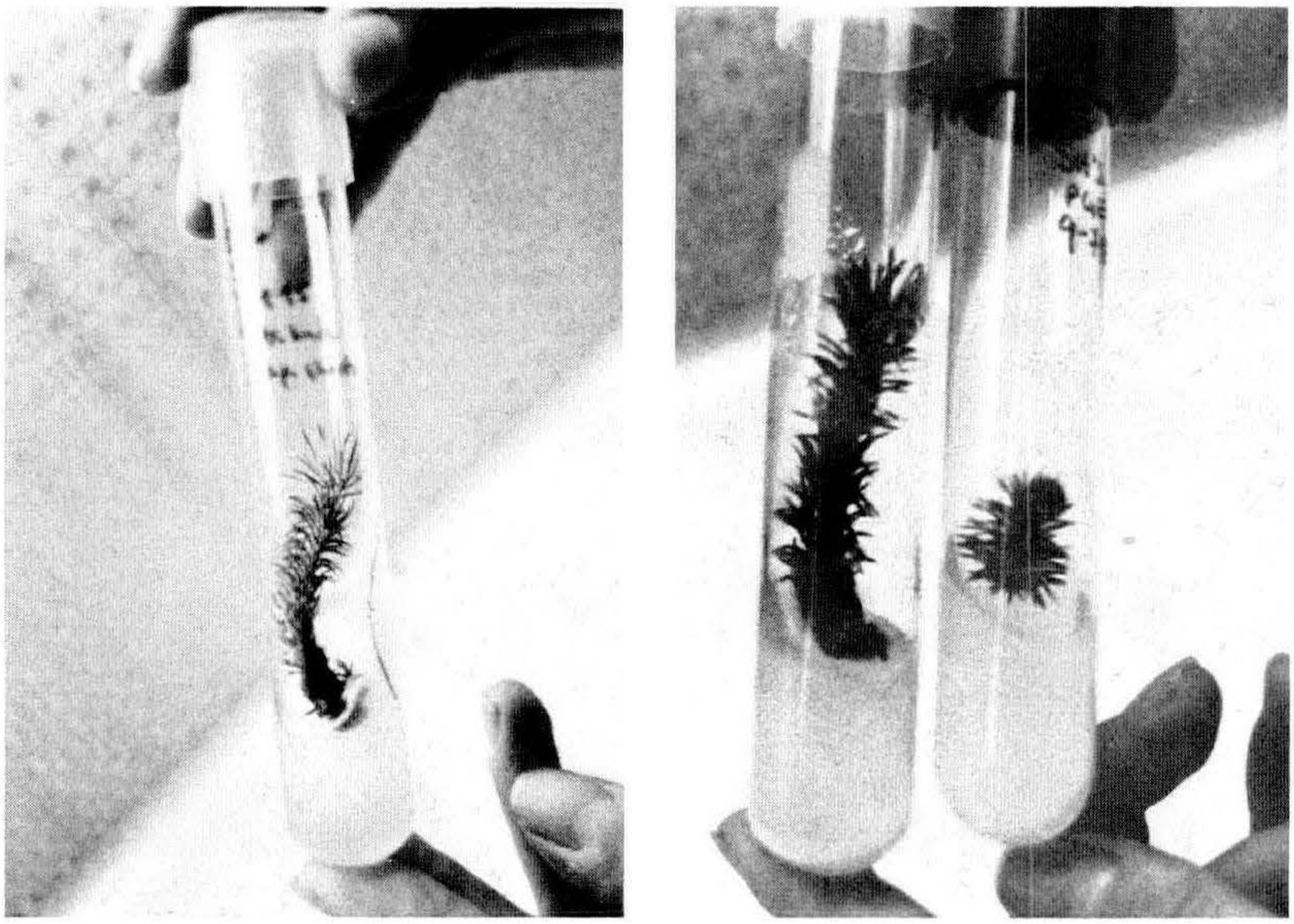

Figure 2. *(Left)*: Elongated single shoot axis of mature white spruce with lateral bud formation.
(Right): Contrast between two distinct types of shoot growth observed in mature white spruce culture.

Secondary Shoot Development. Prolonged exposure of secondary shoots to pulse treatments enabled a trial lot to undergo 1½ years of subculturing with an average increase of 2 to 3 culture tubes each transfer. After that time oxidation of tissue became noticeable. Attempts to reduce browning, which probably resulted from phenolic oxidation of the tissue, were made by using antioxidants singly and in combination at various concentrations and at different stages of secondary shoot formation. However, before a final treatment was selected the cultures had declined beyond the point of responsiveness.

Most recently, new juvenile yellow cedar cultures were established onto 1/2 MSP and 1/2MSP1 media and were then subcultured after 1 to 2 weeks onto 1/2MSPNH (a hormone-free medium), to initiate proliferation of tissue. To date some multiple shoots accompanied by axillary branching and lateral shoot development has occurred.

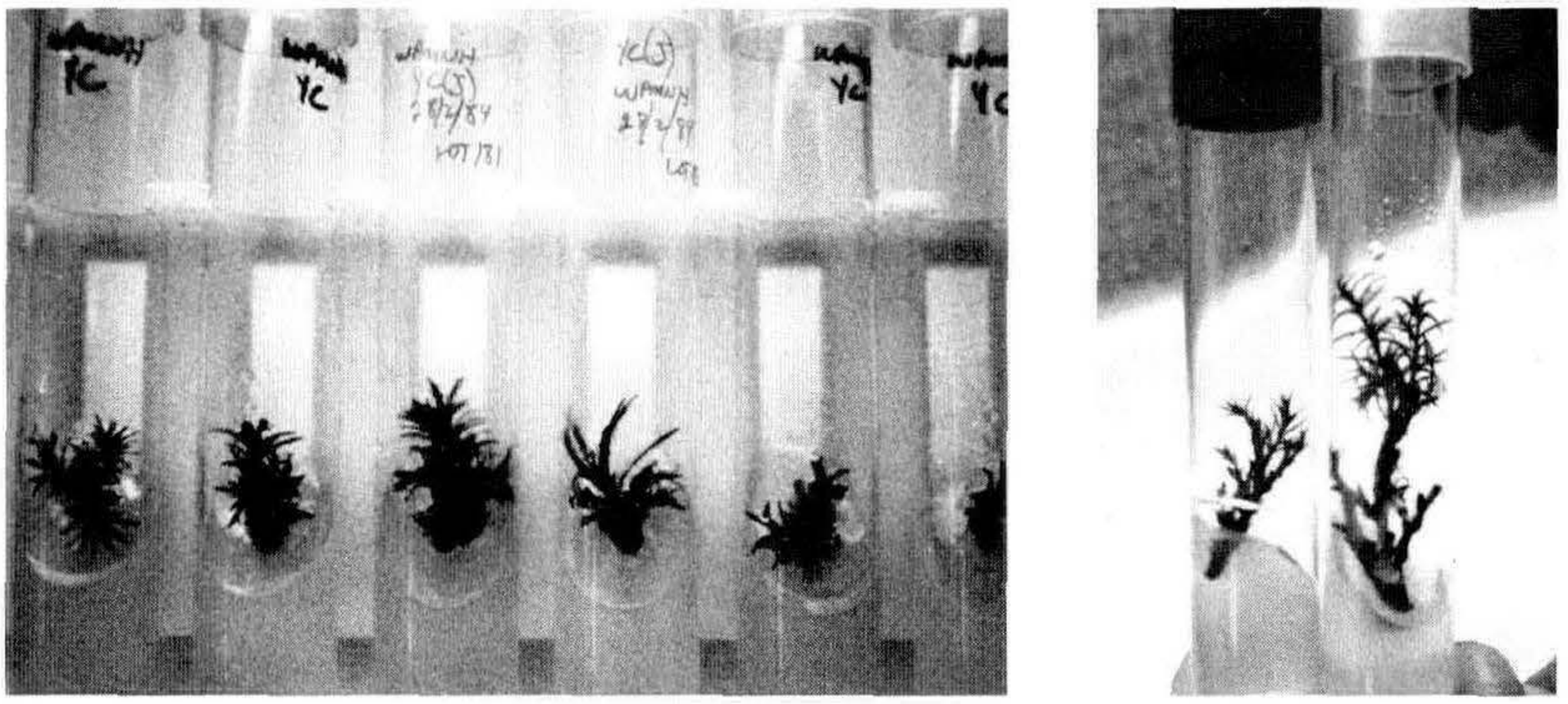

Figure 3. *(Left)*: Juvenile yellow cedar cultures exhibiting multiple shoot proliferation.
(Right): Both apical and lateral shoot growth displaying juvenile characteristics were generated from mature yellow cedar explants.

Growth Levels of Mature Yellow Cedar. Mature yellow cedar tissue was not as responsive when subjected to similar culture manipulations as the juvenile yellow cedar tissue.

Slight lateral branching was observed when the explant was inoculated onto ¼ strength MS mineral salts with low levels of auxins and cytokinin. When MS mineral salts were increased to 50% of full strength with a further reduction in cytokinin levels, apical shoot growth and axillary branch development was enhanced. New shoot growth exhibited distinct juvenile characteristics with dark green prickly scale leaves in comparison with the adult tissue of smooth scale leaves with light green tissue coloration. (Figure 3, right).

Rooting Studies of Juvenile Yellow Cedar Plantlets. Random in-vitro rooting of several juvenile yellow cedar cultures exhibited taproots 3 to 6 cm in length accompanied by lateral roots 1 to 3 cm in length 3 months after initial explant inoculation. (Figure 4, left). No conclusive comparisons can be drawn at this time between rooting of shoots and type of growth medium. Active vegetative growth was noted along with root development.

Greenhouse Care of Yellow Cedar Plants. *In-vivo* rooting trials of juvenile yellow cedar cultures have proven successful. To date only those cultures exhibiting some previous *in-vitro* root formation have survived transplanting to the greenhouse environment.

Upon removal of rooted plantlets from the culture tubes all traces of agar on the root system was washed off so as to prevent substrate sites for pathogen growth.

Figure 4. *(Left)*: A juvenile yellow cedar culture exhibiting *in-vitro* rooting. *(Right)*: One gallon containerized yellow cedar plantlets derived from tissue culture.

Clay's potting mix formula of a well proportioned ratio of peat to perlite provided the soil growing medium. It is essential that the potting mix provide good drainage and aeration otherwise the yellow cedar plantlets, being as susceptible as they are, succumb to basal rot. Plantlets were potted into 2¼ in. pots.

Acclimatization of plantlets included a 10 to 14 week time period under mist tent conditions with high humidity, increased light exposure, bottom bench heat of 20°C, and hand misting twice daily.

Within 3 to 4 months of transplanting, active top growth was observed, indicating an active root structure. One year after initial out-planting, yellow cedar plants were repotted in one gallon nursery containers (Figure 4, right). Root structure was healthy and compact and vegetative growth exhibited excellent color, form and lateral branching. Height of plants upon repotting to one gallon container was 14 to 20 cm. A fertilization program consists of weekly feedings of nitrogen, phosphorus, potassium — 10-52-10, respectively.

The research efforts outlined in this paper are continuing at Les Clay and Son Ltd. But before any method of mass propagation can be considered suitable for use in a tree improvement program, the findings set forth in this paper must be refined to a point where the cultured material can be easily established and maintained, plantlet regeneration can be obtained in a short while, and the newly-formed plants must prove true-to-type and must survive transfer to the field (7).

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PERENNIALS WORTHY OF CULTIVATION

GERALD B. STRALEY

The Botanical Garden, The University of British Columbia
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The University of British Columbia Botanical Garden operates a Plant Introduction Scheme of the Botanical Garden (P.I.S.B.G.) in an effort to introduce new cultivars and recommended plants to the public. The new plants are propagated by the Garden and released to particular nurseries in the province who agree to further propagate them and release them to the public at a later date. Thus far a number of woody materials and ground covers have been released through the P.I.S.B.G. or are now being tested or considered for inclusion. Only one perennial has been released to date, but with the comeback in popularity that perennials have enjoyed in recent years, we are considering other new and under-utilized perennials for inclusion in the P.I.S.B.G.

The first perennial in the P.I.S.B.G. is the blue pimpernel (*Anagallis monelli*). It has been grown to a limited extent in North American gardens, but most plants prove to be annuals or biennials at best. Our perennial plant which we have registered as 'Pacific Blue' is a selection from seed received from the Alpine Garden Society of England in 1980. Large gentain-blue flowers cover the low, spreading plants from late May

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until hard frosts in our climate. Plants root easily from cuttings during the summer. It may be used in front of perennial borders, in alpine gardens, as a container plant to provide summer color, or in hanging baskets. It should be given a sunny location as the flowers remain closed in shade or on cloudy days. Its perennial habit needs to be further tested in hotter and colder climates.

Another plant we are considering selection of good forms of is the South African *Schizostylis coccinea*. This is one of our best fall flowering perennials for cool, wet climates. The erect spikes of brilliant red flowers provide color at a time when it is needed. There are a few named cultivars, especially pink-flowered forms, available in England, but not often found in North America. The plants can be established easily by seed, divisions in spring, or from small plantlets produced on the flowering stems. Seedlings will flower the first year if started indoors in winter. We have recently had the plant successfully tissue-cultured.

We have undertaken a limited selection and breeding program with the blue poppies (*Meconopsis*), in an effort to select more perennial forms of the beautiful blue-flowered *Meconopsis betonicifolia*, which is usually a monocarpic biennial. Crosses have been made between species in an effort to combine the flower color of some of the blue species with the perennial nature of some other species such as *Meconopsis cambrica* or *Meconopsis villosa*.

Diascia rigescens is a perennial in the Scrophulariaceae from South Africa recently introduced into a few gardens in the British Isles and the West Coast of North America. It has received rave reviews whenever seen. The grey-green foliage is partially to completely evergreen depending on the climate making the plants attractive even when not in flower. However, from June until hard frost, at least in the Pacific Northwest, the plants are covered with arching spikes of bright carmen-rose flowers resembling a small snapdragon, to which it is related. The plants look tidy throughout the summer, even if old flower stalks are not removed, as new growth and flowers are produced continuously throughout the summer and fall. The plants root easily from cuttings. Our plants have survived two severe winters and one very hot, dry summer since planting, with no losses.

The Oenotheras or evening primroses are not grown in perennial borders as much as they should be. They probably have a bad name because of the biennial kinds flowering only one season, or reseeding and becoming pests, or because of the evening flowering habit of the common ones. However, there

are two eastern North American species which are perennial and long-lasting in the garden, with large bright yellow flowers which open in the morning. These are *Oenothera fruticosa* and *Oenothera pilosella*, which should have the more appropriate common names of suncups or sundrops. There is much confusion over the naming of forms and cultivars in the former species. When one obtains a named cultivar of this species it is hard to tell what will result. The plant is quite variable in nature and there is much that could be done in selecting and naming good forms or in hybridization. I know of no cultivars of *Oenothera pilosella*, a rhizomatous species especially common in the Ohio Valley. It is cultivated to a limited extent in the East, but very rarely in the West.

Kirengeshoma palmata and *Kirengeshoma koreana* (Saxifragaceae). These two species or forms of a single species are excellent summer-flowering perennials for cool climates. The bold, pale green foliage and tubular yellow flowers are attractive for a partially shaded situation. The leaves sun-burn in full sun even in our cool, wet climate of the Pacific Northwest. *Kirengeshoma koreana* has been much the better of the two in our garden. The flowers are larger and open more widely. *Kirengeshomas are not often seen outside botanical gardens* and collector's gardens.

Papaver spicatum — We received this poppy labelled as *Meconopsis*, which it does resemble, especially when in the basal rosette stage. The soft grey leaves are attractive before flowering and the 3-foot spikes of the tissue-paper like, pale orange flowers are very showy in early summer.

Incarvillea olgae is a very different member of this genus from *Incarvillea delavayi*, the usual stemless species grown in our gardens. We have grown it successfully for a number of years. It is a bit lanky with stems two to three feet tall which usually fall over, but the bright-green, dissected foliage and rose-pink flowers produced in late summer are very attractive. Dwarfer or more compact forms of this need to be selected.

Some other perennials which deserve to be grown more widely include some of the smaller flowered Kniphofias, the blue *Agapanthus* species, hardier forms of *Alstroemeria* and many of the bold-leaved ligularias and rodgersias.

Among the many native perennials which deserve some selection and trials in our gardens include the perennial species of geraniums, the low-growing phloxes, erigonums, asters, *Iliamna rivularis*, and selections of the eastern native butterfly-weed (*Asclepias tuberosa*).

PROPAGATING AND GROWING PRIMROSES IN THE PACIFIC NORTHWEST

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Primula × *polyantha* and *Primula vulgaris* [syn. *P. acaulis*] are popular perennial bedding plants in the Pacific Northwest. The area's cool summers are ideal for seed germination and mild winters allow gardeners to plant primroses as early as February.

Other areas of the United States are showing increased interest in these species. Growers in California and the southern states produce them for November through February sales. Colder areas of the country grow them as winter potted plants and for bedding plant sales in April and May.

Perennial primroses grow and perform best in cool temperatures. Crop time from seed is six to eight months depending on the cultivar and growing temperature. Growers who specialize in finishing plants can cut crop time by three to five months by purchasing starts. In areas of particularly warm summers, this is the preferred method.

PROPAGATION

Sow primrose seeds in open seed flats or plug trays containing a fine-textured peat-lite mix. Sow 500 to 700 seeds per open seed flat or single sow in plugs. Do not cover the seeds. Although the light requirement is low, it is necessary for optimum germination percentages.

Keep soil constantly moist during the 10 day to 3 week germination period. Allowing the soil to become dry for even 30 min. can drastically decrease germination success. Expect 40 to 80% germination depending on cultivar, temperature, and seed freshness.

Cool temperatures are critical for successful germination and seedling survival. The optimum soil temperature is 60°F. A range from 55°F to 70°F is acceptable but higher temperatures result in expensive losses.

As soon as germination begins, expose seedlings to light levels that do not exceed 1,000 foot candles. Greenhouses must be heavily shaded during the summer to provide low light and cool day temperatures.

When germination is approximately 50% and seedlings have their first true leaves, begin fertilization. A balanced fertilizer at 150 ppm nitrogen supplied in the form of calcium

and potassium nitrate is ideal. Keep seedlings moist and as close to 60°F as possible. They will be ready to transplant 8 to 9 weeks after sowing.

FINISHING

Seedlings can be transplanted directly into 4-in. pots, or, if greenhouse space is at a premium, into 1 or 1½ in. cells. Use a well-drained, light soil mix high in organic matter. Maintain pH levels between 5.0 and 6.0.

Once seedlings are established, decrease watering frequency. Allow plants to wilt very slightly between waterings, then feed with a balanced fertilizer at 200 ppm nitrogen, using mostly $CaNO_3$ and KNO_3. Have a monthly soil analysis done to monitor pH and nutrition. Primroses are sensitive to high salts. They also develop iron deficiencies in soils with high pH levels.

Plants that are 12 weeks or older can tolerate higher daytime temperatures, although 60°F is still optimum. Do not subject young plants to night temperatures below 50°F until they have reached the 6 to 10 leaf stage. At this point, they are physiologically mature enough to initiate buds (2) and night temperatures can be lowered to 35° to 50°F to finish. The plants will also benefit from higher light levels as they go into fall and winter, so shade should be washed off the greenhouses.

Although it has been demonstrated that primroses can be grown at temperatures warmer than 50°F, (1) cooler temperatures keep foliage compact and peduncles short. Low growing temperatures are particularly sensible for growers who sell primroses as late winter bedding plants. Under cool temperatures, plants should be allowed to wilt slightly between waterings. *Do not keep plants constantly moist during the winter* months or you will encounter poor growth, chlorotic foliage, and an uncontrollable spread of *Botrytis*.

Maintain good air circulation around the plants at all times to discourage *Botrytis* infections. A weekly application of Exotherm Termil® is an excellent preventive measure. If *Botrytis* is present, remove infected plants and make foliar applications of Chipco 26019 to keep the disease under control.

Insect problems are few, particularly in very cool temperatures. If aphids, mites, or thrips appear, treat with a recommended insecticide.

FLOWER INITIATION

There is a great deal of speculation on what causes flower bud initiation in *P.* × *polyantha* and *P. vulgaris*. Temperature

and day length, (3) juvenility and light intensity (2) have all been cited as influencing factors. My own observations suggest that the primrose crop will have good bud set if plants are 4 months old before being subjected to low temperatures and we are lucky enough to have a bright winter. (Day length is naturally short and night temperature is between 35° and 40°F.)

CHOOSING CULTIVARS

Each primrose cultivar has its optimum bloom time. Bloom times have been divided into three categories:

Early (December, early January)
Mid (mid-January, early and mid-February)
Late (late February, March)

The following list gives examples of cultivars in each category. Note that *P. vulgaris* types make up the early and mid-bloomers, while *P.* × *polyantha* types fall into the late category. Early blooming cultivars are the best for forcing.

Early: 'Julian Mix', 'Julian Bicolor', 'Julian Cheerleader', 'Sunrise', 'Peso', 'Pageant', 'Ducat', 'Olympus'.

Mid: 'Julian Goldridge', 'Aalsmeer Giants', 'Festive', 'Dania', 'Finesse'.

Late: 'Jewel', 'Casino', 'Elite', 'Laser', 'Pacific Giants'.

Growers can guarantee continuous bloom in their crops by growing cultivars from each category.

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AN INTERMITTENT MIST SYSTEM WITH PRESSURE BOOSTED BY CONTINUOUS PUMPING

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Abstract. A mist system with line pressure boosted by a continuously running pump has advantages of design, operation, and cost over a system in which the pump runs intermittently. Between misting periods, the water is recycled at reduced pressure to a storage tank. Operation and safety features of the pump system are discussed schematically. The cost efficiency of the system makes it readily adaptable for large-scale expansion.

Fifty years of experience have established that misting leafy or green cuttings improves their survival and rooting (5). But too much mist can be deleterious (2,6). Therefore, intermittent misting has replaced the earlier practice of continuous misting (3).

The intermittent mist system described here operates with a continuously running pump that creates a misting pressure of 140 psi. The system is installed in a 9 ft by 12 ft propagation greenhouse at Berkeley, California, and has been in continuous use since 1981. The "fail safe" design ensures continued misting in case of power outage or failure of various system components.

DESIGN AND OPERATION

Any mist system is composed of two integral subunits: the "water distribution network," or mist lines; and the "water transmission system" that transmits the water into the mist lines.

Water Distribution Network. Mist is generated through nozzles rated at 2.0 gallons per hour at 100 psi. These nozzles point downward, are spaced 20 in. apart, and interconnect with ⅜-in OD copper tubing. Two such mist lines are mounted 18 in. apart 3 ft above each of two 3 ft by 12 ft benches. Fifteen nozzles are staggered in the two lines. Water left in the lines at the end of a mist period could drip from the nozzles and is therefore dumped to a floor drain by a lower-pressure relief valve that opens at the end of each mist period. A hand valve is installed in each mist line for line shutdown as needed. Three-inch-deep sand covers heating cable that lines the floor of each bench.

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Water Transmission System. After considering two intermittent pumping systems, we designed and built a system that, except for night shutdown, has continuous pumping, with water recycled to a storage tank between mist periods.

Operation of the system can be followed by focusing on pump P, solenoid valves SV_1 and SV_2, and tank T (Figure 1A). (For the moment, ignore hand valves HV_7, HV_8, HV_9, and HV_{10}.) During each mist period, which here is 12 seconds every 3 minutes, neither SV_1 (normally open) nor SV_2 (normally closed) is energized, and water from the pump flows through SV_1 to the mist lines. During recycle (non-mist) periods, solenoids for both valves are energized, closing SV_1, opening SV_2, and routing water from the pump back to the tank.

In daytime, the 6-min. time switch controls the solenoid valves and thus the alternating mist and recycle periods. At night, when misting is unnecessary, the 24-hour time switch and the relay (Figure 1B) leave the pump switched off and SV_1 energized. Thus, both SV_1 and SV_2 are closed at night.

When the water level in tank T lowers, float valve FV opens and the tank refills with water from the supply line. Check valves CV_1 and CV_4, and for an added margin of safety, swing check valve SCV prevent a backflow of water from the system into the supply line. (Local codes have different requirements for preventing potential backflow into supply lines.)

Pressure gauge PG indicates the pressure in the system — about 140 psi during each daytime mist period and 60 psi during each recycle period. Misting pressure is regulated by adjusting hand valve HV_5, at a time when the system is misting, allowing some of the water to recycle, the amount depending on the misting pressure desired. During recycle periods when water is recycled to the storage tank and flow is not restricted by the tiny nozzle orifices, pressure drops, reducing both pump load and energy consumption. Pressure in the system when water is recycling, set during a recycle period by adjusting hand valve HV_{10}, is kept slightly above supply line pressure. Any unusual surge of pressure that could damage system components is released by pressure relief valve RV.

The hand valves — all of ball-valve design — are for operational convenience. Exceptions are HV_5 and HV_{10} which regulate pressure as described, and HV_3 which flushes strainers S when opened. By opening hand valve HV_6 and closing HV_7 and HV_8, for example, mist can be maintained while solenoid valve SV_1 is removed for repair. (Union joints, common in the system to faciliate repair or replacement of components, are on either side of each solenoid valve). Hand valve

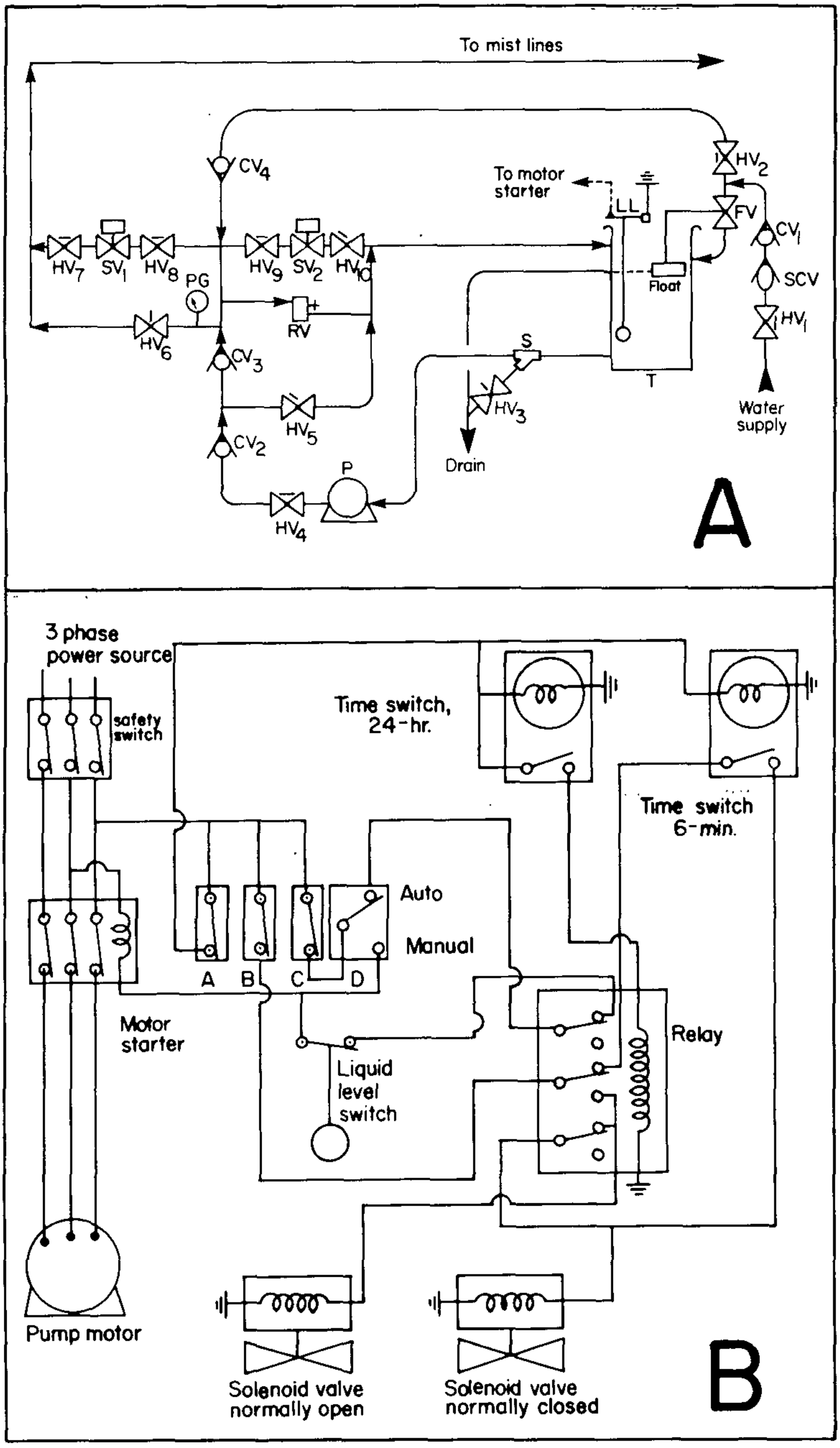

Figure 1. Schematic diagrams for the water transmission system: (A). Hydraulic or flow diagram; (B). Electronic diagram depicting normal, daytime, mist-period operation.

HV_1 shuts off water to the entire system. An appropriately oriented bar drawn next to each hand valve symbol (Figure 1A) indicates whether, during normal operation of the system, the valve is open (bar parallel to piping), closed (perpendicular to piping), or partly open (45 degrees to piping).

An emergency flow route from the water supply line to the mist lines passes through hand valve HV_2, check valve CV_4, solenoid valve SV_1, and hand valves HV_7 and HV_8. The emergency flow, at supply line pressure, is either continuous or intermittent, depending on whether a failure in the water transmission system involves loss of electrical power or only pumping. If power fails, the pump stops running, pressure within the system drops below that of the water supply, and water flows through the emergency flow route to the mist lines. Check valve CV_3 prevents backflow of water through the pump into the tank. Because solenoid valve SV_1 is normally open, water flows through it to produce continuous mist at supply line pressure, although the mist output per unit of time is less and the mist droplets are larger than at the normal misting pressure. If electrical power remains on but pumping stops because of pump failure or, for reasons mentioned below, tank emptying, misting at supply line pressure will be intermittent because solenoid valves SV_1 and SV_2 continue to open and close as controlled by the time switches (Figure 1B). In case water flows through SV_2 in excess of tank capacity it is dumped to a floor drain from the tank overflow outlet. Liquid level control switch LL shuts off power to the pump motor to prevent damage to the pump if the tank empties due to an unlikely event such as float valve malfunction, tank rupture, or lack of water in the supply line.

Electronics. The electrical circuitry of the water transmission system is shown in Figure 1B. Switches A, B, C, and D (all standard home wall switches) are for override purposes. Switch D switches the system between automatic and manual operation. The other switches cut off power to the time switches and relay (A), solenoids (B), and pump motor (C).

COSTS

Components of the mist system cost approximately $1500 when installed in 1981, excluding material for a 4 ft by 4 ft by 10 ft building to house the water transmission system and the heating cable installed in the benches. Numerous sources besides those in the specifications lists (Appendix) are available for each of these components.[2]

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[2] Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

Energy cost is the most significant operating expense and depends on many factors. We estimate energy consumption of the ½-horsepower motor of the close-coupled turbine pump to be between 3.8 and 4.8 kWh per 10-hour misting day for a cost of $0.30 to $0.38 per day at $0.08 per kWh. We mist two 3 ft by 12 ft propagation beds simultaneously, typically applying, as mentioned, 12 sec. of mist every three min. The system could mist a much larger area with only slightly increased energy costs.

DESIGN CONSIDERATIONS

The mist system has had only one unscheduled shutdown. A thumbscrew tripper on the 24-hour time switch loosened one night and the system consequently failed to switch on the next day. Several hours lapsed with no misting before the situation was noticed. A solid-state time switch or mechanical time switch with trippers securely anchored in position (e.g., pull out trippers) could avoid this specific problem. Although the system has a number of fail-safe features, daily monitoring is advisable.

The pump should be built for continuous operation and should be of sufficient capacity to discharge slightly more water during each mist period than the combined output of all nozzles. There is no way to compensate for an undersized pump that delivers too little water to maintain a desired misting pressure. Conversely, an oversized pump that recycles excessive amounts of water to the tank wastes energy.

If the mist propagation area is arranged with propagation benches or greenhouses of similar size, units can be misted serially rather than simultaneously: Solenoid valves can route the flow in turn to each unit. With serial misting, less water is recycled and less energy is used unproductively. For example, if a 15-station time switch and 14 more solenoid valves were added, this system could apply 12 sec. of mist every 3 min. to 15 greenhouses, with energy costs less than doubling.

The basic design of the system could be adapted to systems with pressures well above 140 psi and nozzles, such as those manufactured by Bete Fog Nozzle, Inc., Greenfield, Massachusetts 03102, that are designed to produce fog instead of mist. Fog preserves a humid environment around the cuttings whereas mist restores a thin film of water on the cuttings that is lost by evaporation. When fog is used it is circulated among the cuttings. either passively (1) or by forced air (4).

Acknowledgment. Appreciation is expressed to Four Winds Growers, Fremont, California, for consultation on the principles and merits of boosted pressure mist for plant propagation. Their mist system served as our original model, and we incorporated many of its features directly into our own.

We departed from their system primarily in the use of a continuously running pump to dispense with a pressure tank. Appreciation also is expressed to Stephen Jacobs, Coker Pump and Equipment Company, Oakland, California, who first suggested the framework of continuous pumping for an intermittent mist system. Our design developed from their inspiration.

APPENDIX

I. Specifications and manufacturers of piping components of the intermittent mist system.

Component	Specifications	Manufacturer	Model No.
Nozzle	Machined brass, 2.0 gph @ 100 psi, 120° hollow cone	Monarch Mfr. Works 2505 E. Ontario St. Philadelphia, PA 19134	F110C
Copper tubing and fittings	⅜" for mist lines; 1⅛", tank overflow to drain and tank to pump; ¾" elsewhere	Unknown	
Polyethylene tank	18" diameter, 40" depth, 40-gal. capacity	Chem-tainer Industries 361 Neptune Ave. N. Babylon, NY 11704	None
Strainer	Y type, bronze, 1¼" thread end 150 psi	Mueller Steam Speciality P.O. Box 1569 Lumberton, NC 28358	351
Turbine pump	2.4 gpm @ 150 psi, close-coupled to ½ horsepower, 3-phase motor	Burks Pumps P.O. Box 431 Decatur, IL 62525	35CT5M
Solenoid valve (Open when power is off)	Normally open, ¾" ips, 120 V AC	Automatic Switch Co. 56 Hanover Rd. Florham Park, NJ 07932	8210-C35
Solenoid valve (closed when power is off)	Normally closed, ¾" ips, 120 V AC	Same as above	8210-B26
Pressure relief valve	¾" ips, 5 to 300 psi	TEEL, Div. of W.W. Grainger, Inc. 5959 W. Howard St. Chicago, IL 60648	2P027
Float valve	¾" ips	Robert Manufacturing Co. 10667 Jersey Blvd. Rancho Cucamonga, CA 91730	
Hand valve	Ball type, ¾" ips, sweat end	Watts Regulator Co. 10 Enbankment St. Lawrence, MA 01842	B6001 400 WOG
Check valve	¾" ips	Unknown	

II. Specifications and manufacturers of electronic components of the intermittent mist system.

Component	Specifications	Manufacturer	Model No.
Safety switch	30 A, 240 V AC, 3-pole knife, single throw	Square D Company 4335 Valley Blvd. Los Angeles, CA 90032	D321-NRB
Motor starter	NEMA size 00, 3 pole, 3 phase	Dayton Electric Manufacturing Co., W. W. Grainger, Inc. 5959 W. Howard St. Chicago, IL 60648	5X153B
Time switch	40 A, 240 V AC, 24-hr. repeating, single pole, single throw	Same as above	2E021
Time switch	20 A, 240 V AC, 6-min. repeating, 6-sec. increments	Tork 100 Grove Street Mount Vernon, NY 10550	8061
Relay	10 A, 120 V AC, 3-pole, double throw, 11-pin configuration	Cornell-Dubilier Electronics Corp. 1605 E. Rodney French Blvd. New Bedford, MA 02744	323A10-115
Liquid level control switch	120 V AC	Johnson Controls, Inc. 1250 E. Diehl Rd. Naperville, IL 60540	F59
Wall switch	15A, 120 V AC	Unknown	

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WESTERN REGION 1984 CURTIS J. ALLEY MERIT AWARD

Presented by Robert Weidner, Western Region President, at the Western Region Annual Banquet

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Presented by Robert Weidner, Western Region President, at the Western Region Annual Banquet

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He was immediately hired by the University of Massachusetts where he served as assistant professor from 1953 to 1957, then associate professor from 1957 to 1959. That year he returned to Oregon State University as associate professor, advancing to full professor in 1967.

Our recipient has been a member of the IPPS since 1955 and was a charter member in the founding of the Western Region in 1960. He was Western Region president in 1967-68. He has worked on Membership, Long Range Planning, and Convention Planning Committees.

He has also been very active in the American Rhododendron Society, serving on the National Board of Directors, and as the Society's Secretary-Treasurer, and as President.

Our recipient has received many award and honors, among then being:

Gold Medal, American Rhododendron Society

Honorary Membership, Oregon Holly Growers Assoc.

Research Achievement Award, Oregon Association of Nurserymen

Horticultural Achievement Award, Oregon Federation of Garden Clubs

Horticultural Achievement Award, National Council of State Garden Clubs

Jackson Dawson Gold Medal, Massachusetts Horticultural Society.

It is a great honor to announce our 1985 Award of Merit recipient as Dr. Robert L. Ticknor, Professor of Horticulture, Oregon State University, North Willamette Experiment Station, Aurora, Oregon.

PRINCIPLES OF PLANT FREEZING RESISTANCE AND INJURY

C. J. WEISER

Department of Horticulture
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Water Properties: The unique properties of water are of central importance in plant freezing processes. Pure water freezes at 0°C or 32°F. Impurities depress the freezing point of plant tissue water, by 1° to 2°C in most plants. Additionally the water in some plant tissues supercools substantially below its actual freezing temperature.

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Small volumes of water supercool to a greater extent than large volumes. Very fine droplets or thin sheets of pure water can supercool down to, but not below, -40°C which is the Spontaneous Nucleation Temperature of water. In plant tissues which deep supercool water can avoid freezing a few degrees below -40°C because of soluble impurities in cellular water (1).

Liquid water becomes denser as it cools, but at the moment water crystallizes into ice it increases 4 percent in volume — and releases a large amount of heat (540 calories per gram of water). The heat released when liquid water crystallizes into solid ice is called the Heat of Fusion. The practice of protecting plants from freezing injury by continuously sprinkling to maintain an ice-water interface on the plant surface is based on this energy release from water at the moment it freezes.

Plant Freezing Processes: Tender plant species like tomatoes, beans and melons are killed at the moment they freeze — and some "chilling sensitive" tropical species like bananas, rice and poinsettias are actually killed by cool temperatures well above freezing (5° to 15°C). In contrast many hardy woody plants can survive prolonged freezing at extremely low temperatures in winter — including submersion in liquid nitrogen at -196°C or -320°F. Many cultivated trees and shrubs fall between these hardiness extremes. Even the hardiest plant species are killed at temperatures just slightly below freezing (eg at -3°C or 27°F) during active spring and summer growth. With rare exceptions growth cessation (dormancy) is a prerequisite to cold acclimation in plant species capable of hardening (3).

When ice forms at one or more locations in a plant it is capable of spreading (often rapidly) throughout the plant. Rapid cooling/freezing gives rise to rapid ice spread and formation of many small ice crystals. Slow cooling rates give rise to formation of fewer large ice crystals or lenses, and slower spread of ice throughout the plant. Some plants have tissue zones which ice does not propagate through readily. For example, barriers to the spread of ice from frozen stems into dormant overwintering flower buds have been found at the base of buds in several woody genera including *Prunus* (4).

At the microscopic level rapidly cooled cells are observed to "flash" or freeze intracellularly as thousands of tiny ice crystals form within the living cytoplasm of the cell. Such intracellular freezing is invariably lethal. In plant tissues cooled slowly on the microscope stage water is observed to freeze outside of the living cell (extracellular freezing) in spaces between cells. Some plants have "preferred sites" of ice

formation where large ice masses often form without causing serious damage to the plant.

Extracellular ice crystals grow larger as the temperature is lowered because water in the living cell cyptoplasm migrates through the cell membrane and cell wall to the external ice nuclei, in response to the vapor pressure deficit outside of the cell. When this occurs the living cytoplasm of cells dehydrates and shrinks — sometimes to ¼ of its original volume without injury (3). Hardy plant cells can survive extracellular freezing and thawing to varying degrees. Tender plant cells cannot.

Plant and animal cells can be artificially cooled extremely rapidly in the laboratory, by plunging into liquid nitrogen or helium. Under such conditions cell water can become a solid-liquid, like window glass, with no ice crystal lattice formation. Such "vitrified" cells can survive this extreme cooling — illustrating that ice formation, not low-temperature, is the cause of injury. The vitrification of water in living cells, by cooling and rewarming so rapidly that ice crystallization does not occur, is used in cryopreservation of plant and animal cells — such as sperm and red blood cells.

Intracellular freezing is a cataclysmic event at the cellular level. Cell membrances and enzyme compartmentalization are destroyed and death occurs rapidly and dramatically. Plant tissues become flaccid, water soaked and undergo rapid oxidative browning as soon as they thaw.

Rapid cooling rates (eg. about 10°C per minute) are used in the laboratory to produce intracellular freezing in plant cells. In nature the air temperature never drops that rapidly, but lethal intracellular plant freezing probably does occur in nature when deep supercooled tissues suddenly crystallize, and under some other conditions. For example arborvitae foliage on the southwest side of plants exposed to bright winter sun on a cold winter day can thaw and warm as much as 20°F above the air temperature. When such plants were suddenly shaded the foliage temperature dropped 15°F in one minute. The sun-warmed arborvitae foliage was killed above 0°F when it cooled rapidly and refroze (intracellularly) — even though it was hardy enough to survive slow extracellular freezing to −25°F (5).

Scientists do not know how or why extracellular freezing kills hardened plant cells that are capable of surviving tissue ice formation down to a certain critical temperature. It is known that plant water content decreases markedly as plants harden; that hardy plants can tolerate greater water stress. That extracellular freezing imposes increasingly severe dehydration stress on cells as the temperature decreases; and that

hardy plants survive when more of their water is frozen than less hardy plants (3,4). It is likely that death from extracellular freezing occurs when the living protoplasm becomes too dehydrated.

Important Points

* Tender plants can only avoid freezing injury by not freezing. Ice nucleating bacteria, such as *Pseudomonas syringae*, are widely distributed and prevent plants from supercooling below about −2°C. If no ice nucleating bacteria are present some tender plants can supercool and avoid freezing and injury down to temperatures of about -8°C or 17°F. Eliminating ice nucleating bacteria from woody plants usually does not lower their freezing point (increase their supercooling). This suggests that many woody species may have naturally occurring internal (endogenous) ice nucleators in their tissues. It also suggests that eliminating ice nucleating bacteria may prove to be an effective technique for fostering freeze avoidance in tender herbaceous plants — but not in woody plants.

* Hardy plants can avoid freezing injury by tolerating extracellular ice in their tissues — or by not freezing.

* Some hardy plants (eg. Eastern deciduous forest species) have both avoidance and tolerance mechanims for surviving (1). Many cultivated trees and shrubs, for example, tolerate extracellular freezing in their vegetative buds, phloem, xylem vessels and trachieds, cortex and cambium tissues — and avoid freezing (down to as low as -40°C or F) in other adjacent stem tissues which deep supercool such as pith and xylem ray parenchyma cells (in pears, apples and Eastern hardwoods), and in dormant flower buds (in cherries, apricots, peaches, blueberries, deciduous azaleas and conifers).

* Rapid and lethal intracellular freezing likely occurs in nature when the water in deep supercooled tissues suddenly crystallizes, and when sun-warmed (thawed) plant tissues of small mass are suddenly shaded (cooled) on cold bright winter days (5).

* Freezing injury is caused by ice formations in the plant — not by low temperature — except in chilling sensitive plants of tropical origin.

* Stage of plant development is critically important to freezing tolerance. Even the hardiest plant species, capable of surviving submersion in liquid nitrogen or helium during the winter, are killed at temperatures just slightly below freezing (-3°C or 27°F) when they are in the spring flush of growth.

* Growth cessation (dormacy) is a necessary prerequisite to cold hardening in hardy/woody plants — with rare exceptions (2).

Freezing Resistance/Cold Acclimation: Hardy plant species are extremely adaptable organisms. They are capable of increasing in hardiness from about −3°C during the spring growth flush to −30° or −50° or even below −196°C in midwinter. Seasonal patterns of cold hardiness can be established by sampling plants in the field at frequent intervals throughout the year, subjecting them to controlled freezing tests, and plotting their lowest survival temperatures during the year (3).

Growth chamber experiments, exposing different branches on a single plant to different environments, and studies of grafted, girdled, and defoliated plants have been conducted to establish how environmental signals regulate the processes of hardening and dehardening (3). Metabolic studies, microscopic studies, and measurements of the heat of fusion released as plants freeze identify changes occurring in plants at the cellular level during hardening and dehardening — and the lethal and non-lethal freezing events occurring in plants (4).

Important Points:

Studies of cold acclimation (hardening) in hardy and semi-hardy species which are capable of acclimating indicate the following:

* The developmental stage of a plant has a strong influence on whether, how rapidly, and to what extent the plant can acclimate or deacclimate (2).

* Actively growing plants during spring and summer are not hardy.

* Many hardy woody plants appear to acclimate in three distinct stages under optimum conditions.

* The optimum sequence of developmental stages and environmental stimuli for achieving maximum hardiness development in hardy species is:

a) Exposure to short days and warm temperatures (Stage I).
(Plant vegetative maturity and dormancy.)

b) Exposure to cool temperatures and frost (Stage II).
(Initiation of physiological rest.)

c) Prolonged exposure to sub-freezing temperature (Stage III)

* Stage I of acclimation is induced best by short days and warm temperatures. Many woody species achieve a hardiness of about 0°F or -18°C during this initial stage of acclimation. Short days concurrently induce dormancy in adapted species. The short-day induction of hardiness involves a "biological clock" (a photo reversible enzyme-pigment system called phytochrome) which is located in the leaves; and a translocatable

hardiness promoting factor that carries the "clock" message from the photoreceptive leaves to overwintering plant tissues. The translocatable factor is probably a hormone. It moves through the living bark (phloem) (3).

* *Stage II* of acclimation is induced by low temperatures/ frosts. In contrast to short-day induction the hardiness induced by low temperature is a localized (not a translocated) response. Roots, (or branches) which are not exposed to low temperatures do not become as hardy as exposed stems (or roots). Hardy plant species which are exposed to frost after reaching Stage I increase in hardiness very rapidly — as much as 10° to 20°F per day during Stage II of acclimation (4).

* *State III* Russian researchers have demonstrated with hardy birch species that the maximum hardiness achieved in Stage II can be gradually increased even further by prolonged plant exposure (several weeks) to continuous subfreezing conditions. The additional hardiness may amount to 10° or 20°C. This additional increment of hardiness *(Stage III)* is lost as soon as plants thaw (3).

* The optimum sequence of conditions which have been described lead to the maximum and most rapid development of hardiness — but it is possible to induce, and eventually achieve, maximum hardiness in hardy species without exposure to short days. i.e. low temperature exposure alone can eventually induce maximum hardiness in dormant plants (3).

* Hardiness studies of different climatic races of a plant species that have evolved in climatically divergent parts of the natural range of the species illustrate the important role of the plant's biological clock. A Minnesota field study of climatic races of red-osier dogwood races native to Minnesota, North Dakota and Seattle, Washington illustrates this point (3). The ND clone acclimated (Stage I) earliest in the fall in Minnesota and the MN clone next. Both survived without injury. The Seattle, WA clone was killed back from the branch tips almost to the ground by the first severe fall frost in Minnesota because it failed to stop growing and acclimate to Stage I.

By midwinter however the surviving branch bases of the WA clone were just as hardy (below -196°C) as the ND and MN clones. This illustrates that all three climatic races had the inherent capacity to acclimate to below -196°C — but the WA clone lacked the proper biological clock to stop growing and begin acclimating early enough in the fall to avoid severe injury in Minnesota.

* Most cultivars of landscape plant are grown far from their original sites of origin, and many have been hybridized — to further confuse their biological clocks. The plant biologi-

cal clock is genetically controlled — and cannot be "reset" by progresively growing late acclimating plants in more severe climates.

* Plant cultivars which stop growing and set terminal buds in the field at a given location in late summer are likely to acclimate before severe fall frosts — to achieve maximum hardiness rapidly (2). If their inherent mid-winter hardiness exceeds the mid-winter minimum temperatures at the location they will prove to be well adapted, and survive without injury. Such species can be given optimum growing conditions (water, fertilizer, etc.) throughout the summer and fall without reducing their hardiness — in fact healthy plants often acclimate faster and to a greater extent than less vigorous plants of the same cultivar.

* Plant cultivars which lack the biological clock settings to respond to short days and to stop growing and set terminal buds in late summer at a given location are likely to cold acclimate late, and to sustain freezing injury during the fall and early winter (2). The hardiness and survival of such cultivars can be enhanced by management practices which induce/impose dormancy and initiate Stage I hardening before fall frosts. Withholding late season irrigation and fertilizer, avoiding late summer fertilizer, avoiding late summer pruning or defoliation, interplanting a competitive cover crop, or applying chemical growth inhibitors are practices that have been used to induce dormancy, and initiate cold acclimation in such "unadapted" cultivars. Observations of when and whether cultivars set terminal buds in the field is an easy and effective way to estimate whether or not a cultivar is adapted. Such visual observations can provide a basis for designing appropriate irrigation, fertilization, pruning, defoliation and digging schedules for each cultivar. Plants dug before they are vegetatively mature often sustain die-back in storage and transit.

* Different tissues within the same plant can differ markedly in hardiness. Tissues which avoid freezing by deep supercooling often acclimate earlier in the fall and deacclimate later in the spring than tissues of the same plant that survive by tolerating extracellular freezing — but the deep supercooling tissues seldom become as hardy by midwinter. In apple, for example the pith and xylem ray parenchyma cells in the wood are killed in midwinter at 20°C higher temperatures than the living bark tissues (cambium, phloem and cortex). The lower limit of hardiness for deep supercooling flower buds and wood tissues is about -40°C. Fortunately most plants survive even when these tissues are killed (4).

* Temperature, and stage of plant development, are the primary factors that regulate day-to-day changes in plant de-

hardening and rehardening in late winter and spring. Unseasonably warm days in late winter, when bud chilling requirements (rest period) have been satisfied can cause rapid losses of hardiness (10°F per day). Rehardening does occur, but slowly, in response to subsequent exposure to cool temperatures. The temperature of the preceeding day correlates well with day-to-day change in hardiness at this time of the year (4).

* Hardiness is fully and irreversibly lost when plants enter the spring flush of growth. The only effective management practices to delay dehardening and spring growth are those which reduce/delay plant exposure to warm temperatures. Shading, and misting to promote evaporative cooling are effective up to a point — but temperatures as low as 5°C can promote growth and dehardening in the spring when plant development has progressed through physiological rest (2).

There are still many unanswered questions about plant freezing resistance and injury, but an undertstanding of the principles involved can provide the basis for intelligent nursery managment strategies to enhance hardiness and reduce freezing injury. Selection of the proper plant materials for each locale is still the most effective and important management decision we make — and observation and experience the best teachers.

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FROST HARDINESS TESTING

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Frost damage has long been a problem for the conifer nurseryman. Spring can bring red needles, buds that fail to flush, and often 20 percent or more of the crop is lost. What is needed is a method to assess frost hardiness so that crops judged not sufficiently hardy to withstand expected low temperatures can be protected. If frost protection is not possible, then losses can be calculated immediately rather than waiting for spring which may be months away.

There are a number of methods being used by the research community to test for frost hardiness. A good review of these methods has been provided by Timmis (6) and by Ritchey (5). Few of these methods, however, are being used on an operational basis. There are only two methods being used operationally by the forest nursery industry.

The first method is the electrolytic conductivity of water surrounding a tissue sample that has been frozen. This method is being used by the Ontario Ministry of Forests in Ontario, Canada (2). This technique is based upon the principle that freeze injured cells will allow cell fluid to escape through damaged membranes. This cell fluid has a higher electrical conductivity than water and therefore a large increase in the electrical conductivity of the water indicates severe freezing damage. The second method for determining frost hardiness is one being used extensively in the Western United States and British Columbia, Canada. This method is based on the discoloration of various plant tissues after freeze damage, and is referred to as the whole seedling browning test.

The following steps are common to both operational frost hardiness testing methods mentioned:

1. Randomly select a sample of seedlings from the population of interest (15 to 40 seedlings) (5).
2. Place the seedlings in a programmable freezer.
3. Lower the temperature at a set rate [5°C/hr. recommended (7)].
4. Hold the test temperature for a set time period [2 hours recommended (7)].
5. Return to the starting temperature at a given rate [not to exceed 20°C/hr. (7)].

The rate at which seedlings are frozen and thawed is critical; increased rates of freezing and thawing beyond those recommended may compound the damage. Increasing the duration of the low temperature may also cause more damage. Whatever rates or durations of freezing are chosen, all tests should be carried out in precisely the same manner for results to be comparable (4). Repeated freezing also tend to increase damage levels (3).

The electrolytic method of assessing frost hardiness is described in Colombo, Webb and Glerum (2). This method has limited use when determining the extent of damage to the various seedling tissues such as needles, buds, and stems. It is, therefore, not as useful in determining the economic viability of stock. Since economics is very important to the commercial grower, no further description of this method will be given here.

The whole seedling browning method of assessing frost hardiness involves visually assessing needles, buds, and stem tissue of whole seedlings after the seedlings have been frozen and then placed in a warm greenhouse for 7 days. The percentage of dead needles is recorded, the buds are sliced longitudinally and the percentage with brown meristimatic tissues are noted, and then the stem is scraped the entire length and the location of dead tissue is evaluated. The various tissues each have their own importance in the ultimate fate of the seedling. The buds determine growth potential for the following year and for nurserymen counting on growth in the second season, this is critical. Girdling of the stem by frost near the root collar is common (1) as this area is more sensitive to frost damage and ultimately means loss of that seedling. Losing the top 50 percent of the stem can also make an economically dead seedling for the nurseryman.

The whole seedling browning test is being used to determine the economic viability of seedlings by the Industrial Forestry Association which has four conifer nurseries in Washington and Oregon. It is using this information to determine the need for frost protection in their three bareroot nurseries. Seedling Quality Services is using this test for other private and some government nurseries in determining frost protection needs. Seedling Quality Services is also using this test, along with the British Columbia Ministry of Forests, to determine frost hardiness levels which correlate with stress resistance. Stress resistance levels are needed to judge when seedlings can withstand the stresses involved in lifting, packing, and possibly storing seedlings prior to planting in the field sites.

Frost protection of any crop can prove expensive. Use of frost hardiness data to limit the use of that protection can prove to provide a large savings for the nurseryman. The browning technique for determining frost hardiness is very simple and straightforward and should be readily adapted to most woody plants.

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FOAMS FOR FREEZE DAMAGE CONTROL IN CONTAINER NURSERIES

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Nurserymen across the Southeastern United States have suffered extensive losses from cold temperatures during the past two winters. The minimum temperatures have been considerably below what is expected for the climatic zones. The worst events were associated with fast moving fronts. The fronts brought high winds as the temperature dropped, then clear cold weather for several days.

Killing weather fronts reach our nurseries only a few times each winter even though they are predicted five to ten times. Much more frequent are freezes associated with clear, cold nights. These events have minimums in the mid-twenties

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(0 to -5°C). The following day there is sufficient radiant heating to rewarm the plants well above freezing.

Two Weyerhaeuser Nursery Products Division nurseries, Wight Nurseries, Inc. and Hines Wholesale Nursery, are located in the heart of the problem areas. Although each had a well-managed freeze damage control program, they suffered large losses in 1984 and lesser, but significant, losses in 1985. The primary damage control technique is to "jam" all plants can-tight, wrap the north edge of the beds with paper or poly, and cover sensitive crops with a polyethylene and shadecloth cover. Although effective, the solid poly cover is labor intensive to apply and remove many times each winter.

The Weyerhaeuser Research Development organization was asked to identify and test more appropriate ways to keep container plants from suffering winter kill.

PROBLEM ANALYSIS

It appears that container-grown nursery stock can be killed from either the top down or from the roots up by freezing temperatures. A plant can take a severe beating of the above ground parts and come back to a marketable form as long as it has a vigorous root system. There are a number of cultural techniques available to enhance dormancy in plant tops. However, the cultural management must start early in the fall to be effective. There is no quick dormancy induction treatment. The roots never do go dormant. Root growth and other root activities are slowed by cold temperatures (5). Once the lethal temperature is achieved for the species, the roots die and take the top with them. Even at temperatures above the lethal point, if the soil is frozen, the plant may die from desiccation. This is particularly prevalent on clear days just after a freeze. The air temperature and light levels are causing the plant to transpire but the roots are still encased in a block of soil and ice.

A freeze damage control program must address these three sources of injury:

1. Maintain soil temperature in the cans above the lethal root temperature for the species.
2. Minimize desiccation of the tops when the air warms but the soil is still frozen.
3. Minimize dieback and splitting of the above-ground parts of the plants.

In nursery operations like ours, the possible methods to control freeze damage must be evaluated for practicality when applied on a large scale. While covering an acre or two with poly is practical, covering our hundreds of acres with poly is

impractical to do in just a few hours. The key tests of practicality are:

1. Can be applied prior to the winter season at leisure and left in place until spring.
2. Can be applied to large areas in a few hours and be removed before the heat buildup is too much.

It can be expected that a mix of solutions are applicable to different crops and locations within a nursery. The problem for the development team became one of finding or developing a set of solutions which are cost effective on various nursery crops. A search of methods in use and previously developed methods uncovered waterbased foams. A preliminary screening suggested that the foams should offer adequate protection and be applicable to large nurseries.

PREVIOUS WORK

The application of long-lasting foams for freeze protection was proposed in the 1950's for many agricultural crops (1). Many universities and manufacturers studied materials and application methods. Ironically, the flurry of activity was caused by the same type of weather we experienced these past two winters. When the farmers and nurserymen had a few mild winters beginning in 1970, the demand for new frost protection methods dwindled.

A literature search on frost control foams surfaced a number of researchers and manufacturers who were active during the early 1970's (1-4). Dr. Harry Braud at Louisiana State University was one of the principal researchers. A phone call was made to Braud to obtain his current views of the art. He told us that he thought the technology of using foams for frost protection was workable and that he had gotten good results. He was most successful with a protein-based surfactant. When the cost of the protein went way up, the economic benefit for his target crops was lost and he stopped his development work.

Waukesha Foundry, Ibex was active as an equipment manufacturer. They are no longer in the business and told us they had sold the product line to Cellufoam. Cellufoam has limited their efforts to supplying foam chemicals to the foamed concrete industry.

The other equipment developer, DeTer Company, Inc., was our last hope. Upon contact, they told us that they had worked on foams for frost protection as late as 1978. Their current focus is foam and equipment for dust supression, but they still have interest in foam for frost control.

The apparently most successful surfactant in the past had been a product called Agrifoam. Agrifoam was developed for frost protection on plants and had been approved by the Canadian Department of Agriculture for use on plants. The manufacturer, Wormald, Ltd., told us that the product was not in production but they would get us a sample to test.

The information each of our contacts sent us and the personal conversations supported our earlier view that foams may have a place in a multiple approach freeze damage control program. Foams should meet our objective of being able to be applied in most any weather. We should be able to cover large areas quickly with reasonable labor. The key issues appeared to be the effectiveness of available surfactants in various container nursery plant types and the stability of the foams in windy conditions.

EVALUATION TESTS

Since foam generators for frost control were not available, we leased a DeTer dust supression foam generator to use in our tests. DeTer and Wormald were to supply surfactant for the test. If the tests were successful and the economics looked good we would address the equipment design issue. It was agreed with our Nursery Products Division to conduct the evaluation at the Hines Wholesale Nursery in Houston, Texas.

First Field Test. The first field test was held at Hines Nursery on February 21 and 22, 1985. Three plants were selected by site staff for the test. *Buxus microphylla* var. *japonica* liners were located in a protected area between greenhouses. *Photinia* × *fraseri* and *Lagerstroemia* in No. 1 cans were located in large beds out in the open nursery.

Although the Agrifoam sample had not arrived from Canada, we decided to proceed with the test. The weather system did us no favor as the overnight low was not expected to go below freezing. At 10:00 p.m. the temperature finally dropped to 40°F (4.4°C), our target application temperature, and we began to apply the recommended DeTer material. Winds were calm. In each plant type three plots approximately six feet (2 meters) square were covered with 1.5 to 2.0 in. (35 to 50 mm) of foam. In addition, foam was placed against the upwind edge of the bed of plants. An hour later, at 11:00 p.m., the temperature had warmed to 44°F (6.6°C). The covering over the *Buxus* liner bed was still intact and coverage was good. The other two test areas looked intact also. Before sunrise, at 5:30 a.m. the next morning, the test areas were revisited. The *Buxus* liner bed was still well covered both in the center of each plot and on the edges. The *Photinia* had fair coverage in the plots, but the edges were about dissipated. The *Lagerstroemia* was

poorly covered. An investigation of why the liner bed area was so good ensued. The foam had developed a frozen crust even though the air temperature was well above freezing. It must have been caused by a combination of radiation heat loss from the surface and below freezing dew point. The protected location prevented much air movement. The low dew point would contribute to the mostly water foam evaporation and lowering the surface temperature to freezing.

This odd twist may be of benefit. If the foam does develop a crust, it will be much more resistant to wind destruction and should reduce the rate of sublimation.

At 6:00 a.m. we again foamed the three locations so we could see what happens to the foam when the sun comes up and shines on it. When the sun came up the foam dissipated in less than an hour. Only a slight residue film was left on the test plants.

We were still encouraged enough to keep the DeTer equipment and wait to test more surfactants. Hopefully the test could be conducted on a colder night. The Hines staff was trained to operate the foam generator so they could be more opportunistic in scheduling the test than we could from Tacoma, Washington.

Results. The night that the foam was tested, the low temperature was 33°F (0.5°C). In the *Buxus* liners, the foam provided 5.5°F (3°C) protection on edge liners and 1°F (0.5°C) in center liners (See Figure 1). The temperature problems were measuring soil temperatures in the liners and one gallon pots. The protection that the foam afforded in the *Photinia* was 1°F warmer with foam than the black poly shielded control pot. We did not quantify the protection that foam gave on center pots in *Photinia* because the probe got accidentally pulled out of the pot during the night when the foam was applied. The probe was sitting in the foam just above the soil in the pot and showed again the phenomenon of the foam freezing although the air temperature was well above freezing. Degree of protection is not really meaningful in this test since the ambient never dropped below freezing. If the ambient had been well below freezing we would expect better protection.

Second Field Test. When the new surfactant samples arrived in Houston from Wormald and DeTer, the foam equipment was set up and the second field test was conducted. Again several different plant types were foamed.

These tests were conducted during the second week in March when the temperature was in the low 60's°F (16 to 17°C). There were five surfactants tested. Millifoam and Millifoam 130 made by Onyx, DeTer 4027 and DeTer 1010 (foam

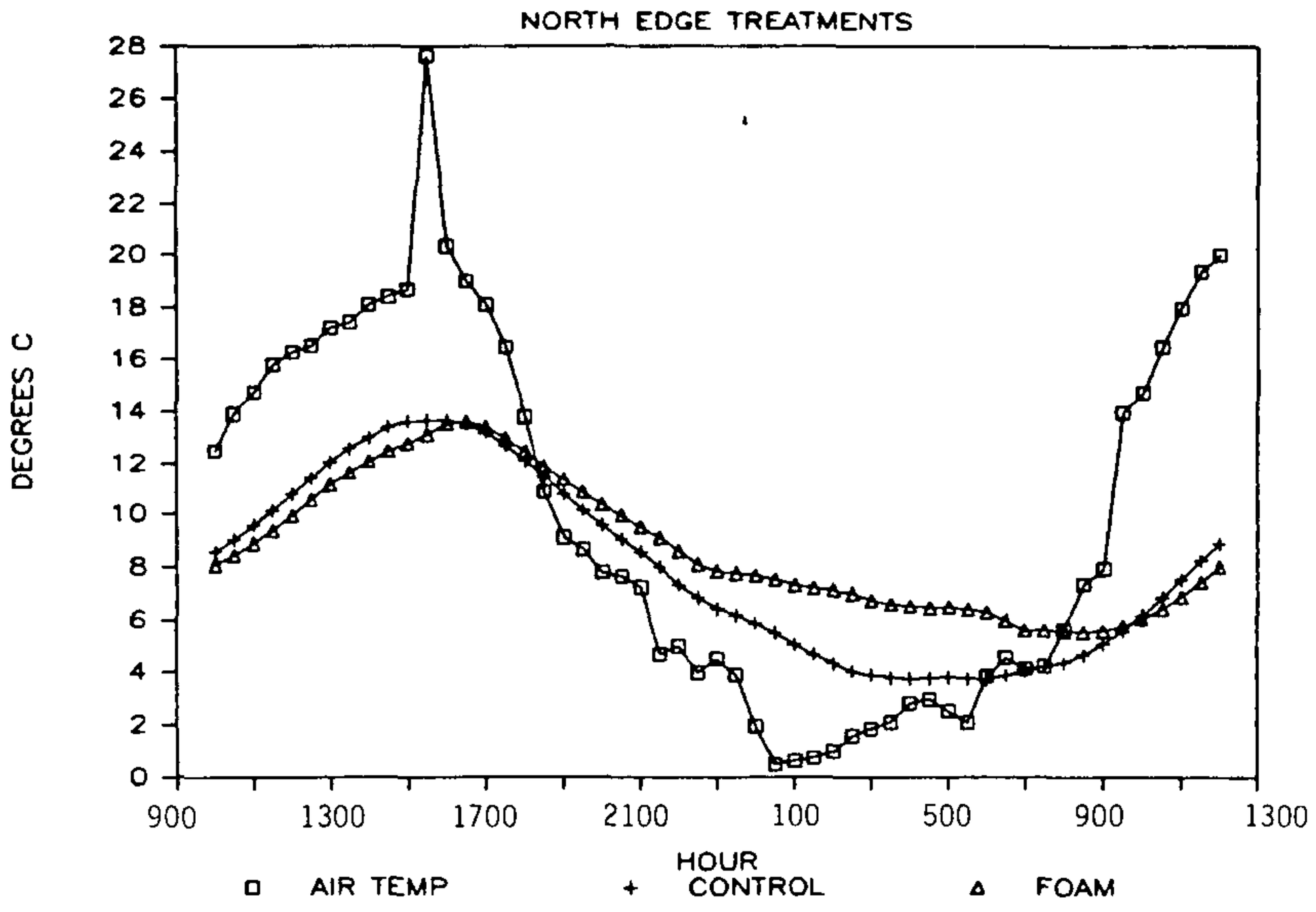

Figure 1. Temperature curves from first field test of foam applied to *Buxus microphylla* var. *japonica* liners.

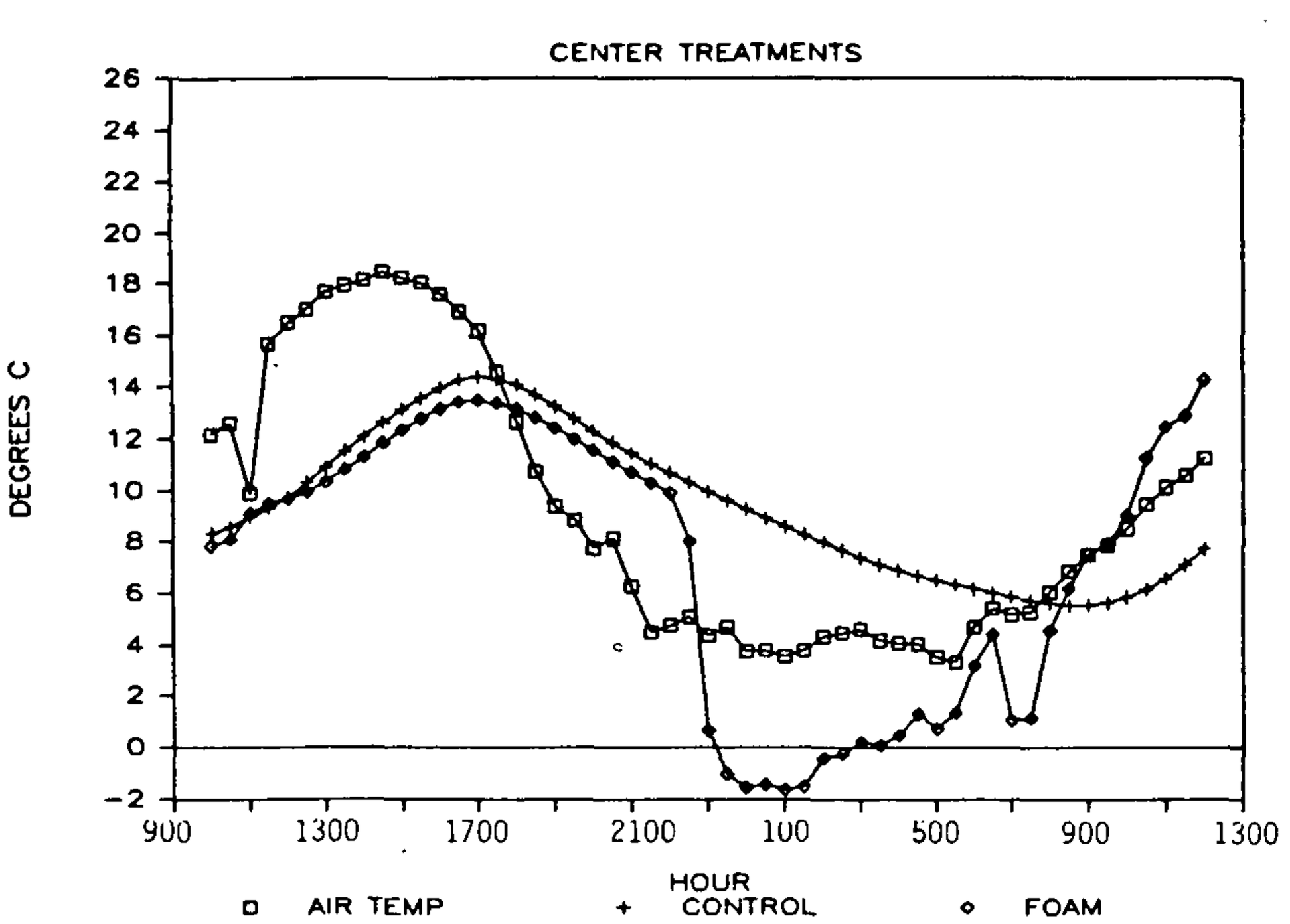

Figure 2. Temperature curves from first field test of foam applied to #1 *Photinia* × *fraseri*. Notice foam temperature drop below freezing even though air temperature was +3°C.

used in February tests), and Agrifoam. Each foam was applied to five different plants; *Buxus microphylla* var. *japonica*, *Lagerstroemia*, *Ligustrum*, *Lonicera*, and *Nandina domestica* 'Nana.' After application, the *Lonicera* showed some leaf drop and the *Lagerstroemia* showed some tip burn with both Millifoam samples and the DeTer 1010 material. No plants were killed. The DeTer 4027 and the Agrifoam caused no ill effects. The DeTer 4027 and 1010 and both Millifoam samples all are short lived foams. During the March test they all dissipated in less than an hour. The Agrifoam was much more stable and had noticeably more body to it. Even in the warm temperatures, the Agrifoam was stable for most of the day. Also, a sample of each foam was collected and frozen in a freezer. All foams, except Agrifoam, reduced in volume and left a thin frozen layer. The Agrifoam froze as a solid mass without any noticeable reduction in volume. Overall, Agrifoam exhibited the best physical characteristics for protecting plants of all the foams tested.

Cost of Foam for Frost Protection. Based on the surfactant used during our field trial, the cost of the foam itself is not great. With a material cost of 0.01-0.02 cents per cubic foot of foam, it would cost $1.60 per inch of thickness per 1000 square feet. That equals about $140 per acre for a two-in. foam blanket. These costs represent only the cost of the surfactant. They assume that water is available and very inexpensive. There are no labor costs or equipment costs included.

CONCLUSIONS

At the conclusion of our field testing and after reviewing our results, we were convinced of the practicality of a foam frost control system to protect plants in one of our nurseries. The cost does not appear prohibitive when compared with the cost of covering and uncovering a nursery bed with poly several times per year. The stumbling block may be the development of equipment to apply the foam over a large area in a short time.

Although foam systems are exciting, we refocused our attention and resources to evaluate non-woven materials as structureless bed covers. Such covers, if effective, could be left in place for long period of time. Compared to applying foam at each freezing event, non-woven bed covers may be as economical, especially when we include the necessary cost to develop foam application equipment.

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KEEPING PLANTS WARM WITH COVERS

CHARLES H. PARKERSON

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For the past five years we have used a practical and inexpensive system for protecting container nursery stock during the most severe periods of winter, i.e. late December to late February. The procedure involves laying white 4 mil. plastic directly on top of the plants.

The Development. Our standard practice is to overwinter plants in unheated plastic houses; however, to overcome the high construction cost involved, we began to investigate structureless systems such as Gouin's Microfoam (1). This effective practice was discarded because Microfoam is available only in narrow widths and the material is costly. In addition, I could not see my way clear to lay several hundred thousand plants on their side and then have the monumental task of setting everything back up again the following spring.

I constantly asked myself, "What purpose does the poly-house provide that can't be done by poly alone"? I realize that there are many complex factors that are involved but the one function I kept coming up with is that the poly-house provides a means of holding the plastic cover in place.

The System. Before covering, to help reduce the possibility of a fungus problem, we apply a shotgun fungicide mixture of Benlate, Manzate 200, and Daconil. A thorough watering just prior to covering is necessary because you will not be able to get to the plants for the next several months.

In our area late December through mid-February is the time of our most severe freezes and is our period of covering. To expedite the covering process we constructed a 3-point tractor mounted pipe boom that extends half way across our standard 17 ft. wide bed. A 20 ft. roll of 4 mil. white plastic is put over the pipe and the tractor travels down a roadway adjacent to the bed unrolling the poly directly over the plants.

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Working with the tractor are 4 men, 2 on each side of the plant bed, pulling the plastic over and down sealing along the edge with previously placed pots filled with potting mix. Immediately following the poly tractor is a second tractor and crew unrolling 78% shade cloth which has grommets installed every 2 ft. The shade cloth is pulled over the bed and stretched tight then secured using ¼ × 12 in. gutter spikes driven into the ground at each grommet thus holding the poly in place. This anchoring procedure is the most critical step in the entire operation; if not done properly you can be sure the plastic will blow off during the first big wind that always accompanies a cold front.

Rainwater collecting on the top of the plastic sheet can present a serious weight problem. This is easily prevented by drilling a new unrolled sheet of plastic with one row of ¼ in. holes 12 in. apart. These small holes are closer together toward the center of the roll but do not appear to reduce the protection provided by the plastic cover. The weight of snow, up to 18 in., seems to be no problem because the weight is uniformly distributed over the cover surface.

Removal of the covers the following spring must have its own systematic method. Our shop man, Johnny Patterson, designed and constructed a tractor-driven trailer device for rerolling the plastic and shade cloth. Putting the heavy bulky material on rolls accomplishes not only having a convenient easy way to handle and store but also facilitates the application operation.

The ground stakes are removed from the shade cloth and the material is folded on top of the plants so that the overall width is reduced to 10 ft. Then the shade is rolled up by the device, parked at the end of the bed, producing a neat package that we can handle easily with fork lift tractors. An average roll will contain 2 pieces of material 20 × 300 ft. The plastic is folded on top of the plants and handled in a similar manner. Using this system and with proper storage we have been using the same plastic for over 4 years.

Using this method we have successfully protected many broadleaf evergreen species at temperatures below 0° F.

Table 3. Height of clones rooted in 1978 and field-planted in 1980. Recorded July, 1985.

Clone No.	Height
8303-06	210 cm
8303-15	230
8303-27	220
8303-35	290
8303-50	170

Clones grown as stock plant hedges. Rooting of cuttings started in 7 cm pots was recorded by carefully removing the pots from the compost ball and recording the plant as rooted, if roots were visible on the surface of the medium. The rooting of cuttings harvested and inserted in the rooting compost at two dates is shown in Table 4. Data is given for untreated cuttings as well as for cuttings treated with a rooting hormone.

Precautions. Slow-release fertilizer, such as Osmocote, will continue to release under the covers and salts have a tendency to accumulate in toxic amounts. If you are using slow-release fertilizers then please make sure you flush the containers as soon as they are uncovered to remove these excess soluble salts.

Evergreen azaleas have not responded well to this system. *Botrytis* seems to develop heavily in the environment under the covers, so go slow in storage of your azaleas.

SUMMARY

There is a great deal that we do not know about the system. Every new production technique creates a series of new problems that must be worked out. This practice is no different, but from what I have seen to date, "Keeping Plants Warm with Covers" is a viable production tool.

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DIANE ERICKSON: Using irrigation for frost protection, I can understand how the heat of fusion works when the first ice layer is right next to the plant foliage but as you irrigate through the night and ice is 3 or 4 in. from the plant it seems that the energy given off is also 3 or 4 in. from the plant — so how is the plant tissue actually protected?

C.J. WEISER: As long as there is a ice/water interface, the ice is a pretty good heat conductor, and it does work. The one thing you do not want to do is to shut the water off before the temperature gets above freezing. Tissues will cool down very quickly when there is not a free water surface.

VOICE: A salesman told me that if I sprayed his micronutrient spray on my plants right before cold weather they would be protected from freezing. Is there anything to that at all?

C.J. WEISER: No!

GARY HARTNETT: What about snow-making machines they use on ski slopes. Has this been tried for frost protection in nurseries?

SALLY JOHNSON: Yes, it has been used extensively in British Columbia for frost protection. Several nurseries there are considering buying snow-making equipment because they cannot depend on natural snow for winter freeze protection.

BRUCE BRIGGS: If you had a plant that had been attacked by insects or diseases, or poorly fed and lacking certain micronutrients, wouldn't that plant be more likely to be winterkilled?

C.J. WEISER: A healthy plant, growing well, and going into proper dormancy in the fall will withstand low temperatures best. Withholding nitrogen in late summer to cause growth cessation is good strategy. But I have not seen any experimental evidence that a micronutrient spray just before cold weather will impart any hardiness.

BACTERIZATION OF PLANT PROPAGATION PROPAGULES TO ENHANCE PLANT GROWTH

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INTRODUCTION

Reports have been published recently about the enhanced growth of plants achieved through inoculation of plant propagating propagules with specific kinds of bacteria, a process called "bacterization".

Now, these bacteria have been reported to increase the growth of plants, by as much as 500% over the non-inoculated control plants. The rhizobacteria have been subdivided into three value groups (beneficial, deleterious, and neutral) (30) based on how these bacteria affect the plant.

The purpose of this paper is to describe the bacterization process, provide examples of positive and negative results, list proposed mechanisms of action, evaluate the findings, and discuss some of the theoretical and practical considerations about use of PGPR in plant propagation.

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WHAT IS BACTERIZATION?

Bacterizaton is used in this paper to mean the process of growing selected bacterial strains to high populations in laboratory culture media and then adding these bacteria to plant propagules used for propagation (seed, cutting, vegetative parts, bare-rooted plants, etc.) for the purpose of improving plant growth.

Examples of Enhanced Plant Growth Induced by Rhizobacteria. Some amazing growth responses have been reported for plants grown from seed inoculated with PGPR especially in greenhouse trials. Greenhouse soil is often steamed or sterilized, thus removing many of the natural factors that compete with or reduce survival of the PGPR. This system could be an advantage to greenhouse operations that produce bedding and ornamental plants to increase the probability of success with PGPR (1,3).

Certain kinds of plants, such as radish, respond more favorably to PGPR than others, probably because of the relatively short time of maturation for radish plants. However, even woody plants can respond to inoculation with PGPR as evidenced by growth stimulation of rough lemon and sweet orange seedlings (116% greater than the control) (11). A field experiment where almond seedlings were inoculated with *A. rhizogenes* and planted in sandy soil in Israel resulted in about 2 times more leaves per inoculated tree at 120 days, 30% greater stem caliper at 90 days, 43% longer branches at 90 days, and 65% longer branches at 120 days — compared to the noninoculated controls (33).

Since 1975, Schroth and co-workers have established 46 replicated field plots, each testing 3 to 6 different strains of rhizobacteria, to evaluate their ability to increase growth and yield of potatoes, radish, melons, lima beans, lettuce, and sugar beet. In all cases, specific rhizobacteria were isolated and tested which caused statistically significant increases in yield, ranging up to 144% in the case of radish. Other examples of statistically significant yield increases were: potato, 5 to 33% in 12 of 16 plots in CA and ID; sugar beet, 4.4 to 8.4 tons per hectare, with increases in total sugar from 20.7 to 26.9 cwt per hectare in 6 of 8 plots; radish, a short-growth period crop, exhibited spectacular increases of 60 to 144% in root weight in 7 trials.

Bacteria tested on seedpieces of a variety of potato cultivars grown in the field at three different locations in North Carolina gave significant yield increases of 1.17 to 1.37 over controls at two of the three sites (13).

Research in Czechoslovakia (37) also showed a growth and

yield increase from potato plants inoculated with rhizosphere bacteria. Again, results from greenhouse pot experiments were the most dramatic compared to field experiments. Potted tuber pieces inoculated with PGPR produced young potato plants that were 111% larger than the controls; seedpieces inoculated and planted to the field caused 4 to 30% improvement in plant growth and tuber yield.

Examples of Growth Reduction Caused by Rhizobacteria. As noted earlier, not all rhizobacteria are beneficial to plant growth (40). Reports from nearly every study of beneficial rhizobacteria have indicated that they commonly find, simultaneously, bacteria that are deleterious to plant growth. Only 2 to 5% of the bacteria isolated from the roots of plants in California caused a positive plant growth response, compared to 8 to 15% that were deleterious, causing stunting, root necrosis, and decreased stand counts (30). In Czechoslovakia, potato growth was retarded by as much as 66% below the controls (37). Even the "good guys" (PGPR) can enhance growth of one plant species but actually retard growth of another species (39).

Most bacterial strains tested on citrus seedlings and budlings in Florida were growth-inhibiting (causing up to 52% growth reduction) compared to the few that were stimulatory (11).

Deleterious rhizobacteria are not widely recognized as being in the same category as the "major" plant pathogens, but they may act as "minor" pathogens and retard plant growth. Control of these pathogens and other known parasites has been suggested (35) as a major contributing factor for the plant growth increases achieved following soil fumigation, chemical seed treatment, or use of certain antagonists for biological disease control.

Variable Results from Use of Rhizobacteria. Nearly all of the studies mentioned above also indicate that results from use of PGPR can be variable from one site to another, among different host species, or from one year to another, especially when the experiments are performed in the field.

The reasons for the frequent variability (6, 25, 27) in these experiments are not clear. The variability is often ascribed to changes in the activity of the rhizobacterium strain over time. The effect of bacterization is also dependent on the size of inoculum, which may be a reflection of the amount of growth-active substances produced by the strain (14).

Obviously, the rhizobacteria must function in a complex environment which is ever changing, and it is not surprising that variability is observed among data from bacterization ex-

periments. Indeed, it is impressive that we observe the uniformity that has been reported given the complexity of the experimental system! Our task is to gain a greater understanding of this system so that we can reduce this variability and manipulate it to the benefit of plant production.

GENERA OF BENEFICIAL AND DELETERIOUS RHIZOBACTERIA

Beneficial Rhizobacteria. Taxonomically, most of the rhizobacteria whether beneficial or deleterious fall into the *Pseudomonas fluorescens — P. putida* group (11, 13, 18, 22, 34). They typically produce a water-soluble fluorescent pigment which appear to play an important role in binding to iron in the soil and at the root surface to make it unavailable to the pathogens. Since iron is an essential element required by microbes to grow, the iron-deficient pathogens are unable to attack the plant, which results in protection and better growth.

Other genera of rhizobacteria have been reported occasionally as beneficial and include: *Agrobacterium* (26, 28, 33), *Azotobacter* (27), *Bacillus* (3, 28), and *Streptomyces* (8, 30). Undoubtedly there are other beneficial rhizobacteria yet to be identified.

Deleterious Rhizobacteria. At least seven genera of "deleterious rhizobacteria" (35) have been tentatively identified: *Enterobacter, Klebsiella, Citrobacter, Flavobacterium, Achromabacter, Arthrobacter,* and *Pseudomonas.* Other researchers have implicated *Bacillus* and *Streptomyces* spp. as agents that cause plant growth reductions (3, 5, 9).

POSSIBLE MECHANISMS BY WHICH BENEFICIAL RHIZOBACTERIA STIMULATE PLANT GROWTH

No single hypothesis has been accepted to explain the phenomenon by which bacteria stimulate plant growth; rather there may be two or more mechanisms that function together or at different times during changes in the environment and life history of the plant and bacterium. The following list includes potential mechanisms by which the beneficial rhizobacteria stimulate seed germination and/or plant growth:

Production of Growth Regulators. Bacteria, such as the pseudomonads, may increase plant growth by producing gibberellin-like compounds that are adsorbed by the roots (4, 10). Fifteen percent of the beneficial bacteria in another test (24) produced a different growth hormone (*in vitro*) — indole-3-acetic acid (IAA) but these IAA producing strains caused root deformities and decreased root elongation when applied to sugar beets.

Mineralization. The term "bacterial fertilizers" has been

used to describe the application of living bacteria to seeds, roots, or soil to improve crop yield, supposedly via a fertilizer effect. In Europe and the Soviet Union, bacterial preparations of *Rhizobium* are called "nitragen" (7). The Soviet agriculturalists applied other bacterial fertilizers such as "azotobacterin" (nitrogen fixers) prepared from *Azotobacter* spp. and "phosphobacterin" (for solubilization of phosphate rock) prepared from *Bacillus megaterium* var. *phosphaticum*. More than 35 million hectares of land were reportedly treated with these bacteria in Russia with reports of 10 to 20% increases in production for 50 to 70% of the crops tested (9). However, these reports have been criticized for the lack of good statistical design and analysis, thus throwing suspicion upon the claims of increased crop production.

It is difficult to measure whether the stimulated plant growth comes from a fertilizer response or displacement of undesirable rhizosphere microorganisms by the beneficial rhizobacteria or both (2).

Biological Protection of Roots. It is likely that one of the major mechanisms by which beneficial rhizobacteria aid plant growth is by displacement from the root of harmful microorganisms, either through exclusion from selected niches, substrate competition, or production of antibiotics or other biologically active substances that are toxic to these harmful microbes (19, 20, 32, 34). Many of the plant growth promoting rhizobacteria (PGPR) that have been studied were initially selected on the basis of inhibiting the growth of pathogens such as *Erwinia carotovora* (13, 18, 19, 22, 34), *E. stewartii* (11), and *Fusarium* (1, 11, 31, 38) in an *in vitro* plate assay.

If the PGPR are to exert a physiological and/or protective effect on plant growth they must obviously be able to actively colonize the root system rather than be passively adsorbed to the root surface. Binding experiments (15) and use of antibiotic resistant mutants of PGPR (17) all demonstrate that the successful PGPR do aggressively colonize the roots.

The data suggest that these PGPR are functioning much like biological disease control agents. As Cook and Baker (8) point out, plant growth responses are to be expected when the roots and rootlets are maintained in a state of health necessary for uptake of nutrients and synthesis of growth factors for the tops.

Other Mechanisms. The biological diversity observed in nature makes it obvious that there must be other mechanisms by which PGPR function to enhance plant growth. These new mechanisms will likely be discovered or identified at some point in the future if we but keep our minds open to other possibilities.

FINDING AND TESTING BENEFICIAL RHIZOBACTERIA (PGPR)

Most of the PGPR have been isolated from the roots of plants (11, 13, 16, 34). Typically, the bacteria are isolated, purified, and tested *in vitro* for antibiosis against some known plant pathogen. Most of the strains that have ultimately proven to be good PGPR also produced antibiotics against a wide spectrum of organisms in vitro. However, antibiotic production in vitro was also common to many of the rhizobacteria which never showed any efficacy in greenhouse or field tests. Conversely, some strains have proven to be effective PGPR, but they did not produce antibiotics in vitro. Strains that show antibiotic activity or enhance plant growth are inoculated to plant propagules and tested for their ability to enhance plant growth in comparative pot tests with uninoculated controls. Strains that show PGPR characteristics are then tested in the field. Since only about 2 to 5% of the strains isolated from the root system provide a positive growth response (30), one must test a large number of strains.

FACTORS AFFECTING THE EFFICIENCY OF PGPR

Based on the literature reports, there are certain conditions that accentuate the growth promoting ability of beneficial rhizobacteria. For example, plants inoculated with PGPR in greenhouse studies typically show markedly greater growth responses than the same treatments in the field (2, 3, 11, 13, 17, 23, 34).

The best plant responses to PGPR usually occurred when high populations of rhizobacteria were applied to the seed (21, 34, 37). Vrany and Fiker (37) also observed that bacterized potato plants produced better than the controls when grown under shortened photoperiods (less than 12 hr). Even the presence of different kinds of fungi in the root environment can influence the way plants respond to bacterization (31).

In addition to specificity of the PGPR for particular crop species or cultivars (2, 13, 39), there appears to be a specificity of PGPR for certain soils. Strain SH5 increased sugar beet yields in several California test sites but failed to do so in two consecutive years in Idaho.

HOW AND WHEN TO APPLY PGPR

Beneficial rhizobacteria have been applied to seeds or vegetative propagules in various ways: liquid suspension and gels (34), as a soil drench (11,12), as a powder formulation (21), or in peat — but one of the best methods to enhance survival and activity, especially when seed were planted in dry soil, occurred with PGPR-pelleted seed (34).

Placing the PGPR directly on the seed or plant parts in high numbers, and under conditions favorable for maximum colonization, gives them a competitive advantage over the other rhizosphere microbes. PGPR can be applied to seed or plant parts anytime before planting, but care should be taken to protect the treated propagules from excess desiccation, sunlight, heat, or anything else that would kill or dilute the viable concentration of rhizobacteria before they are planted. The planting site should be prepared well. Irrigation of dry soil after planting may be needed to help maintain a high population of PGPR.

Suslow and Schroth (34) discuss the various alternatives of treating seed, describe in detail the kinds of materials tested as bacterial preservatives and adhesives, and provide data of shelf life of the rhizobacteria pelleted on seed.

SUMMARY AND CONCLUSIONS

Bacterization Works With a Variety of Plants. Plant growth promoting rhizobacteria (PGPR) have been shown to increase the growth of both herbaceous and woody types of plants. The kinds of plants reported to respond positively to PGPR include vegetables, cereals, row crops, floral crops, citrus, almond, olive, and apple trees. PGPR can be applied to seeds, cuttings, bare-rooted seedlings, and as a soil drench over roots of potted plants.

Greenhouse vs. Field. The largest growth responses from applications of PGPR to plant propagules were observed when the plants were grown under greenhouse conditions. Results from field tests were not as pronounced as those from greenhouse studies and may vary from one planting site to another. The correlation between results from greenhouse and field tests was generally low.

Beneficial and Harmful Bacteria. Beneficial rhizobacteria have been isolated from all of the plants examined and from all soil types tested, regardless of whether the soils were disease-suppressive or nonsuppressive. Of the bacteria isolated from roots, only about 2 to 5% enhanced plant growth, whereas 8 to 15% were deleterious and caused stunting, root necrosis, or reduced stands.

Inoculum Concentration and Colonizing Ability Important. The concentration of bacteria applied to the plant propagule is very important; application of high concentrations usually resulted in the best growth promotion and yield. Equally important is the ability of the PGPR to colonize the root system and to survive in high numbers (near 10^5 per cm of root) during the growing season.

Mixtures of PGPR More Effective. In some experiments, mixtures of two or more PGPR caused greater yield increases than a single strain, perhaps due to each strain colonizing a different preferential site on the root of one being more active at any time than another during maturation of the plant.

Selecting PGPR Based on Antibiotic Production vs. Growth Enhancement. Antibiotics are produced *in vitro* by most of the rhizobacteria (including the PGPR) against a wide array of microorganisms. However, some nonproducers were also efficacious as PGPR. Antibiotic production *per se*, therefore, is not the best criterion for selecting a candidate PGPR. Rather it has been suggested that the most effective strains have been selected on the basis of a plant growth response.

Reasons for Failure of PGPR. Lack of establishment of the PGPR on the root appears to be the most common reason for failure of the PGPR to increase plant growth, which probably is due to the poor condition of the inoculum on the bacterized seed or soil dryness at planting time. Use of dry formulations of PGPR or seed pelletized with PGPR resulted in better survival of the bacteria on seed than when aqueous suspensions of PGPR were used.

CONCLUSIONS

There are some striking reports of plant growth promotion following application of beneficial rhizobacteria to plant propagules, which indicates that the phenomenon is real. Variability between tests (especially in the field) is a nagging problem that has not been eliminated. The factors contributing to this variability are poorly understood or unknown, and commercialization of the PGPR will probably be slowed until this variability is reduced and the expected yield benefits become more predictable. At present it would appear that the use of PGPR is still promising but in a juvenile stage of development. Perhaps the best approach would be to concentrate on developing a PGPR system for such things as greenhouse-produced crops, plantlets produced via tissue culture, and bedding plant transplants. Such a system would have fewer variables to contend with and opportunities of modifying the environment to aid the PGPR. In any case, it appears that development of these bacteria into a reliable commercial product is still a few years away, and that it will require considerable research and funds to develop a good predictable system.

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CUSTOM SEED PREPARATION FOR OPTIMUM CONIFER PRODUCTION

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Brown Seed Company
P.O. Box 1792
Vancouver, Washington 98668

I would first like to describe how we test and stratify conifer seed at Brown Seed Company and then discuss some of the different methods which can be used for handling the more difficult species.

The germination possible for a seed lot is determined by the basic soundness of the seed and the care given that seed during collection, processing, and storage. After the seed comes out of freezer storage we then attempt to design or "customize" our treatment procedures for each lot to obtain this maximum possible germination.

SEED TESTING

In order for any program of so-called custom stratification to work, the seed handler needs as much information as possible about the seed lot. This includes:

1. *Purity Test.* This test determines the percentage of pure seed in a sample. For container sowing the seed should be as clean as possible and handpicking is available to bring the seed to 100% purity. A purity test is also necessary to calculate with accuracy the amount of seed needed for sowing.

2. *Seed Count.* The seed count determines the number of seeds found in a pound or gram of pure seed in a lot. The number of seeds/lb. can vary widely within a species and this information is essential to calculating seed needs.

3. *Standard Germination Test.* This test compares the actual germination of chilled with non-chilled seed. The results are especially useful if two different chill periods are used (Table 1). Besides being the best tool for deciding the optimum period of stratification, the standard germination test will also usually indicate if a customer is likely to have mold problems with his seed.

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Table 1. Typical standard germination test results using two different chill periods.

COMPLETED GERMINATION TEST RESULTS

Test # 2894 Date May 4, 1984

Ownership	Check No. Chill			14 Day Chill			28 Day Chill		
	Day	G%	Firm	Day	G%	Firm	Day	G%	Firm
Sp. grand fir	7	0		7	4		7	20	
Lot ID CWD-35-83	14	22		14	63		14	53	
Processing Lot #B-101	21	61		21	70		21	54	
Strat. Began 3/9/84	28	66		28	70		28	54	
Seed C/T or VAS 80/69									

Optional Information:
(By request only)
Purity
Seed Count/lb. 18,000
Moisture
Sizing: Reg. S M L
Other Info. 50.0 Lbs.

When there is no time for a standard germination test, or a further test is wanted after seeing the results, two quick tests for seed viability are also available.

1. The *tetrazolium chloride* (TZ) test is based on the fact that respiring seeds give off hydrogen which reacts with the colorless triphenyl tetrazolium chloride to give the red colored, triphenyl formazan. Essentially the test determines if there is a living embryo. Some nurseries use only TZ tests and claim they give the best correlation with field results. In our experience, while the TZ test predicts the average and better than average lot quite well, very poor lots, particularly in the true firs, will sometimes give excellent TZ readings. The TZ test takes about 48 hours.

2. The *hydrogen peroxide* (H_2O_2) test is based on the observed elongation of the radicle of a viable seed in response to a 1% solution of hydrogen peroxide. The H_2O_2 apparently overcomes dormancy by stimulating the early stages of respiration. While in general we have had pretty good correlation between hydrogen peroxide tests and standard germination tests, an occasional lot of ungerminable seed, usually true fir, will give positive results with this test. The H_2O_2 test takes about 10 days.

STRATIFICATION

At Brown Seed Company seed is stratified "naked" in plastic bags rather than being mixed with a moisture holding material such as peat or sand.

1. The seed is weighed and placed into 4 ml. clear plastic bags. A maximum of 5.0 lbs. of seed is put in a 26 × 26 in. bag.

Smaller amounts of seed are put in proportionately smaller bags.

2. The open end of the bag is gathered around a "breather tube", a short piece of plastic pipe 5 × 1½ in. (smaller for smaller bags). The bag is fastened to the tube with a wire tie by means of a tie pulling device. The loop remaining at the end of the wire is used for attaching the identification tag and for hanging the bag during soaking and stratification.

3. Cold tap water is added to the plastic bag to at least double the volume of seed. The seed is soaked for 40 to 48 hours. At least once during this period the seed is agitated by hand to ensure that the seed is uniformly moistened.

4. After soaking, the water is *thoroughly* drained from the bag by punching several small holes with a nail in the bottom and bottom corners of the plastic bag. After tilting the bag and allowing water to run out the corner holes, there should be *no* standing water in the bag. The seed is soaked and drained in a greenhouse at a temperature of 40° to 65°F.

5. The bag with the moist, drained seed is hung in the cooler at 36°F. Because of the clear plastic the seed can easily be checked periodically for mold or signs of germination. The breather tube helps provide adequate aeration and can also be used to add water during stratification, although this is usually not necessary, except perhaps with ponderosa pine.

6. After stratification is complete, the seed is surface dried in shallow layers of newspaper at room temperature in front of fans. Stirring the seed occasionally helps insure even drying. When the seed is dry enough to be handled easily, it is placed in clean *cloth* bags and returned to the cooler immediately. The seed is kept refrigerated until it is sown and it can be stored in the cloth bags for several months, if mold is not present. When shipping stratified seed to customers, the seed is packed in "Blue Ice" and express service is used to ensure delivery within 24 hours.

While it is preferable to have specific germination information on each seed lot, this is not always possible and at Brown Seed Company we use some general guidelines when stratifying various species of seed. (Table 2) When using these guidelines one must remember to check the seed periodically for signs of seed deterioration, such as mold or odor, and for signs of germination, such as cracking of the seed coat or beginning emergence of the radicle.

While most of our conifer seed is stratified as described above, there are other techniques which can be used to speed up germination or to increase the total germination in those species which do not respond well to conventional methods.

Table 2. General guidelines for stratification for various conifers

Species	Approximate Length of Stratification (Days)
Abies concolor (white fir)	14-21
A. grandis (grand fir)	14
A. magnifica var. shastenis (Shasta red fir)	21-28
A. procera (noble fir)	28-35
Thuja plicata (western red cedar)	28
Picea engelmannii (Engelmann spruce)	21-28
P. pungens (blue spruce)	7
P. sitchensis (Sitka spruce)	21-28
Pinus monticola (western white pine)	120
P. mugo (mugo pine)	14-21
P. contorta murrayana (lodgepole pine)	42
P. nigra (Austrian pine)	7-14
P. ponderosa (ponderosa pine)	42-56
P. strobus (eastern white pine)	60-90
P. sylvestris (Scotch pine)	14-21
Pseudotsuga menziesii (Douglas fir)	35
Tsuga heterophylla (western hemlock)	28-42

1. Aeration *(Pinus monticola).* We use either medical oxygen from a tank or air from an aquarium type air pump during the soak and 2 or 3 times during the stratification period. With this method we have gotten much more consistent results, and results closer to germination test predictions than by layering with peat or naked stratification alone.

2. Warm-Cold *(Juniperus scopulorum).* Soaked juniper seed is kept at room temperature for 2 months then given a normal moist chill for another 2 months.

3. Post-stratification (true firs, particularly *Abies procera*). Seed is given a normal period of regular stratification and then surface dried to 30-35% moisture. The seed is put in a cloth bag and returned to the cooler for approximately 2 months. For some lots this process seems to even out variations in dormancy within the seed lot allowing very dormant seeds to catch up while preventing the germination of less dormant seeds until the lot is sown.

4. Double stratification (*Abies procera, Pseudotsuga menziesii).* In this procedure seed is soaked and stratified as usual then either surface dried *or* dried to storage levels (ca 8%) and then returned to the cooler *or* the freezer for a specified period. The seed is then resoaked and restratified. In our experience this does not increase overall germination but it greatly speeds up the time it takes for the seed to sprout. (Table 3) In fact the length of the second stratification period should probably be shortened for some species to prevent pregermination in the cooler.

Table 3. Results of double stratification treatments on *Pseudotsuga menziesii* and *Abies procera*.

Final Germination Test - Percent germination based on 200 seeds.

Abies procera (noble fir)

Treatment		Days in Germinator 7	14	21	28
Normal strat. only	A	29.5	62.0	63.0	63.0
Strat. + post-strat.	B	27.0	62.5	63.0	63.0
Strat. + post-strat. + strat.	C	*63.0	63.0	63.0	63.0
Strat. + dry-freeze + strat.	D	41.0	52.5	53.0	53.0

Pseudotsuga menziesii (Douglas fir)

Treatment		Days in Germinator 7	14	21	28
Normal strat. only	A	33.0	76.5	83.0	86.0
Strat. + post-strat.	B	56.0	79.0	81.0	82.0
Strat. + post-strat. + strat.	C	70.5	84.5	84.5	84.5
Strat. + dry-freeze + strat.	D	66.0	85.5	86.0	86.5

* Approximately 0.5% of the seed germinated in the cooler and was removed before the seed was tested.

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NEW IDEAS IN THE USE OF PLUG SYSTEMS

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The development of the seedling plug is one of the major advances in the bedding plant industry in the last decade. As more growers have recognized the potential of plugs, demand has been created for improved seeding equipment, higher quality seed, and more advanced environmental controls, as well as more efficient methods of handling plug flats and plugs. This is a brief overview of those advances.

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Skagit Gardens is a 155,000 square foot glass bedding plant range located in Northwestern Washington. Among other things, we produce over 80,000 flats of annuals and vegetables, 1,000,000 flowering perennials, 500,000 4 in. flowering annuals, and 300,000 primroses. Ninety-five percent of these plants are grown from plugs. As little as four years ago, all this seed was hand broadcast on open flats and transplanted bareroot into the finished containers. In the winter of 1982, we purchased our first automatic seeder and quickly converted to a plug system.

There are a number of automatic seeders now available. We use a Hamilton seeder which was developed in England. It is a pneumatically operated vacuum seeder, capable of sowing up to 80,000 seeds per hour. It drops a single row of seeds at a time, with a maximum of 18 seeds per row. The brass tipped nozzle-bars are available with 1, 2, or 3 holes per nozzle, allowing multiple seeds to be sown in a single pass. The seeds are discharged down nylon tubes to funnel-shaped seed cups, which slow them down before they hit the plug tray. The seed cups can be spaced to fit a large number of different plug trays.

The Hamilton needs a separate compressor which can supply at least 2 CFM of clean air at 60 PSI. Various accessories include a dibbler, a vibrating seed tray to aid in seed pick up, self-cleaning nozzles, a percussion singulation hammer to remove excess seed from the nozzle, and a vermiculite dispenser that, under the control of an electric eye, will cover the seed flats as they emerge from the seeder.

The electrically driven Blackmore Transplanter Company's automatic seeder uses a self-contained vacuum pump/compressor to supply the air for the machine. Using any one of four plug trays, the Blackmore can sow up to 62,400 seeds per hour. Like the Hamilton, it uses a vacuum to pick up seeds from a vibrating tray and a positive burst of air to discharge them, one row at a time.

The Blackmore uses rubber nozzles rather than brass to pick up the seed and has a slotted seed tray. This feature, not found on other seeders, positions seeds for pick-up even when there are few seeds left in the tray. At this time, the Blackmore is limited to using specially designed plug trays. The Waffle Tray® can be used in conjunction with Blackmore's mechanical transplanter.

Similar in principle to the Hamilton and Blackmore, but somewhat less expensive, is A. E. Nichols Little Seeder®. It has a built-in vacuum supply, can handle seed size from petunias to peppers, and will sow about 43,000 seeds/hour.

JVK of Canada has introduced somewhat of a hybrid of the Hamilton and Blackmore seeders called the Niagara Seeder®. It has many features of both machines and is adaptable to nearly any plug tray.

Growing Systems of Milwaukee, Wisconsin, manufacturers two seeders. The Vandana #400® is of simpler design than the Hamilton or Blackmore. The seeds are manually distributed over a drilled seed plate and are held in place by vacuum at each of the holes. The holes are spaced to conform with the cells of the plug tray. The seed plate is then tilted so that excess seed that is not held by vacuum can slide off. The seed plate is then inverted over a series of tubes, the vacuum released, and the seeds dropped into the plug tray.

The Vandana Direct Seeder® follows the same principles as the Model #400 but rather than having discharge tubes, the seed plate inverts directly onto the plug flat. This is an advantage with large or coarse seed that will not fit down small diameter discharge tubes. A Vandana seeder can be very accurate because the operator has the opportunity to visually inspect the seed plate for misses before sowing it, but such accuracy does cost time. The position of the discharge tubes of the Model #400 limits the types of plug flats that can be used with this seeder, but Vandana has developed an adaptor which allows it to fit more trays.

An earlier version of the Vandana Seeder is now marketed under the name Vanloon 288 Direct Seeder®. There is also a direct seeder called the Seed-Rite® which is similar to the Vandana Direct Seeder.

The Old Mill Company of Maryland has developed a line of seeders which differ from the others in that they use electronic and optical systems for supervision of the seeding process, rather than the observation of a human operator. Old Mill uses the same concepts used in mechanical seed counters. Seeds are placed in a circular bowl mounted on top of a vibratory feeder. The bowl adjusts for various seeds by a knob narrowing the width of the track so that they feed from the unit one at a time. The seeds travel by gravity to a drop head. An electric eye insures that the machine will not advance until a seed has been dropped into each cell. Flats move through the unit on the indexing conveyor belt. Guide and dropping assemblies can be adjusted to run a flat either direction on the conveyor. A plug tray can be handled having up to 14 cells in a row. The seeder will direct seed into any cell pack or tray.

Although the Old Mill seeders are relatively costly and not as fast as some of the other mechanical seeders, they are

highly accurate. The Old Mill Company is currently using its technology in the development of a combination extractor/ sorter/transplanter that will mechanically lift seedling plugs from the plug tray and pass them through a seedling inspection station, where they are inspected for size and form. If acceptable, they continue on to the transplanter unit and are planted.

Williames High Tech International of Australia manufactures a high speed rotary seeder capable of sowing row seeds ranging in size from lobelia to peas, at a rate up to 400,000 seeds per hour. Although very expensive, this machine could be very practical in the vegetable seedling industry.

Williames has also developed the Cell Chain, a system in which seeds are sown into a cell built into a link chain. When the seedlings are transplantable, that chain can be fed through a machine which selects only viable seedlings of a predetermined size and mechanically transplants them at high speed.

A relatively new concept developed in England is fluid drilling, in which seeds are "pre-germinated" in an oxygenated water tank that can be heated to precise germination temperatures. As soon as the radicle emerges, the seeds can be sown with a specialized vacuum seeder, or even stored for several days by immersing the seeds in oxygenated water at a temperature close to freezing. Between the germination and sowing stages, it is possible to separate the germinated from the ungerminated seed by using a sugar solution. Seeds from the germinator are placed in this solution, where most of those that have germinated will float, and those that have not will settle to the bottom.

Along with advances in seeder technology have come various related equipment for handling plug flats. Still rather unique is the Blackmore Transplanter, which according to the manufacturer, allows growers to increase transplanting rates 400 percent or more. Designed exclusively for the Blackmore 648 Waffle tray, the transplanter uses moveable pins to push seedlings through the pre-cut waffle bottom into the flat below. One drawback of this transplanter is that it will punch out a cell whether there is a seedling in it or not. Blackmore has also developed a pin-type extractor to loosen plugs from its other sized plug trays.

The system used at Skagit Gardens is centered around a 512 cell plug tray. An Antal® pin-type dislodger is used to break the surface tension between the root system and the cell wall of the tray. The dislodged plugs can then be easily lifted from the tray without damage. We have mounted our dislodger on a stand and added a foot pedal for increased leverage.

Dislodged seedling plugs are the main ingredient of our assembly line transplanting system. We use a Granterplanter® transplanting belt to move flats past the transplanting crew. As the flat moves by, plugs are inserted into pre-dibbled holes. The transplanted flat leaves the belt and is automatically irrigated with fertilizer by a series of mist nozzles. The flow volume of the nozzles is totally adjustable.

The flats can be conveyored directly to greenhouse benches or stacked on pallets and transported to the growing area by a forklift.

The success of any plug system relies on a high percentage of useable plugs per plug tray. As important as accurate seeding equipment is, the environmental factors which influence germination must be optimized. Methods of controlling soil temperature range from Agritape® root zone heaters, which use heat from electrical resistance in Mylar covered copper strips, to time-proven skirted heat benches. Fairly new are the hot water root zone heating systems sold as Biotherm®, Root Zone® or Ball Seed's Bench-Mate®. All three use synthetic rubber tubes through which heated liquid flows, radiating heat as it goes. The tubes are installed parallel to one another, on or directly below the bench, and are spaced according to heat distribution required.

Moisture control is also critical for germination. Intermittent mist systems in conjunction with capillary mats, are probably the most widely used system. Mists are often uneven or leave the soil too wet, and dripping water from suspended mist lines can wash out plug cells below them.

Plastic tents provide a near ideal environment for most seedlings, but tents tend to be labor-intensive when they must be opened and closed frequently to irrigate or control temperature. Some growers are using a plastic covering directly on the flats to maintain high humidity. Sub-irrigation with capillary mats keeps soil moist under the plastic. Often plug flats are simply hand misted by a vigilant grower, although there can be much room for error in this method.

Fog Systems, such as the Mee II Cloudmaker® or the Baumac Micro Mist System®, have been used by a few growers for seedling germination. The tiny droplets (about 10 microns) provide the high humidity around the seed without overwetting the soil. The flats still need to be irrigated occasionally.

Once germinated, the irrigation of plugs becomes more complex. Growers who produce large quantities of a single crop can take advantage of boom watering systems, such as Growing Systems' Travelling Irrigator® or the Andpro Spray-rite® boom. Both irrigators provide fairly sophisticated control

of irrigation functions. In situations where many different plant cultivars and sizes are mixed, a skilled person with a hose is still an intricate part of the system.

Nutrition of plugs is a matter of some research. Generally, it is being found that early feeding of plugs does not produce "stretched" plants as it would in crowded open seed flats, but actually promotes stronger, more compact seedlings. Sierra Chemical has developed a down-sized version of Osmocote, called Micro-Fertilizer®, that can be incorporated into plug mixes. It appears that when used with a liquid feed program, the Micro-Fertilizer improves seedling development over the use of liquid feed alone.

The popularity of plugs has created a demand for high germination seed. Some seed producers are using breeding and selection for more uniform and higher germination, while other companies are improving germination by refining the seed cleaning and sizing techniques. The exact processes used are closely guarded secrets. In any case, the term "High Tech" seed can mean anything from a pelleted begonia seed to a marigold with the tassle removed.

Improved cleaning processes can now eliminate the small or misshapened seed from a lot, leaving only the larger and heavier seeds, which generally have higher germination. Marigolds are extremely difficult to sow raw, but with the tassles removed, sowing marigolds is within the capabilities of many mechanical seeders. These refining processes significantly add to the cost of the seed so growers expect high yields from their seed.

Pelletizing seed is still controversial because it is said to decrease germination; however, the use of pelletted seed is convenient. Pelleting seed allow accurate singulation and gives uniform size to the seeds. Seeder operators can easily visually inspect their work for skips even when sowing begonia seed.

Harris-Moran Seed Company is now experimenting with the effects of immersing seed in a solution of ethylene glycol. The process, called "priming" allows the seed to inbibe enough moisture to begin germination. Before emergence, the seed is removed from the solution and dried and it remains viable in short term storage already well into its germination cycle. Priming has already been successful with direct seeded field peppers and may have applications in plug culture.

Improvements in equipment, environmental control, and seed technology have already begun to revolutionize the bedding plant business. Increased mechanization using plugs will insure that it remains a healthy industry in the future.

®Denotes registered trademark

VOICE: What temperatures do you use for initial seed stratification, post-stratification, and your second stratification?

SHARON DELONG: We use 36° F, but the seeds are soaked first in water at about 60° or 70° F. They are taken out after stratification, dried, and then put back at 36° F.

VOICE: In your hydrogen peroxide test do you leave the seeds in the hydrogen peroxide until the radicles emerge?

SHARON DELONG: Yes, you soak the seeds before you cut the tip off — the tip of the radicle may be cut without damage. The rest of the radicle will elongate. Then the seeds are put back in the hydrogen peroxide in the dark.

MIKE EVANS: Sharon, when would you use the quick, tetrazolium or hydrogen peroxide seed viability test rather than the standard germination test?

SHARON DELONG: When you have thousands of pounds of seeds that look good inside and out, but they will not germinate. You need these other tests to determine viability.

MICHAEL SMITH: Dr. Moore, has any research been done on the possible effects of the PGPR (Plant Growth Promoting Rhizobacteria) bacteria on seed germination — by way of hormones, or breaking down the seed coats, etc. — which might suggest their commercial use of difficult seeds?

LARRY MOORE: If there is, I am not familiar with it. The work was initiated primarily with things like potatoes and then it spread to other plants that would respond, which response was measured by increased mass or yield.

WESTERN REGION QUESTION BOX

Bruce Briggs and Charles Parkerson, Moderators

QUESTION: What time of year is best to take cuttings of Colorado blue spruce?

DICK BUSH: We take current season's growth — one year old growth — taken in February. If they still are not rooted by mid-summer, we put them in a coldframe and they root in the fall.

QUESTION: What is the advantage of a rooted conifer cutting over a grafted conifer?

VERL HOLDEN? A grafted conifer might break off in a strong wind. I would much rather have a conifer on its own roots.

QUESTION: How do you get cutting-grown conifers to grow straight?

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VERL HOLDEN: I believe they will naturally grow straight and they are very uniform. Terminal dominance starts earlier with the cuttings, but this can vary with the cultivar.

MICHAEL SMITH: With redwoods and podocarpus, by proper pruning and staking we can easily establish dominance of a leader.

QUESTION: How do you determine the best time to begin budding in fruit trees?

DICK SNYDER: When the bark "slips" well — toward the end of July (in Wenatchee, Washington).

ALLAN ELLIOTT: Another factor is the maturity of the budwood. The buds should be fully matured. If the budwood is too green the bud will not "take". Over-maturity can also be a problem.

QUESTION: What is the best way to defoliate nursery trees in the fall before digging? Does chemical defoliation work?

DICK SNYDER: Chemical defoliation seems to cause some injury. A lot of research has been done on this by Dr. Fenton Larson at Washington State but it still has not been perfected.

CHARLES PARKERSON: Just get a good pair of gloves and start hand-stripping.

QUESTION: When a patented plant is propagated and a variation appears, to whom do the rights belong to the new variant — the original patent holder, or the one who found the variant?

JAMES WILL: The patent licenses for our roses states that — for any patented plants that are mutated by bud sports or by any other mutagenesis, the mutants belong to the original patent holder. But this may vary according to what is stated on the patent license.

QUESTION: Can a fogging system be set up using only half a greenhouse:

MARK MIRMAN: We are installing a Mee fogging system at City College in San Francisco, and they now make a small unit to use in a small sized area. Just block off part of the house with polyethylene.

QUESTION: What is being done in the area of tissue-culture of citrus:

JAMES WILL: It is my understanding that tissue culture in citrus is mainly work with embryos or portions of the seed — as the nucellus — to develop clonal reproduction from the nucellar embryos.

QUESTION: How do you develop a medium in tissue culture to prevent the formation of excess callus — as occurs with maples?

EUGENE BLYTHE: By reducing auxins or cytokinins, or by incorporating activated charcoal. The latter seems to work real well to hold down excess callus in nandina. But we don't work with maple.

DALE KESTER: Too much auxin will cause excess callus formation. Try changing the kind and strength of auxin.

BRUCE BRIGGS: Talking to people in Belgium, they felt that the location of the tissue on the stock plant could have an influence on the amount of callus developing from the explant.

QUESTION: How do you get tissue-cultured Douglas fir trees to grow straight:

STEVE McCULLOCH: Work at Weyerhaeser with Douglas fir from tissue-culture has shown no problems once they are field-planted, even though this tree is known to be plagiotropic — tends to grow out flat. Ninety-nine percent grow straight once they are in the field.

QUESTION: Does a rooted tissue-cultured plant store better than one without the roots:

STEVE McCULLOCH: Yes, they do. The rooted plant is more mature and well developed and will store better.

QUESTION: If you have two seedlings — one with a good root and one with a poor root, then you tissue-culture these, will these differences be maintained in the tissue-cultured plants:

DALE KESTER: I have not made such a comparison but my expectation would be that whatever is the genetic capacity of each seedling, it would be maintained in the tissue-cultured offspring — although exceptions can occur.

BRUCE BRIGGS: With rhododendrons, 'Pink Pearl' has a poor root system from cuttings and poor roots from tissue culture.

QUESTION: What are the procedures for seed propagation of madrone (*Arbutus menziesii*)?

MICHAEL SMITH: There is no problem in getting the seeds to sprout. Gather the berries in November, mash and allow to ferment so as to extract the seeds — allow for flotation of the pulp. Once planted, the seedlings appear in about 2 weeks. The big problem is avoiding damping-off. Put Truban or other terrazole powders in the seeding mix. Keep seedlings growing strongly, avoid becoming pot-bound. Fertilize and

treat as any other nursery crop. Madrone tends to fail in the landscape, however, after planting. Perhaps it is the lack of a mycorrhizal fungus that they need.

QUESTION: How do you propagate smoke tree (*Cotinus coggygria*) by softwood cuttings:

PHILIP McMILLAN-BROWSE: It propagates relatively easily by softwood cuttings. Prune the stock plants hard in the winter. After a flush of spring growth, take the softwood cuttings and they will root under mist fairly well. The closer the stock plants are cut back to the ground the easier the cuttings will root.

QUESTION: Has anyone tried super-high, 10 to 30 thousand ppm, concentrations of IBA on hard-to-root woody plants?

VOICE: *Photina* × *fraseri*, very softwood cuttings, rooted well with IBA at 10,000 ppm. at Monrovia Nursery. Cuttings are taken just as the new growth flushes — in the bright red growth stage.

QUESTION: What is the best way to propagate Leyland cypress (× *Cupressocyparis leylandii*)?

PHILIP McMILLAN-BROWSE: Take cuttings only from stock plants less that 10 years old. Sub-terminal leader cuttings are best to take. The base of the cutting should be about where the brown scales start, at the beginning of the hard wood. February, June, and October have been the peak times for taking cuttings in Britain. Hormone doesn't seem to help. We have been getting almost 100% rooting.

QUESTION: What are the most successful techniques for propagating *Rosa rugosa* cultivars?

JAMES WILL: A shade house with mist propagation may give the best results with cuttings. Field-stuck cuttings give only 30 to 40% success for us at Armstrongs.

JIM McCONNELL: We generally have good success with softwood cuttings under mist but sometimes certain plants never seem to harden up and you cannot prevent rotting before the roots come out.

QUESTION: What percent hydrogen peroxide is used in this seed test:

VOICE: Take the hydrogen peroxide 3% solution, as you get it from the drugstore, and dilute it 2 to 1 with water to make a 1% solution.

QUESTION: Is verticillium wilt fungus carried within seeds:

MARK MIRMAN: The fungus is on the outside of the seed and hot water treatment will eradicate it. It is not found within the seed.

QUESTION: How do you get *Gaultheria procumbens* seeds to germinate and not have the moss cover it up?

WILLIAM SMITH: At Briggs Nursery we lay down a fine layer of screened sphagnum moss then sow the seed on it and use a real fine nozzle to force the seed into the moss. Then we cover with a sheet of glass then forget about it until the seeds germinate.

QUESTION: How do you get *Acer griseum* seed to germinate quickly?

CHARLES TUBESING: This is considered to be a 2-year seed and has a hard seed coat. First, crack and remove the seed coat, then stratify. But still you get poor germination the first year. Further growth of the embryo, or something like that, is needed during the second summer, then germination will occur.

PHILIP McMILLAN-BROWSE: Collect the "seeds" (samaras) when they are green — in July, just when they turn from green to a yellow-buff color — before the hard seed coat develops. Then stratify and you will get some germination.

QUESTION: Has anyone had success with hard or softwood cuttings of filbert?

PHILIP McMILLAN-BROWSE: *Corylus avellana*, (hazelnut) softwood cuttings will root successfully under mist, but with *C. maxima* (filbert), if put under mist, the buds will rot off. They may root but no shoots develop, since the buds are gone. They both can be rooted as hardwood cuttings where the base of the cuttings is given a heat treatment before planting out — the so-called "Garner-bin" technique.

QUESTION: How do you root *Cedrus atlantica* 'Glauca' (blue Atlas cedar) cuttings?

VOICE: We treat them with Dip-N-Grow, 1-10. They can be rooted easily — no wounding — just rip off the needles. Collect cuttings December through February (in the western Washington area). Make cuttings with a little of the hardwood tissue at the base.

QUESTION: *Wisteria floribunda* or *W. sinensis* — how are these propagated — by cuttings or grafts?

MICHAEL SMITH: Cuttings taken from young stock plants root best, particularly if they are grown under greenhouse or semi-greenhoue conditions. Cuttings are best made from slender shoots, while they are still quite soft. They may root in

less than a month. Thick material from outdoor stock plants may take 2 or 3 months to root. Overwintering may be a problem. Keep them quite dry in the flats then pot them up in the spring when the buds start to swell.

QUESTION: *Nandina domestica* cultivars — is there another time to propagate them other than late fall:

DON KLEIM: We propagate all year long, as long as the plants are actively growing. We use softwood cuttings — no hormones — and use intermittent mist. Rooting takes 20 to 30 days. We retain 2 or 3 leaves on top, with the basal leaves stripped. We use young, soft growth, barely starting to harden. The cuttings are only 1 to 1½ in. long. We are located in Clovis, California, where it is relatively warm all year.

QUESTION: How do you get *Daphne cneorum* to grow on, once cuttings are rooted? Rooting is no problem.

BOB GOUVEIA: We grow them in the field in sandy soil in our area in Massachusetts. It is almost impossible to grow them in containers.

PLANTS FOR THE DISCRIMINATING PROPAGATOR

DENNIS M. CONNOR

Monrovia Nursery Company
P.O. Box Q
Azusa, California 91702

New plants are always coming onto the market. Sometimes they are not new at all, but just some old favorites that have gained popularity in our gardens again. The consumer today tends towards more dwarf and compact shrubs and trees because of limited space problems such as in the case of smaller lots, apartments, or condominiums. The consumer also looks for a more maintenance-free landscape. Nevertheless, we are a nation of people who love our gardens. Whether one has acres of land or only a small parcel to work with, one toils hard to keep greenery and flowers around our homes.

I have selected a few plants to discuss, ranging from the subtropical zone to the hardiest of zones, from large growers to compact, dwarf growers. Arranged alphabetically, they are as follows.

Aucuba japonica 'Mr. Goldstrike' (Family Cornaceae)

This plant came from New Zealand from Duncan and Davies. It is well noted for its excellent variegation and grows to a height of about five feet. Plants propagate easily from cuttings. Hardiness is to zone six.

Carex buchanani (Family Cyperaceae)

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Carex buchanani (Family Cyperaceae)

The common name is fox red sedge. It originated in New Zealand, with our first plants being obtained from Skylark Nursery. It grows to about two feet tall with reddish brown foliage in summer. Plants are propagated by division, done preferably in cool weather; it is rated to zone five.

Ceratostigma plumbaginoides (Family Plumbaginaceae)

Originally from China, this is the hardiest of the *Ceratostigmas*. We obtained our first plants from the Huntington Botanical Gardens, in San Marino, California. This plant grows to about 9 to 12 in. in height and has profuse showy indigo blue flowers from June to the first frost. The foliage turns a red bronzy color in the autumn before going deciduous. *Ceratostigma plumbaginoides* is propagated from cuttings and is rated to zone five.

Cercis canadensis 'Forest Pansy' (Family Fabaceae or Leguminosae)

This beautiful tree came from Forest Nursery. It has bright pink flowers in early spring just before it leafs out with its maroon red leaves. It grows to about 20 feet. The trees are grafted, usually with the stick bud technique to get best results. This tree is hardy to zone four and is deciduous.

Coreopsis verticillata 'Moonbeam' (Family Asteraceae or Compositae)

This perennal *Coreopsis* seems to be well known in the northeastern part of the U.S. and is now just coming on to the scene on the West Coast. It has single creamy yellow flowers on a plant that grows 18 inches to three feet. It is a prolific bloomer, especially in the summer, and tolerates heat very well. Plants are propagated from cuttings. However, seed was collected to see if they come true and are currently being evaluated. This plant is hardy to zone three.

Deutzia crenata var. *nakaiana* (Family Saxifragaceae or Philadelphaceae)

Originally from Japan and introduced by the U.S. National Arboretum, Washington, D.C., this low growing *Deutzia* is a good ground cover. It grows to about 1½ ft. tall with a 2 ft. spread. The flowers are white and the plant is propagated from cuttings. The plant is deciduous with a rating to zone six.

Hardenbergia violacea 'Happy Wanderer' (Family Fabaceae or Leguminosae)

Hardenbergia violacea, a vine, has been around for years, but the 'Happy Wanderer' strain is new. Introduced by University of California — Santa Cruz, this *Hardenbergia* has bright purple racemes. We obtained ours from Leonard Coates Nursery. Plants are propagated from cuttings, but they are not hardy beyond zone nine.

Hibiscus rosa-sinensis 'All Aglow' (Family Malvaceae)

Also known in the trade as Estelle Kanzer, this hibiscus with bright orange flowers with blotches of yellow came to us through Colors Nursery in Florida. It is a prolific bloomer, the plant itself being well shaped. Plants are propagated from cuttings and is tender at zone nine.

Hibiscus rosa-sinensis 'Sunny Delight' (Family Malvaceae)

Also known as 'Kitchen's Yellow', this hibiscus is a prolific bloomer with lemon, chiffon-like flowers with white centers and are 5 to 6 in. across. This hibiscus came to us from Colors Nursery in Florida. Plants are propagated from cuttings and are tender to zone nine.

Hydrangea macrophylla 'Mariesii Variegata' (Family Saxifragacea or Hydrangeaceae)

Commonly called the silver blue hydrangea, this plant's foliage is variegated with a white to cream border on the leaves. It will grow to about 5 ft. Ours were originally obtained from Western Hills Nursery in Occidental, California. Plants are propagated from cuttings and are rated to zone six. This plant is deciduous.

Miscanthus sinensis 'Gracillimus' (Family Poaceae or Graminae)

This perennial grass is also called maiden grass. Growing to a height of 6 to 7 ft., the leaf blades are ¼ in. wide or less The plant makes a good specimen in the landscape with showy feathery inflorescences. Our first plants came from Bluemel Nursery in Maryland. This grass is propagated by divisions during the cooler months and is hardy to zone five.

Miscanthus sinensis 'Variegatus' (Family Poaceae or Graminae)

Also known as variegated Japanese silver grass, this grass is very similar to the *Miscanthus* 'Gracillimus' except for its vertical variegation. Not quite as good a grower as 'Gracillimus' and harder to propagate, we received this grass from Bluemel Nursery also and the plants are rated to zone five.

Miscanthus sinensis 'Zebrinus' (Family Poaceae or Graminae)

This grass is again similar to the other two previous *Miscanthus* except that the leaf blades are a little wider and the variegation is horizontal. From Bluemel Nursery also, the plant is propagated from divisions in the cooler months and is rated to zone five.

Nerium oleander 'Ruby Lace' (P.P.A.F.) (Family Apocynaceae)

This *Nerium* was introduced by a homeowner in Anaheim, California, named Dick Pervis who thought it had merit. The plant is a large growing *Nerium* with very large red flowers two to three inches across. The Monrovia Nursery Company is patenting this *Nerium* which is being propagated from cuttings and is rated to zone eight.

Pennisetum alopecuroides 'Hameln' (Family Graminae)

Also known as dwarf fountain grass, this Bluemel Nursery introduction grows to two to three feet with dark green foliage. The feathery inflorescence does not seed so the plants are propagated from divisions, being hardy to zone five.

Pennisetum setaceum 'Rubrum' (Family Graminae)

This grass is also know as purple fountain grass. The plants grow to about 4 ft. and their feathery inflorescence does not set seed. The leaf blades have a maroonish coloring to them. Plants are propagated by divisions during cooler weather, and is rated to zone seven.

Photinia × *fraseri* 'Indian Princess' (P.P. No. 5237). (Family Rosaceae)

This is an introduction and a plant patented by the Monrovia Nursery Company. A sport from *Photinia* × *fraseri* found by an employee gave way to a dwarf compact *Photinia* with coppery-orange new growth and red foliage, smaller than the foliage of *Photinia fraseri*. This slow growing plant is difficult to propagate from cuttings however, so grafting onto *Cydonia* understock is also done. *Photinia* × *fraseri* 'Indian Princess' is hardy to zone seven.

Rhodendendron 'Bruce Hancock' (Family Ericaceae)

This azalea is a Satsuki type that is excellent for hanging baskets. It is a James Harris hybrid from Georgia. The flowers are white with pink borders and it is a prolific bloomer. This azalea propagates with ease from cuttings and is rated to zone seven.

Spiraea × *bumalda* 'Limemound' (P.P.A.F.) (Family Rosaceae)

This spiraea came to Monrovia Nursery Company via Perron Nursery in Canada. It is a small growing spiraea to 2 ft. with lime-green foliage and pink flowers. The plants get excellent fall color in the leaves and is now under patent application by the Monrovia Nursery Company. Propagation is from cuttings and it is deciduous, being hardy to zone three.

Weigela florida 'Minuet' (Family Caprifoliaceae)

This dwarf compact weigela came to us through the Ottowa Research Station and a royalty is paid to the Canadian Ornamental Plant Foundation. The plant grows 1 to 4 ft. tall and is a prolific bloomer with pink flowers. The plants are propagated from cuttings and are deciduous, rated at zone four.

Weigela florida 'Red Prince' (Family Caprifoliaceae)

This weigela is not quite as compact as 'Minuet', but it offers bright red flowers that do not fade. The plants are patented with the Iowa Nurserymen's Research Corporation and grow 4 to 5 ft. tall. This weigela is propagated from cuttings and is deciduous, rated to zone five.

Wisteria floribunda 'Texas Purple' (Family Leguminosae)

This wisteria is quite interesting as it produces beautiful lilac purple flowers rather prolifically at a young age, only 2 to 4 ft. tall. Although its mature habit is as large as any wisteria, its profuse flowering continues. This wisteria came from Verhalen Nursery in Texas and has also been known as 'Verhalen's Purple'. The plants are propagated from cuttings and are deciduous, being hardy to zone five.

This report gives an overview of a few new and not so new plants to watch for on the market. There certainly is a plant to please everyone's needs and tastes and space, whether one grows them for a living or to beautify his home.

PROPAGATION OF WESTERN NORTH AMERICAN NATIVES

GEORGE PINYUH
Washington State University
Cooperative Extension
312 Smith Tower
Seattle, Washington 98104

We have been in the West long enough now and I hope that our need to prove that we are masters of the land, to prove we are in control by beating back its flora and fauna is coming finally to an end. We as horticulturists, plant propagators, educators, and landscapers and nursery people may actually be coming to the conclusion that among the best possible plants for our western gardens and landscapes are those that are native to our region. We are, perhaps, at last becoming more aware and appreciative of our superb native flora. A growing segment of the public certainly is.

Along with our colleagues on the East Coast, those in California have been much more involved in the use of native plants than we have here in the Pacific Northwest. Through the efforts of organizations like the Saratoga Horticultural Foundation, as well as a number of botanic gardens and arboreta involved in growing and exhibiting native plants, the

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industry and the public has been made much aware of the aesthetic value and the supreme adaptability of native plants in California.

In the Pacific Northwest a fine and profound first step has been taken with the publication of Professor Kruckeberg's authoritative book, "Gardening With Native Plants of the Pacific Northwest". Perhaps, we, too, need a Saratoga Horticultural Foundation. Perhaps the University of Washington's Center for Urban Horticulture will address this as a priority in the near future; indeed, perhaps more of us in Northwest Research and Extension will also look more seriously toward the positive exploitation of western native plants.

The ongoing pressure on our resources, particularly water, will continue to make the desirability of using West Coast natives obvious to the gardening public. These plants' long evolution in this region has made them well adapted to our Mediterranean climate, the wet winter/dry summer combination, which frequently puts so much stress on exotic plants introduced from regions of the world with climates quite different than ours. Most need a huge expenditure of water for optimum growth during our arid summers; indeed, this is often necessary just to keep them alive. We may not long be able to continue the unlimited use of such a precious resource.

There is also, I believe, a strong trend toward low maintenance plantings not only in public places like parks and along highways, but also in home gardens where the average "yuppie" homeowner may not have the time or the inclination to devote a great deal of activity and effort toward his plants. The movement toward the use of natives is and will be an integral part of this process.

Certain native plants are so much in danger of being made extinct that their salvation may lie largely in our hands. If we do not collect, propagate, grow, and distribute them, who will? This may especially be true of our rare native western carnivorous flora which will be the subject of one of our speakers.

It will be our job as plant propagators to not only identify which native plant species are appropriate for landscapes, but also to identify the best forms within each species. Those of us in the Pacific Northwest also need to select for hardiness. And, of course, we need to determine the best methods of propagation and production for these plants.

For some of us, as communicators, it will also be our job to educate the public about the advantages of their use. We also need to be educated ourselves: thus, the reason for today's program on the propagation of western North American natives.

PROPAGATION OF MAHONIA SPECIES AND CULTIVARS

DENNIS M. CONNOR

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When I am asked the question of which plants are the hardest to propagate, I recall to mind several, and the mahonias are always on that list. While seed propagation is generally easy for most cultivars, propagation from cuttings can be difficult. There are many species and cultivars of *Mahonia*, and I myself have worked with *M. aquifolium*, *M. aquifolium* 'Compacta', *M. repens*, *M. bealei*, and *M. lomariifolia*. *M. bealei* and *M. lomariifolia* are easy to grow from seed and do not require and special treatments. Germinating seed of *M. aquifolium* and *M. repens* require a more elaborate procedure. *Mahonia aquifolium* 'Compacta', which is grown from cuttings, is rather difficult to root. It seems that I have tried every propagation technique and combination thereof to root 'Compacta'; 20% to 50% rooting is normal for myself, working with 300,000 to 500,000 cuttings a season.

This report will then be on the germination of *Mahonia aquifolium* seeds, with the same principle applied to *Mahonia repens* seeds, and also on the rooting of *Mahonia aquifolium* 'Compacta' cuttings.

Let us discuss germinating *Mahonia aquifolium* and *Mahonia repens* seeds first. *Mahonia* seeds ripen in Southern California from late May to mid-June. We collect the seed from field-planted stock and also our container stock. The seed is taken to our seed department and put into a commercial blender, along with a little water, where the seed is removed from the fruit. The mash of seed and pulp is then put into a small tub and washed and strained several times, leaving the clean seed as the end product. The juice from the seed pulp is a dark blue-black color which stains readily, so the use of gloves and an apron is recommended. The clean seed is then put into cloth bags and undergoes a leaching process using domestic water. Evidently, seeds of some *Mahonia* cultivars contain chemical inhibitors which make the leaching process necessary. We made up a PVC pipe manifold to which we can fasten with string the bags of seed to be leached. Water is run through the seed for about a week. After leaching is completed, we then need to stratify the seed for 90 days by mixing the leached seed with perlite and putting it in clean plastic bags, and refrigerating it at 38°F. After the stratification time is up, we are now ready to plant the seed into flats with a seed soil

composed of two-thirds peat moss plus roughly equal amounts of very fine perlite and plaster sand. We steam pasteurize the soil before any planting is done. The surface of all the planted flats receive a light topping of silica sand, a #12 grade. This helps in keeping the surface dry and in preventing damping-off problems, yet the soil underneath stays moist. Next, we put the flats onto racks in a refrigerator at 45°F for another 60 days. This second stratification just seems to enhance germination of the seeds. We then remove the flats from the refrigerator as germination begins and put them outside under a 55% saran shade and let them grow for a while before potting the seedlings into liners. We prefer to grow them as multiples of three plants in a 3 in. pot. That is also the way we grow them on in one gal. cans. A single plant usually looks too scraggly even when mature. It is also important not to root prune the mahonias during transplant as they do not take it too well. Also avoid potting them if the weather is very warm. Production time from the collection of seed to a usable liner is about nine months.

Since *Mahonia aquifolium* 'Compacta' does not come true from seed, cuttings are necessary for propagation. Cuttings are collected from field-planted and container stock. Preferably, cuttings should be collected in fall or winter. However, some success with summer cuttings has been achieved. We spray all of the stock plants with 200 ppm Physan prior to collecting the wood. Tip cuttings are taken. After collecting the wood, the workers in the cutting department prepare the cuttings, making them 4 to 5 in. long. We recut the stem again about ¼ in. below the basal-most node. The lower ¾ of the leaves are pulled off the stem, leaving 4 or 5 leaves at the top. Once the cuttings are prepared, we immerse them into a pre-wash solution of 15 ppm chlorine followed by a second immersing into a solution of Benlate. Next, the cuttings are ready to stick into flats of 90% perlite and 10% peat moss which is steam pasteurized right in the flats before use.

A quick basal dip of 3000 ppm IBA is used as a rooting hormone, putting only 25 to 35 cuttings to a flat because of the cutting size. The finished flats then go to the outside full sun mist beds for rooting where bottom heat of 75° to 80°F is supplied. Rooting occurs in about six weeks and can run from 20% to as high as 80% on rare occasions. The rooted cuttings are then hardened off for about a week and then potted. During potting, avoid root pruning and warm weather conditions. We pot one plant to a rose pot which will eventually go to a one gal. can and then to five gal. cans. Production time from cutting to a one gal. can is about 4 months. Rooting the cuttings in a root cube or pots might help at the transplant

stage if your operation and room permits. We have rooted *Mahonia aquifolium* as well.

The tissue culture of mahonias also has its possibilities, but current multiplication of the shoots is poor and inconsistent. Hopefully this is an obstacle we can overcome in the near future.

VOICE: Can you comment on problems with looper worm in the production of mahonias?

DENNIS CONNER: It is a problem — not so much on cuttings as with seedlings. But at Monrovia Nursery we are generally on a preventative program to keep these problems from ever developing.

VOICE: When do you start fertilizing your mahonias?

DENNIS CONNER: We normally do not fertilize any cuttings until after they have developed a root system. But for mahonias, they do not go through an acclimating period before potting. They go from the mist bed right to the potting shed. They tend to go backwards if you hold them too long. Once they get in the potting soil they receive fertilizers, also subsequently during irrigation they get fertilizers. The same with seedlings — they are not fertilized until potting.

ARCTOSTAPHYLOS PROPAGATION

DARA E. EMERY

Santa Barbara Botanic Garden
1212 Mission Canyon Road
Santa Barbara, California 93105

Manzanitas, *Arctostaphylos* species, have been propagated at the Santa Barbara Botanic Garden for several decades. Over the years various treatments have been tried to improve seed germination. None has been very satisfactory. The two methods that have repeatedly given some or even good seed germination are the use of fire and acid.

The seeds of this genus have thick, impermeable nut-like seed coats and seeds of many species also exhibit internal dormancy.

For the fire treatment, after the seed is sown and covered, an additional layer of 3 to 4 in. of dry pine needles or excelsior is added and ignited. When the resulting hot flash fire is finished and the seed bed has cooled, it is watered thoroughly. This treatment should be done outside well away from any

stage if your operation and room permits. We have rooted *Mahonia aquifolium* as well.

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combustible material. It should also be done in the early fall, and the seeded containers left outdoors for germination so that if internal dormancy is a factor its rectification will occur naturally during the winter.

The ripe fruit of the manzanita is like an orange in that it is composed of separate locules. With some species these locules or sections separate into individual nutlets or chips that do not always contain embryos. In other species, two or more nutlets remain fused together, or all the locules remain fused together.

The concentrated sulfuric acid treatment is painstaking as the length of time the seed needs to be soaked in the acid must be determined empirically with each batch of seed. Also, single nutlets, fused groups, and whole fruit may need different amounts of time in the acid. While soaking in the acid (at room temperature) the seed should be stirred occasionally with a glass rod. The acid bath must be continued long enough to almost, but not quite, burn through the seed coat to the embryo.

After the acid treatment (which is done in early summer), the seed must be washed thoroughly several times to remove all the acid and then sown out of doors. Germination should occur by the following spring. A word of warning — concentrated sulfuric acid is very caustic and is dangerous to use.

Specific recommendations for two species indicate the problems involved: *A. glauca*, bigberry manzanita, requires 6 to 15 hrs. in concentrated sulfuric acid (2). *A. uva-ursi*, bearberry, needs 3 to 6 hours in concentrated sulfuric acid, then 2 to 4 months warm (8 hrs. at 65°F, then 16 hrs. at 86°F), followed by 2 to 3 months cold (35° to 40°F) stratification (2), or 6 hours acid and 2 months each of warm and then cold stratification (1). If the acid-only treatment is done in early summer and the seeded container is left outdoors, germination can be expected by spring. In some areas of southern California with relatively warm winters, artificial cold stratification may be necessary.

Small seedlings do not tolerate root disturbance very well, and the mortality rate from spotting-off may be high. This spotting-off is most successful after the second to fourth pair of true leaves has appeared.

In this author's opinion vegetative propagation is much easier (more practical) than any known seed germination technique and, of course, the only way to preserve clonal forms.

Asexual propagation of *Arctostaphylos* presents no unusual problems where cuttings are being taken from cultivated plants. At the Santa Barbara Botanic Garden we prefer to take

cuttings between the last half of November and the first half of February. This enables us to produce gallon can plants of sufficient size to plant-out or sell by fall. Also, cuttings produce heavier caliper roots when rooted in the cool part of the year. We usually use 3 to 4 in. tip cuttings from garden plants. The cuttings are submerged in a 5 to 10% household bleach; then the basal ½ to 1 in. is dipped in a root-inducing hormone. Hormex (60 sec. dip) seems to induce quicker rooting than Rootone.

The cuttings are stuck in perlite (Sponge Rok), medium grade, and peatmoss (2:1) or vermiculite and perlite (1:1), using medium grade for both components. The cuttings are rooted with bottom heat (70°F.) and intermittent mist. our mist unit is in a lathhouse, and an artificial electronic leaf works well to control the mist. Our intermittent mist unit uses deionized water, and no fertilizer is added during the rooting period.

The cuttings are checked for rooting every two weeks after the first month. The rooted ones are potted, usually in 3 in. pots; unrooted cuttings are returned to the mist unit. Once potted the rooted cuttings are hardened-off over a two week period in the hot bed (70°F.) They are then watered with $Ca(NO_3)_2$ and placed in a glasshouse or lathhouse depending on the season. In winter the outside temperature is too cold to promote much new growth.

Our potting mix is a U.C. soil-less mix of 1:1:1, #30 crystal white (washed) sand, peatmoss, perlite (medium grade) and an inorganic fertilizer component. As soon as root growth is sufficient, the plants in liners are transplanted to 1 gal. cans. The can yard, with a concrete floor, has 30% Saran shade, which is insufficient to cause any "stretching," yet is adequate to prevent the plants' root systems from overheating during periodic heat waves. The canning mix is also artificial: builders sand, peatmoss, and fir shavings (not redwood) at a ratio of 8:2:6. A fertilizer component is also added. None of our media is sterilized.

Among those species and clones which are commonly grown every year at the Santa Barbara Botanic Garden, the percentage of cuttings that root is often 100% or nearly so. This long-term success persists even when cuttings are taken from the same stock plants. In one case the same stock plant has been used for 17 consecutive years with no decrease in rooting percentage.

Cuttings from plants in the wild, particularly those with pubescent or hairy stems, may root very poorly and then only sporadically over a period of up to five months.

Rooting time normally starts in as little as 30 days and is

usually finished in 60 to 75 days. It is not unusual to be canning the first rooted of a particular batch, while the slower ones of the same batch are still rooting. In some cases we make enough cuttings so that 60 to 80% will have rooted over a two-week period, then the balance are discarded.

During the past several years a disease problem has developed in the nursery, which is limited to the manzanita — mainly to those in gallon cans. Random leaves and twigs die and turn brown. The dead leaves do not drop off the plant. When the main stem is attacked at the surface of the canning mix, the whole plant dies. The pathogen involved is *Botryosphaeria*, which is common among various manzanitas of our area. As a result, last year we started using a plant drench consisting of 0.3 ml of Subdue and 0.76 gm of benomyl per gallon of water. This is applied once a month as a preventive spray, starting with the first canning.

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2. USDA Forest Service. 1974. Seeds of Woody Plants in the United States. USDA Agricultural Handbook No. 450. U.S. Government Printing Office, Washington, D.C.

VOICE: Dara, when you treat your manzanita seed with fire to aid germination — are they cleaned first?

DARA EMERY: The seeds are cleaned, sown on the medium, covered lightly, then the excelsior is added and burned. We start with dry seed for the burning.

VOICE: What level of seed germination do you get with *Arctostaphylos*?

DARA EMERY: Germination rates are still very low — due particularly to seed coat dormancy — despite all our treatments.

HUDSON HARTMANN: Have you tried the hot water treatment to overcome your seed coat problems?

DARA EMERY: No, I haven't. *Arctostaphylos* seed has such a thick seed covering that I doubt if it would work. As I remember, the hot water treatment works best on seeds having a thin seed coat.

HUDSON HARTMANN: It may be worth a try. It is simple to use. Just dump the seeds into a large container (4 to 5 times or more the seed volume) of boiling water, turn off the heat, and allow the seeds to soak in the gradually cooling water for 24 hrs.

PROPAGATION AND CULTURE OF SOME WESTERN NORTH AMERICAN CARNIVOROUS PLANTS

DOUGLAS M. BURDIC[1]

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For centuries, carnivorous plants have fascinated and captured the interest of all those who have studied their many unique adaptations which have enabled them the ability to lure, entrap, and digest small animals. From the tropical jungles of New Guinea, where *Nepenthes* species grow as vines beneath the forest canopy, to the rocky slopes of the Pacific coastal range, where *Darlingtonia* flourish in the spring-fed serpentine bogs, carnivorous plants survive in extremely fragile habitats that are all too often being destroyed by either land reclamation operations, or massive wholesale collecting.

In the past, the predominant method of producing carnivorous plants for the market can only best be described as the "search and destroy technique." Some of the species in the eastern U.S., such as *Sarracenia oreophila* have already succumbed to this pressure and are now only grown as relics in a few scattered botanical sanctuaries. This same fate could very possibly befall the western populations of *Darlingtonia californica* (even though it is now semi-protected under both the Endangered Species Act of 1973 and the CITES agreement), unless all field collecting is stopped and substituted with competitively priced nursery grown stock. In support of this goal, I offer this paper as a tool that will demonstrate time-proven propagation/culture regimes for *Darlingtonia* and eight other species of carnivorous plants that are endemic to the Pacific coast region.

DARLINGTONIA CALIFORNICA TORR. (CALIFORNIA PITCHER PLANT)

Brief Description: *Darlingtonia* is a monotypic genus that is only endemic to the Pacific coastal bogs and mountain slopes from western Oregon to northern California. The plant has erect, tubular pitcher leaves which can reach a height of 90 cm., but are usually smaller. The apex of the leaves terminate in a globose hood, with a fishtail appendage projecting out from the pitcher entrance. This interesting morphology gives the plant an overall reptilian appearance to many who observe it for the first time.

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[1] Horticulturist

General culture:

1. Exposure: 50% shade during summer months.
2. Optimum temperatures: Growing season: 26.7°C day; 20°C night
   Winter: 6.7°C day; 1.1°C night
3. Humidity: 75 to 90%
4. Fertilization: No fertilizers should be applied.

Darlingtonia is an acid-loving plant as are most carnivorous plants, and will thrive in a variety of well-drained mixes, providing that the pH does not exceed 4.5 to 5.0. I have had the best results by using a mixture of Canadian sphagnum peat moss and washed silica sand in a ratio of 2:1. Other mixes that work easily as well are: live sphagnum moss alone, permalite/peatmoss 1:1, pure vermiculite, coarse granite gravel or various combinations of these ingredients. Besides using a medium with a low pH, the grower must be extremely careful about the quality of water that is being used while growing these glycophytic plants. Irrigation water used on *Darlingtonia*, and for that matter, any carnivorous plant, should have a measured total solid content of less than 50 ppm. (equivalent to 100 micromhos electrical conductivity) (4). Tap water is almost always unacceptable for this purpose because of high salt levels as well as other impurities. There are several ways of securing relatively pure water for carnivorous plant cultivation; collecting rain water, reverse osmosis, and distillation are the most commonly used methods. In cultivating *Darlingtonia*, water temperature is also an important factor for success. In their natural habitat, even though the ambient air temperature surrounding their leaves may exceed 30°C, their roots are constantly kept at approximately 11°C by slow moving natural waters. In cultivation, *Darlingtonia* roots begin to die when rhizophere temperatures reach 18.3°C, and unless high humidity levels are maintained and root temperatures decreased, the plant will perish (3). A grower can simulate this natural cooling effect of *Darlingtonia* by either manually pouring cool water through the containers at least once a day during the hot summer months, or by installing a timer controlled pump connected to drip irrigation tubing. A simple method of maintaining a cool water supply without refrigeration is by sinking the storage tank into the soil and protecting it from solar radiation. Containers recommended for *Darlingtonia* are unsalted clay pots or fiber pots. Both of these types allow for more air exchange and aid in keeping the roots at a lower temperature (4). Fiber pots are short lived, but are used for a reason that will be explained below under propagation.

Darlingtonia requires a dormancy period of 3 to 5 months if they are expected to survive more than one or two growing seasons. During this period, my plants are cultivated in a cool house where temperatures are kept just above freezing at night and average 6.7°C in the day. During this period watering should be reduced. A monthly spray with Benlate is beneficial in guarding against fungus attacks.

Propagation:

Seed: In nature, flowering time is usually from April to August. Pollination should be done about 3 to 5 days following anthesis — when pollen matures. The seed should mature in approximately 10 weeks and should then be stratified at 4.4°C for 3 months. When ready, the seed can be sown on moist sphagnum moss or peat moss, and germinated in a closed propagation case or greenhouse to maintain a high humidity. Bottom heat of 23°C will aid in germination, but should not be used once seedlings have developed their new root system for reasons stated earlier. *Darlingtonia* plants undergo a juvenility phase during their first year's growth and sometimes into the second season, but gradually typical adult leaves will form from the center of the rosetted seedlings. To produce a saleable plant using the seed method, will usually require about 3 years.

Rhizome cuttings. In a container situation, a mature *Darlingtonia* plant will send out several rhizomes which will encircle the pot several times if they arise from an older plant. These rhizomes will form buds at their apex, eventually forming new individual plants which can then be severed and repotted. In using fiber pots, these new plants will grow through the container walls, form roots, and can be removed much easier than they could be if they were grown in more restrictive clay pots. If a grower had several large stock plants, this method could produce a substantial number of new plants each year with a minimum of effort.

A second method of propagation using the rhizome is to divide it into 1 in. segments, treat with a mild benomyl solution and place it in flats of live sphagnum moss (2). If these are kept humid new plants should form in 3 to 6 months.

PINGUICULA VULGARIS L. (BUTTERWORT)

Brief Description: Of the 48 known species of butterworts in the world, only one inhabits the bogs of western North America, *Pinguicula vulgaris*. Its range extends up to the northern boreal region, south to the Great Lakes, and west to northern California. In the Pacific Northwest, these small, rosetted plants usually measure 5 to 9 cm across, and are very

easily overlooked unless one happens by them during their flowering season which is from June to August. The leaves feel greasy to the touch because of glandular secretions used in trapping and digesting small insects. This plant is predominantly found in rocky seeps in the surrounding soil of serpentine bogs.

General culture:

1. Exposure: 50% shade during summer months.
2. Optimum temperatures: Growing season: 26.7°C day; 20°C night
   Winter: 6.7°C day; 1.1°C night
3. Humidity: Maximum humidity.
4. Fertilization: No fertilizer should be applied.

Whereas most carnivorous plant do best in a very acid medium, this plant is said to grow equally as well in acid, neutral, or alkaline soils. I grow my plants in a mixure of Canadian sphagnum peat moss/washed silica sand (1:1). They require a cool root system also, but they tend to develop root rot when constantly wet, so a fast-draining medium is recommended. These plants can not tolerate intense full sun. I shade them at least partially during middle to late summer to aid in cooling and to encourage winter bud formation. Dormancy can be a problem in this species of *Pinguicula* because of their characteristic formations of winter hibernacula. The hibernacula are very susceptible to a variety of fungus problems, and to avoid this, some growers suggest that they be removed from their containers, dusted with sulfur and subjected to a 4 month period of refrigeration. In my greenhouse, the hibernacula are left in their pots, sprayed with a dilute fungicide, and kept much dryer than normal until they resume growth in the spring.

Propagation

Seed Production: Pollination of this species of *Pinguicula* can be accomplished with a steady hand and a small brush. The beautiful zygomorphic flowers are partly sympetalous and are morphologically designed to discourage self-pollination. The anterior stigma lobe must be first lifted with a brush to expose the anthers, or one can cut away the corolla which greatly simplifies the operation. When ripe, the seed should be stratified for 4 months at 2.0°C after which they can be sown on a bed of granulated peat moss, sprayed with a fungicide, and kept moist. Seed germination should take place in 6 to 8 weeks. *Pinguicula* species do not tolerate root disturbance and should never be transplanted during their growing season.

Gemmae: This is, by far, the fastest and most efficient

method of propagation for this particular species, both in its natural habitat and in cultivation. At the end of the growing season, these small reproductive structures will form at the base of the hibernacula. At the end of the dormancy period, these can be easily removed and replanted separately and will shortly form their own root system independently.

Leaf cuttings: I have never had any degree of success with this method of propagation for this species, nor has anyone else I've corresponded with, but it works very well for several other species of *Pinguicula* so it will be mentioned here to encourage experimentation. Leaves should be removed in late spring and an attempt should be made to include part of the leaf base with it. The leaf should be sprayed or dusted with a fungicide and then placed on a bed of live sphagnum moss which can then be covered. The problem with this method of propagation in the past has been in preventing degeneration of the tissue long enough for plantlets to be formed.

UTRICULARIA VULGARIS L., *U. GIBBA* L., *U. FIBROSA* WALT., *U. MINOR* L., *U. INTERMEDIA* HAYNE. (THE BLADDERWORTS)

Brief description:

Of the 250 species of *Utricularia*, these five are found in the Pacific Northwest. These aquatics and semi-terrestrials are rootless, free-floating carnivorous plants that probably possess the most sophisticated trapping mechanism of any of the known carnivorous plants. Since the culture and propagation of our western species is essentially similar, they will be combined into one category for explanatory purposes. The plants can range in sizes from 1 in. to 3 meters in length. They consist of rootless, branching, free-floating stems, which bear more delicate lateral branchlets arising as whorls along its length. These smaller branchlets in turn, give rise to very small bladders that are capable of catching small aquatic prey. Basically, there is an unequal water pressure gradient from outside to inside the trap lining and when small animals disturb one of the trigger hairs located at the entrance, an electrical potential causes the negative pressure area inside the bladder to suddenly become flooded with an inrush of water containing the intruder. At the instant that this is occurring, the bladder door closes and seals off the trap preventing any chance of escape. As with the butterworts, these plants would probably be overlooked by most people, except when they are flowering which is from May to September when their tall yellow flowers can be seen rising above their aquatic environment.

General culture:

1. Exposure: 75% shading all year.
2. Optimum temperatures: Growing season: 26.7°C day; 20°C night
   Winter: 6.7°C day; 1.1° night
3. Fertilization: No fertilizer should be applied.

All of our *Utricularia* species are aquatic with the exceptions of *U. gibba* and *U. fibrosa* which can also be grown in a sphagnum slurry (sphagnum/water 1:1). The simplest way to grow aquatic utricularias is by filling a large wading pool with 4 cm. of a peat/sand mix, 2:1, and then adding pure water. This should be allowed to age for at least one week before the *Utricularia* plants are introduced. Ideally, the pH should be at about 4.6 for optimum growth and should be checked as a final precaution. If the water is still too alkaline, cedar chips, sphagnum moss, or dilute sulfuric acid (only by a qualified person) can be used to lower the pH to an acceptable level. The temperature regimes mentioned earlier for *Darlingtonia* and *Pinguicula* are also acceptable for this genera.

Propagation:

The simplest method is to simply break the stems into smaller sections in the spring. I do not recommend seed propagation except for the obligate terrestrial *Utricularias* in the eastern regions of North America.

DROSERA ROTUNDIFOLIA L. AND *D. ANGLICA* HUDS. (SUNDEWS)

Brief description:

The genus *Drosera* includes over 90 species, worldwide. The genus is represented in the western region by two species, *Drosera rotundifolia* (round leaved sundew) and by *D. anglica* (English sundew). Both of these plants are found in sphagnum bogs located throughout the northwestern states, north to Alaska and east to Newfoundland. These rosetted plants usually do not exceed 8 cm. in diameter, but even for their small size, they are seldom overlooked due to the spectacular color display they present which results from the pigmented mucilage secretions on their leaves. This secretion arises from tentacles that are used to ensnare and digest small insects and, at times, these tentacles, along with the entire leaf blade, will bend totally around the captured prey to prevent escape. The flowers of both species are usually white and are borne from June to September.

General culture:

1. Exposure: 25% shade during summer months.
2. Optimum temperatures: Growing season: 26.7°C day; 20°C night
   Winter: 6.7°C day; 1.1°C night
3. Humidity: 75% humidity.
4. Fertilization: No fertilizer should be applied.

These *Drosera* species will grow in the same mixes used for *Darlingtonia* and *Pinguicula*. I do not recommend using pure live sphagnum moss since it has a tendency to over-grow the small plants in a greenhouse environment. *Drosera* should only be watered by a capillary system, not by overhead irrigation. Care should also be taken to keep the leaves from being constantly wet as this will encourage disease problems. I usually keep my plants in the section of the greenhouse farthest from the humidification system.

Both species form winter hibernacula and it is during these winter months that most plants are lost to the grower in cultivation, usually due to incomplete winter bud formation, or from overwatering. Losses can be minimized by removing the plants from the greenhouse environment in the fall to encourage healthy winter bud formation, and by treating with a dilute fungicide. Dormancy temperatures and conditions are identical to those discussed for *Pinguicula vulgaris*.

Propagation:

Seed: Both of these species self-pollinate with very little assistance and seed is produced profusely. After the seed has ripened it should be stratified for at least three months at 3°C. The seed should be sown on granulated peat moss and kept moist. Germination should occur in 4 to 6 weeks.

Leaf cuttings: This method is recommended over seed propagation. Young, healthy leaves should be removed in late spring through early summer and placed on damp peat moss. If kept humid, new plantlets should form on the leaves in about one month. I have also had success simply by floating the severed leaves on the surface of a container filled with distilled water. When the plantlets develop individual root systems, they can be transplanted.

TISSUE CULTURING CARNIVOROUS PLANTS

Only limited information is presently available on this subject, but due to the recent advances made in that field, we are now able to propagate many species of carnivorous plants using these new techniques. I am not yet involved in this

aspect of carnivorous plant propagation, but Carroll (1) has suggested the following medium be used as a standard. He has had success using variations of this formula on both *Darlingtonia californica*, using a surface-sterile seedpod, and on certain *Pinguicula* species, using the shoot meristem. He also suggests that when making a liter of this medium, one should take 200 ml. increments and vary the amount of hormones added starting with 0.1 mg/liter and not to exceed 1.5 mg/liter initially. (Table 1)

Table 1. Medium for tissue culture propagation of *Pinguicula*[1](1).

	milligrams/liter
Calcium nitrate ($CaNO_3$)	1000
Ammonium nitrate (NH_4NO_3)	300
Potassium phosphate (KH_2PO_4)	250
Magnesium sulfate ($MgSO_4$)	250
Manganese sulfate ($MnSO_4$)	10
Iron chelate, Fe Chelate	20
Thiamine	10
Inositol	100
Sucrose	20,000
Agar	12,000

[1] Plant hormones for shoot multiplication are kinetin or 2ip in a range of 0,5 to 2.0 mg/liter of solution. Auxins for rooting are IBA or NAA in a range of 0.1 to 1.0 mg/liter.

The medium is brought to a boil while stirring constantly, dispensed into test tubes or other containers, and steam sterilized for 15 min. at 15 lbs. pressure (120°C. or 250°F).

CONCLUSIONS

For many years, knowledge concerning the culture, propagation, and conservation of carnivorous plants was practically unattainable, but due to the efforts of serious individuals and the International Carnivorous Plant Society, we now have an internationally organized network of growers who freely exchange information and ideas concerning all aspects of these frequently endangered species. Even as this paper is being written, huge stands of carnivorous plants in this country are being bulldozed in land reclamation projects. In many instances, by the time all the paperwork required in classifying a species as endangered is finished . . . so is the plant. Hopefully, this paper will inspire some readers to put into practice the ideas and techniques stressed in its content and to pursue further knowledge on the subject of carnivorous plants in general. I sincerely recommend to any interested individuals or growers desiring more information to consider contacting: *The International Carnivorous Plant Society*, c/o Mrs. Pat Hansen, 3321 Hamell Road, Fullerton, California 92635

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MIKE EVANS: You mentioned that you do not fertilize the *Darlingtonia* plants. Do you need to feed them insects?

DOUGLAS BURDIC: Not at all. It is almost impossible to keep insects away from them. In fact, sometimes the traps are almost bent over due to the weight of the insects in them. Wasps are especially attracted to the nectar.

VOICE: What are the winter temperatures at which you hold these carnivorous plants?

DOUGLAS BURDIC: In the coldest months in my greenhouse the night temperature is about 30° F and in the day about 49° F. In nature they become frozen in winter, although they are mulched by the surrounding grasses.

VOICE: Can you feed meat to these carnivorous plants?

DOUGLAS BURDIC: Sure, hamburger or cheese — any kind of a protein substance.

CUTTING PROPAGATION OF *PAXISTIMA MYRSINITES*, *VACCINIUM OVATUM*, *RIBES SANGUINEUM*, AND *ACER GLABRUM* V. *DOUGLASII*

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PAXISTIMA MYRSINITES. OREGON BOXWOOD

Its common name, Oregon boxwood, accurately describes the foliage of this evergreen shrub, which is similar to that of box in size and color. This species is found on well-drained

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Its common name, Oregon boxwood, accurately describes the foliage of this evergreen shrub, which is similar to that of box in size and color. This species is found on well-drained

sites in full sun or open shade, from British Columbia to Oregon and east to Alberta and the Rocky Mountain states. It is variable in habit, sometimes prostrate, but more often upright and spreading, reaching a maximum height of three feet.

Paxistima myrsinites is readily propagated from cuttings, which may be taken at any time after the new growth has firmed in mid-summer until bud break in the spring. Cuttings will root in high percentages without hormone treatment, but the application of 0.8% IBA in talc will produce a larger, more branched root system in the same interval of time. In one trial, 965 out of 1,000 cuttings were well-rooted. Percentages such as this make direct sticking of cuttings an economical alternative. Contact polyethylene film propagation maintains the cuttings in excellent condition, and is the method I would recommend in the fall and winter, but mist is also quite satisfactory. With either method, basal heat is provided (70°F, 21°C), and cuttings are ready for potting in eight weeks.

It should be noted that *Paxistima myrsinites* is susceptible to *Pythium irregulare*, a soil-borne fungus which slowly destroys the root system. The symptoms of infection are a progressive decline, beginning with cessation of growth, followed by dulling, then browning of leaves and gradual defoliation. An outbreak which we experienced was traced to the peat used in our container medium. The only practical control is pasteurization of the medium and avoidance of re-contamination.

VACCINIUM OVATUM. EVERGREEN HUCKLEBERRY

Although it is one of our most ornamental native shrubs, evergreen huckleberry is rarely encountered in nurseries. In landscape effect it is similar to Japanese holly, both bearing small, dark, glossy leaves, but evergreen huckleberry surpasses the holly in beauty, with fawn to reddish-colored new growth and pale pink flowers in profusion.

Vaccinium ovatum is reported to perform well in sun or shade (2), reaching from 3 to 5 ft. in height in full sun and taller, to 15 ft. in shaded sites. Its growth is somewhat slow and irregular, with strong shoots emerging from the base and branching at their tips, similar to the behaviour of *Pernettya mucronata*.

Evergreen huckleberry can be propagated by cuttings from fully matured shoots taken in fall and winter. Cuttings made from the previous year's growth taken the third week in April rooted 100%. Tip cuttings can be used, and the unbranched basal shoots can be sectioned into 4 to 6 in. cuttings as well. A talc-based rooting hormone containing 0.3 to 0.4% IBA is sufficient to promote rooting, in combination with basal heat (70°F,

21.C). Rooting is slow, three months normally being required to produce a root system large enough for potting. *Vaccinium ovatum* has proven amenable to container production, tolerating an occasional drying out with no signs of injury.

RIBES SANGUINEUM. RED FLOWERING CURRANT

Ribes sanguineum is probably the best appreciated flowering deciduous shrub native to the Pacific Northwest. Ranging from British Columbia into California on the coast, and to the eastern slope of the Cascades in Washington and Oregon, this species bears flowers ranging from cerise to pale pink and even white. The size of the inflorescence is also variable, and several cultivars have been selected for intensity of flower color and/or length of flower clusters.

Red flowering currant is easily propagated by softwood cuttings, which can be taken throughout the summer into early September. Plants overwintered in a polyethylene-clad "tunnel" made early growth, which permitted the taking of cuttings in May. Cuttings treated with 0.8% IBA in talc and stuck under mist with basal heat (70°F,21°C) are ready for potting in four to six weeks. Many of the root systems are large enough to permit potting directly into one gallon containers.

Ribes sanguineum can also be propagated from hardwood cuttings taken in January. The cuttings are made with a short "heel" of two-year-old wood and tied in bundles. The cutting bases are dipped in 0.8% IBA in talc, then the bundles of cuttings are heeled in right-side-up in a basally heated (70°F,21°C) frame in an otherwise unheated structure. After two to three weeks, short roots begin to emerge, and at this point the cuttings should be lined out in the field or potted and placed in a shade house. The potted cuttings should not be placed in a glass or plastic covered structure, where it will become too warm on sunny days. Rather they should be maintained at outdoor temperatures to delay bud break until sufficient roots have formed.

ACER GLABRUM SUBSP. *DOUGLASII*. DOUGLAS MAPLE

Douglas maple is a small tree, often multi-stemmed, found on rocky slopes from the Rocky Mountains west to the coast (1). It bears three to five-lobed leaves, up to 4 in. in width. In some individuals the leaves are so deeply cut that the leaf blade is divided into three leaflets. Fall leaf color varies from orange and red to yellow. Douglas maple shows good drought tolerance in cultivation. I believe that it has promise as a small tree for urban use, and that there is much potential for the

selection of superior ornamental forms, as has been done with red maple (*Acer rubrum*).

In order to propagate selected clones of this maple, vegetative methods must be used. When it was requested in 1981 that I propagate a plant of *Acer glabrum subsp. douglasii* with compound leaves, I decided to try cuttings. Because material was in short supply, single node cuttings were used, similar to the method developed for red maple (3). Cuttings were taken on August 11, 1981, and three hormone treatments were contrasted, with eight cuttings per treatment. After hormone application, the cuttings were stuck into a flat filled with a mixture of equal volumes of peat and perlite and placed under mist. On October 7, 1981, rooting was assessed. Of eight cuttings treated with 0.8% IBA in talc, six were rooted. All eight cuttings treated with 0.25% IBA in 50% ethanol were rooted. Only three cuttings treated with 0.5% IBA in 50% ethanol were rooted. Because difficulties were anticipated in overwintering the rooted cuttings, only a few with large root systems were potted, and the rest were left undisturbed in the flat. One of the two leaves on each rooted cutting was removed and the cuttings were given 24 hour daylength in an attempt to induce shoot growth, but none was produced that fall. The rooted cuttings were overwintered in a cold greenhouse maintained above freezing. In the spring of 1982, all of the rooted cuttings which had been potted died without making new growth, while the majority of cuttings which had not been disturbed broke bud and grew vigorously. Although the number of cuttings inserted was small, this trial established that Douglas maple can be rooted from single node cuttings and thus provides an efficient method for propagating superior clones.

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VOICE: Have you rooted *Physocarpus capitatus* (ninebark)?

CHARLES TUBESING: Yes, we can root them — if we use very soft cuttings. If they start to firm up a bit, however, then they deteriorate before rooting.

DON RUSK: Do you get better plants of *Ribes sanguineum* when you use hardwood rather than softwood cuttings?

CHARLES TUBESING: There is a potential for getting a bigger plant by using heavy, 2-year-old wood cuttings, with a large diameter. You get a stouter plant right away. It is a less expensive method than using your valuable mist space for leafy cuttings.

VOICE: I find in the Portland area that *Vaccinium ovatum* will propagate from cuttings very readily taken almost any time during the year. Here it grows best in the shade.

PROPAGATION OF SOME NATIVE DECIDUOUS SHRUBS

ROBERT BRUCE McTAVISH

Reid, Collins Nurseries Limited
Aldergrove, British Columbia, Canada

Propagation of deciduous native plants can be accomplished by seed or, in many cases, softwood and/or hardwood cuttings. The choice of techniques is usually species specific though, in some cases, may be dependent on availability of the propagating material.

This paper will deal with the following species: *Alnus crispa*, *Amelanchier alnifolia*, *Rosa acicularis*, *Rosa woodsii*, *Shepherdia canadensis*, and *Vaccinium parvifolium*. The paper will summarize approximately 7 years of experience with these species as well as results from controlled experiments.

PROPAGATION BY SEED

Many of the species grown at Reid, Collins Nurseries come from northern British Columbia or Canadian prairie provinces. Species such as *Shepherdia canadensis*, *Rosa acicularis*, *Rosa woodsii*, and *Amelanchier alnifolia* exhibit both physical and physiological seed dormancy. Physical dormancy is usually due to hard seed coats, whereas physiological dormancy is directly due to metabolic conditions within the embryo.

Methods of Breaking Seed Dormancy. A standard method of breaking dormancy due to hard seed coats is soaking of the seed in concentrated sulfuric acid for various periods of time, or by warm stratification. This is followed by cold stratification to break the physiological dormancy.

Table 1 shows that optimal results are obtained from a warm stratification followed by cold stratification. Extensive

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Table 1 shows that optimal results are obtained from a warm stratification followed by cold stratification. Extensive

work done by King *et al* in 1983 found that for native roses of Alberta that 60-day warm stratification followed by 90-day cold stratification was the optimal combination to maximize seed germination. Recent results from both experimental trials and full scale production at Reid, Collins Nurseries confirm these findings. Use of acid scarification does not seem to enhance germination. Longer periods of acid scarification than we used may be needed to significantly affect the seed coat.

Table 1. Germination percentages of *Rosa woodsii* and *R. acicularis* seed under various stratification treatments.

Species/Provenance	Treatment	Percent germination	Data source
Rosa acicularis	118 day warm, 25°C 90 day cold, 3°C	90+	Desmond, Zasada-1977
R. woodsii, Banff	120 day cold, 3°C	0	Reid, Collins
R. acicularis, Fort McMurray	60 day warm, 20°C 90 day cold, 3°C	45	Reid, Collins
R. acicularis, Fort McMurray	120 day cold, 3°C	10	Reid, Collins
R. woodsii, Alberta	60 day warm, 20°C	49	King, *et al*-1983
R. acicularis, Fort McMurray	1 hour H_2SO_4 300 day cold, 3°C	30-50	Reid, Collins

An alternate method to the warm/cold stratification is to sow into outside seed beds in the fall. This usually results in 25 to 35% germination during the second year. At Reid, Collins Nurseries, both the seed bed method and the controlled stratification methods are used. This insures protection from total germination failure due to poor seed or equipment malfunction in the stratification procedures.

Table 2 shows a very wide range of results under varying treatments for *Shepherdia canadensis*. In general, acid scarification seems to result in enhanced germination. The effects of cold stratification after acid treatment may be debatable based on results from Heit, 1970. One of the major problems with *Shepherdia canadensis* is the quality of the seed. Our experience has shown widely varying germination percentages from year to year under identical treatments. This seems to be due to poor embryo development; it is therefore important for seed collectors to check their seed before collection to insure proper embryo development has taken place.

Alnus crispa seed does not seem to need pregermination treatments as can be seen from Table 3. Stratification does, however, speed up the germination process. This makes it much easier to produce an even crop which is particularly important for alder. If seedlings of various sizes are in a single tray, the smaller ones quickly die, due to shade intolerance. We have also found that germination percentages are enhanced by 30-day moist-cold stratification when using seed

that has been stored for one or more years. This could be due to relatively low moisture content of the seed and the need to imbibe water before germination can take place.

Table 2. Germination of *Shepherdia canadensis* seed.

Species/Provenance	Treatment	Percent germination	Data source
Shepherdia canadensis, Saskatchewan	15 min. acid 30 day cold	89	Cram 1978
S. canadensis, Fort Murray, 1981	90 day cold stratification	30-40	Reid, Collins
S. canadensis, Hinton	Fermented in pulp 5° 290 days	50-60	Reid, Collins
S. canadensis, Banff	120 day cold stratification	14	Reid, Collins
S. canadensis, Fort Murray, 1980	15 min. acid 30 day cold stratification	0	Reid, Collins
S. canadensis, Fort Murray, 1982	7 min. acid 30 day cold stratification	50-60	Reid, Collins
S. canadensis	20-30 min. acid No stratification	71-80	Heit 1970

Table 3. Germination results from various treatments of *Alnus crispa* seed.

Species/Provenance	Treatment	Percent germination	Data source
Alnus crispa, Fort McMurray	None	50-60	Reid, Collins
A. crispa, B.C.	30-day cold stratification	67	McLean 1967
A. crispa, Rogers Pass B.C.	14-day cold stratification	50	Reid, Collins

Table 4 shows that with *Amelanchier alnifolia* seed cold stratification from 90 to 120 days, or warm stratification followed by cold stratification, produce nearly identical results. Cold stratification for 90 to 120 days in our experience has proved adequate to insure good germination. One problem encountered with *Amelanchier alnifolia* during the cold stratification period is control of fungus. The seed seems to be very prone to heavy infestation of fungus which can quickly destroy the seed. This can be controlled by adding captan to the stratification medium.

PROPAGATION BY CUTTINGS

Propagation by cuttings of the species mentioned earlier has been attempted. However, the rose species are the only genus with which we have had much success. *Rosa woodsii* and *Rosa acicularis* taken from softwood cuttings and treated with #2 hormone have rooting success of approximately 80%.

Table 4. Germination results from various treatments of *Amelanchier alnifolia* seed.

Species/Provenance	Treatment	Percent germination	Data source
Amelanchier alnifolia, Fort McMurray	90 day cold stratification	60-70	Reid, Collins
A. alnifolia	4 month warm, 4 month cold	95	Heit 1971
A. alnifolia	120 day cold stratification	98	McLean 1967

One species not mentioned in seed propagation that has recently been propagated successfully by cuttings is *Vaccinium parvifolium*. Cuttings were taken in October, 1984, and treated with both #2 and #3 rooting hormone and stuck into a 50% peat, 50% perlite propagating mix on heated benches. Under both treatments success was 95% based on two hundred pots in each treatment. This is the first time that propagation of *Vaccinium parvifolium* has been successful at our nursery. We believe the reason for success was the quality of the cutting wood. The cuttings were "semi-hardwood", taken from plants grown under nursery conditions thus producing considerable new one-year wood for cuttings.

SUMMARY

The species discussed in this paper can be propagated in large numbers with reasonable reliability by seed germination or by rooting cuttings, following the methods outlined. Most are hardy and rapid growing and need minimal maintenance and thus are ideal in both land reclamation and in low maintenance landscape settings.

VOICE: What time of year do you take your *Vaccinium parvifolium* cuttings? And how long are they?

BRUCE McTAVISH: September or October (in Aldergrove, B.C.). The cuttings are 4 to 5 in long.

ALLAN ELLIOTT: What is your procedure for collecting and cleaning *Amelanchier* seed?

BRUCE McTAVISH: For cleaning, we put them in a commercial macerator, then float the pulp off. It is quite easy. Our problems are with fungus diseases in the seed stage. During stratification a great mass of mold will appear all through the seeds. We have been using captan in the peat-perlite stratification mixture, then sowing that — with varying degrees of success.

VOICE: What is your method of propagating *Populus tremuloides*?

BRUCE McTAVISH: We have had little success with seed propagation — but I know some people do. You have to collect the seed in the exact maturity stage — 3 or 4 days either way will not do. We use root division very successfully. Or we use sprouts from root pieces over bottom heat for cuttings — and these will root. Under our weather conditions *P. tremuloides* is very susceptible to a leaf blight. Young plants set out-of-doors soon defoliate and die.

VOICE: We have had good success with softwood cuttings of *P. tremuloides*, taken in early spring from trees at 8000 ft. Also from our 1 and 5 gal. containers plants. Take cuttings when new growth is 6 to 8 in long and slightly hardened.

PROPAGATING CEANOTHUS

MICHAEL NEVIN SMITH
Wintergreen Nursery
358 Mark Road
Watsonville, California 95076

Ceanothus, the wild lilacs, are horticulturally among the most interesting and popular of western North American native plants. At least half the 40-odd western species and many hybrids have been cultivated during the past century. Yet they are regarded to this day as cranky and unpredictable by nurseryman and gardener alike. I would like to consider this group from a propagator's viewpoint, perhaps separating some myth from fact while describing how several nursery friends and I deal with the problems we encounter[1]. We will briefly review three alternative methods of propagation, each with unique problems and applications.

Cuttings. The overwhelming majority of *Ceanothus* in commerce are propagated by cuttings. This is not only because most have shown themselves amenable to cutting techniques but they also exhibit enormous genetic diversity in the traits for which they are valued most — such ornamental features as plant size and shape, abundance and color of flowers, and disease resistance — making clonal selection and perpetuation nearly a must.

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Botanists divide the genus *Ceanothus* into two subgenera, *Cerastes* and *Euceanothus*, and we are finding this subdivision an increasingly useful predictive tool when we encounter unfamiliar species or hybrids. Most of the *Cerastes* species, including *Ceanothus gloriosus* (Pt. Reyes ceanothus), *C. cuneatus* (buckbrush) and *C. prostratus* (squaw carpet), are recognized easily by opposite (paired) leaves. The branches of most members of this group mature or "harden" quickly even under nursery conditions (two popular selections of *C. gloriosus* being striking exceptions). Thus they tend to require stronger rooting hormones and longer periods on the bench for successful rooting than those of *Euceanothus*. However, they are also tougher, and the relatively thick, hard leaves last well, permitting them more bench time without deterioration.

Members of *Euceanothus* include most of the species and hybrids familiar to Californians and are identified most easily by their alternate ("normal") leaf arrangement. Their branches generally mature more slowly than the last, remaining in a relatively soft, active state both over time and in distance along each branch. Though most are classed as evergreen, the individual leaves generally last less — sometimes much less — than a season and may drop suddenly, even while apparently healthy, in response to such stresses as fluctuations in temperature or moisture and even (as nearly as I can discern) rooting hormones. Cuttings made from young, vigorous shoots often root quite rapidly with mild hormone concentrations, yet there is always an implicit race for time between rooting and deterioration, expressed in yellowing leaves and browning stems.

We have learned through experience some general do's and don'ts applicable to both categories, as well as some areas of latitude. For the evergreen species and hybrids, the time of year seems to be less crucial than the condition of the cutting stock, *if* (and this is important) moderate temperatures can be maintained in the propagating facility. Nursery plants grow and are "cuttable" almost continuously, while those in the wild respond to cycles of moisture and drought. We tend our stock plants carefully, keeping them well fertilized and watered and doing preventive fungicidal applications well in advance of cutting. We have also learned to avoid marginal material, regardless of need: cuttings from plants under obvious drought or other stress usually decline slowly and die, while even apparently healthy material from plants affected by fungus leaf spotting or twig blights can be lost overnight, in spite of disinfective treatment.

In selecting shoots for the actual cuttings, we avoid those that are thick and pithy, which are prone to quick collapse,

and opt for more slender ones (say, ⅛-in. or less). We prefer shoots in current or just-completed growth, long enough to permit a firm basal node, heel or otherwise (again insurance against collapse in the early stages), and at least three, preferably more, leafy nodes above the medium (the extra productive and storage area seems to help prevent the slow decline which often plagues *Ceanothus* cuttings).

We remove soft tips from the main shoots, partly to avoid immediate wilting, but even more to prevent the sort of rapid growth which can make it impossible to transfer even well-rooted cuttings out of the greenhouse without collapse. I should add that the alternative of short, soft tip cuttings can yield quick, spectacular success with such species as *C. griseus*, *C. thyrsiflorus*, and *C. impressus* and their hybrids, though without near-perfect propagating conditions overnight disaster is more likely.

A further step, where possible, is removal of incipient flower-cluster buds; when the flower clusters fade and die, *Botrytis* often attacks — first the dead flowers then the live stems and leaves. The cuttings are finished in the normal manner, except that in many cases the lower leaves or branchlets must be cut, rather than stripped from the stems, given the tough, fibrous nature of the tissues.

I strongly recommend a fungicidal dip (we combine Benlate and Subdue) with one of the plastic resin-type stickers, allowed to dry on the cuttings before they are hormone-treated and stuck; this helps avoid the "mysterious" disease problems for which *Ceanothus* cuttings are noted.

Our hormone treatments are generally moderate, ranging from nothing, or perhaps 0.1% IBA, with the small tips mentioned above, to 0.5% or more IBA/NAA on really "hard" cuttings out of the wild, particularly of *Cerastes* types. There is evidently an absorption problem, too, with hard cuttings, because use of one of the alcohol-based dips to which we have added about 20% (by volume) DMSO yields spectacular improvement in rooting; it also avoids basal "scorch," which often destroys the basal node and can kill the cutting.

There are two points worth making on the "sticking" stage. We give the cuttings what would be an extravagant amount of space for most items. However, this pays off in limiting the spread of any diseases which may crop up in the flats. The medium is negotiable but must be well-drained; ours is roughly 80% medium perlite, 20% screened peat.

We consider misting, more with *Ceanothus* than with most plants, a necessary evil. Frequent or heavy misting or too long a period on the mist bench almost invariably results in prob-

lems with fungal and bacterial disease. Thus we reduce misting needs by maintaining moderate temperatures and some shading and wean our cuttings to dry/shady bench conditions as rapidly as possible (generally when callused). Bottom heat of 65 to 75°F speeds rooting dramatically for most species, but we find it causes rapid deterioration on *C. prostratus*, *C. Purpureus*, and some other *Cerastes* types if applied before callus forms. Once the cuttings are at least callused, we find light but regular fertilizing to be of considerable assistance in completing the rooting process. From this point on, they may be handled like most common shrubs; in fact, after a two- or three-stage hardening process, we plant most of our *Ceanothus* directly into one-gallon containers.

Layering. It seems odd to discuss layering as a propagating technique for shrubs. However, some matting *Ceanothus* species, such as *C. prostratus* in *Cerastes*, and *C. diversifolius* (pine mat) in *Euceanothus*, root where the nodes touch the ground. These may be carved into chunks of a few branchlets each and replanted separately. This method is easy and quick, especially with container-growth stock, though not as productive numerically as cuttings.

Seeding. For purposes of natural revegetation and large-scale ground cover, seeding is a useful and relatively inexpensive technique, even for *Ceanothus*. Since I am growing only clonal selections, I will be speaking mostly of others' experience[2]. The first problem encountered is collecting the seed. These plants have explosive seed capsules capable of flinging their contents several feet in all directions. This presents us with two alternatives: Pluck the small, clustered capsules when they are just ripe — reddish to tan in color, but not dried, and the seeds brown to black. Or sweep the fallen seeds and assorted debris from beneath the plants and separate them by screening, winnowing, and perhaps flotation.

At sowing time (which can be any time for the southern coastal species, probably fall for northern and montane species), steps must be taken to make the hard, dense seed coats more permeable to water. Immersing them in nearly (not quite) boiling water and allowing the mixture to cool and stand at least overnight will get them imbibing water and aid germination considerably. Seeds of such northern and mon-

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[1] I especially thank Gerd Schneider, of Gerd Schneider Nursery, and Harry Marken, of Leonard Coates Nurseries, for the information they have shared over the years on these and other "difficult" native subjects.

[2] Harry Marken has supplied data from many years' seedling experience with eight *Ceanothus* to which I have added my own field experience and general techniques for seeding "touchy" shrubs.

tane species as *C. prostratus* and *C. sanguineus* are further assisted by stratifying in moist perlite or other porous medium at normal refrigerator temperatures (35 to 45°F) for a couple of months.

The seeding medium *must* be fast-draining (ours is about 50% medium perlite), and I would recommend mixing in Truban or another Terrazole compound at the recommended rate to avoid damping-off. Germination times will vary widely among species. From the point of germination on, except for quick remedy of whatever fungus problems may develop, the seedlings are handled like those of most common fibrous-rooted shrubs.

VOICE: What rooting medium do you use for your ceanothus cuttings?

MICHAEL SMITH: We use the same rooting medium for everything — 80% medium grade perlite and 20% screened Canadian sphagnum peat.

VOICE: Have you been able to root *Ceanothus cordulatus* or C. *velutinus* cuttings?

MICHAEL SMITH: I have tried but never rooted either one satisfactorily. I have rooted a related species, C. *incanus*; these rooted rather well. *C. prostratus* cuttings do not root well, either under mist or with bottom heat. Just place them on a shady, cool bench and finally a good percentage will root.

PHIL BARKER: What size screen do you use for your peat moss, and are there different kinds of Canadian peat moss?

MICHAEL SMITH: In central California we have to use whatever we can get. Some brands are excellent and some are filled with all kinds of foreign material. We use a ¼ in. mesh for the screening.

VOICE: Do you find your peat moss to be free of diseases?

MICHAEL SMITH: We do not trace any diseases to the peat moss but we do get weed problems from it. Pearlwort comes from some batches of peat moss — also bittercress. We use less and less peat moss — due to the cost and the labor of screening it. We now substitute for the peat our regular canning mix — aged and sprinkled redwood sawdust plus some dolomite lime.

PRODUCTION OF NATIVE PLANTS IN TISSUE CULTURE

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Abstract. Tissue culture propagation methods were successfully applied to the production of these native woody plants; *Mahonia repens*, *Alnus oregona* [syn. *A. rubra*], and *Populus tremuloides*. Successful initiation of cultures was strongly dependent on the conditon of the donor plant. Multiplication in all three species was achieved on low salt media supplemented with only a cytokinin. *In vitro* rooting treatments were applied to microshoots obtained from multiplying cultures; for *M. repens* shoots, the medium was unsupplemented; for *P. tremuloides* shoots, rooting occurred on a medium supplemented with IAA; and, In *A. oregona*, rooting occurred in the presence of either IAA or IBA. After *in vitro* rooting, plants were routinely established in a conventional nursery environment.

REVIEW OF LITERATURE

Native plants have emerged as desirable alternatives for use in the home landscape and have a major role in the revegetation and reclamation of disturbed sites. In the production of native woody landscape materials, there is much variability in growth rate, form, disease susceptibility, and stress tolerance when individuals arise from heterozygous seeds. *Mahonia repens*, *Alnus oregona*, and *Populus tremuloides* are examples of native plants which are typically seed propagated and such propagation results in a variable plant populations. Modern production systems can be more resource efficient and products more uniform when the genetic background of a crop is limited as a result of vegetative propagation. Macropropagation has been achieved in quaking aspen by the use of root sprouts (1) but has been of limited applicability in the production of *Mahonia* and alder. Superior individuals were recognized in populations of *Mahonia repens* plants based on growth rate and plant habit; a superior selection of quaking aspen was made based on bark coloration and leaf shape, and a superior red alder was selected based on growth rate. Having recognized elite plants from heterozygous seedling populations there was a need to rapidly multiply these superior individuals. This paper describes the experimentation which was undertaken with the goal of developing micropropagation methods for the rapid multiplication and commercial exploitation of these superior native plants. Both *Populus* and *Alnus* spp. had been previously investigated and shoot tip propagation methods had been described (2, 8). These systems were reviewed and used as a basis for the work.

MATERIALS AND METHODS

a) *Mahonia repens*

Cuttings were obtained from greenhouse grown stock plants. Defoliated stems were rinsed under running water for 15-min. followed by a 10-min. soak in 0.5% aqueous sodium hypochlorite supplemented with two drops of detergent per liter. The stems were rinsed 3 times with autoclaved distilled water. Under aseptic conditions, at a laminar flow hood, shoot tips and lateral buds ranging in size from 2 to 4 mm were transferred, 1 per vessel, to 25 ml aliquots of nutrient medium contained in test tubes. The tubes were placed under fluorescent lamps which provided a light intensity of 2,000 lux for 16 hours per day. The culture room was maintained at 26 ± 2°C. Cultures were routinely transferred at 28 to 35 day intervals.

The basal nutrient medium was composed of ½ strength Murashige-Skoog (7) salts except for iron which was added at full strength. The following organic supplements were included in mg per liter; i-inositol, 100; thiamine HCl, 0.4; pyridoxine HCl, 0.5; nicotinic acid, 0.5; glycine, 2.0; sucrose, 30,000; and Sigma™ agar, 7,000. The pH of the medium was adjusted to 5.8 ± 0.02 prior to dispensing into culture vessels and autoclaving at 121° C for 20 min. Explants were initiated onto either basal medium with no growth regulator supplement or onto basal medium plus 0.3 mg per liter benzyladenine (BA). Cytokinin response studies were carried out with successfully initiated cultures by transferring explants from 0.3 BA medium to basal medium alone, or supplemented with 0.1, 0.3, 1, or 3 mg per liter BA. The BA experiment was maintained for 4 culture cycles during which time all shoots produced per vessel were separated and transferred to fresh aliquots of a similar medium. The quality of multiplied shoots was determined by visual inspection.

The effects of activated charcoal addenda (0, 0.03, 0.01, 0.1, and 0.3%) to multiplication medium supplemented with 1.0 mg per liter BA were determined. Multiplying explants were also placed on media supplemented with charcoal at either 0.1 or 0.3% and BA at 10 or 30 mg per liter. In order to induce root formation, shoots from multiplication were transferred to basal media alone or supplemented with indolebutyric acid (IBA) at 1, 3, 10, or 30 mg per liter. The shoots were transferred to soil after 4 weeks *in vitro*. Both rooted and unrooted shoots were transferred to a peat, vermiculite, perlite (1:1:1) mix and maintained under warm humid conditions for 2 to 3 weeks. After 8 weeks in the soil, surviving plants were evaluated in the greenhouse.

(b) *Populus tremuloides*

Explants were obtained from 3 sources: an individual tree planted in a landscape, root sprouts from the specimen tree, and greenhouse grown plants resulting from *in vitro* grown buds. Soft vegetative shoots were collected and, after removal of the leaves, were disinfested by soaking for 15-min. in 10% Clorox under a partial vacuum. The stems were rinsed 3 times with sterile water. Shoot tips and lateral buds were placed onto 25 ml aliquots of medium contained in test tubes. The basal medium was a modified woody plant medium (WPM) described by Lloyd and McCown (5) supplemented with FeNa-DTPA in place of $FeSO_4$ and NaEDTA, 30 g per liter sucrose, 6 g per liter Sigma™ agar and 1 micromolar BA. The pH of the medium was adjusted to 5.75 ± 0.01 prior to autoclaving. Cultures were incubated on lighted shelves (2,000 lux, 16 hour photoperiod) in a room maintained at 25 ± 2°C.

A benzyladenine dose response experiment was undertaken by transferring successfully initiated explants to either basal medium alone or supplemented with 0.3, 1, or 3 mg per liter BA. The experiment was initiated with 10 explants per treatment and maintained during 5 subculture cycles of 4 weeks duration. Explants were multiplied by division of clumps and placed in culture vessels containing aliquots of similar media. In those treatments where multiplication rates were high, samples of 12 vessels were taken for detailed observation at each subculture.

Shoots were removed from multiplying cultures and placed on rooting medium consisting of ½ strength MS salts except nitrates which were at ¼ strength and iron at full strength. The medium was supplemented with MS organics, 7 g per liter Sigma™ agar, 30 g per liter sucrose, and 0.03 mg per liter indoleacetic acid (IAA). The pH was adjusted to 5.75 prior to autoclaving as described previously. Shoots were also rooted directly from multiplication medium under high humidity conditions maintained by a low volume mist system in a controlled environment tented bench maintained at 25 ± 2°C by hot water bottom heat and illuminated with fluorescent lamps at 3,000 lux for 16 hours per day. The microcuttings were stuck into a pasteurized 1:1:1 peat:vermiculite:perlite mix contained in plastic flats. Plants from *in vitro* rooting medium were planted, when 50% of the shoots showed roots, in similar media and maintained under similar conditions. The plants were gradually acclimatized to the open greenhouse by manipulation of relative humidity, temperature, and light intensity in the plant environment.

(c) *Alnus oregona*

Shoot tips and lateral buds were collected from several

greenhouse grown stock plants. Disinfestation was achieved as described for aspen and explants were transferred to aliquots of modified WPM enriched with 1 micro-molar BA. The cultures were incubated in conditions similar to those for aspen and were transferred at 2 to 3 week intervals to fresh aliquots of medium.

In vitro derived shoots from two rapidly multiplying genotypes were transferred to either ½ MS or WPM supplemented with either IBA or IAA at either 1 or 3 mg per liter. Shoots and plantlets were transferred to soil and acclimatized at described for aspen plantlets.

RESULTS

(a) *Mahonia repens*

Shoot tips developed into single shoots after 2 or 3 weeks incubation whereas lateral buds developed over 4 to 6 weeks. BA was not necessary for shoot development in initial cultures but in the absence of BA, shoots exhibited a pronounced yellow or red pigmentation. Such pigmentation was not apparent in the presence of 0.3 mg per liter BA.

The response of acclimated initiates to various levels of BA in the medium is represented in Table 1. During the first subculture cycle all treatments produced new shoots; however, a BA concentration of more than 0.1 mg per liter was necessary for continued multiplication. The mean values for multiplication rate averaged over the four subculture cycles would indicate no difference between the 1 and 3 mg per liter treatments; however, the shoots produced on the higher level were stunted in height and often developed a yellow or reddish pigmentation. The 1 mg per liter BA medium produced shoots which were of the highest quality.

Table 1. Influence of BA concentration, and time in culture, on multiplication rate in *Mahonia repens* shoot cultures.

Cycle Number	BA concentration, mg per liter				
	0	0.1	0.3	1.0	3.0
1	1.8	1.3	1.5	2.1	2.3
2	1.1	1.0	1.2	1.5	1.4
3	1.0	1.0	1.1	1.4	1.4
4	1.0	1.0	1.3	1.5	1.3
Mean	1.2	1.1	1.3	1.6	1.6

On continued culture on a medium supplemented with 1 mg per liter BA explants multiplied but some pigmentation appeared and shoot height began to decrease. In an attempt to improve shoot quality activated charcoal was added to the medium. The results of such additions are presented in Table 2 and clearly show that the addition of activated charcoal

inhibits multiplication. The shoots produced on charcoal media were tall with well developed unpigmented leaves and were regarded as good quality shoots. However, the addition of BA at 10 and 30 mg per liter in combination with charcoal at 0.1 and 0.3% did not overcome the inhibitory effect of charcoal on shoot multiplication.

Table 2. Effect of activated charcoal supplements on multiplication in *Mahonia repens* cultures on medium containing 1 mg per liter BA.

Cycle	Percent Activated Charcoal			
Number	0	0.03	0.1	0.3
1	2.4	0.9	1.1	1.7
2	1.6	1.2	1.0	0.9
3	1.6	1.0	1.2	1.1
4	1.5	1.0	1.0	1.0
Mean	1.7	1.0	1.1	1.2

The results of adding IBA to media in order to stimulate rooting are presented in Table 3 and show that IBA did not affect root formation during a four week period. However, increasing the concentration of IBA in the medium drastically influenced the survival of shoots when they were transplanted to soil and maintained in the greenhouse.

Table 3. Effect of IBA on rooting of *Mahonia repens in vitro*.

IBA Conc.	Number of Shoots Cultured	Number of Shoots Rooted at 4 wks	Number of Plants After Transfer to Soil
0 mg/l	10	5	7
1.0 mg/l	10	4	4
3.0 mg/l	10	5	5
10.0 mg/l	10	5	1
30.0 mg/l	10	5	0

(b) *Populus tremuloides*

The influence of the stock plant on successful initiation was pronounced. Initiation phase is concerned with the establishment of clean cultures which are capable of multiplication. However, explants taken directly from the select tree cultivated in the landscape resulted in 100% contamination in all initiation attempts. The culture of explants derived from shoots produced on root cuttings cultivated in moist vermiculite in the greenhouse also resulted in contaminated cultures. When shoots from bacterially contaminated cultures were established in the greenhouse and explant tissue was taken from resulting vigorous soft growth, aseptic cultures were obtained.

The results of the BA concentration experiment with multiplying cultures which are presented in Table 4, clearly show

that the low level of BA, 0.3 mg per liter, stimulated the highest multiplication rate in aspen shoot cultures. The quality of the shoots in this treatment was also superior to other treatments in terms of shoot height, appearance of leaves, and general overall color.

Table 4. Influence of BA concentration and time in culture on multiplication rate in aspen shoot cultures.

Culture Cycle Number	Concentration of BA, mg per liter			
	0	0.3	1.0	3.0
1	1.0	1.0	1.0	1.0
2	1.1	3.0	1.1	1.2
3	0.9	2.5	1.4	0.6
4	1.0	3.6	2.5	1.0
5	1.2	3.6	2.7	0.8
Mean	1.04	2.74	1.74	0.9

Aspen microshoots were successfully rooted *in vitro* on a medium supplemented with IAA and were also successfully rooted *in vivo* by sticking into a conventional rooting medium under controlled conditions. In wet situations aspen microshoots were subject to rapid leaf loss and did suffer a severe check in growth. However, plants were rapidly established after an *in vitro* rooting treatment and were easily handled by nursery staff once the plant was acclimatized to the greenhouse environment.

(c) *Alnus oregona*

Alder shoot tips and buds were more difficult to establish in culture than the aspen explants. Alder explants exuded substances into the medium and these substances seemed to be detrimental to explant growth and survival. This exudation of substances compounded the problem of establishing clean vigorous explants during the initiation phase. Figure 1 shows the fate of 160 initial alder shoot cultures during 6 months *in vitro*. It can be seen that after 10 weeks only a small fraction of original cultures remained and only after 22 weeks had the cultures multiplied to the point at which the original numbers were exceeded. However, once multiplication was established, numbers of cultures increased very rapidly indeed. The alder cultures were allowed to form clumps and the division and reculture of clumps was the basis for multiplication.

Microshoots were harvested from shoot-producing clumps and these were either rooted directly in soil under greenhouse conditions, or were put into culture for *in vitro* rooting treatment. Table 5 shows the results of a trial involving the rooting of alder microshoots. Considering plant A, the WPM stimulat-

ed a higher incidence of rooting than ½ MS medium in the presence of both IAA and IBA. However, in the case of plant B, the inhibition of rooting due to ½ MS salts was overcome by the presence of 1 mg per liter IAA.

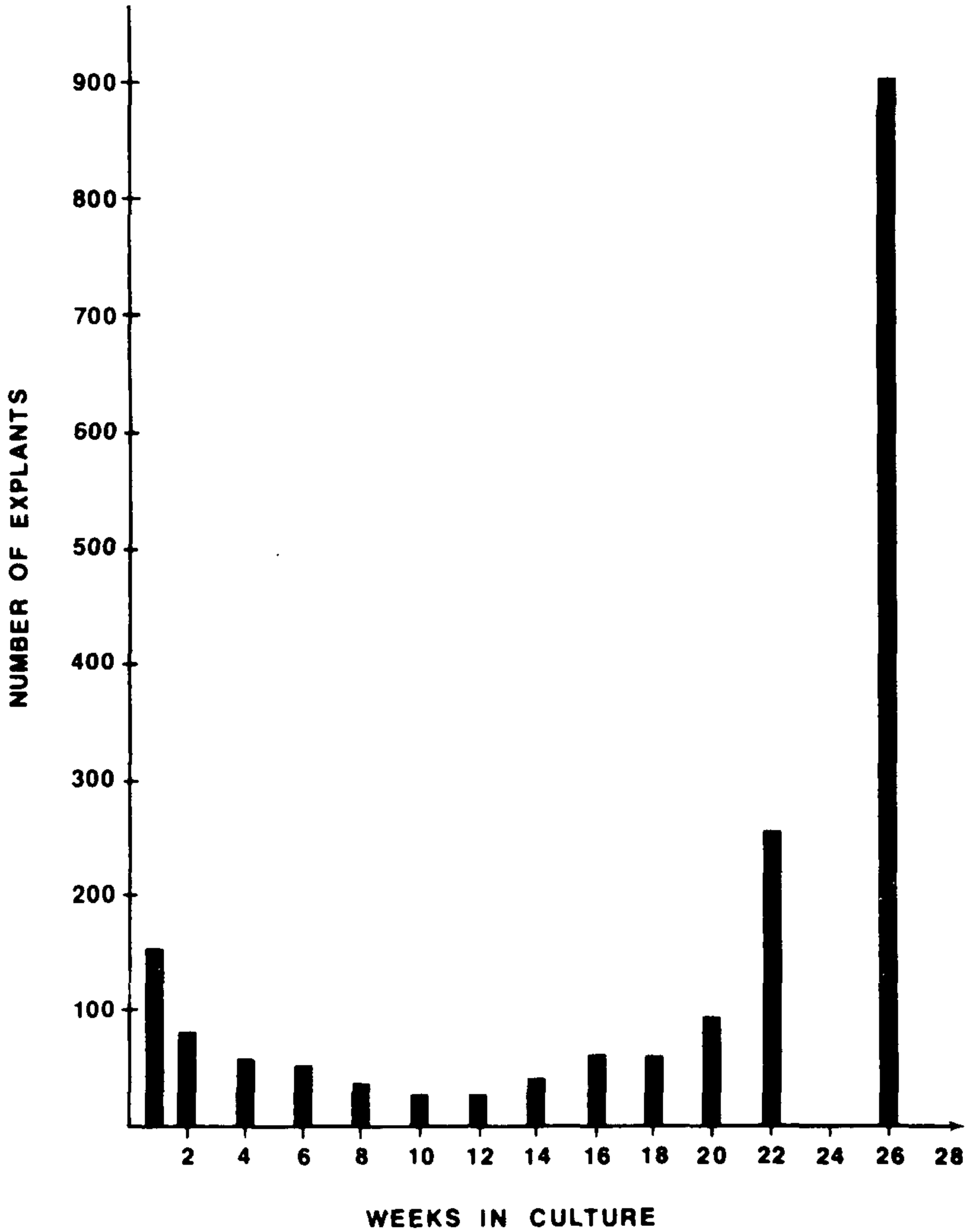

Figure 1. Number of explants vs. time in culture for alder shoot tip and lateral bud cultures.

Greenhouse plants were established from both *in vitro* rooted microshoots and microshoots which had been stuck directly into soil. A higher percent survival was always ob-

tained with *in vitro* rooted plants and such plants required shorter acclimatization periods than did unrooted microshoots. The plant quality was generally superior in plants which had a rooting treatment prior to planting in soil.

Table 5. Effect of basal salt medium and auxin supplements on rooting of alder microshoots from two stock plant sources[1].

	Concentration of IAA, mg per liter		Concentration of IBA, mg per liter	
	1	3	1	3
½ MS Plant A	3	2	3	2
WPM Plant A	9	7	7	9
½ MS Plant B	8	5	6	5
WPM Plant B	9	10	10	8

1 Numbers of microshoots rooted in a sample of 10 from each treatment.

DISCUSSION

The work with the three woody natives resulted in the development of micropropagation systems which were applied to the production of plants for wholesale customers. The observed multiplication rates in *Mahonia repens* cultures were low in comparison to other commercial systems but the alternatives for vegetative propagation of this plant are very limited. In all three species the condition of the stock planted and the presence of new soft, vigorous growth was of paramount importance in establishing not only aseptic cultures but also cultures which maintained themselves during a sometimes protracted acclimation period. Preliminary work involving the initiation of *Mahonia repens* cultures from field-grown material had resulted in either death of explants due to disinfestant damage or contamination of cultures with fungi and bacteria due to incomplete disinfestation. The aspen example serves to illustrate that, if the condition of the original stock plant is not conducive to the establishment of clean cultures, then contaminated shoots, if allowed to grow up as plants in the greenhouse, can produce a stock plant from which clean cultures can be initiated. The aspen tree that was selected as desirable due to its ornamental characteristics was the only tree of its kind from which to begin the propagation program and, therefore, very few alternatives were available other than use of contaminated shoots for the production of new stock plants.

The response of alder initiates to culture *in vitro* serves to illustrate the phenomenon of acclimation which is exhibited when materials are introduced to the *in vitro* environment. This phenomenon has been attributed to a gradual "rejuvenation" of the explant tissues and is typified by almost no multiplication and gradual attrition of initial cultures (4, 6). However, after a 5 month lag period this tissue expressed a rapid

multiplication potential and could be regarded as fully acclimated to the tissue culture system. The lag phase, during which explants slowly adapt to the culture environment, can be a source of concern and is a dramatic contradiction to some of the less informed claims made by inexperienced micropropagators.

In vitro multiplication was achieved in all three species by the addition of only a cytokinin to the multiplication medium. The aspen and alder cultures responded to incubation on a medium containing around 1 micromolar BA whereas the *Mahonia* culture responded to a higher level (approximately 4 micromolar BA) of cytokinin. *Mahonia* cultures were also the least stable during multiplication since these cultures tended to alter in color and form even when cultured on a medium which had previously produced good quality explants. The instability of the *Mahonia* cultures was thought to be due to the presence of autointoxicating substances in the explant since activated charcoal supplements were able to restore shoot quality. However, the presence of charcoal inhibited multiplication probably as a result of adsorption of cytokinin. It is also possible that the instability in these cultures was due to incomplete acclimation.

Shoots which were produced in multiplying cultures were successfully established as plants in the greenhouses either with or without an *in vitro* rooting step. However, under the prevailing conditions, plants which were established after a rooting treatment in culture produced more vigorous plants more rapidly than unrooted shoots under nursery production conditions. The relative merits of the two methods were compared, both horticulturally and economically and the production systems adopted for the three species included the *in vitro* rooting step. The production of roots in *Mahonia* microshoots was unaffected by the level of IBA but subsequent survival of the microshoots was severely prejudiced by an *in vitro* IBA treatment. The effect of IBA on the *Mahonia* microshoots may have functioned to enhance the production of autointoxicants and therefore inhibited future growth, rooting and plant establishment. In alder microshoots there was a strong influence of plant genotype on rooting success and this was particularly apparent if the *in vitro* rooting medium was suboptimal. Such genotypic effects have been noticed previously in the response of plants to *in vitro* culture (3).

The three examples of native plants to which tissue culture methodology was successfully applied serve also to highlight some general principles of commercial micropropagation; i.e. there must be a market for such plants and the market must be willing to bear the added cost of a high technology

propagation system. These added costs can only be justified if the product is competitive with existing alternatives or is superior to existing genotypes in the market place. In the case of aspen the parent plant was superior in landscape value since the tree form and color of bark were selected as outstanding characteristics. In *Mahonia* the limited availability of an alternative vegetatively propagated product made the tissue culture product readily acceptable, and in alder the absence of reliable rapid vegetative propagation systems prompted the use of micropropagation. However, the utility of a particular micropropagation process in an overall commercial enterprise should be carefully evaluated before large investments of resources are committed.

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VOICE: I am interested in the bacterial leaf spot of *Populus*. Is it carried within the tissues of the explants and do your tissue culture techniques give any lasting freedom from this?

STEVE GARTON: I do not think that our techniques would necessarily mean that our plants are disease-free. *Populus tremuloides* in our area is tremendously susceptible to bacterial leaf spot, but our two-year-old tissue-cultured plants seem to be reasonably clean.

STEVE McCULLOCH: *Have you tried meristem culture at* all with quaking aspen?

STEVE GARTON: No, we have not. Meristems are very labor intensive to obtain and they need a considerable time period in culture. For a rapid propagation system we would not want to start with a meristem.

VOICE: Are you propagating for large scale revegetation sites by tissue culture?

STEVE GARTON: No, we are not considering tissue culture at all for revegetation sites, like mines, highways, or pipelines. Such plants would be too costly for those applications. We use tissue culture for perpetuation of selected genotypes for their superior landscape properties. This market, we feel, would carry the added cost of tissue culture propagation.

PROPAGATION OF *STEVIA REBAUDIANA* BY CUTTINGS

JOHN M. FOLLETT

Ruakura Agricultural Research Centre
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Abstract. Three trials were carried out to evaluate the potential of *Stevia rebaudiana* when propagated by cuttings. The effects of cutting collection date, rooting hormone, wounding, position of cutting on parent plant, and length of cutting were compared using a rooting score. October was found to be the optimum time for collecting cuttings, with tip cuttings producing more rooted cuttings than basal cuttings. Wounding was found to improve rooting in tip cuttings but application of high levels of rooting hormone decreased the root score of tip cuttings. The length of cuttings had no effect on the root score.

INTRODUCTION

Stevia rebaudiana Bertoni, a member of the Asteraceae, is a small herbaceous perennial shrub, native to Paraguay, which grows to 80 to 100 cm high.

Stevia is grown primarily for its leaves which contain sweet glucosides. Among these are steviocide, rebaudioside A, and at least six other glucosides. The sweetening power of these glucosides is estimated to be 150 to 300 times that of cane sugar and all are water soluble. Studies at the University of California (7) have shown that the production of stevioside could be equated to the sweetening power of 70 tonnes/ha of sucrose. As a sweetening agent steviocide is non-fermentable and apparently does not encourage mouth bacteria.

Stevia has been used historically as a sweetener in Paraguay and was seriously considered as a sugar substitute in England during World War II (4). At present, it is being grown commercially in Japan (2) and Korea (1). Little is known of the commercial prospects of this crop in New Zealand. As a first step for commercial production there is a need to obtain information on the propagation requirements of this plant. This paper evaluates the propagation of stevia by cuttings.

MATERIALS AND METHODS

Softwood cuttings were collected from one year old plants grown in planter bags in a well ventilated, unheated glasshouse. All cuttings were approximately 20 cm long with at least 5 nodes. The rooting medium for the cuttings was washed silica sand. Watering was by means of an electronic misting system. To prevent fungal attack, the cuttings were alternately sprayed with either Sumisclex (procymidone), Rovral (metalaxyl), or Benlate (benomyl) once every 7 to 10 days. The insecticide, Attack (pirimiphos-methyl and permethrin) and the miticide, Plictran (cyhexatin) were also sprayed when

necessary.

Three trials were carried out:

1. *Cutting type and time of collection.* The first trial was to evaluate the time of the year when the cuttings rooted best and whether single node cuttings near the base of the stem had the same rooting potential as shoot tip cuttings. One collection of 14 cuttings was made each month from spring to late autumn (October through May). Due to winter dieback, no material was available during the winter (June through September). Each of the 20 cm long cuttings was then divided into 4 single node cuttings, i.e., one tip cutting, one upper middle cutting, one lower middle cutting, and a basal cutting.

2. *Hormone application and wounding.* The second trial established on November 2, 1983 was to determine whether hormone application or wounding would improve rooting in stevia cuttings. As in the first trial, cuttings were single node with a record made of their relative position on the parent plant, i.e., tip, upper middle, middle, lower middle, or basal. The cuttings were then prepared by either wounding, applying a rooting hormone, or both. Wounding was carried out by removing a thin slice of stem without cutting too deeply. Three hormone treatments, "Seradix" numbers 1, 2 and 3 were used. These contained 0.1%, 0.3% and 0.8% β-indolebutyric acid active ingredient, respectively. Where cuttings received both wounding and hormone treatment, the wounding was carried out first. There were 5 cutting positions for each treatment. Two wounding treatments, three hormone treatments and a control. There were 8 replicates giving a total of 320 cuttings.

3. *Length of cutting.* The third trial was to determine whether the length of the cutting would affect rooting potential. The treatments were cuttings 10 cm long with 4-6 nodes, cuttings 15 cm long with 6-9 nodes, and cuttings 20 cm long with 9-13 nodes. There were 3 replications with 5 cuttings in each treatment. This trial was established in mid-summer, January 20, 1984.

After 5 to 6 weeks, all cuttings were carefully lifted with a spatula and examined. A general score was then assigned to each cutting on a scale from 0 to 5 summarising the growth, vigour, and general health of the root system. The scoring system was designed to cover the range of rooting potentials of stevia and was standardised by a set of line drawings (Fig. 1). The scoring system was as follows:

0 — No roots initiated.

1 — Poor, few roots, unevenly distributed.

2 — Below average — moderate number of small roots or smaller number of longer roots more evenly distributed.

3 — Average — moderate number of roots of average length. Fairly even distribution of roots around stem.

4 — Above average — plentiful number of roots of good length with an even distribution of roots around the stem.

5 — Excellent — abundant long roots, excellent distribution around stem.

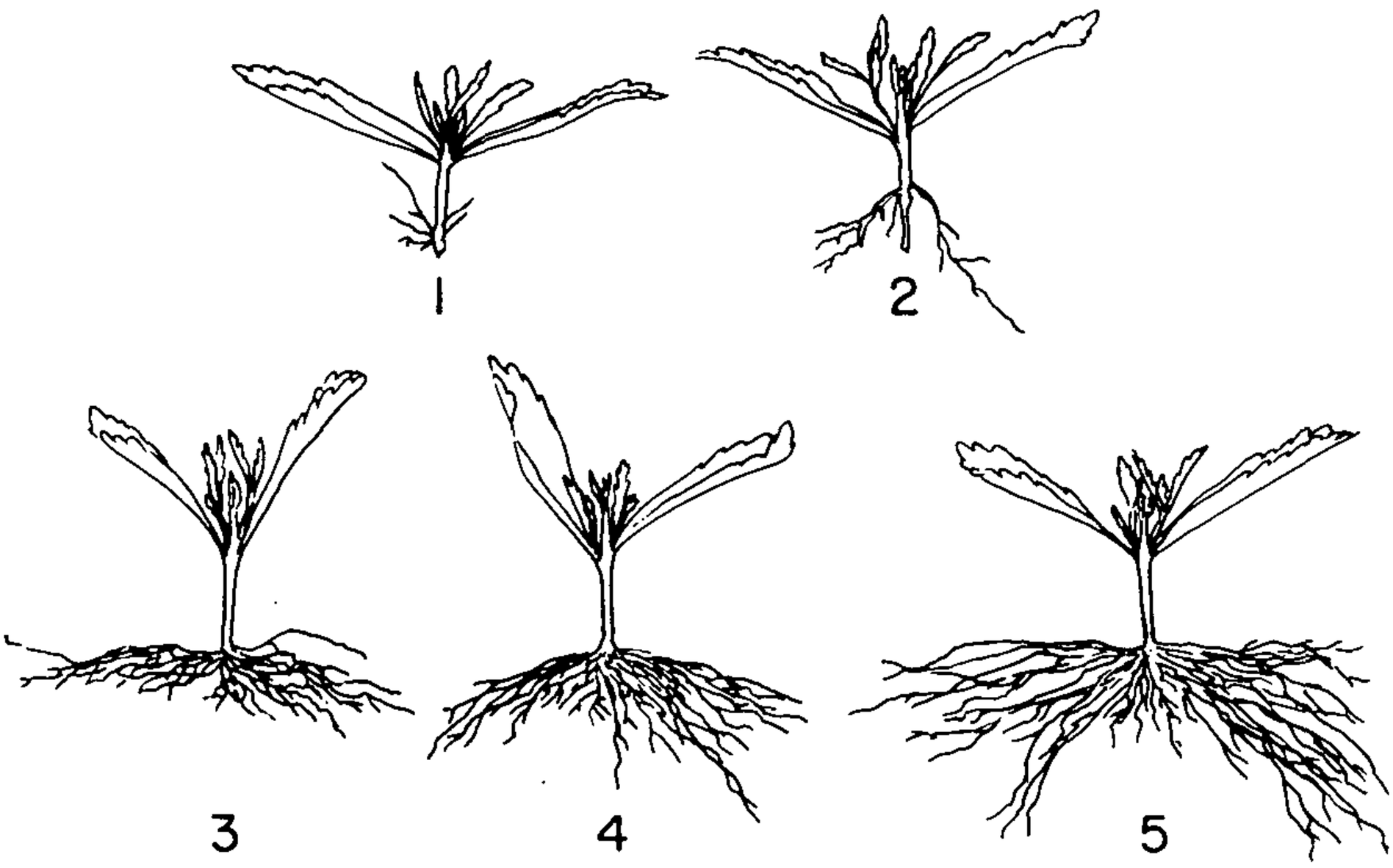

Figure 1. Drawings used as standards for awarding root scores to *Stevia rebaudiana* cuttings.

RESULTS

The highest mean root score was obtained from cuttings collected in October (see Table 1). All cuttings collected in March, April, and May failed to root, this period being associated with flower development. Flower buds were first observed on cuttings collected in March.

For all cutting dates, tip cuttings had the highest root scores (see Table 1). This was followed by cuttings from the upper middle stem, the lower middle stem, with basal cuttings having the lowest root score.

In the second cutting trial, wounding had no effect except on tip cuttings where wounding increased root score (Table 2).

Table 1. Effect of cutting collection date and cutting position on rooting score.

Month	Tip Cutting	Upper Middle Cutting	Lower Basal Cutting	Basal Cutting	Mean
July	*	*	*	*	
Aug.	*	*	*	*	
Sept.	*	*	*	*	
Oct.	3.14	1.86	0.50	0.36	1.46
Nov.	2.50	0.71	0.21	0.14	0.89
Dec.	3.50	0.29	0.07	0.00	0.96
Jan.	1.64	0.21	0.50	0.00	0.59
Feb.	0.93	0.29	0.36	0.07	0.41
Mar.	0	0	0	0	0
Apr.	0	0	0	0	0
May	0	0	0	0	0
June	*	*	*	*	
Mean	2.34	0.67	0.33	0.11	

* No cuttings collected.

Table 2. Effect of cutting position and wounding on root score.

Cutting Position	No Wounding	Wounding
Tip	1.4	2.1
Upper middle	1.3	1.4
Middle	0.8	0.6
Lower middle	0.3	0.3
Basal	0.3	0.3
SED	0.14	

Using β-indolebutyric acid in two concentrations (0.3% and 0.8%) decreased the root score of tip cuttings while there is a suggestion that for other cuttings the effect of applying hormone increased the root score (Table 3). There was no significant interaction between hormone application and wounding.

The third trial to evaluate the effect of cutting length on root score demonstrated no differences among cutting lengths (Table 4).

Table 3. Effect of cutting position and hormone concentration on root score.

	Indolebutyric acid concentration			
Cutting Position	0	0.1%	0.3%	0.8%
Tip	2.3	2.2	1.8	0.9
Upper middle	1.1	1.3	1.8	1.3
Middle	0.5	0.8	0.9	0.7
Lower middle	0	0.3	0.8	0.4
Basal	0.1	0.3	0.2	0.6
SED	0.2			

Table 4. Effect of cutting length on root score.

Cutting Length	10 cm	15 cm	20 cm
Root Score	2.5	2.8	2.6
SED	0.5		

DISCUSSION

To obtain optimum rooting of stevia cuttings only those with a terminal bud should be used, collected early in the season from new growth produced after winter dieback (see Tables 1, 2, 3). It appears that the terminal bud is essential in promoting healthy root growth.

It is well known that auxins are produced in the terminal bud of a plant and that they are essential for root development (6). This is supported by this work which has demonstrated that in the absence of a terminal bud rooting can be improved by the application of β-indolebutyric acid. However, even with the application of this hormone, the rooting of cuttings without a terminal bud was still inferior in rooting potential to those with the terminal bud, suggesting the need for other root forming compounds besides auxin to be present.

The application of high levels of hormone (0.3 and 0.8% indolebutyric acid) to cuttings with a terminal bud had a deleterious effect on the root score suggesting that additional hormone may have a toxic effect on root development when the presence of naturally occurring hormones and root prompting factors is adequate.

There was no root initiation from stevia cuttings when the parent plant was in a state of strong floral induction. As flowering is also a plant process that requires a considerable resource in terms of carbohydrate, nutrients, and plant hormones, including auxins (6), competition for these resources may occur with flower development being promoted at the expense of root development.

Wounding generally had no effect on root scores except for tip cuttings. Wounding is carried out to either increase the uptake of water (3); or promote wounded cells to produce root primordia (8), encourage the natural accumulation of carbohydrates and hormones in the wounded area, or increase the respiration rate which may aid root production (5). It is, however, difficult to determine why one of these factors should be operating on tip cuttings and not on cuttings collected from further down the stem.

It has been widely reported that the presence of leaves on cuttings exerts a strong stimulating influence on root initation (5) with more leaves supplying more carbohydrate to aid root

initiation and development. This appears not to be a major factor in rooting stevia cuttings with additional stem length and therefore leaf area having no effect on the root score.

For the purpose of bulking up large numbers of plants, single node tip cuttings collected before flower initiation should be used.

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PERSIMMON PROPAGATION: RESEARCH HIGHLIGHTS FROM RUAKURA

JENNY C. SMITH, DAVID J. JORDAN, and FRANK H. WOOD

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The recent upsurge of interest in persimmons *(Diospyrus kaki)*, particularly the non-astringent or "sweet" persimmons, has resulted in an increased demand for plants. Persimmon plantings have increased from 3,000 trees (about 4 ha) in 1981 to 200,000 trees (350 to 400 ha) in 1984 (2). Size of commercial plantings range from small units of 0.5 ha to areas of 10 to 15 ha. In 1985 a further 60,000 trees were planted (2).

Demand for plants of preferred cultivars has far exceeded supply and this situation is likely to continue for at least the next 2 to 3 years. Consequently, plant prices will remain high — presently, grafted plants sell for $NZ10-15. Persimmon rootstocks sell for $NZ3-5.

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At conventional plant spacing of 5 × 5 metres, 400 trees per hectare are required. Consequently, for orchard establishment plant cost alone is up to $NZ5,000. With inflated land values, high establishment costs, and high debt servicing costs there is increasing pressure for intending persimmon growers to implement systems for maximising early production and returns. Closer plant spacings, particularly within a row, are becoming more popular so plant costs of $NZ8,000 to 10,000 are common.

Persimmon propagation research at Ruakura Soil and Plant Station began in 1982. Our initial involvement was stimulated by the need to quickly produce plants of non-astringent cultivars for management trials at other MAF research stations in the Northern Region. Plants were not readily available commercially, scion wood was in limited supply, and grafting success was reported to be very unreliable for persimmon.

Preliminary results were sufficiently encouraging for us to carry out a systematic evaluation of our grafting options for the next season. Our objectives were to:

1. Maximise possible plant numbers from limited scion material.
2. Standardise a procedure which would provide consistent grafting success

In meeting these objectives we considered:

1. Graft-timing and conditions
2. Summer green-grafting
3. Field grafting
4. Propagation of rootstocks

ROOTSTOCKS

Seedling *Diospyrus kaki* rootstocks were used for all grafts. These were grown from imported Japanese seed, which was sown directly, without stratification. Locally collected seed requires stratification and should be stored in a moist environment at 0 to 4°C for 60 to 90 days (1).

SPRING GRAFTING UNDER GLASS

Reports of variable grafting success had been interpreted in some industry circles to reflect the time grafts were made. To investigate this aspect we grafted seedling rootstocks in the glasshouse at monthly intervals from spring through autumn (September to April).

For spring grafts, one-year-old potted rootstocks were forced into early growth in a glasshouse prior to grafting.

Stored scions of 'Tauranga Fuyu', collected in late July, were grafted when the first leaves on the stocks were well-formed. Simple cleft-grafts were made with one or two-bud scions; two bud scions were most successful when wood was less than 1 cm diameter. The exposed scion end was covered with a smear of pruning paste, the union taped and covered with a plastic bag to maintain a humid environment. Under warm conditions (22 to 25°C), callus around the graft union formed quickly and bud burst occurred within 14 days of grafting. The plastic bag was loosened and later removed to gradually acclimate the new grafts. Under these conditions grafting of 'Fuyu' (Tauranga Hospital clone), was almost 100% successful from September through to February using stored scions.

SUMMER GREEN-GRAFTING

In the previous year we had found that it was possible to propagate from current season's growth. The reliability of this method and conditions required to achieve success were examined more precisely.

The spring-grafted plants remained in the glasshouse until early summer (November) to promote shoot growth and were then transferred to a shadehouse. By late summer (January) the new shoots had reached an average length of 55 cm (10 to 16 buds). Growth then slowed and the wood matured. By this time, each spring-grafted plant had produced at least 30 buds considered suitable scion material for green-grafting.

Selected shoots were cut from the spring-grafted plants, leaving two buds to continue growth. Shoots with and without leaves were wrapped in damp newspaper and stored for 7 to 10 days at 4°C to slow wood respiration rate.

Deleafing green-wood scions prior to cool storate was not necessary; however, if cool store space is limited, deleafed scions occupy less space.

On removal from cool storage, two-bud scions were prepared for grafting using the same procedure as for spring-grafted plants — a simple cleft-graft. Grafted plants were left in a glasshouse for five days to promote callus formation, then were moved to a shadehouse.

Although 100% "take" was achieved for green-grafted 'Tauranga Fuyu' in February, March, and April (compared with 90%, 50%, and 60%, respectively, for dormant conserved scions grafted at the same time), bud movment of green-grafted scions was much slower and more uneven than dormant conserved scions (Figure 1). In April, all plants were successfully grafted — these callused well, and the plants became dormant, with bud break occurring the following spring.

Green-wood scions collected in January, surplus to our needs, were grafted after 7 weeks' cool-storage and still gave a 60% successful take.

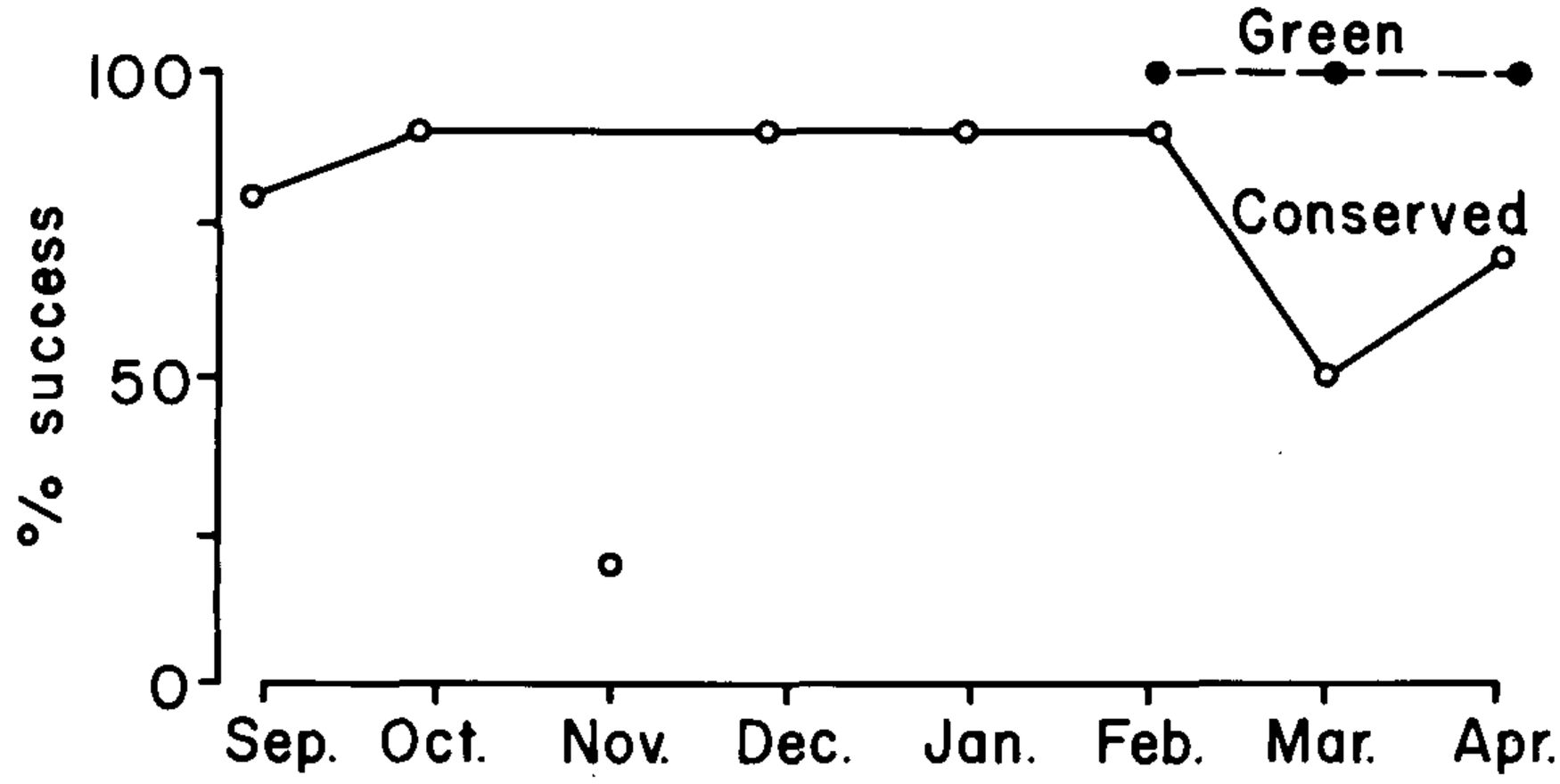

Figure 1. Grafting success of conserved and green scionwood of 'Fuyu' for 1984 season.

A sharp blade and clean cuts are important for grafting current season's growth. Any crushing action will quickly reduce the success rate.

Using this method of forcing spring-grafted container-grown plants and using this early growth for summer green-grafts, it is possible to produce, in one season, enough trees to plant one hectare (5 × 5m plant spacing), from an initial purchase of only 8 to 10 mother plants. This means that almost half the total cost of buying in grafted plants could easily be achieved:

10	mother plants @ $12 each purchased in winter	$120
640	rootstocks @ $4 each "	$2,560
=	100 grafts in spring (assume 90% "take)	
=	force growth for summer green-grafts	
=	assume 12 buds from each suitable for green-grafting	
=	424 plants assuming 60% success rate	
	TOTAL COST:	$2,680

There is potential for even greater savings if growers are able to raise their own rootstocks!

FIELD-GRAFTING

Shelter and irrigation are essential requirements for field-grafting, which should be carried out in late spring when the weather becomes warm. We grafted field-grown stocks on four

occasions at monthly intervals from spring to late summer (October through January). As temperatures increased, success rates for field-grafting increased from 40% in October to 70% in November. We achieved best results for field-grafting in November and December.

Using similar techniques, two Hamilton growers achieved high success rates with field-grafting. One successfully field-grafted in October last year. Another grafted in November two-year-old rootstocks individually sheltered and irrigated, which were about two metres high after one year's growth in the field. Consequently, smaller branches often had to be selected for grafting, rather than the central leader. Grafting continued through to early January using a hand-held grafting device to make a cleft graft. Here it was also found that callusing was much slower and bud break more uneven than for equivalent grafts in a glasshouse. Often, it took a month or longer before bud movement was evident.

Heading back these large field-grown stocks was delayed until the new graft had shoots about 10 cm long. It was considered that the high root pressure from larger stocks would have had deleterious effects on the graft union if they had been headed back at bud burst.

PROPAGATION OF ROOTSTOCKS

Further cost savings are possible if clonal propagation of rootstocks could be achieved. From our work at this stage *D. lotus* softwood cuttings root readily, and results from *D. kaki* are promising. Our interest in clonal rootstocks has been stimulated by recognition of the advantages which could be inferred from an "elite" selection. Between-plant variability would be reduced, and specific characteristics, such as low vigour, selected for and developed. Low vigor or dwarfing stocks could, for example, be used for high density plantings to advantage.

It may be possible to minimize calyx dehiscence or green blotch through rootstock effects.

We anticipate further advances in this area and our propagation programme emphasis has shifted accordingly.

FUTURE DIRECTION

We believe that we do now have the tools to produce plants and produce them quickly. The persimmon industry is at a very early stage of development and there still remains an opportunity to capitalise on improved plant material if it can be identified. There are many clones of 'Fuyu' cultivar being planted and we are trying to type and compare the relative

merits of these as fast as possible. In the meantime everyone in the industry could participate by observing individual tree performance, measuring key parameters which describe vigour, season, yield, quality, and reporting outstanding performers.

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PROPAGATION OF TWO KINDS OF SOUTH AFRICAN BULBS

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Bulb reproduction has mainly been carried out by offsets, seed, and by some vegetative means such as the scooping of hyacinths, the single scales of lilies, and the twin scaling of hippeastrums and daffodils.

Two South African bulbs worthy of a place in most gardens are the lachenalias and nerines.

Lachenalia is a genus comprising over sixty recorded species and is in the Family Liliaceae. It is multiplied by offsets, a means in which it is quite generous. Seed provides an opportunity for plant breeders, as the need for new clones does not appear to have been met in recent times. The current favourite New Zealand hybrid is *L.* 'Pearsonii,' raised in 1922 by Aldridge, curator of Parks and Reserves, Auckland, by crossing *L. bulbiferum* [syn *L. pendula*] with *L. aloides* 'Nelsonii' as seed parent, which was the result of crossing *L. aloides* 'Luteola' and *L. aloides* 'Aurea' in 1882 by Rev. Nelson. It is difficult to find hybrids in commercial trade lists.

A large gene bank of species along with such a range of colours as light blue, sky blue, blue, purple, red, greens, yellows, tricolour and quadricolour, a scent worth enhancing, some attractive spotted foliage, and the ease of growing the black shiny seed, should help the opportunity to become a reality.

Vegetatively propagated bulbils can be produced by leaf cuttings. This is carried out at flowering time when the leaves are firm. They are removed as close as possible to the bulb. A

merits of these as fast as possible. In the meantime everyone in the industry could participate by observing individual tree performance, measuring key parameters which describe vigour, season, yield, quality, and reporting outstanding performers.

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PROPAGATION OF TWO KINDS OF SOUTH AFRICAN BULBS

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Bulb reproduction has mainly been carried out by offsets, seed, and by some vegetative means such as the scooping of hyacinths, the single scales of lilies, and the twin scaling of hippeastrums and daffodils.

Two South African bulbs worthy of a place in most gardens are the lachenalias and nerines.

Lachenalia is a genus comprising over sixty recorded species and is in the Family Liliaceae. It is multiplied by offsets, a means in which it is quite generous. Seed provides an opportunity for plant breeders, as the need for new clones does not appear to have been met in recent times. The current favourite New Zealand hybrid is *L.* 'Pearsonii,' raised in 1922 by Aldridge, curator of Parks and Reserves, Auckland, by crossing *L. bulbiferum* [syn *L. pendula*] with *L. aloides* 'Nelsonii' as seed parent, which was the result of crossing *L. aloides* 'Luteola' and *L. aloides* 'Aurea' in 1882 by Rev. Nelson. It is difficult to find hybrids in commercial trade lists.

A large gene bank of species along with such a range of colours as light blue, sky blue, blue, purple, red, greens, yellows, tricolour and quadricolour, a scent worth enhancing, some attractive spotted foliage, and the ease of growing the black shiny seed, should help the opportunity to become a reality.

Vegetatively propagated bulbils can be produced by leaf cuttings. This is carried out at flowering time when the leaves are firm. They are removed as close as possible to the bulb. A

cut is put from the centre leaf base upwards to about 6 cms. The bulbils form on the cut edges after being in a propagating medium.

Incision, another means of producing bulbils, is to take a bulb during summer and from the base remove a slither of flesh about 1 cm. wide and 1 cm. deep to almost the diameter of the bulb; then repeat this from the opposite direction to form a cross. Bulbils will form on the exposed cuts after being placed on a cool shelf. Plant the bulbils, about the size of a pea, at the usual planting time the next summer. Tissue culture would not be economical unless a new clone of considerable worth is produced.

Nerine is a genus of more than 40 known species in the Family Amaryllidaceae. Reproducing nerines from offsets is not particularly bountiful — some five or six flowering bulbs each three years is used to continue named clones.

Seed propagation holds great promise still. Species are acceptable as garden plants, and modern hybrids advance for the better. It is a great method of gaining numbers, the resultant varied expressions of hybrid crosses being most satisfactory, particularly the ones with extra chromosones. Chromosome increase is illustrated with the accompanying improvements, by the pedigree of the first recorded tetraploid. The haploid count is eleven.

Basic cross — *Nerine bowdenii* (22) × *N. curvifolia* var. *fothergilli* (24)
result — N. 'Aurora' (33)
2nd cross — N. *flexuosa* alba (22) × N. 'Aurora' (33)
result — N. 'Alice' (36)
3rd cross — N. 'Lady Foster' × N. 'Alice'
result — N. 'Inchmere Kate' (44).

(Geneticists suggest 'Alice' in fact, must have been selfed to get the tetraploid result). N. 'Aurora' is much larger than the parents. N. 'Alice' was superior in appearance to most nerines, then N. 'Inchmere Kate', the welcomed genotype. This advance was produced in Exbury, and we in New Zealand were fortunate to have obtained many of their better nerines in order to produce the better hybrids we now have.

The manipulative vegetative propagation of nerines is twin scaling. The method is to take a mature bulb, remove papery skins, the neck, and the roots. Cut the bulb vertically in half and repeat until you have eight fractions. From a fraction you remove the two outer scales down to the base, which is cut with enough base to hold the scales together. Repeat until the fraction is divided up into twin scales. If large quantities are made, they would best be benched at about

2,000 to a square meter, otherwise boxed. The medium of choice may be sand, pumice, or some open mixture. The bulbils should show at about 8 weeks. Later a single leaf will appear before the bulbil itself roots. From then on the bulbils will accelerate in size to planting out stage some 10 months later.

Another method is planting the fractional scales as they are, or dividing them into two. If you so desire, at a time the bulbils have formed, you can remove them with some scale attached, and plant. The remaining scale is re-inserted in the medium.

Care in the culture is necessary, particularly cleanliness, such as dipping the scales in a systemic fungicide for about 10 seconds, then allowing to dry before planting. Also keep the utensils absolutely clean — we use a bleach. An essential matter is to never use any bulb that appears dwarfed, distorted, or discoloured, or has any viral suspicion whatsoever. So with maximum care and culture you should, in the minimum time, produce more flowering bulbs.

Tissue culture now appears to have a place with nerines, especially good clones in short supply. The nerine cut flower trade appears to be accelerating, and the need for numbers is a long way off from being satisfied.

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IN VITRO CULTURE OF MATURE COMMERCIAL *PISTACIA VERA* L. CULTIVARS

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INTRODUCTION

The *in vitro* micropropagation of *Pistacia* species (1) and commercial *Pistacia vera* cultivars from nodal segments taken from seedlings up to 2 years of age (3) has been previously reported. This paper presents results of a study which examined the *in vitro* culture of *Pistacia vera* cultivars from mature tissue.

MATERIALS AND METHODS

The mature *P. vera* cultivars included in this study were: 'Kerman' (female), 'Peters' (male), 'Lambertin' (male and female), 'NAZ' (male), 'Red Aleppo' (male), 'ASK' (male), and 'Rashti' (male). Nodal axillary/apical bud segments or meristem tips (containing 2 to 3 leaf primordia) taken from mature, fruitbearing trees, were cultured *in vitro*. Sterilization, medium preparation, and incubation conditions were as reported previously (2).

The following combination of treatments was used to establish mature explants in culture:

(a). Pre-soak of explants prior to culture for 0, 10, and 20 min in 100 mg/l malonic acid (MA), with or without the same treatment between each subsequent subculture. Alternatively, MA was supplemented to the medium at 0, 50, and 100 mg/l in combination with the pre-soak treatments;

(b). Murashige and Skoog (MS) or Woody Plant Medium (WPM), supplemented either with 0.3 mg/l 6-benzylaminopurine (BAP) plus 0.05 mg/l indolebutyric acid (IBA), or with 2 mg/l BAP;

(c). Removal or reduction of ferrous sulphate to one-half concentration in the MS medium;

(d). The concentration of agar was increased from 7 g/l to either 10 or 14 g/l in the MS medium;

(e). Attempts were made to select rapid, vigorously growing material for cultures or, alternatively, to rejuvenate the mature mother plants prior to selecting material for culture by: (i) severe pruning; (ii) applying a foliage spray of either 500

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mg/l gibberellic acid (GA3) or 200 mg/l BAP; (iii) repeatedly grafting mature scion material onto a vigorous juvenile rootstock *(P. vera)*; (iv). *in vitro* micrografting of a mature scion meristem tip (containing only a few leaf primordia) onto a juvenile *P. vera* rootstock.

RESULTS

Unless specified the results are only for the 'Kerman' cultivar.

Establishment of nodal segment explants in culture was very difficult due to severe browning and high contamination. Meristem tip explants dissected after the standard sterilization had very little contamination and transfer of explants in the same jar once the browning was apparent improved the establishment of cultures in all cultivars.

Pre-soak of the explants in MA for up to 20 min and the presence of MA in the medium at 50 mg/l delayed browning only marginally. From the earlier tests no difference was noted between the performance of explants in either WPM or MS medium, so the latter was used throughout this study. Browning of explants and medium was more severe on MS medium at 2.0 mg/l BAP than the medium supplemented was 0.3 mg/l BAP, with or without 0.5 mg/l IBA. Browning was almost eliminated when ferrous sulphate was excluded. However, it was included in the medium for later subcultures to prevent the development of iron deficiency; browning was not severe at these later stages. Increased concentration of agar was inhibitory to the growth of the explants.

Pruning, grafting, BAP and GA_3 spray treatments [(i) to (iii) above] stimulated new growth of shoots on the mature plants and these shoots appeared to be more suitable for culture. However, plants which had been sprayed with GA_3 produced material which subsequently showed poor establishment in culture. Gibberellic acid supplements added to the culture medium was previously reported not to be beneficial to growth of seedling material explants in culture (2). *In vitro* micrografting [(iv) above] was tried in an attempt to obtain results from the repeated grafting approach at a shorter time period. *In vitro* micrografting of mature scion material onto a juvenile rootstock was carried out on an MS medium containing 0.3 mg/l BAP and 0.05 mg/l IBA. Most of the failures in the micrografting were due to desiccation of the scion explant, its small size, or its poor contact at the cambium region with the rootstock. Placing the scion explant on a flat cut surface of the rootstock resulted in a greater number of successful grafts than insertion of the scion in a vertical cut made on the decapitated rootstock

shoot. Although a successful method for micrografting of *P. vera* was established, the growth of the scion was very slow and application of GA_3 to the medium did not stimulate elongation of the grafted scion. A good callus was made at the union point of the scion and rootstock, but the vascular connection between the two was not invested. The mature scion on a successful micrograft could be cut off from the rootstock and cultured independently and such material had very good subsequent growth and establishment in culture. Only one generation of *in vitro* micrografting has been completed to date.

When shoots from mature explants were treated with MA, or when rejuvenation of the mature plant had been attempted using severe pruning, GA_3 spraying or repeated grafting, and where there were a number of frequent subcultures at an early stage of incubation in the presence of 0.3 mg/l BAP, there were some cultures which produced multiple shoots. Most of the explants producing multiple shoots became vitrified and the subsequent growth of individual shoots was reduced.

DISCUSSION

This study has shown that results obtained from procedures used successfully with seedling material can be usefully adapted to the establishment of mature material *in vitro*. However, at maturation the physiological and biochemical status of a plant appears to change, so that a mature explant does not respond in the same way as a seedling explant to the various treatments. Culture establishment was improved in this study through treatments that conditioned the mother plant, although none of the treatments produced rejuvenation. The results indicate that more improvement can be anticipated from further conditioning and possible rejuvenation of mother plants. Repeated grafting will need to go through a number of generations before its effectiveness can be assessed.

Acknowledgement - Assistance and help of Dr. A. Martinelli in this study is acknowledged.

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IN VITRO MICROPROPAGATION OF *PISTACIA* ROOTSTOCKS

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INTRODUCTION

Pistachio nuts have been planted in the Middle East for a very long time and are gaining more and more popularity in the world. *Pistacia vera* L. is the only species in this genus which produces commercially acceptable large edible nuts. Most of the other *Pistacia* species are used as rootstocks for *P. vera*. Among the important factors limiting the expansion of pistachio plantations based on superior selected lines, is the difficulty of propagation as they are only propagated by the relatively slow method of budding scions to rootstock. *In vitro* mass clonal micropropagation of *Pistacia* has been reported before (1), and this paper presents further work on *Pistacia* rootstocks.

MATERIALS AND METHODS

Seeds of *P. vera* L., *P. mutica* Fisch. & C.A. Mey., *P. khinjuk* Stocks., *P. atlantica* Desf. and *P. palaestina* Boiss. were either germinated aseptically or germinated in vermiculite and grown in plant pots for up to 2 years. The experimental explants were collected as needed. Growing conditions in the glasshouse, sterilization treatments, media preparation, in *in vitro* incubation conditions were as reported by Barghchi and Alderson (2). Murashige and Skoog (MS) medium containing 4 mg/l 6-benzylaminopurine (BAP) was used as standard medium unless specified otherwise. The factors studied were: (a) size of explant; (b) incubation temperature of 20 and 25°C; (c) prewashing of explants in distilled water prior to culture; (d) p. *mutica* and *P. khinjuk* were cultured in MS medium containing naphthaleneacetic acid (NAA) at 0.0, 0.2, 0.5, 1.0, 2.0, and 5.0 mg/l; kinetin at 0.0, 0.2, 0.5, 1.0, 2.0, and 5.0 mg/l in addition to the standard medium; (e) different concentrations of macronutrients (full, ½, and ⅓); (f) initial incubation of some cultures in the dark for up to 4 weeks.

There was a minimum of 10 replicate cultures for each treatment.

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RESULTS

Apical dominance was much stronger in the 1-year-old *P. vera* explants than in the seedling explants and apical buds of 1-year-old plants had better extension growth than axillary buds — (average shoot length 18 and 5 mm, respectively). After a few subcultures there was no difference between the two explants. Removal of the apical bud in the first culture encouraged more axillary buds to develop into shoots. The production of callus or shoots did not appear to be related to explant size. However, explants with three axillary buds showed a slight increase in shoot growth over those with two or one bud (average shoot numbers were 6.77, 5.50, or 4.15, respectively). Shoot growth and proliferation was not affected by pre-washing the explants in water for up to 60 min prior to culture.

Cultures produced more callus at 20° than 25°C, the fresh weight values per culture being 0.623 and 0.310 g, respectively. The lower temperature did not affect number of shoots or shoot growth, but leaves were curled and abnormally thick at 20°C. In general, 25°C was a better incubation temperature.

The use of different concentrations of macronutrients did not produce any beneficial effects; the total shoot length per culture averaged 32.7, 18.6 and 16.5 mm and number of shoots produced averaged 5.30, 6.80 and 3.50, respectively, in full, one-half, and one-third strength macronutrient concentrations.

Apical and axillary buds of *P. mutica* and *p. khinjuk* seedlings produced good shoot growth in the presence of 0.2 to 0.5 mg/l kinetin and NAA. Initial incubation of explants in the dark for 7 to 10 days on a medium containing 0.2 mg/l kinetin and NAA produced plants, complete with roots, within 4 to 6 weeks (Table 1). These plants could be readily established in soil. Cultures on this medium could be stored under the same cultural conditions for a year without any subculture. These two species had best shoot growth and proliferation on MS medium containing 4.0 mg/l BAP (Table 2). However, shoot tip necrosis was common in some shoots when they became greater than 15 mm in length.

Table 1. Comparison of shoot and root growth of seedling explants of *Pistacia mutica* and *P. khinjuk* cultures on MS medium containing 0.2 mg/l kinetin + 0.2 mg/l NAA. (15 cultures per treatment).

Species	Root no.	Total root length (mm)	Shoot no.	Total shoot length (mm)
Pistacia mutica	0.29	2.1	1.14	5.7
P. khinjuk	3.43	17.7	1.00	6.4

Explants from 2-year-old plants had poor establishment in

culture due to severe browning and high levels of phenolics.

Transfer of cultured explants, within the same jar, once the browning of the medium was apparent, improved *in vitro* establishment (*P. atlantica* = 80%, *P. khinjuk* = 60%, *P. mutica* = 80%, and *P. palaestina* = 50%). Axillary bud explants had much lower establishment than apical bud explants in culture.

Table 2. Shoot growth of seedling explants of *Pistacia mutica* and *P. khinjuk* on MS medium supplemented with 4.0 mg/l BAP. (30 cultures per treatment).

Species	Shoot number per culture	Total shoot length per culture	No. of shoots with tip necrosis per culture
Pistacia mutica	3.84	47.3	2.16
P. khinjuk	1.82	22.4	1.50

DISCUSSION

Apical bud explants had better growth and were usually 3 to 5 times larger than axillary bud explants in *in vitro* culture. The basipetal movement of auxin produced on the mother plant and its accumulation in the lower buds, may be responsible for this growth inhibition. Successive subcultures on a medium which prevented apical dominance led to the growth of shoots which were more uniform in size.

The explants with only one axillary bud produced more shoots per bud than those explants with three axillary buds. However, the increased time required for the cutting and preparation of single-bud explants, the further exposure of these explants to desiccation, and the increased oxidation of phenolics at the cut surface, may reduce this small advantage.

The absence of any significant effect of pre-washing suggests that there was no significant leaching of substances from the explant within the time period examined (60 min).

Dilution of macronutrients in MS medium has improved growth in some plants; however, reduced concentration of nutrients can be beneficial to growth only if sufficient nutrients are available. From this study it would appear that a lower macronutrient concentraiton is not beneficial for the shoot growth of *P. vera*. Barghchi and Alderson (1,2) reported that a reduction of macronutrients to half following the shoot proliferation stage improved subsequent root development. This indicates that different stages of growth may have different nutrient requirements.

P. mutica and *P. khinjuk* produced most shoots in MS medium which contained 4.0 mg/l BAP. This medium was optimum for shoot growth and shoot proliferation with *P. vera* and with the commercial cultivars of pistachio also (1,3). In

these previous studies shoot growth improved after a number of further subcultures in the same medium, and it is anticipated that *P. mutica* and *P. khinjuk* would have further improvement after further subcultures.

A practical solution to overcome shoot tip necrosis was to subculture more frequently, which is costly and time-consuming. Shoot tip necrosis is common in suboptimum growth conditions in the *in vitro* culture of many woody plants, and is under further study at the moment.

Shoots cultured on a medium containing kinetin and NAA had a lower shoot growth than those cultured on a medium containing 4 mg/l BAP. The medium with 0.2 mg/l of kinetin and NAA at a lower incubation temperature may be useful for even longer storage of cultured material.

The accumulation of phenolics and other growth inhibitors may occur in plants due to aging and maturation. Rejuvenation of parent material in black locust (*Robinia pseudocacia* L.) improved the establishment and growth of cultures *in vitro* (Barghchi, unpublished). Although two-year-old plants of *Pistacia* were not mature, they had grown through certain stages of aging and maturation; treatments which change the physiological and biochemical state of the explants to a more juvenile form would be expected to improve the establishment and growth *in vitro*. Treatments applied to mature plants of pistachio cultivars to rejuvenate them or to achieve a more active and vigorous growth improve the *in vitro* establishment of explants (4).

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CUTTING PROPAGATION OF RHODODENDRONS

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There are several different methods used in the production of rhododendrons, but each propagator has his own particular method. Ted Van Veen in Oregon, U.S.A. is right when he says "rhododendron propagation conceals many mysteries — most successful one year and poor performance the next. The mysterious something has yet to be discovered in order to produce dependably successful rooting."

This genus is one of the most complex of plant life, with literally hundreds of different species and thousands of hybrids available today. The range of plant material is still increasing as hybridisers continue their work for superior quality in flower colour, leaf texture, and hardiness.

The rooting ability of the cultivar is of paramount importance to nursery management and many hard-to-root cultivars have been completely dropped from production lines in favour of those more easily rooted. This has resulted in many excellent ones being unavailable to the general public through local garden centres, and possibly available only through specialist retail growers.

Before considering whether or not to take cuttings of an individual clone, it is sometimes wise to have a knowledge of its parentage. This information can be valuable in assessing if the cultivar should root easily, or if any difficulty in rooting can be expected, e.g. *Rhododendron* × *loderi* 'Fairyland'. The parents of *R. loderi* are *R. griffithianum* × *R. fortunei*. Both of the parents are difficult to root from cuttings so, therefore, it stands to reason that the offspring could also prove difficult to root. There are always exceptions to this rule, but it does give a reasonable guide.

With modern equipment and rooting aids, it is now possible to root many more cultivars than was thought possible a few years ago.

A great deal of work at the present time is being done in tissue culture of rhododendrons and many kinds are now being propagated by this method. There are however, many that have not been tried and some which have been tried but without success.

I feel there will always be demand for conventional methods of cutting propagation as the cost of establishing a good tissue culture laboratory is high and a great deal more work

still remains to be done in this field.

Propagation House. Our propagation houses consist of two Durolite tunnel houses 10 m × 5 m. The interior of the houses is designed with various bench pits and cuttings are set straight into the medium. Our propagation pits have Pyrotenax heating cables in them and an overhead mist system is provided.

Rooting Medium. Over the years different rooting media have been tested, with varying degrees of success. The medium we use at the present time consists of 50% peat and 50% recycled polystyrene beads (coarse grade). The medium must have adequate aeration and be retentive of water. The peat/polystyrene mix very adequately fulfils these two essential requirements. Poor aeration and water-logged media will result in a total crop failure. These two points cannot be more strongly emphasized.

Coarse sawdust is another excellent medium that gives very good results.

Environmental Factors. There are definite relationships among moisture, light, and temperature; failure to provide a balance on these points will ultimately affect the rooting percentage of the cuttings.

We have found that far better results will be achieved if a minimum of moisture is applied to the foliage. Misting to the point of "run-off" should be avoided. In our experience we have had more crop failures by over watering than by any other reason. Likewise, insufficient moisture can cause stress. Leaves will curl, stems may shrivel, and ultimate death of the crop will occur.

Maximum light intensity (without causing burn) is also essential for good results and, in association with high humidity, rooting of most cultivars occurs within two or three months.

Timing, Collecting and Selection of Cutting Material. Cuttings are taken at a half-ripe stage. Here in Rotorua we commence in mid-November (late spring) and continue through until March or April (autumn). The large-leaf and some of the dwarf cultivars usually start growth early in the season and therefore cutting material is ready in early summer (November/December). Never take cuttings too soft. It is better to err on the hard side rather on the soft. If taken too soft, cuttings are susceptible to hormone burn or fungus infection.

We collect cutting material early in the morning when they are turgid and still have a coating of dew on them. Only enough cuttings are collected for the day's activities. These are

immediately placed into polythene bags to prevent dehydration (particularly during the warmer months). Care should be taken in the handling of the cuttings — too much material placed into one bag should be avoided as this can cause bruising of the foliage.

Thin to medium thickness cuttings, 4 to 6mm diameter are ideal. These cuttings usually root readily as opposed to the thicker and much harder material. Juvenile cuttings are much superior to older material and where possible these should be used. Cuttings taken from young, one to two year old plants make ideal material but care should be taken not to destroy the balance and shape of the plant.

Cutting Preparation. Cuttings are made to 4 in. long, the basal leaves removed, and the remaining leaves shortened back where necessary. The terminal bud is also removed. As soon as the cuttings have been trimmed they are immediately dipped in a Captan/Benlate solution, allowed to drain for a few minutes and then commencement and preparation of the base is carried out.

The base of the cutting receives a straight, clean cut immediately below the selected node. A double heavy wound is also given. Wounding should just expose the cambium and care must be taken not to cut too deeply into the heart wood. Wounding too deeply can sometimes lead to basal rot and ultimate death of the cutting.

Rooting Hormones. For most rhododendron hybrids we now use a standard 2% indolebutyric acid (IBA) concentrate in talc. This is suitable for 90% of the cultivars propagated. For small-leaved cultivars, e. g. 'Mary Fleming', or soft-leaved cultivars we use Seradix 3 (or 0.08 IBA).

Care should be taken when rooting some of the yellow-flowered cultivars, as these seem to be more susceptible to hormone burn.

Cutting Insertion and After Care. As soon as the cuttings have been wounded they are immediately dipped into the appropriate rooting hormone. Any surplus hormone is tapped off. Then the cuttings are then ready to set.

Cuttings are inserted directly into the medium to a depth of about ½ in., each cutting being gently firmed in. They can be placed reasonably close together but it is advisable to allow some air movement to occur among cuttings. If this is not allowed, then risk of disease may increase. After the cuttings have been set they are watered in with a solution of Benlate/ Previcur. During the rooting process the medium is kept at a temperature of approximately 23° C. The cuttings should be checked regularly for dry spots, blocked nozzles, or disease.

Any dropped leaves should be removed immediately and a regular spraying programme should be adopted.

Spray Programme. An effective spray programme is necessary for good management and cleanliness within the propagation house is essential.

We spray at 2 to 3 week intervals alternating Benlate, Previcur, and Captan. Occasionally we will apply an insecticide to guard against leaf roller or thrips.

Potting Of Rooted Cuttings. Cuttings should be lifted from the medium when a sufficient root ball has developed. Care in the lifting procedure is essential; insufficient care can result in the whole root ball dropping off. The rooted cuttings are potted into 7 cm square propagation tubes and then placed back in the mist house on open benches for weaning. Young plants remain in the weaning house for 2 to 3 weeks until new roots develop. They are then transferred to the shade house for hardening off.

Black Vine Weevil. Because of our extremely light soil the number one enemy of rhododendron production in Rotorua is the black vine weevil and great care should be taken to avoid getting the pest into the propagation medium or potting mix. The grubs, (similar to grass grub) are root feeders and will devour practically all of the roots of the young plants. The eggs are deposited in the soil during late summer (January/February), hatch into larvae which feed on the roots, but they also chew off the bark just above the below soil level. The result is ring barking which, as everyone knows, is fatal for any plant. Black vine weevil is very difficult to eradicate and requires the use of a potent chemical for good control of the pest. An application of Dieldrin as a soil drench to the young plants is given after they have been transferred into the shade house for hardening off (January - April).

CONCLUSION

Every propagator has his own method. The information given above is only one of these methods. I trust this may be of assistance to someone who may be experiencing difficulty in this field. There still remains a vast amount of knowledge to be learned. Many rhododendrons are still very difficult to root, e. g. *R.* 'Lems Cameo', but with time and effort, an acceptable rooting percentage of these difficult-to-root rhododendrons can be achieved.

PLANT SELECTORS' RIGHTS IN NEW ZEALAND — DO YOU KNOW THE FACTS?

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INTRODUCTION

Although the Plant Selectors' Rights (or PSR) scheme has been in operation in New Zealand for ten years now there are still people in the industry who are unaware of the implications of Plant Selectors' Rights, or have misunderstandings about its operation. This paper is designed to explain the facts.

PLANT VARIETIES ACT 1973

The original Act governing the operation of PSR, the Plant Varieties Act 1973, was prompted by Sam McGredy, the international rose breeder, who wanted to gain some form of protection for his new rose cultivars and to prevent piracy. Initially protection was available only to roses but it is now possible to gain PSR in New Zealand for any type of plant, other than fungi, algae, and bacteria.

A grant of PSR gives a breeder the exclusive right to reproduce for sale and to sell reporductive material of his new cultivar (or license others to do so). He is thus able to control the distribution and marketing of the reproductive plant material (i.e. plants, buds, cuttings, seeds, rootstocks) and in doing so may recoup his breeding costs and hopefully make a profit from the collection of royalties.

Criteria for Rights. To be eligible for Rights a cultivar has to meet five criteria: (1). It must be *new*. In PSR terms this means that it must not have been sold in New Zealand for more than one year before application or overseas for more than four or six years (depending on the type of plant). Rights are not available to existing cultivars.

(2). It must have an acceptable *name*. This is normally a fancy name which must conform to guidelines for international usage. If a cultivar is also protected in other countries it should have the same name in all countries.

(3). It must be *distinct* from all other cultivars of common knowledge by one or more morphological, physiological, or other characteristics. For example, plant height, flower colour, disease resistance.

(4). It must be sufficiently *uniform*.

(5). It must be *stable* or remain true to its description after repeated propagation or reproduction.

With vegetatively propagated fruit and ornamental cultivars uniformity is not usually a problem although the stability of some sports is questionable. Note that horticultural merit is not taken into consideration.

To assess the criteria of distinctness, uniformity, and stability the cultivar is test grown, preferably alongside existing similar cultivars, and a detailed description of its characteristics is prepared. For ornamentals and fruit this examination process may occur in one of four ways:

(1) Centralised trials, e.g. for rosès where an applicant supplies plant material which is grown and tested at Palmerston North. An officially appointed Advisory Panel inspects the cultivar and assesses its eligibility for Rights.
(2) A Ministry of Agriculture & Fisheries (MAF) officer inspects plants on an applicant's property and/or government research station and prepares a detailed description over a full growing season (the most common procedure).
(3) The applicant supplies all technical and descriptive data to the Plant Varieties Office. This procedure is followed for applications from MAF or DSIR (Department of Scientific and Industrial Research).
(4) If a report is available from an overseas testing authority this can be accepted if the description is checked against plants growing under NZ conditions.

The last three options are each followed by assessment by an independent expert — someone with a specialised knowledge of existing varieties.

Fees. The current fees payable are set out in Table 1. A renewal fee must be paid annually to keep a grant of PSR valid, up to a maximum of 15 or 18 years (depending on the type of plant).

Table 1. List of fees payable in connection with an application for Plant Selectors' Rights ($NZ)

	Orchids, Fruit	Other Ornamentals Forest & Nut Trees
Application for grant	100	100
Examination or test trial fees	200[1]	100[1]
Notice of grant	100	100
Annual renewal	70	70

[1] - Reducible if all data supplied by applicant.

Development of the scheme. Since the scheme was opened up in 1980 to allow protection for any type of fruit and ornamental plant there has been a steady number of applications for PSR received (see Table 2). Roses account for a considerable proportion of the ornamental applications (67% in 1984)

whereas most interest in PSR for the fruit crops has been for apples. The total number of grants valid is given in Table 3.

Table 2. Number of applications received for Plant Selectors' Rights.

	1980	1981	1982	1983	1984	(1985[1])
Ornamentals	16	19	15	38	27	26
Fruit & nuts	1	32	17	9	9	16
Agricultural crops herbage, and pasture plants	13	8	14	14	12	13
TOTAL	30	59	46	61	48	55

[1] January to September, 1985

Table 3. Total number of grants of Plant Selectors' Rights valid as at 30 September, 1985

Ornamentals	134
Fruit and nuts	25
Agricultural crops, herbage and pasture plants	66
TOTAL	225

Obligations of Rights holder. Although the holder of a grant of PSR has certain rights, he also has certain obligations which result in the interests of the public being safeguarded. A rights holder must ensure that reproductive material of reasonable quality is available to the public in reasonable quantities at a reasonable price. If this is not done another person may apply for and obtain a compulsory license which would force the Rights holder to release the cultivar to other people. The purchaser of a plant of a cultivar with PSR is quite free to grow that plant in his own home garden, propagate it for non-commercial purposes, use it for human consumption, or in plant breeding but, of course, may not propagate from it for further sale.

Labelling of cultivars with Rights It is the responsibility of the Rights holder to protect his interests in his cultivar. This may include the appointment of licensees and the negotiation of licenses with propagators to bulk up and sell a protected cultivar, and the correct labelling of plants distributed. Obviously a purchaser cannot be blamed for infringing the Rights of a grant holder if he had no reason to believe that the cultivar was protected by PSR. This matter should be of major importance to plant propagators and distributors.

A protected cultivar should be so indicated on any label, in catalogues and advertisements, by using the words

"Protected by Plant Selectors' Rights", or
"Protected under the Plant Varieties Act 1973", or
"Protected", if this term is commonly understood.

In a catalogue an abbreviation (e.g. "P") may be used if

there is adequate explanation of the term.

If an application for Rights has been made for a cultivar but a decision has not been reached, the following wording is suggested:

"Plant Selectors' Rights applied for", or
"Protection applied for"

It is also advisable to include wording to indicate the practical effect of Plant Selectors' Rights: e.g. "Unauthorised Propagation Prohibited", or similar.

It is incorrect to indicate that a cultivar is protected by Rights by using the words "Patented" or "Subject to plant patent rights" or the symbol ®. Using the word "Registered" is misleading, if not meaningless. It is also quite incorrect and, in fact, an offence under the Plant Varieties Act, to indicate that a cultivar is protected by Rights when it is not.

A list of protected cultivars appears in the NZ Plant Varieties Journal, published quarterly, and annually in the NZ Nurserymen's Association July or August newsletter. Alternatively, it is possible to make enquiries direct to the Plant Varieties Office for up-to-date information.

OTHER FORMS OF PROTECTION

There are other forms of protection available to a breeder in order to control the marketing of his cultivar. In the past a few cultivar names have been registered as trademarks. While this prevents the use of that trademark for any other plant or plant product, it does not prevent unauthorised propagation and sale of the cultivar.

Civil contracts are used widely in the field of plant distribution. Depending on the terms of the contract a grower may agree to propagate for his own use but not sell any reproductive material, or not to propagate at all. On its own — that is, without PSR protection, a civil contract may be of limited value. In the case of cultivars that are protected by PSR, especially cultivars used by commercial growers, civil contracts may usefully supplement the Rights by assisting in the policing and management of the cultivar.

PLANT VARIETY RIGHTS BILL 1985

The Plant Variety Rights Bill 1985 has been drafted to improve the present legislation and is presently under study by a parliamentary Select Committee. One important provision will strengthen the rights of breeders of fruit and ornamental plants which under the present Act are rather inadequate. The Bill will extend the rights of a breeder to include the exclusive right "to propagate that variety for the purposes of the

commercial production of fruit, flowers, or other products, of that variety". This means that a grower will not be able to buy a few protected plants, bulk them up himself and sell the resulting cut flowers or fruit without permission of the Rights holder. Under the present Act this is quite legal as long as the product sold is not reproductive material.

Further major changes incorporated in the Bill are the introduction of provisional protection (a cultivar will be provisionally protected as soon as application is made), a period of sole rights (a period of 2 to 3 years following the isue of a grant during which time the Rights holder will have a mono;ly and compulsory license applications will not be allowed), a change in the mechanism for making appeals, and several changes in terminology (Plant Selectors' Rights will become Plant Variety Rights etc).

ADVANTAGES OF PLANT SELECTORS' RIGHTS

The Plant Selctors' Rights scheme thus exists to:

(1) Encourage plant breeding. The development of a new cultivar usually involves several years selection and trialling and considerable expense before it is considered suitable for commercial release — the control of marketing and collection of royalties for PSR provides a reward for that financial input.

(2) Encourage the release of overseas varieties in New Zealand. Many overseas breeders will not release their varieties in New Zealand without adequate protection from PSR legislation.

(3) Allow NZ bred cultivars to be protected overseas. Similar schemes to Plant Selectors' Rights exist in Great Britain (Plant Breeders Rights), in the United States (Plant Variety Protection and Plant Patents) and in many other countries, especially in Europe (Plant Variety Rights). UPOV, the international plant breeders rights organisation, has 17 member countries of which New Zealand is one. The legislation of some countries only permits applications from other UPOV members. Because New Zealand is a member of UPOV, New Zealanders are able to apply for protection for their cultivars overseas (although most UPOV countries have a much more restricted list of plants eligible for Rights).

There have been claims that PSR, in fact, disadvantages the public. The legislation has been blamed for causing loss of genetic diversity and exploitation of the resources of Third World countries. These arguments are misdirected towards PSR and are more of a result of agricultural development and the Green Revolution. There is also a concern that PSR has

resulted in an increase in "cosmetic breeding" — the production of cultivars with very minor distinctive characteristics which represent little or no improvement in horticultural or agricultural merit. This is a problem faced by all Rights authorities and the question of "minimum distances" between cultivars is continually under discussion.

New Zealanders, in general, have benefited from the introduction of Plant Selectors' Rights. An increasing number of cultivars (both overseas and local) are now available and further plant breeding is continuing, particularly in the horticultural sector. The breeding of improved plant cultivars which may contribute to the national agricultural and horticultural productivity is thus encouraged.

REFERENCES

1. Bezar, H.J., H.C. Smith and F.W. Whitmore 1982. Plants stand up for their rights. Crop Research Division, DSIR. Agricultural Bulletin No. 8.
2. Guide to Plant Selectors' Rights. 1983. MAF Media Services, Wellington, New Zealand.
3. Plant Varieties Act 1973. Government Printer, Wellington, New Zealand.
4. Plant Varieties Amendment Act 1979. Government Printer, Wellington, New Zealand.

SHRINK WRAP — OUR EXPERIENCE

IAN DUNCALF

Duncan & Davies Nurseries
P.O. Box 340, New Plymouth

The processing of open ground grown nursery plants in preparation for sale and despatch, is a very expensive and time consuming operation. This factor, coupled with the lack of customer appeal of the traditional "balled" plant, lead us to look at shrink wrap plastic as a means of speeding up this "processing" operation and to improve the plants' appearance and handleability.

Our programme was to shrink a plastic cover to the outside of our field-balled plants, just prior to despatch, which would improve the packaging and handling of the product, as well as carrying the company's logo and planting instructions. The shrink wrapping system was designed to allow the plants to be held for the normal length of time for balled products in garden centres and retail outlets, and to be easily and conveniently handled by the customer who would remove the film just like an ordinary polythene bag prior to planting.

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We carried out this programme for one despatching season, and as far as we are aware we are the only nursery to have tried shrink wrap plastic on a commercial scale with nursery stock. The shrink wrap system did have some problems, and we have recently returned to more traditional methods of processing. However, we would like to share the considerable experience we gained with this product with other nurseries who may well have other applications for this fascinating material.

WHAT IS SHRINK WRAP?

Shrink wrap is a plastic film that is similar to other plastic films in that it can be extruded, welded, printed and coloured in the same way as normal, but it differs in that it has undergone a process called orientation. This orientation process changes the molecular alignment in the film so that when it is exposed to heat it shrinks and returns to its original dimensions. Simply, the film is stretched during its manufacturing process, but retains a "memory" of its original size and will shrink to try to reach its original state when heat is applied.

When a bag made of this film is heated, it will shrink uniformly and surround its contents closely and tightly, revealing their actual shape, which usually is an attractive form of packaging. At the same time the film increases in thickness during the shrink process and so becomes tougher and stronger. Shrink plastic is commonly used in the presentation of foodstuffs and in a wide range of other product presentation operations.

It was the shrink plastic's properties of shrink, toughness, and appearance that attracted us to look at it as a means of packaging plants. After various trials and experiments we used the following method to shrink this plastic film on to our plants.

SHRINKING WRAPPING METHOD

This operation was used on field-grown plants that had been lifted and balled using an elasticised netting with either a hessian or a raylon biodegradable liner. The process was carried out just prior to the plants being despatched from the nursery.

A number of various sized printed bags were made for us with shrink film and the bag size used on any plant was such that the bag would easily slip over the ball giving a very loose fit. The loosely fitting bag was then held in place over the ball with a rubber band which was positioned at the neck of the plant and kept some tension on the bag to hold it in place,

while allowing for air movement out of the bag during the shrinking process.

The operator held the plant by the stem, (not the bag) and immersed the ball of the plant to the depth of the rubber band at the plant's neck into a water bath kept at a temperature of 91°C ± 3°C. This dipping process was very quick and a one second immersion was sufficient time for a full tight shrink.

To ensure hot water did not spill into the inside of the bag, which would damage sensitive plant roots, the bags were designed to be of sufficient size to allow for at least a 10cm "collar" above the plant neck. After shrinking, this collar was either rolled down or ripped off at a tear line scored on to the bag.

Finally, the shrunk wrapped balled plant was dropped onto a plate of pointed nails to make a series of drainage holes to allow irrigation or rain water to drain out of the balled plant as normal. This completed, the plants were then ready for despatching in the usual way.

Although this shrink wrap operation was basically very simple and quick, we did identify a number of key points as being important for the successful operation of the process.

a) *Water temperature* — It was essential that the water bath be maintained at approximately 91°C. Temperatures lower than this resulted in poor and incomplete shrinkage, often leaving untidy "ears" on the bottom ends of the bag. On the other hand, water temperatures too close to boiling point caused shrinking to be too rapid which could lead to ripping of the bag at the widest point of the ball.

To maintain our water baths at the desired temperature, we used simple water heating elements thermostatically controlled in an insulated metal tank and floated polystyrene balls on the water surface to reduce heat loss.

b) *The method of attachment of the bag to the ball prior to shrinking* — We found it to be essential that the bag was positioned correctly prior to shrinkage to ensure that any printing was correctly located after shrinking and that the bag sat uniformly on the ball. Because the plant cannot be held by the bag during shrinking (the bag simply moves out of the operator's hands) the rubber band system of support was very good. It provided tension and allowed positioning of the bag, yet didn't restrict the movement of the air from the inside of bag, but allowed it to escape through the open top during shrinkag.

c) *Smooth, uniform-shaped balls* — Ripping of shrink bags occurred during shrinking if any pointed or sharp roots pro-

truded outside the plant's ball. This was a particular problem on some types of plants with thick lateral roots. As these roots sat proud of the main ball, they would take all the initial tension during shrinkage, and would become a weak point in the bag and often pierced the skin, resulting in serious ripping.

d) *Operator skill* — One of the properties of shrink film is that it only shrinks once. If for some reason the first shrinkage was not complete, such as when the ball was not placed deeply enough in the water bath, or the bag was not aligned properly, then it was almost impossible to get a further shrink by re-dipping. Hence it was most important that the operator was skillful enough to get it right the first time.

To summarize our experience with this process, we can identify the following points in favour and points against this type of "processing" balled nursery plants.

Favourable features includes:

1) Shrink wrap is a safe, simple, rapid, and cost effective method of applying an outer cover to balled nursery plants.

2) Shrink wrap provides a tough and durable protective cover, which can be printed and coloured as required.

3) Shrink wrap provides a neat, tidy cover over well shaped uniform balls that improves the appearance and presentation of traditionally balled plants.

The unfavourable features include:

1) The tight plastic skin rounds the shape of balls and this rounding at the base can reduce the stability, especially of taller plants, once put down or spaced out in the nursery.

2) The variability in shape of field balling presents difficulties in controlling the shrinkage of the film at the neck of the plant. Over-shrinkage can reduce the top opening which restricts water entry into the shrunk wrapped ball during the plant's holding period prior to sale. Under-shrinkage leads to a loose, rather untidy covering.

3) The tight fitting cover reflects exactly the shape of the ball underneath and odd-shaped or uneven balls can detract in appearance with the shrunk film on. This problem is magnified by the glossy reflective surface of the film.

4) Exposed root stubs in a ball leads to ripping during shrinkage.

Our experience illustrated that shrink wrapping using the water bath system can safely be used on nursery stock without damaging the plant. It does have some other drawbacks, but there may be other possible uses for shrink wrap film, in nursery production, even using other ways of inducing shrink-

age, such as hot plates, or hot air blasts.

Despatching operations that need to keep plants tightly held together with a protective skin to reduce in-transit drying out could utilise the speed and handling advantages of shrink wrap. Two operations in our own nursery are presently being investigated in this regard. Firstly the export of small rooted cuttings or liners sent by air, which are presently packed in plastic insulated rolls, may be better prepared and presented using shrink wrap film. Secondly, plants that are held in cold store during transporation or storage, and are therefore likely to dehydrate, could also benefit from a protective shrunk wrap coating.

Whatever shrink wrap plastic's potential is in nursery production, it is an extremely fascinating and interesting product and one option that nurserymen may look to in the future, to improve the handling, despatching, and presentation of plants.

PROPAGATION OF AMARYLLIDS: A BRIEF REVIEW

C.B. CHRISTIE

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INTRODUCTION

The amaryllids comprise a family of interesting monocotyledonous plants that have long been prized for their very attractive inflorescences. A small number of the genera have become economically significant as cut flowers and potted flowering plants, e.g. *Narcissus, Nerine,* and *Hippeastrum.*

The propagation of the Amaryllidaceae may be achieved by use of the following four methods: seed, separation, bulb cutting, and tissue culture. The techniques employed in each of these methods will be briefly reviewed.

PROPAGATION BY SEED

Most species will produce seedlings that are reasonably true to type; however the natural heterozygosity and capacity for interspecific and intergeneric hybridisation has been exploited in the production of hybrid nerines (20) and plants such as × *Amarine* (*Amaryllis belladonna* × *Nerine*) and × *Brunsdonna* (*Brunsvigia* × *Amarylyis belladonna*).

Plants are easily propagated from seed if it is set. Seed of amaryllids is of two distinct types:

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Plants are easily propagated from seed if it is set. Seed of amaryllids is of two distinct types:

(a) fleshy berry(ies) clustered in an umbel borne on top of the old peduncle. e.g. *Amaryllis*, *Clivia*, *Hymenocallis* and *Nerine*. The fleshy endosperm of these seeds contains sufficient moisture to permit germination of seed on top of the ground without additional moisture. However, when this is allowed to happen seedlings often fail to penetrate the ground and obtain sufficient anchorage for rapid, continuous development. Sowing seed in a free draining medium, e.g. 60/40 pumice/peat at 20°-25°C. (as soon as the seed matures) usually results in prompt germination within about four weeks. *Scadoxus* and *Haemanthus* may show a type of epicotyl dormancy with the germination process taking about six months to complete (4).

(b) Dry membranous seeds borne in loculicidal dehiscing capsule (s), also on top of the old peduncle, e.g. *Habranthus*, *Hippeastrum*, *Narcissus* and *Zephyranthes*. This type of seed will usually germinate readily if sown under warm conditions as above, but some species may benefit from moist stratification, e.g. *Narcissus* as they have a low temperature requirement for germination. Therefore, sow in autumn outdoors and expect seedlings to appear in the spring (17).

Seed germination is basically hypogeal in form with seedlings producing only a limited number of leaves that may persist for more than one growing season. During this time a small bulb will be enlarging at the base of the leaves. Seedlings of many species will flower in two or three years from seed but some, e.g. Crinum and *Narcissus* may take four or five years to mature.

SEPARATION (OR DIVISION)

Offsets or daughter bulbs are produced in two ways, either the replacement system seen in *Narcissus* where the primary growing point divides slowly producing double-nosed bulbs before separating into independent plants. This results in a slow rate of increase of about 1.6 bulbs per year. Some daughter bulbs may also be produced by the following system.

Or in the case of *Chlidanthus*, *Hippeastrum* and *Sternbergia*, bulbs are initiated in the bases of senescing bulb scales on the perimeter of the bulb. The death of the outer scales allows these daughter bulbs to continue development, only being weakly attached to the mother bulb. Bulbs are best left undisturbed until a separate root system has developed, then during the bulb's dormant period large offsets may be detached from the mother bulb (17). The number of daughter bulbs produced in some genera, e.g. *Eucharis* is proportional to the size of the mother bulb (3).

The scale or leaf bases are the primary regions of meriste-

matic activity; rapid multiplication occurs where more than one new bulb is initiated in each of these regions. The small amaryllids e.g. *Sprekelia*, may often increase fairly rapidly by this method; however the large bulbed amaryllids e.g. *Brunsvigia* and *Crinum* are very slow to increase in this manner.

BULB CUTTING

Efforts to stimulate bulb propagation by controlled mutilation (22) produce better results than leaf cuttings as for many Liliaceae. Cross cutting and scooping of bulb bases (as for *Hyacinthus*) produced up to 10-15 new daughter bulbs for every parent bulb sacrificed this way (12). Investigation reveals that each bulb base contains many preformed bulb meristems and in addition, further meristematic loci may arise adventitiously (7). Further increases in bulb multiplication rates are possible by slicing a bulb into a number of sectors each composed of scale pieces and a section of basal plate. This practice was originally called fractional scale-stem cuttage (22), but has more recently become known as bulb-chipping' (5). If the subdivision of bulb sectors is continued the multiplication rate continues to rise for a while. The limit of subdivision for most amaryllids is reached when two scales remain connected together by a small amount of basal plate; this is twin-scaling (1,2,10,11). The procedures employed in twin-scaling and chipping are discussed in the following literature (6,9,12,21) and pertinent points are highlighted below.

Select healthy bulbs of a good size for the genera undergoing propagation, e.g. (*Narcissus* 10cm, *Nerine* 14-16cm); very large bulbs of some genera, e.g. *Brunsvigia* and *Crinum* have proved less useful than smaller bulbs. The optimum time for propagation is usually shortly after the bulb enters its normal resting phase. Bulbs should be dug up at this time and cleaned by removing any persisting foliage, the dry outer scales, the roots and the dead outer exterior of the basal plate with a sharp knife. Protective gloves should be worn for the remainder of the dissection process as the sap of amaryllids contain a number of alkaloids that may irritate the skin. Knives used for the preparative work should be cleaned and possibly sterilised in alcohol before being used for further work. Bulbs may also be disinfected at this stage by swabbing with alcohol or dipping in a 0.5% a.i. formalin solution for 1-2 minutes (avoid inhalation of the fumes).

With a clean knife cut off the neck of the bulb and discard; now proceed to cut the bulb into a number of sectors with their common center passing through the central axis of the bulb; this should ensure that each of the "chips" prepared at this stage contain both leaf bases and basal plate. The

number of "chips" prepared from each bulb depends on the bulb size or circumference; unlimited subdivision may not be restricted by meristematic sites but most probably by limitations in growth regulator and carbohydrate supply in both small chips and twin-scales. (Very small scales produce bulbils that are slow to commence normal vegetative growth).

Small bulbs, e.g. 10-12cm may be cut into 8-16 chips; if this material is going to be cut into twin-scales then 8-10 *sections would be made. The number of scales within each* bulb depends both on the genera and bulb size. *Eucharis*, *Haemanthus* and *Narcissus* contain relatively few scales compared with *Amaryllis*, *Brunsvigia* and *Crinum*. The large number of scales and the presence of many fibres interconnecting scales in these bulbs makes them prime subjects for chipping and not scaling.

If bulbs are going to be scaled then each of the chips must be carefully cut into twin-scales. Separate the scales into pairs and then proceed to cut through the basal plate to detach each pair of scales, working from the exterior to the interior of the bulb. Store cut scales in a plastic bag to minimise desiccation. When a batch of scales has been cut they should be soaked in a fungicide to inhibit growth of *Penicillium* and other fungi that attack the scales during incubation. A 20-30 min. soak in 0.2% benomyl has been used with limited success and would be better replaced by or used in combination with 0.4% captafol or 0.4% clorthalonil.

Excess moisture must be removed prior to incubation, but as this can be quite difficult when dealing with large batches of scales, encouraging results have been attained when the fungicide was added to the incubation medium. Best results are obtained when scales are incubated in thin plastic bags containing a slightly moistened (0.25-10%) material such as vermiculite, perlite, or peat/perlite (10/90) which have all proved satisfactory when sufficient material is used to separate each piece of bulb tissue. Bags are sealed and stored in the dark at 20°C. for 12-20 weeks. The plant material should be checked regularly to remove senescing scales.

Bulbils arise most frequently at the base of the innermost scale on the abaxial side (24) and first become visible between scales after 4-6 weeks incubation. As bulbils develop, the parent scales lose weight and begin to shrivel as reserves are transferred to the new bulbils. When this process is complete the bulbils will have attained their maximum size and will be ready for transfer to a potting medium and growth in an unheated greenhouse.

Most genera will flower in 2-4 years from scaling. Follow-

ing propagation by scaling some rejuvenation has been noticed with very rapid development of daughter bulbs occurring at the base of the new bulb in some *Nerine* and *Hippeastrum* cultivars (9,22).

The following amaryllid genera have been propagated successfully by twin-scaling in New Zealand and overseas: *Amaryllis, Brunsvigia, Childanthus, Clivia, Crinum, Eucharis, Galanthus, Habranthus, Haemanthus, Hippeastrum, Hymenocallis, Leucojum, Lycoris, Narcissus, Nerine, Pancratium, Sprekelia, Sternbergia* and *Vallota* (1,9,2,23).

TISSUE CULTURE

Sterile culture techniques have been developed for the propagation of many important amaryllids, e.g. *Eucharis, Hippeastrum, Narcissus* and *Nerine.* However the techniques have been relatively slow to be exploited by commercial laboratories because of large differences in the response of individual cultivars, reduced growth after several subcultures, and lack of growth after transfer to *in vivo* conditions (13,14,16,18,19). The early work concentrated on the use of shoot apices and excised twin-scales as explants (8,15), but this has been extended to include meristematic tissue located on individual leaf bases, scapes, peduncles, and ovary tissue.

Explants are sterilised in alcohol rinses and by soaking in a hypochlorite solution, followed by sterile water rinses and aseptic transfer to a suitable culture medium based on a standard Murashige and Skoog medium. Cultures are most often incubated at 15-25° C. with an extended (16-24 hr.) photoperiod.

The optimal explant response to plant growth regulators was cultivar-dependent but some growth will occur on a range of media. Growth of callus through a more organised state of shoots and bulbs occurs in 2-12 months. Continuous adventitious shoot formation has been difficult to sustain; further multiplication has been possible with regular splitting of shoots and bulbs as an *in vitro* "chipping" technique.

Transfer of dormant *Narcissus* bulbils to *in vivo* conditions requires a period of chilling *(in vitro)* before normal growth will resume. Substantial losses will occur with some genera if initially transferred to a non-sterile *in vivo* growing medium.

Literature shows that the following amaryllid genera have been multiplied by tissue culture laboratories in New Zealand and overseas: *Amaryllis, Anoiganthus, Clivia, Eucharis, Galanthus, Haemanthus, Hippeastrum, Ipheion, Leucojum, Narcissus, Nerine, Scadoxus, Vallota* and *Worsleya* (13,15,16,23).

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OUR WAY WITH FOG PROPAGATION OF TISSUE-CULTURED PLANTS

PETER W. SPEAR

Pe Ge Pe Enterprises,
51 Amberly Avenue, Auckland, 8.

For many years I have advocated the propagation and growing on of plants using fog as opposed to mist. The advantages I saw as an engineer and operator of a tissue culture lab were many. Although the initial cost of the first unit is a little high, subsequent units are comparatively cheap.

Our experience in the lab and with growing on plants out of flask was such that they required a high humidity but no great water application.

What was it we required?:

i) Control of transpiration and evaporation during propagation, and initial planting out of tissue-cultured plants.
ii) Application of chemicals to plants after establishment — foliar feeds, fungicides, insecticides, or any other crop enhancing water soluble chemicals.
iii) No over-wetting of growing media.
iv) Frost protection during winter.

Considerations:

Safety — we were conscious of the need to have no extreme high pressure lines for water. Many systems in use here and overseas use up to 500 psi water pressure and correspondingly piping and installation can be expensive when lasting qualities are considered, e.g. stainless steel or copper lines. Filtration of water in high pressure units is expensive and involves considerable maintenance.

The system involves the use of a small air compressor and receiver delivering up to 6 cfm. This will allow up to 6 units to be run off the compressor. Each nozzle is controlled by an indicating Martonair 25/5 solenoid valve for air and water so that there is no dripping or air escape when not in use. Water is controlled by a Martonair flow control, and air with a Norgren regulator and gauge.

How does the system fit into the plant propagation scene?

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We all know that a zero transpiration loss is required and desirable for good propagation. This ideally must be achieved with minimum overwetting or leaching of the growing media. These factors can only be achieved by use of "fog", and with proper control, transpiration losses can be eliminated completely without overwetting of soil or growing media. The value of this is that plants can be guaranteed sufficient oxygen for roots, with no loss of moisture through leaves.

Relative humidity at 100% will assure zero transpiration loss and this will maintain a light mist of liquid on plant leaves — not enough to precipitate to droplets, but sufficient to ensure that good growth conditions are obtained. So by maintaining a light fog around plants, the plant leaves will be slightly wet so that leaf surfaces will always be slightly warmer than the surrounding area. This is also good for foliar feeding, either high nitrogen (30-10-10 or 40-1-1) to force rooted cuttings or plantlets, or a 10-30-20 for promotion of root growth, the rates of application being 1:600 to 1:1000. All foliar feeds must include trace elements. Weekly application of fungicide can also be applied in this way.

Fog density can be controlled by several means: —

1. Number of nozzles
2. Water volume
3. Air pressure

In a propagation house, the ventilation can be reduced to 25%, as fog is the cooling medium. Air is introduced at a rate of 1 cfm per nozzle, so air changes are being affected regularly.

The proper use of fog is accompanied by a visible and dramatic increase in plant production, but remember fog is not mist. Fog must not be sprayed directly onto plants and precautions must be taken to prevent this. With our system, there is no danger of nozzles producing water drops or flow onto valuable plants. It can be said that the fog will travel up to 5 to 7 metres from nozzles. Also it must be remembered that fog does not irrigate your plants. Trays stay the same as when put in fogging areas, so preparation of trays for cuttings, etc. is of great importance. Potting mix with minimal fertiliser is required if foliar feeding is used.

Finally, several pluses: —

With pest control all surfaces of the plants are reached by fog, not just upper leaf surfaces. In a cost conscious, energy conserving society, fans can only be required to go 50% of the time. In winter, fog acts as a frost preventative — ever seen a frost on a cloudy night? Fog reflects back heat from heaters, so saving energy. Fog on leaves in frost will produce latent heat

on plant leaves as it condenses on plants.

Nozzles in our units are supplied by Spraying Systems Co. of USA and are type ¼ in. with integral filters.

The compressor was run on a time clock from 8 a.m. to 4 p.m. daily; solenoids are set from main control console where interval of 5 minutes and duration 60 seconds of fog was set for daytime. It was found that we required fog at night, 60 seconds every 1 hour.

Two nozzles can maintain fog in a 60 × 20 ft. house, but a more satisfactory operation would be obtained from four nozzles.

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A SHORT HISTORY OF THE PRIMROSE AND POLYANTHUS

TERRY C. HATCH

Pukekohe, R.D. 2

> *"And in the wood where you and I upon faint primrose beds were want to lie".*

Did I say a short history? Mention of these plants goes back to the earliest herbals, and "Will" Shakespeare uses them in botanical ramblings throughout his works. I can only manage a scant 40 years love affair with them. Collecting flowers and plants as a small child, the wonder of finding clumps of softest yellow flowers nestling in the long grass beneath hazel coppices and that delicious fragrance: — still eagerly awaited every spring. "Will" mentions the cowslip and oxlip too.

Hands up, those of you who do not know where the bee sucks?

And of the oxlip — "I know a bank where the wild thyme blows, where oxlip and the nodding violet grows quite overcanopied with luscious woodbine, with sweet musk rose and with eglantine".

Primula vulgaris [syn. *P. acaulis*]	Primrose
Primula vulgaris 'Rubra'	Primrose (Asia Minor)
Primula veris	Cowslip
Primula elatior	Oxlip

Are these the parents of the modern-day gaudy polyanthus

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Are these the parents of the modern-day gaudy polyanthus

hybrids, *Primula* × *polyantha*? It would seem so but it has taken many years of work by bee and man to achieve. Wild primroses and cowslips rarely have bronzish colour forms and these variants have always been eagerly sought, equally by the early peasants and the modern-day gardener.

By the 17th century a small polyanthus type flower with reddish brown flowers was grown; a hundred years or so later, gold lace polyanthus were being grown and became a mania with the population in the mid to north of England where "every man and his dog" had his own named variety, these being grown to rigid standards for competition — the craze passed and they almost went into oblivion.

In 1870, Miss Gertrude Jekyll began to select and work on a strong yellow form, this being a cross from 'Golden Plover' and a near white type, and in the 1880's she introduced her Munstead polyanthus in white and yellows. Selection work seemed to take about 10 years for each new form to become apparent.

Anthony Waterer was breeding red types in the 1890's and with Miss Jekyll's plants, produced crimsons, magenta, and muddy pinks. By the late 1920's many seed firms had their own "special strains". Mr. G.F. Wilson, who owned Wisley Gardens was working on the blue side of things and developed violet-blue-purples, not quite the true blue we now know. In the mid 1930's, Florence Bellis started her years of dedicated work and this resulted in perhaps the finest of clear colours ever grown. This was possibly the first concentrated effort in the USA on these plants; her colours included true blues, clear pinks, and sunsets. She also worked on the Cowichan polyanthus with hardly any eye, solid pools of colour and bronze leaves. In my opinion her major work was with the double primroses. From the old Marie Crousse, the silver-edged 'Magenta Double', she created by the 1960's a range of colours never dreamed of, all frost hardy and most heavily scented.

The Pacific Giants came into being in California, grown by Frank Reinelt, his work being done under glass — great strong plants, brilliant colours, sold in tens of thousands all over the world. A severe winter in the 1960's nearly wiped out the Giants for they had become soft and lost their frost resistance and for a few years seed was hard to come by.

Over the years odd types have appeared:

Hose in Hose: Each flower held by another instead of a calyx.

Jack in the Green: Buds like moss roses and a green ruff.

Jackanapes: With a coloured ruff, striped green.

Gally Gaskins: With a large calyx.

and many others, collectors items, all.

Still the work goes on by patient pollinators, to mention a few:

Jared Sinclair, heir to the Florence Bellis collection.
Our own: Noel McMillan, with his strange chartreuses, grey blues, and others.

And even from Japan, brilliant colours, once again mostly for pot work and not long-lived. I wonder what "Will" S. would have made of them for his were "faint and pale".

"Perchance in pair of glassed 'sun'
their brightness maketh my eyes to run".

REFERENCES

Shakespeare, W.
A Midsummer Night's Dream, II ii 249
A Midsummer Night's Dream, I i 3
The Tempest, V i 88

POLYANTHUS PONDERINGS

R. NOEL McMILLAN

McMillan's Garden Centre, Ltd.
State Highway One
Ohinewai, Waikato

I will restrict this paper to areas that will be most useful for people having a go at producing polyanthus (*Primula* × *polyantha*) from seed and, judging by last spring supplies, must number thousands.

SEED GERMINATION

Polyanthus seed is very expensive to produce and likewise to purchase. To pay, one must maximise germination rates. I find that no matter the size of the seed or the rate of germination, the resulting plantlets always grow to presentable plants. The main factor affecting size of plants is the type of growing season in the autumn and how long this lasts. Planting dates do not seem to matter as much, but there is an optimum time to allow for the vagaries of the weather. We find early summer, November to December, with a preference for the second week in December, is best for us. This allows sufficient time to mature seed and avoids a bottleneck of freshly germinated seedlings waiting to be pricked out when the staff and family are away for Christmas vacations. A further planting is done in fortnightly batches to the end of

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January in order to spread the work of pricking out.

Most of the older strains of polyanthus were planted in spring — October to November, because of their growing requirements and, at this time, conditions are less critical for success in germination. Because we plant later, the January/ February sun can create problems for plants that do best under cool conditions; 18°C. is about the limit for good seed germination so conventional glasshouse conditions need to be avoided.

Having bred and sold the seed we produce, it is necessary for us to know what to expect with each year's batch. The method we use is to plant in a normal seed sowing mix of peat and sand. Flats are levelled and drenched with Thiram. Seed is row sown across the flat — a preference we have in case there are any hold-ups when pricking out. The seed is anchored with a light covering of vermiculite, No 2 if available (No 3 will do). This merely creates an environment around the seed and doesn't cover it completely.

Flats are then stacked in double rows to allow light penetration from one side, and placed in a cool, shady draught-free spot. To maintain moisture levels, the stacks are dampened every couple of days. The top flats are covered, as they dry out the quickest. The exposed edges do tend to dry out if not watched. After eight to ten days the rising seed coats can be seen, and the flats are then unstacked, and the seed given a full cover of vermiculite to anchor the seed firmly.

The flats are then re-watered and transferred to the coolest covered house we have, i.e. top cover shade cloth sides. Normal maintenance follows and once a good mat of true leaves has developed, the flats are transferred to under 50% shade cloth to await pricking out.

Our routine might appear labour intensive but we are trying to maximise germination with the facilities available. Critical points are:

1. Allowing light for germination.
2. Checking stacked flats to avoid seedling elongation after germination.
3. Anchoring plants after striking.
4. Preventing drying out at any stage.
5. Keeping temperatures below 18°C.

We have been producing polyanthus and cyclamen seed for many years. The beginnings of our polyanthus strain goes back to the American firm of Vetterle and Reinelt, whose strain was known as the "Pacific Strain". When this firm changed from the original principals, a New Plymouth nurseryman, Alex Purdie, received some seed from one of the

principals who was a good friend of his. Alex knew my brother and I were trying to breed polyanthus and passed the seed on to us saying "I think you'll find this interesting". From a series of self-pollinating and selecting, our present strain has developed.

The Pacific Strain is known for its range of colour and it has been our aim to extend this, particularly to the ruffles Picotee and unusual combinations. Where colours have weakened, further strains have been added and selected from. Each year we try to emphasize a particular characteristic. Vigour and colour come first, but in some seasons we have concentrated on disease resistance, heat resistance, size of flower, and strength and length of stems, multi-stems, and flower weathering. The plants selected have to pass these criteria before they are used in the breeding programme.

Introducing new forms into the strain follows Mendel's laws, but the main difficulty producing seeds of new cultivars in a small business is that one has to remain profitable while all the development takes place. Rejects have to have commercial value and this is not always possible. Hand crossing only is carried out between our strains and this is very time consuming.

The main difficulty we face in the humid Waikato area is keeping the plants free of botrytis during the breeding season. We always cut off the stigmas to avoid seed pods going off and the plants are sprayed regularly.

There is no doubt selecting a type of plant and trying to improve it is a very interesting and worthwhile project for a young person to take up, but in your interest I humbly suggest you select plants that can be named individually and thereby come under the terms of the Plant Varieties Act. "Personal satisfaction" has little collateral value in the eyes of a bank manager.

SOME DO'S AND DON'TS OF PLANT BREEDING

1. Do have a plan or set of objectives — one that does not need a computer to maintain it. It is very easy to get distracted from your original objective.

2. Ensure the vigour of your strain and, if possible, produce an F_1 for sale.

3. Do not get upset when people criticize the results of your years of work. No strain is perfect for every climate or situation. I notice strains that head ours in some areas do poorly in our climate.

WHAT OF THE FUTURE

The trend at the moment is toward the compact plant for pot culture with the emphasis on a range of set defined colours. We have to recognise these trends and so have started this season to add greater uniformity to our strain, a factor we have been unable to do to date without sacrificing colour. By crossing selected cultivars of ours with acaulis, this should produce some interesting F_1 results for us. There remains much to do. It is no easy matter to compete with the best the world has to offer, but it's quite a challenge to try.

PROPAGATION OF THE CORDYLINES BY VEGETATIVE MEANS

GRAEME C. PLATT

Platt's Nursery, Albany

Traditionally, *Cordyline* propagation in New Zealand has been by seed germination. This technique has been most satisfactory for general *Cordyline* production, and will continue to be so for species production.

However, with the increasing number of New Zealand cordyline cultivars worthy of clonal propagation appearing — and with the added problem of hybrid pollution, causing frustration with some species, particularly *Cordyline kaspar* and *Cordyline baueri* (from Norfolk Island) — vegetative propagation is becoming increasingly more attractive.

In addition to seed, cordylines can also be propagated from large cuttings and chips of bark. Micropropagation is also used on some species. However, each of these techniques has its problems. Large cuttings have a high failure rate and are highly destructive to stock plants. Bark chips have exactly the same problem. Micropropagation has been a failure with variegated *Cordyline australis* 'Albertii,' and has not yet been successful with *Cordylines kaspar*.

However, a few years ago some Japanese visitors to this country introduced a vegetative method that is proving satisfactory in a number of nurseries. This method requires the severing of the underground stem of a mother plant — as in Figure 1. The mother plant is removed from its container and severed in the middle of the mass of roots; leaving half of the roots on the mother plant, and the other half on the severed basal stem. The mother plant is then re-planted in fresh potting mix and kept well watered for a few days to minimise stress. The mother plants will then develop a new under-

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ground stem, and continue to grow normally — diagram B, Figure 1. These plants may then be sold as stock, or retained for a repeat stem severing. Cordyline is a hardy plant and, while the plants may wither and wilt for a few days, they then recover quite quickly. Some of these plants will re-grow up to three new stems, all of which can be severed again.

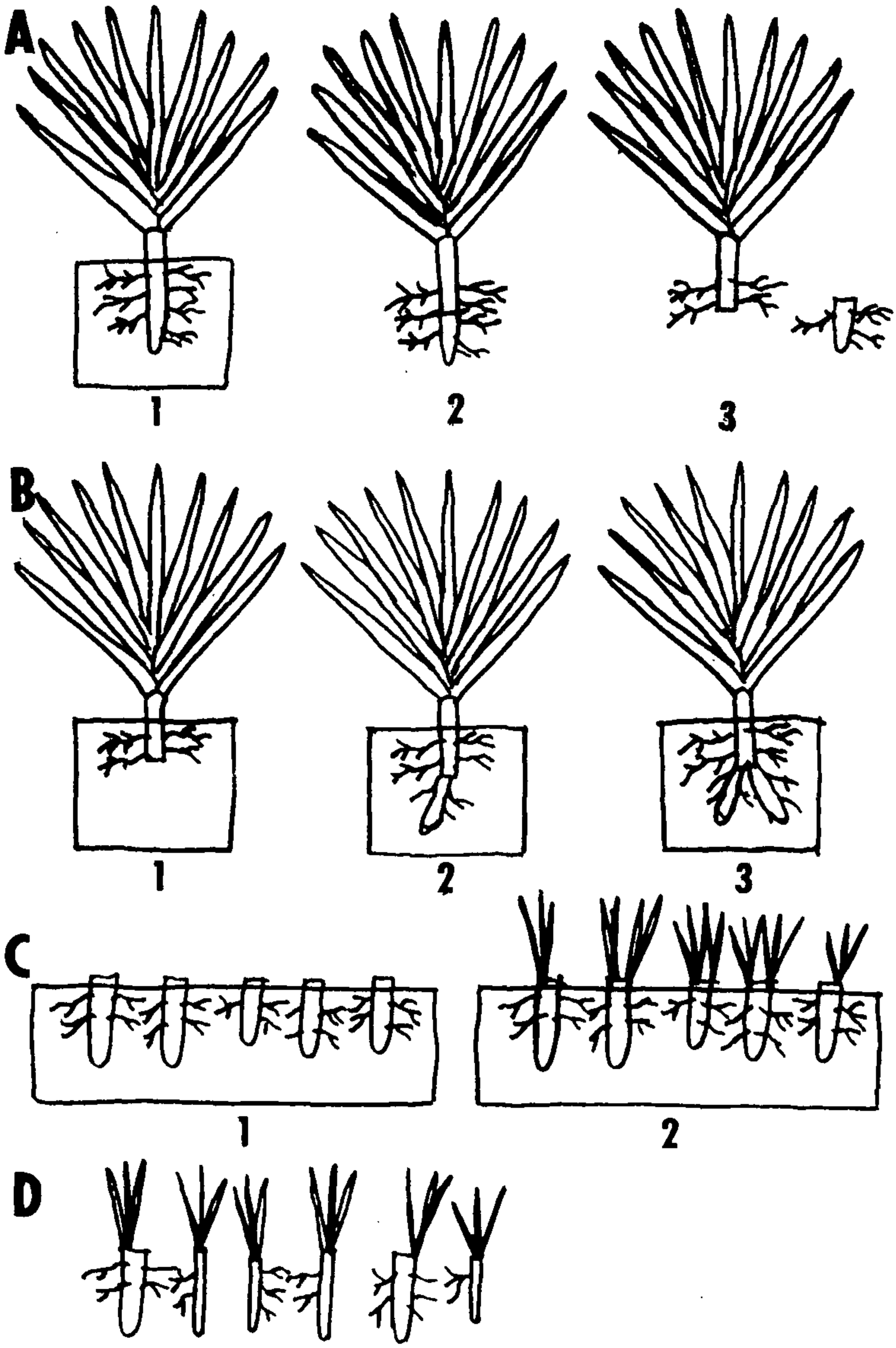

Figure 1. Steps in a vegetative propagation method for producing cordyline plants.

The severed stems are then washed in Captan fungicide and planted in a tray to develop shoots and leaves — as in C, Figure 1. These basal stems will develop shoots and continue to grow into normal plants. As an added bonus, these stems can produce a number of shoots, which are then split into separate plants — D, Figure 1. After splitting, these plants are washed in Captan fungicide and planted out in the normal manner.

This technique for growing cordylines is very satisfactory with *Cordyline australis*, *C. kaspar*, and *C. pumilio*.

The timing of the year could be an added advantage. Any losses I have had with the basal stems have been during the cooler winter season when some have decayed. I would, therefore, recommend that this procedure be carried out during a period of favourable growth — particularly early spring. Also, during this period these basal stems should not be kept waterlogged. They should be in a relatively free-draining, well-aerated mix.

To summarize, this technique for growing cordyline species and cultivars is highly satisfactory, and once sufficient plants are available, it is also very efficient — 200% to 300% increase can be achieved.

PRODUCTION OF CONTAINER-GROWN NEW ZEALAND NATIVE PLANTS FOR REVEGETATION

MARK A. DEAN

Omahanui Native Plants
Oropi Road, R.D. 3, Tauranga

The concept of revegetation is a relatively recent one, having its basis in the environmental awareness which has developed over recent years. The advantages of retaining or re-establishing native revegetation around water shed areas, on very steep hillsides, or in unusable gullies are becoming increasingly appreciated. Environmental awareness has also led to the planting of natives plants on a large scale for conservation purposes and aesthetic reasons.

In response to this trend, a range of native plants was grown to test the feasibility of producing plants for revegetation. The initial response was most encouraging and now plants grown specifically for revegetation are an important part of our nursery production.

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REVEGETATION PROCEDURES

The majority of revegetation projects this nursery has been involved in have consisted of planting native plants into an open grassland type environment. The procedure to re-establish a natural native bush cover in this situation is a lengthy one involving the planting of a nurse crop.

Stage one involves clearing the land and planting:

1. The area is first cleared of all exotic weeds such as gorse, *Ulex europaeus* L.; and blackberry, *Rubus fruticosus* L.; by mechanical or chemical means.

2. A 2m x 2m grid pattern is then spot sprayed with Round-up (glyphosate).

3. Nursery grown plants are planted in the sprayed spots when the grass or weeds have died down.

4. Plants need to be released from weed growth once or twice during the following summer.

Stage two takes place in the following years when specimen trees are interplanted between the now well-established nurse crop.

PLANT MATERIAL

For revegetation to be successful, the species used for stage one of the project need to have certain qualities:

1. They must be fast growing, early colonisers in natural regeneration, so that they quickly establish a canopy to suppress weed growth.

2. These plants should naturally attract birds so that natural self-seeding of other species occurs.

3. The species selected for revegetation must be capable of growing in the open, often in an unsheltered situation.

4. Preferably, the species used should be ones that occur naturally in the district.

After considering these qualities, a range of 12 kinds of plants is now grown for revegetation at our nursery. (Table 1).

SEED PROPAGATION

Most kinds of plants that are produced for revegetation purposes are propagated by seed. An exception to this was a special project undertaken for the Mount Maunganui Borough Council to produce plants for revegetating part of Mount Maunganui, using cuttings taken from material presently growing on the site, in order to maintain genetic purity.

Production by seed is preferable for two reasons — *Firstly*, large numbers can be produced at relatively little cost and,

secondly, for revegetation purposes it is desirable to have some genetic variation in the plant material. Care is taken to have a number of different seed sources, as clients often require plants from one particular source because of the problem of genetic pollution (4).

Table 1. New Zealand native species grown for revegetation.

Species	Seeding Time (in Southern Hemisphere)	Suitability
Aristotelila serrata	January	Very Good
Coprosma Robusta	April	Excellent
Cortaderia toetoe	February	Good
Dodonea viscosa	March	Good
Hebe stricia	May	Very Good
Leptospermum ericioides	May	Excellent
Leptospermum scopiarum	June	Excellent
Melicytus ramiflorus	April	Very Good
Phormium tenax	April	Good
Pittosporum eugenioides	April	Good
Pittosporum tenuifolium	May	Excellent
Pseudopanax arboreus	April	Good

Many New Zealand native plants show considerable variation from one district to the next, *Leptospermum ericoides* being a prime example. There is increasing concern that only the particular genetic strain growing in the area being revegetated be used for any revegetation project.

Seed collection time varies from mid-January to June (mid-summer to early winter); see Table 1. Seed is collected by nursery staff from trees of good quality, health and form, growing in the wild. The seed is separated from fruit material and sown immediately after collection into trays of a standard seed raising mix. (N.Z. Nursery Research Centre, 1984). Seeds are covered with 3 to 5 mm of seived potting mix and are well-watered. Seed trays are then placed in an unheated greenhouse to germinate.

Germination takes from 2 weeks to 4 months, depending on the species. Germinated seedlings are pricked out into a seedling mix (N.Z. Nursery Research Council, 1984). The seedlings are spaced at 70 per tray to make maximum use of available space and so reduce costs. At this stage they are placed in an unheated tunnel house for 6 to 8 weeks, following which they are moved into a shade house covered with 30% shade cloth.

POTTING

Potting of revegetation grade plants was initially done into a PB2 planter bag. However, the requirements of many clients for a smaller container for ease of transport to project sites and to reduce transport costs, resulted in the development of a

smaller bag. The bag now used is made of 50mμ polythene film and measures 200 × 80 × 80 mm. Plants appear little affected by this smaller bag and clients have responded favourably.

Potting is done by hand using a team of workers. The plants are removed from the seedling trays by cutting the potting mix and roots into cubes, the complete cube being planted as one would plant a liner taken from a tube.

A standard soilless potting mix is used of 40% peat, 30% ground pine bark, and 30% coarse sand. Fertilisers are included in the potting mix and no further fertiliser is added while the plants are in the nursery (Table 2). Plants are placed on standing areas which are covered with Sarlon weed mat and have overhead sprinkler irrigation. Potting is timed to allow 4 to 6 months growth before plants leave the nursery. Minimum height for a revegetation plant leaving the nursery is 30cm with 45cm being average. Some pruning is done of fast growing species to keep them compact, but this is kept to a minimum to reduce cost, and is usually done with a pair of hand shears.

Table 2. Growing mixes.

Use	Composition	Fertiliser Per M^3
Seed Germination	50% peat	750 gms. superphosphate
	50 coarse sand	400 gms. potassium nitrate
		3000 gms. dolomite lime
		150 gms. F.T.E.
Seedling Mix	35% peat	1500 gms. Osmocote (14-6.1-11.6)
	15 ground bark	
	50 sand	720 gms. calcium ammonium nitrate
		560 gms. superphosphate
		3000 gms. dolomite lime
		150 gms. F.T.E.
Tree Mix	40% peat	4 Kgs. dolomite
	30 ground bark	1 Kg. superphosphate
	30 coarse sand	1 Kg. calcium ammonium nitrate
		4 Kgs. Osmocote (18-4.8-8.3)
		150 gms. F.T.E.

SPRAY PROGRAMME

Seedlings are sprayed regularly every 14 days using Ridomil MZ 72 (metalaxyl), Phaltan (folpet), or Benlate (benomyl). With each spray, Wuxal foliar feed is included.

During the growing season the plants are subjected to the normal nursery spray programme. This alternates Phaltan (folpet), Mancozeb, and Benlate (benomyl). When the need arises

an insecticide is included, usually Attack (pirimiphos-methyl, plus permethrin).

WEED CONTROL

All weed control is done chemically using Ronstar (oxadiazon) applied with a small garden sprayer as a basal spray. Ronstar is applied as soon after potting up as possible, but after plants have been placed in the standing out area. The rate used is 30 ml per 100 litres of water, which is ⅓rd the normal application. This has been found to give effective weed control for up to six months.

CONCLUSION

Because revegetation plants are required in large numbers for any one project, it is essential that cost be kept to a minimum. The techniques outlined have been developed to keep labour input low and thus keep the cost per unit down. However, quality cannot be sacrificed for quantity and it is important that the plants be sturdy enough to meet the rigorous demands of harsh planting sites.

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TISSUE CULTURE: IS IT THE ULTIMATE IN ASEXUAL PROPAGATION?

BRIAN J. CALLAGHAN

Lifetech Laboratories Ltd.

55 View Road, Auckland 9

The New Zealand's locality and consequently its climatic conditions make it idealy suited to grow a large range of plants. With the added advantage of having an out-of-season market in the Northern Hemisphere, the horticultural industry has grown rapidly in the last few years. Typical "Kiwi ingenuity" has prompted the successful production of many different

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vegetables, fruits, and more lately new cut flower crops.

With the fast growth in horticulture, plant tissue culture has emerged as an alternate way of propagating new plant material and the industry is well serviced by a number of competent commercial laboratories.

It has been my experience as one closely involved in commercial tissue culture, that many potential users of this technique neither appreciate the basic mechanisms involved nor understand the relative advantages or disadvantages. I welcome the opportunity to try to explain in practical terms what is involved in commercially producing plants by using tissue culture and to then discuss some of the factors relating to producing an economically viable product.

What is plant tissue culture? For the purposes of my talk we will define plant tissue culture as micropropagation, although the term can embrace a much wider range of potential uses. What we are able to achieve is an asexual propagation in a controlled laboratory environment with the potential for producing thousands of genetically indentical off-spring. Steps involved are shown in Figure 1.

Plant selection. To justify the expense of using plant tissue culture, the original "mother plant" must have special attributes.

The consequences of producing large numbers of inferior off-spring must be fully understood prior to commencing the propagation.

Also the requirement for relatively large numbers of plants must be determined for the project to be considered economic.

Plant preparation. This is an often neglected part of the tissue culture process. Education is required to show customers that material supplied for tissue culture propagation is properly prepared prior to culture initiation.

Pre-conditioning of the plant under a still air environment away from other plants, the absence of overhead watering, optimum nutrients, light and heat, and the selection of the correct season of the year will ensure that new soft growth with a minimum of biological contamination is available for the initiation of cultures.

Culture media. Before any actual tissue culturing takes place artificial culture media must be prepared in a laboratory. Normally for the initial stage a very basic media formulation is used.

Macro and micro nutrients, vitamins and an iron source, sugar, and other essential growth factors must be accurately

mixed together and sterilised in the optimum proportions to support plant growth. The addition of agar as a gelling agent is normally used.

Culture initiation. This is a potentially very difficult area in plant tissue culture and many different methods are in commercial use.

Basically the aim is to surface sterilise the plant material without killing the plant itself. From this point onwards the culture must remain completely sterile as microbes would overwhelm the cultures and prevent growth.

The use of a range of chemical sterilants together with various physical methods will normally achieve the desired results.

Once the pieces of tissue (called explants) are sterilised they are transferred aseptically to the sterile culture media. All the transfer operations take place in a specially designed laminar flow work station which provides a clean air work environment.

Culture multiplication. Having achieved sterile cultures and with the emergence of new shoot growth from the explants, a multiplication of the cultures must now take place.

This is achieved by sub-culturing the plants onto a more complex culture medium containing plant hormones. This stage is really the heart of the whole process and the multiplication rate largely dictates the economics of the whole project.

There may often be very long and expensive periods of time before an optimum multiplication medium can be determined, a factor which many customers cannot fully appreciate. Once the multiplication rate is known production scheduling can begin.

Rooting. Shoots resulting from the multiplication need to be rooted. This is often achieved in culture by changing the plant hormones in the medium.

Wherever possible the rooting should take place in the nursery rather than in the laboratory where shoots are normally dipped in rooting hormones prior to hardening off. Rooting of tissue culture plants can be very difficult particularly with some of the woody species.

Weaning and hardening off. Tissue culture plants are succulant with very little cuticle layer on their leaves. It is important that they are weaned with gradual exposure to dry air. Specially designed nurseries are required to handle tissue cultured plants with equipment such as humidity tents, misting, fogging, hot beds, etc. being required to handle the plants from the laboratory.

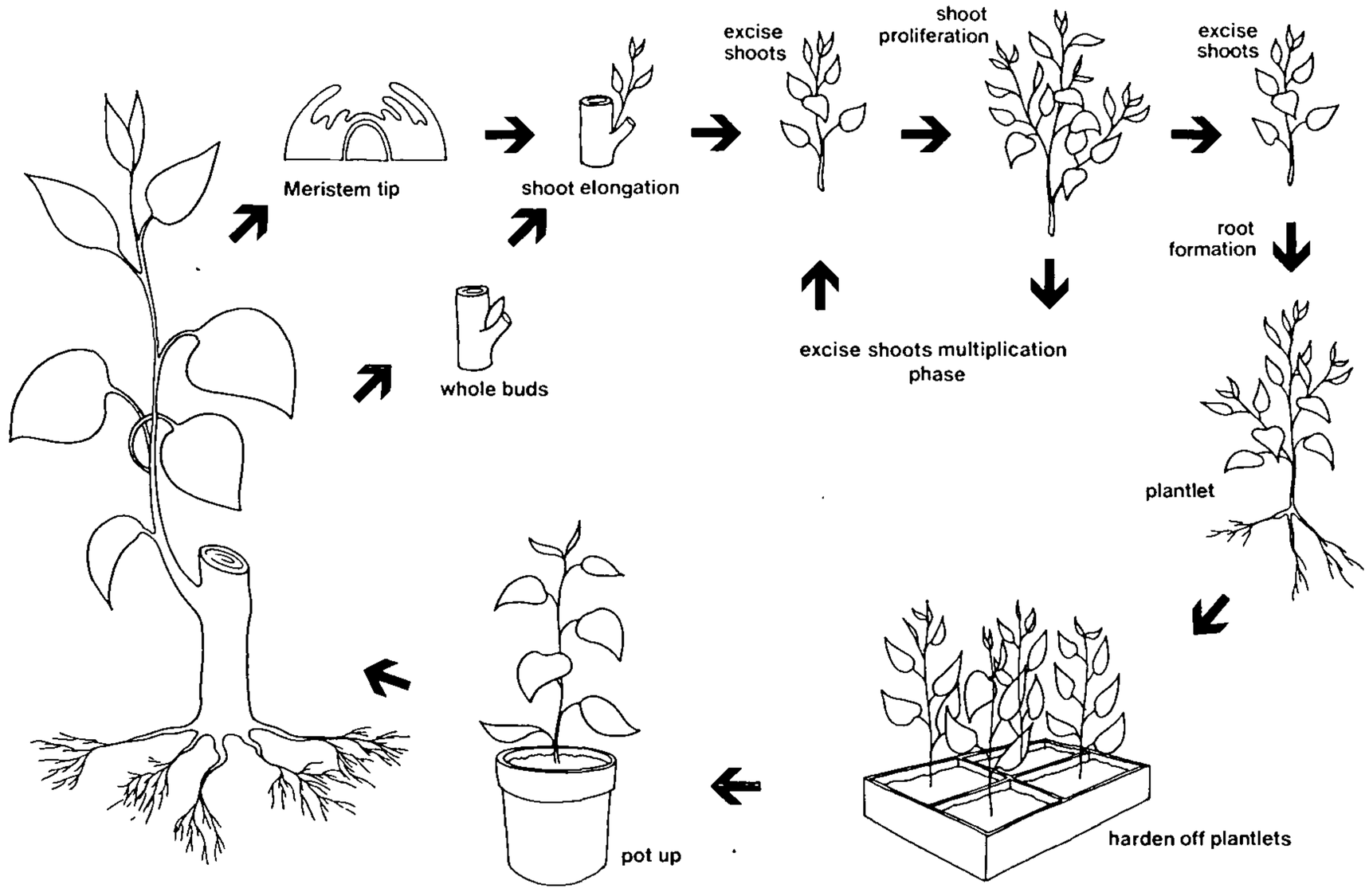

Figure 1. Steps involved in a typical tissue culture micropropagation process.

Growing on. Once the plants are fully hardened off and rooted they can be potted up like conventional plants. Tissue culture is often used to produce a uniform line of plants, e.g. squat multi-branched syngoniums.

What costs are involved? The requirement for expensive facilities and the need for trained personnel means that tissue culture is a more expensive form of propagation than the usual conventional methods. Some factors influencing costs include:

. . . is the species easy or difficult to establish in culture?
. . . multiplication rate.
. . . do the plants need to be rooted in culture?
. . . ease and success rate of hardening off the plants.
. . . the final number of plants required?

Advantages of using tissue culture:

. . . rapid clonal multiplication of valuable selections of plants
. . . multiplication of difficult-to-propagate cultivars
. . . availability all through the year
. . . elimination of viruses from infected plants
. . . maintenance of a nuclear stock of high health material
. . . reduction in a number of nursery stock plants
. . . importation and exportation of plant material
. . . production of new cultivars

Disadvantages:

. . . expensive setting up costs
. . . requirement for skilled staff
. . . the large numbers of plants required
. . . often lengthy research and development
. . . potential for some mutation to take place

So, to answer the question I orginally posed:- Is tissue culture the ultimate in asexual propagation? I believe that definitely it is not. It should not be considered as a replacement for the more traditional forms of propagation but, after considering a number of the points I have made, and understanding the basic principles of the process, it may be a realistic option when considering the propagation of a particular plant.

PROPAGATION OF RHODODENDRONS BY CUTTINGS: VARIATIONS UTILIZED IN THE WILLAMETTE VALLEY OF OREGON

W. JUNE BRENNAN

Brennan's Farm
8920 Hopewell Road, N.W.
Salem, Oregon 97304, U.S.A.

The Willamette Valley of Oregon is approximately 50 miles wide. Salem is located in the middle, some 60 air miles from the Pacific Ocean and 50 miles south of Portland. Walls of the valley are formed by the Coast Range on the west with a ridge crest of approximately 3000 feet above sea level; to the east the Cascades rise to approximately 5000 feet above sea level.

Rainfall in the valley ranges from 35 to 45 inches; 70% of our rain falls during the months of November through March with only 6% during the three summer months.

Only five times since weather records began in 1892 has 0°F or lower been observed; highs of 100°F or more seldom occur. There is a range of about 28°F between January, our coldest month, and July our warmest. The mild temperature, long growing season, approximately 6½ months, and plentiful moisture are ideally suited for a wide variety of nursery stock, particularly rhododendrons.

The variations in rhododendron propagation that will be discussed are from six different nurseries, all with rhododendrons as their main emphasis. The combined resources account for a production in excess of ½ million cuttings a year. Most are fellow members of the International Plant Propagators' Society.

Glenn & Darolen Sorum, Sorum's Nursery, Sherwood, Oregon.

Sherwood is about 30 miles north of Salem.

The propagating structure is set in the full sun. The base is built up from ground level 5 or 6 inches, the frame structure is of 2 × 4 wood or lighter to cast the least amount of shading. Sorum's propagate in flats, the heat cable is strung on the base and set at 72° to 74°F, with the flats placed directly on top.

The framing is low enough to conveniently reach over and down to pick up a flat. There is a mist system on a clock timer which mists to moist, then repeats after the leaves dry. The frame structure sides are wrapped with clear poly to contain the mist from wind; the top is open to the sky. In some beds they have insulated under the heat cable with a foil-covered

2½ in. poly board. This is covered with plastic, then the heat cable and flats. They feel this is a worthwhile conservation method for electric usage.

Sorum's start propagating in early July. Cuttings are trimmed, leaf area reduced and trimmed double or single cut depending on cultivar. Cuttings are washed but not sanitized; they are stuck in a ½ coarse peat, ½ perlite mix in flats. They feel it is important to firm cuttings when stuck, then watered well. After that they sprinkle can with a systemic fungicide (Benlate).

Ted Van Veen and Kathy Van Veen, Van Veen Nursery, Portland. Timing of cuttings at Van Veen's is early July through early September, with the exception of *R.* 'PJM', which is taken in late November after leaves have darkened.

Sanitation to forestall any possibility of fungus or disease is emphatically adhered to at this nursery. All items that may come in contact with the cuttings, i.e. clippers, gloves, table-top, knives, burlap, are sanitized with a hospital sanitizer — Physan 20-a, 1:10 solution. All cuttings are washed with a Physan mix (3 oz. to 4 gal. water) using a 1:16 Syphonex forceful spray, then drained on clean mesh of a washing bin.

They remove all flower buds, hanging leaves, and damaged parts from each cutting. They cut only leaves that are extremely long.

They wound the cuttings with a clean sharp knife. A standard cutting should be about 2 in. long. They cut the base at a 45° angle and make the wound itself about 1 in. long and just deep enough to expose the cambium.

For most cuttings Hormodin #3 is used; for dwarfs and lepidotes a 1:10 solution of Dip & Grow is used.

Preferably, cuttings are prepared and stuck the same day. If there is a need to hold processed cuttings they are stored in 40°F cool room in containers with clean, damp burlap.

They utilize a planting stick (board with wooden dowels) which marks bed row and allows each cutting a 2 in. square. The bed mix is 60% peat, 30% perlite, and 10% sand, steam sterilized and replaced each year. All greenhouses are thoroughly cleaned before each crop.

The following morning the beds are well watered so the rooting medium comes in good contact to the cutting; a short time later Wilt Pruf is applied.

Van Veen greenhouses vary in types of structures and heat source. Most are beds set up with the rooting medium in the beds. In some, the cuttings are put into wooden flats. All utilize heat beneath the cuttings and have electronic leaf con-

trol mist systems. The houses are heavily shaded with white wash; a look to the sun through the covering should not cause a person to squint. For approximately the first two months, the cuttings are watered each morning with the leaf control mist system on from 11 a.m. to 7 p.m., depending upon the weather of the day. The greenhouse tops are open all night until mid-September or until temperatures at night remain in low 40°'s F.

The bed temperatures are kept at 72 to 78°F. They expect callusing within 1 to 2 weeks, rooting within 2 to 4 months.

Jack and Lurlyn Long, J & L Nursery, Silverton, Oregon.

J & L Nursery is approximately ten miles north-east of Salem.

This is the latest state of the art in propagation — at this point experimental, though looking good so far.

The house is 44 × 96 fiberglass walls, low raisable panels at each end for air circulation, no added fanning or cooling. The roof is double poly with a fan to create air space between the layers. The floor area has 7000 ft., ¾ in. poly pipe with a gravel top. The propane-fired hot water boiler is so controlled that the house floor is kept within one degree of the setting, 70 to 72°F.

The house has three air condition controls: 1) time, 2) humidistat, and 3) temperature. The boiler controls the evenness of floor temperature and the water control has a filtration of particulants, pressure booster, and injection system of a chemical to suspend any minerals that may cause fogger orfice blockage. Each fogger line in the house is rated to withstand the 600 lbs. pressure; it is a poly pipe with brass fittings. Each line has a reverse pressure drain so each line drains all water between activation.

Cuttings are taken from early July through August and September. Only the amount that can be handled that day are taken — early in the morning. Cuttings are washed and sanitized with Physan, then rinsed.

Leaves are removed back to the top whorl (3 to 5 leaves), stems shortened, stems wounded with ½ to 1 in. cut; some cultivars are double cut. Leaves are not shortened. Cuttings are dipped in a 1:5 solution of Dip & Grow for 5 to 20 seconds.

Flats filled with 2 in. pots are then filled with a rooting mix of 1 part bark, 2 parts peat, and 2 parts pumice. This is mixed by loader scoops which averages out 2 cubic yards. This mix is not sanitized. The cuttings are stuck in the individual pots and well soaked, with no further watering.

In the house the timer is for "on" from 6 a.m. to 10 p.m. in

the summer, with the humidistat set at 95%. The temperature control (which will override all) is set at 90°F. Later, and at shorter days, the timer is set for 8 a.m. to 6 p.m. It is off at night; 85% humidity is used. At this point the cuttings look excellent; the rooting percentage and quality of roots will be the final answer.

Adrian and Dorothea Olson, A & D Olson Greenhouse, Silverton, Oregon

Olson's Greenhouse is located about 20 miles east of Salem.

They use heat cables set at about 70°F, a rooting mix of 50% coarse peat and 50% perlite. They take their cuttings in October and November, refrigerate them in plastic bags until they are ready to prepare them for the bed. The preparation is quite like the majority as to size and trimming of cuttings. In talking with them we found they used no particular sanitary safeguards. This may be due to the lateness in the season and the lower temperature. Sanitation problems may be encountered more during the earlier warm weather propagation.

Olsons utilize an 18-hour soak for their cuttings; 150 ppm IBA is used with cuttings banded in groups of 25. In this method the cuttings should be held at normal room temperature (70°F) so the cuttings will take up the solution. If the area the cuttings are to be placed into is cool and moist the amount of IBA taken up may not be enough. This method is explained in Leach's, "Rhododendrons of the World".

Dr. Herbert and Betty Spady, Honsuchachac Rhododendron Gardens, Salem, Oregon

Honsuchachac Rhododendron Garden is approximately 10 miles east of Salem.

The Spady's use a modified Nearing frame system with no heat. The frames are set on top of the ground with about 10 in. of bark protection. The frames are somewhat A-shaped with the opening side facing true north so no direct sun is on the cuttings. The frames are made of redwood and all surfaces facing north are painted white for best light reflection.

The frames are placed in the brightest and lightest position available (no shade). The frames are thoroughly cleaned and a sterilant is used, rinsed, and dried before new rooting medium is added — to a depth of about 6 in. Old bark, taken from the middle of a year-old pile, is the rooting medium used now, though other combinations have worked well.

Cuttings are taken as early as possible in the new growth season, trimmed, wounded, and Wood's Rooting Compound is used. Sometimes "Wiltpruf" is used if the cuttings are very

young. Cuttings are watered about once a week during hot summer months, but only every two or three weeks during cold or wet periods.

Rooting takes place in 2 to 3 months for most smaller-leaved cultivars, but up to 2 years for the most difficult-to-root.

W. June and Herb Brennan, Brennan's Farm, Salem, Oregon

Our farm is ten miles northwest of Salem.

I propagate in a poly hoop style house with table high beds. I use a bark dust base of 2 in. topped with 4 in. of a peat (4 cubic foot bale), perlite (3 to 4 cubic foot sacks) mixture.

Depending on the cultivar I start taking cuttings in mid to late June and like to be finished by the first week or so in September.

The propagation house, which is situated in the protection of trees, runs north and south with the west side and over the top covered with shade cloth. The house has doorways at each end that can be opened or closed for better ventilation. I use no heat but have a mist system that is manually controlled.

On preparing the cuttings for the bed, the unwanted leaves are removed. I usually retain the top 3 to 5 leaves on smaller-leafed cuttings with no further leaf reduction; on larger-leafed cuttings the leaf area may be trimmed back by over half. I use a utility knife with replaceable blade for wounding and trimming. Most cuttings I double wound; some smaller leaf or known easy rooters I may single wound. As the cuttings are prepared they are dropped into a pail of clear water, then lifted out, put into poly bag with a bed label and refrigerated until I have acquired enough to stick them down in the propagating bed.

All cuttings go through a bleach water bath as they are put into the beds. The bath (1 cup bleach to 1 pail of water) receives all cuttings, including the label, so everything is as clean as possible at the latest moment. Each cutting is shaken of excess water and dipped into a talc (8000 ppm IBA rooting hormone — Hormodin 3). To the rooting hormone I add 1 teaspoon Benlate per 2 oz. I feel this helps forestall fungus damage.

I wear rubber gloves during this last procedure as I have found the bleach irritates my hands.

The cutting is dipped into the rooting hormone to cover over wounded area, the excess talc is tapped off, then stuck in the bed to cover the wounded area by ½ to ¾ in. of rooting medium. The mist system is set on and may run 5 to 10

minutes to help settle the cutting. (I do not heavily water them in). After the beds are filled I usually only mist for a couple minutes morning and evening, unless there are some exceptionally hot days.

IN SEARCH OF NEW PLANTS: PLANT INTRODUCTION, METHODS, AND APPLICATION

DICK J.W. ENDT
Landsendt Subtropical Fruits,
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The frost-free regions in the northern parts of the North Island of New Zealand have been a challenge to many horticulturists in the past century, as the climate in this zone has unique qualities, being without extremes in temperature. This allows plants of both a tropical and temperate type to be grown in close relationship.

In early times, pioneers introduced both food bearing and ornamental plants into New Zealand, from the mother country — England. Most of these early introductions thrived, although some of the temperate fruits did not thrive in northern regions of the country, due to lack of winter chilling. In the last fifty years, many new plants have been introduced, mainly those that grow well in this sub-tropical region. The Kiwifruit, brought into New Zealand in the first decade of this century, has only become a commercial success in the last twenty years. Other lesser known fruits have also become commercial fruits in New Zealand, such as the feijoa, *(Feijoa sellowiana)*, the tamarillo, *(Cyphomandra betacea)*, the pepino, *(Solanum muricatum)*, and many species of citrus. There are still many plants, unknown in New Zealand, that warrant introduction and evaluation. The author has been directly involved in plant introduction since 1976.

Why more plant introduction? Early plant explorers who travelled to foreign lands were hampered by difficult transportation and inadequate collection facilities. Places visited were often pristine, presenting an enormous challenge to collect the many unknown plant forms. Today a reverse situation exists, where transportation is instant, and plants may be sent over large distances in a relatively short time. What is alarming however, is that many natural plant habitats are rapidly disappearing, as the rate of plant removal and clearing increases every year. In spite of modern communications there are many

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plants that are little known and in some cases undescribed. Often plant species simply vanish in the face of the onslaught of forest destruction.

It is important therefore, that plant introduction should be encouraged, to save plants from being lost altogether. Instances have occurred where introduced plants perform better in the country of adoption than in their native habitat, hence improving the changes of survival of the species. My plant introduction programme was planned so as to introduce plants most suited to our northern New Zealand climate. The climate of the high altitude regions in the equitorial regions of South America closely resembles that of New Zealand. In order to carry out such a programme, close planning is required.

Plant exploration, aspects of planning. Unprepared travel to a foreign country rarely results in successful plant introduction. Plants are intimately associated with people. In order to learn more about the plants of a country it is equally important to study about the people that live in these areas.

1. *Study the geography of the country to be visited.* Land contour often decides what plant species may be expected. Factors such as mountains, lakes, plains, etc. create ecological niches for certain plant species.

2. *Political history, economic, and ethnic studies.* These factors often decide to what degree plant life has been preserved or destroyed.

3. *Language study.* In the case of South America, it is essential to have a working knowledge of Spanish. This may take about 3 years of study in which to become adequately conversant. It takes a lot of motivation to maintain the will to study in addition to other commitments in one's working life.

4. *Study of known plant species in the country to be visited.* Apart from rather encyclopeadic references, little has been described about plants in western South America. References of value may be found in literature, mostly in Spanish, hence the ability to translate is of great value. Knowledge in taxonomy is necessary to assist in the identification of plant species unknown to the collector.

5. *The establishment of reliable contacts* in order to establish a correspondence network. Much trouble can be spared when useful information is gathered from correspondents who are familiar with the areas to be visited. Find out about the customs and life styles of the people you will come into contact with. Much embarrassment can be caused by one inadvertant remark. Any assistance in travel arrangements can save much time. Local knowledge of interesting collection areas can often be found in the districts.

Once all your plans fall into place, consider the mechanics of plant collecting.

1. *Permission to collect wild plants.* Some countries have strict rules about the collection of native plants.

2. *Pre-arrange the method of transport once the plants have been collected* — for instance, in the case of New Zealand it is quicker to route the consignment via Europe than to try to fly it across the Pacific. Flights across the Pacific to New Zealand are few and far between from South America.

3. *Make arrangements with the Ministry of Agriculture and Fisheries in New Zealand* to obtain importation permits. Some plants are prohibited or restricted for entry into New Zealand.

4. *Have suitable post entry quarantine facilities.* The success of plant introduction often depends on the ability of the importer to care for the material imported. This includes the monitoring for possible plant diseases and pests.

Tools for collection — Secateurs, a knife, a simple digging tool, plastic bags, foam rubber to keep collected specimens moist, rubber bands, ties, plant labels, felt pens and, of course, a notebook. A good camera with various lenses, binoculars, magnifying glasses and a light carrying case for it all are necessary.

A slide presentation can be summarised as follows: — Photographs were shown of native plant collections in Colombia. Those of the Jardín Botánico and Bogotá provided a wide range of plants which would be difficult to find if a collector had to travel throughout the country in order to see the same range. The National University of Colombia in Bogotá has an active plant propagation programme with aims to multiply native plant species, now becoming rare in Colombia.

The author visited fruit orchards in Ecuador growing crops such as babaco, *(Carica × heilbornii, C. pentagona)*, cherimoya, *(Annona cherimola)*, tamarillo, *(Cyphomandra betacea)* — important crops in that country but little known elsewhere. Vegetation changes abruptly according to altitude. Distinct "fajas" or zones offer different plant species. Areas visited were near Baños, Ecuador, between 1500 m to 2000 m altitude. Many forest species of tropical nature were found — palms, cecropia, orchids, bromeliads, and many species of the Araliaceae to name a few; 2000m to 2700m offered different plant species, often hardier forms of those growing at lower belts, a typical example being the cecropia. Those growing in tropical regions will not thrive in New Zealand, yet those collected at 2500m altitude grow well. This also applies to tropical forms of tropical fruits. Some forms will reach into higher altitudes

which make them interesting for introduction into a climate such as we have in New Zealand. In the family of Caricaceae, a number of species exist in the mountains of Ecuador which have now been established in New Zealand as commercial cultivars. Bromeliads and orchids are particularly striking in this altitude range.

Above 2700m to 4000m the vegetation becomes more sparse. Such areas are termed the Páramo. Often shrouded in mist and cold, heathlike plants exist with a stature no more than 2 metres. The Family Compositae is very common and so are ferns and lichens. One fruiting plant, *Vaccinium floribundum*, carries numerous small berries, refreshing in flavour.

The botany of the west coast region of South America is still incomplete. The rapid disappearance of the native vegetation offers a challenge for those adventurous enough to visit these areas. Plant life in South America is extremely rich and varied.

VEGETATIVE PROPAGATION OF RADIATA PINE

MICHAEL I. MENZIES

Forest Research Institute,
New Zealand Forest Service, Private Bag, Rotorua

Abstract. Systems used for vegetative propagation of *Pinus radiata* (radiata pine) in New Zealand are briefly described. Mature trees are propagated by cuttings or grafts for the establishment of archives and seed orchards. Several propagation techniques are being developed for multiplication of scarce seed of the best genetic material. Options include collection of cuttings from young plantation trees, manipulation of seedlings in nursery stool beds, and micropropagation.

INTRODUCTION

Radiata pine plantations traditionally have been established using seedlings. This programme has used up to 5000 kg of seed each year, with over ¾ of it being improved seed from open-pollinated seed orchards.

Further significant improvements in tree quality can be made using seed from controlled pollinations between the best parents (12). It would be feasible, but logistically difficult, to produce all New Zealand's requirements by controlled pollinations. An alternative method is to combine a programme of controlled pollination with some form of vegetative propagation (4). Rapid advances are being made in propagation techniques for juvenile planting stock, including collection of cuttings from plantation trees of improved seed origin,

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manipulation of young seedlings in the nursery beds as seedling stools, and micropropagation (8).

A. VEGETATIVE PROPAGATION OF OLD MATERIAL FOR SEED ORCHARDS AND ARCHIVES

Grafts and cuttings are used for cloning physiologically old (10 years or older) radiata pine to establish seed orchards and clonal archives. Cuttings are preferred because of the problem grafts often present with delayed incompatibility. However, cuttings taken from old parent ortets rarely root satisfactorily, necessitating grafting as a first step in propagation procedures for newly-selected trees.

Bud scions are taken in winter from parent ortets for grafting, and the grafts used for establishing temporary clonal orchards (usually hedged), or for initiating new seed orchards. Once the grafts are large enough for repropagation (3 years after planting), they are used as a source of cuttings for setting up permanent archives and seed orchards.

For cutting production, the current season's shoots are cut back in late summer (mid-February) to where foliage is dense and fully developed (topping). In March, 3 to 4 weeks after topping, when the cuttings have developed small needle fascicle buds, they are ringbarked 50 to 150 mm below the terminal topping. Then in April, 4 to 6 weeks after ringbarking, the cuttings are collected and set in polythene tunnels which maintain a temperature of 15 to 28°C during daylight hours and a humidity of 70 to 100%. If the prescribed propagation system is adhered to, 70% of the cuttings strike successfully and develop balanced root systems.

B. VEGETATIVE PROPAGATION OF JUVENILE MATERIAL FOR PLANTATION ESTABLISHMENT

(1) *Vegetative propagation using field cuttings*

Cuttings can be readily propagated from young radiata pine trees in the forest. Plantations best suited to cutting collection are those established with seedlings from special seedlots, collected from the best seed orchard clones (3) or from control-pollinated crosses. Collection from field trees also allows some selection for vigour and form of the parent ortet.

Cutting material should have dense, fully elongated healthy needles, with a cutting length between 100 and 150 mm, and a minimum diameter of 6 mm. Collection is made during the period of slowest growth (in Rotorua from late April to late June) and the cuttings are set outside in raised nursery beds. Overhead irrigation is necessary during warm or dry windy weather, particularly during the first few weeks

after setting. Rooting occurs in the spring following setting, with acceptable rooting of about 80% from 3-year-old ortets. The cuttings are later conditioned by undercutting, lateral root pruning and wrenching, and are ready for lifting one year after setting.

Field collection of stem cuttings is time consuming and expensive, as it involves travel, and only a few cuttings can be collected from each tree. Cuttings from older trees have advantages in that ortets can be selected for desired characteristics, and malformation is greatly reduced, but they do have reduced initial diameter growth and are not always easily rooted.

(2) *Vegetative propagation of juvenile material using nursery stool beds*

(a) *Seedling pruning*: Seed is sown in spring (September/early October). In February, when the seedlings are 100 to 180 mm tall, they are topped 5 mm above the highest side shoot. Several side shoots then develop into stem cuttings. Cuttings 50 to 100 mm long can be collected and set in winter either in open beds or open containers. Any remaining lengths of new leaders can also be collected and set. This method gives a multiplication factor of up to eight. Open bed cuttings are conditioned as for field collected cuttings and are ready for planting the following winter. Containerised cuttings are grown on a low nutrient regime to produce woody stemmed plants 100 to 200 mm tall. Rooting percentages for these types of stem cuttings exceeds 90%.

(b) *Seedling pinning down*: Various techniques are being developed to raise elongated fascicle shoots suitable for open bed or container setting. The two most promising options are:

(i) *Open-bed cuttings*: Seed is sown in September. Stock plants are grown for 14 months to about 1 metre tall. They are then topped to about 750 mm to remove soft top growth, and pinned down to the ground. The resulting fascicle shoots are thinned to 30 mm apart along the seedling stem after 4 to 6 weeks. By May, 20 months after sowing, the seedlings have produced shoots 100 to 150 mm in length. These shoots are collected and set in outside nursery beds. The multiplication rate is 30 to 40× if only first-order cuttings are collected, or up to 80× if two cuttings are collected per shoot. The stool beds can be used for more than one year, by saving the shoot closest to the root system for pinning down the following November.

(ii) *Container cuttings*: Seed is sown in early spring (September). Six months later, in March, when seedlings are 100 to 200 mm tall, they are topped and pinned down. The develop-

ing fascicle shoots are left unthinned and are collected in June, 9 months from sowing, and set in containers outdoors. Cuttings are ready for planting in February-March. The average multiplication rate is 17×, with rooting success of 99%.

C. MICROPROPAGATION

Micropropagation methods have been developed for a variety of explants, including embryos, cotyledons, and seedling shoot tips (2,6,9). Amongst the many steps involved are shoot initiation, shoot elongation, shoot multiplication, and rooting.

Shoots can be initiated from: excised embryos, cotyledons from 5- to 7-day-old germinated seeds, or induced fascicle shoots from 9-month-old seedlings. After sterilisation, all explants are cultured on a shoot-inducing medium containing cytokinin. The shoots are then placed on an elongation medium without cytokinin. Several transfers (two to six) are necessary to get fully elongated shoots of about 15 to 20 mm. At each transfer clumps of shoots are cut into smaller pieces and the newly cut surface placed in contact with the medium. Small shoots can be multiplied in culture to build up numbers of a clone by topping and allowing new side shoots to grow out, or by placing shoots on a medium with cytokinin. Shoots can also be cold-stored in culture at any stage of elongation, thereby arresting growth. Growth resumes when the shoots are replaced in the controlled environment chamber under normal culture conditions.

For root initiation, shoots are first given a 5-day auxin treatment, then planted in a non-sterile potting mix in trays and kept in a high humidity chamber. After rooting, the plantlets are transferred to a plastic tent in the glasshouse, hardened off, and lined out in nursery beds under shade cloth. The plantlets then receive the standard nursery treatments given to seedlings. From auxin treatment of shoots to planting out of micropropagated stock takes 12 months.

The multiplication rate from micropropagation depends on the time *in vitro*. A 1000 × multiplication is feasible for a propagation period of 22 months, from seed to plantlets at the nursery gate, but higher multiplication rates would be possible given a longer time, with *in vitro* stages of remultiplication.

By holding micropropagated shoots in cold storage (1) it may be possible to test clones in the field while ramets are kept in juvenile state in the cold store, rather than growing in hedged archives, as previously described (7,10).

DISCUSSION

There are two main reasons for the upsurge of interest in vegetative propagation of radiata pine in New Zealand. Firstly,

the tree breeding programme at the Forest Research Institute is continually producing control-pollinated seed, in limited quantities, from the best available parents. Progeny from these seedlots are measurably superior to those from open-pollinated seed orchards. With vegetative propagation, progeny from this scarce seed can be made more widely available, thereby permitting greater areas of forest to be planted with the best genetic stock. Secondly, the improved form of cuttings from older ortets has become apparent from field trials (11,13), and this has led to a demand for these cuttings (3). As a consequence of the improved genetic quality of the seed stock, and the improved form associated with age, cuttings can be planted confidently at comparatively wide spacing. Although the cost per plant is higher than for seedlings, the cost per hectare appears very competitive.

There is a wide variation in multiplication rate, time taken to produce cuttings, and cost of the various forms of vegetative propagation (Table 1). The method used will depend on the relative importance of these three factors.

One of the easiest methods for multiplication of seedlings is top pruning, using nursery stool beds. Cuttings can be set bare-root or in containers, and the time in the nursery is less than two years, although the multiplication rate is low. A higher multiplication rate can be obtained from stool beds using the pinning-down method, but the cuttings must be set in containers, unless the time in the nursery is extended to three growing seasons. However, the multiplication rate is more than doubled with an extra year in the nursery and the stool beds can be used for more than one crop of cuttings.

Table 1. Summary of approximate costs for various propagation options.

Method	Multiplication rate	Bare-root or containers	Minimum time in nursery (months)			Cost (NZ$/1000) plants
			Stool bed	Rooting	Total	
Seedlings	1	B	—	—	10	50
Field	3-5	B	—	12	12	160
Topped stools	8	B	9	12	21	77
		C	9	8	17	90
Pinned down stools	17	C	10	8	18	87
Pinned down stools	80	B	20	12	32	70
Micro-propagation	1000	B	—	11	22	450

Recently research interest has focused on propagation from control-pollinated seed of genetically improved families. The original idea of using rooted cuttings for plantation forestry was to use clones that had been field tested (4,5,7,10,13), but there were found to be several problems, the main difficulty being that of maintaining hedges in a juvenile state. Micropropagation, and cold storage of ramets as micropropagated shoots, could be a viable alternative. For multiplication of control-pollinated families, micropropagation is very expensive compared with other propagation methods (Table 1). Either the labour cost must be significantly reduced or alternative techniques (e.g., somatic embryogenesis) need to be developed if this method is tto be competitive. Besides the high cost, there can be problems achieving a balanced root system on plantlets. Both problems could be resolved if, after initial micropropagation from seed, plantlets were lined out as nursery stools, pinned down, and used as a source of stem cuttings for open-bed or container setting (8). If micropropagated plantlets cost $450/1000 to produce, this would add only $5.60/1000 to the cost of the resulting cuttings, assuming an 80× multiplication rate from the stools.

CONCLUSIONS

With seed of improved genetic quality becoming available from controlled crosses between progeny-tested parents, vegetative propagation is seen as a useful way of extending this scarce seed. Several methods of propagation can be used, but the most promising involve use of nursery stool beds, by topping and pinning down seedlings to produce cutting material that can be set in the open nursery bed or in containers.

If clonal forestry is judged desirable for gaining benefits of further genetic improvement, then use of micropropagation techniques may allow clonal testing in the field while maintaining clones in a juvenile state in cold storage as micropropagated shoots.

Cuttings will be used more widely for planting radiata pine in the future as these new propagation methods are developed and adopted by forest nurseries.

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RAISING BEDDING PLANTS FROM SEED

MARK HEATH

The term "bedding plant" at one time applied only to half-hardy plants planted outside once the danger of frost has passed. In the 1980's this term has a far wider meaning and can be divided into three groups:

Group 1. summer bedding. Group 2. autumn and winter bedding. Group 3. spring bedding.

The majority of bedding plants grown today are raised from seed. Each genus of plants produces different types of seed which require different germination conditions to obtain the maximum seed emergence from each lot.

The basic requirements for successful seed germination are:

1) Adequate moisture
2) Adequate heat
3) Adequate air
4) Adequate hygiene
5) Good seed

Adequate Moisture: Water the compost before sowing and allow time to drain and warm up. When sowing for our trials we use Fison's Levington compost and drench with the fungicides, Filex and Basilex, to give protection against damping-off diseases. Bedding plants fall into 4 categories for moisture requirements in the propagation stage.

1) Seed that germinates in dry to wet composts, e.g. marigold.
2) Seed that germinates in composts from an intermediate moisture level to a high moisture level, e.g. pansy, *Salvia*.
3) Seeds that require high moisture levels, e.g. *Lobelia*, *Begonia*.
4) Seeds that germinate well at low moisture levels but do not germinate at high moisture levels, e.g. *Verbena*.

The maintenance of adequate moisture levels whilst the seed is germinating can be difficult, especially for small seed. Covering the trays with polythene or glass and paper has been practised for many years but now misting or fogging is being used by large scale propagators and is giving excellent results.

Adequate heat: Singly this is the most important environmental factor in good seedling emergence. Most species of plants have an upper and a lower level at which seeds will not germinate. When the temperature rises above the upper limit, seed goes into a state of secondary dormancy which may or may not be broken; e.g. *Delphinium* seed becomes dormant

above 15.5°C. Dormancy is broken by subjecting the seed to 5°C for 3 weeks and then germinating at 15°C. An emergence of 70% is then possible. If seed was subjected to 5°C after sowing and then germinated at 15°C, an emergence stand of 80 to 85% is possible.

Adequate Air: Three points to bear in mind are:

1. Gaseous exchanges between the medium and air are reduced by depth. Depth of covering is not only critical for air exchanges but also for light requiring species.
2. Oxygen intake limited by water content of the compost medium.
3. Capping on the compost surface reduces gaseous exchanges.

We recommend all sowings to be covered with horticultural grade vermiculite. The material does not cap even when wet and it also allows sufficient light to those seeds that require light but need covering to obtain maximum seedling emergence, e.g. *Impatiens*.

Good hygiene: Clean propagation area, propagation house, growing structures and sensible use of chemicals to prevent disease will keep crop losses to a minimum.

Good seed: This is the most important factor in producing quality bedding plants. Most seed is produced abroad for reasons of environment and economics. Open pollinated cultivars are field-grown in California. Hybrid seed production is in Guatamala and Kenya. Primrose seed production is confined to Europe. Upon arrival here at Adderbury the seed is tested for moisture content and inspected to see what further processes are required to the seed batch before packing. Samples are taken from the batch for: 1) germination tests; 2) emergence tests; and 3) cultural and stock trials.

The seed is stored in a temperature and humidity controlled store. Some seed, such as sweet pea and lupins are stored in a temperature controlled room as fluctuating moisture levels are necessary to ensure the seed coat does not harden. All seed is packed by hand. Seed is sold by weight or by count and packed into crystal liners before being placed in foil packets which are then heat sealed to ensure that seed viability remain high for long periods. After packing, the seed remains in the warehouse until it is collected for despatch to the customer.

Germination tests are carried out on all incoming stock and stock held over from one year to the next. Flower seeds are not governed by EEC regulations for purity and emergence. Our standards of germination are based upon the N.S.T.O. and

its American counterpart. Batches of seed which fail to come up to standard are discarded and burned.

Germination tests are carried out in petri dishes which are placed in cabinets. These provide optimum conditions for germination. Germination is said to be complete once the radicle has emerged from the testa.

Emergence tests are carried out on all System Seed items. Seed is sown in Levington compost and germinated in a specially constructed germination room.

Cultural and stock trials are carried out each year in our own trial ground. Seed is raised in the glasshouse unit in a propagator of similar design to the Electricity Council's small propagator, or in a specially constructed germination room. Each batch is tested for quality, trueness-to-type, and compared with new cultivars on offer from plant breeders.

Production costs for growers of bedding plants are continually rising. Seed accounts for approximately 7% of the total production cost. Any saving in the annual seed bill, without affecting the quality of the plant produced and garden performance is always welcome. Construction of more sophisticated propagation areas will enable higher germination rates to be achieved, or purchasing seedlings and plants from a specialist propagator are ways which growers can achieve a reduction of production costs.

The pressure on seedsmen to supply better quality seed has resulted in many improvements in seed quality.

Alternaria, once the greatest disease problem of bedding plant growers is now a disease which is easily controlled. It is mainly seed-borne but treatment of the seed before packing with a warm water/alcohol soak is now standard practice with *Alternaria* susceptible species, e.g. *Lobelia*.

Improvements in the techniques of seed cleaning ensure that dust, dirt, and disease spores are at a minimum in a particular batch. Air column blowers are used to clean seed as small as *Begonia* (67,000 seeds per gram).

Clipping of marigold seed to remove the halm — where diseases can be carried over from one crop to the next — is one of the latest seed quality improvements now being seen by the bedding plant grower.

The biggest single improvement in providing better quality seed has been the introduction of System Seed. Cultivar selection starts in the trial grounds at Adderbury in the U.K., Holland, and Germany. System Seed cultivars are those in their own right and have been bred for European conditions. The seed crops produced must be of a high quality and, upon

testing the seed, the germination percentage, and emergence time must fall within a given specification. When the seed is received it is graded by either size, density, shape, weight, or colour.

A chemical treatment is then applied to the seed to enhance the vigour of emergence. The batch is then subjected to compost emergence tests to check the uniformity and vigour, after which, by use of a simple formula, we calculate the number of seeds to put into a packet to provide a predictable amount of uniform seedlings.

System Seed is used for plug production by our seedling and plant department. It saves time and money so growers can benefit by cutting their production costs, but still produce a quality bedding plant.

At present the number of plant genera, species, and cultivars is limited to:

Ageratum houstonianum 'Blue Champion'
Cineraria maritima 'Silver Dust'
C. 'Cindy'
Dianthus Princess Series
Geranium Century Series
Impatiens 'Accent'
marigold 'Perfection'
pansy 'Universal'
pansy 'Lyric' × *hybrida*
Petunia Express Series and Cloud Series
Salvia splendens 'Fury'
Verbena × *hybrida* 'Garden Party'
Zinnia 'Peter Pan'

but further developments are underway.

LARGE SCALE APPROACH TO CROP PROTECTION

JOHN ADLAM
Blooms Nurseries Ltd, Bressingham, Diss, Norfolk

I look at the job of a grower as one of eliminating the variables of the environment. I see these variables as follows:

1) Moisture levels
2) Nutrient levels
3) Gaseous levels
4) Temperature levels
5) Pest and disease levels

Many of the so-called crop protection duties are a result of an imbalance of one or more of these variables, not just pest or disease factors. Crop protection is not, therefore, just the appli-

testing the seed, the germination percentage, and emergence time must fall within a given specification. When the seed is received it is graded by either size, density, shape, weight, or colour.

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Many of the so-called crop protection duties are a result of an imbalance of one or more of these variables, not just pest or disease factors. Crop protection is not, therefore, just the appli-

cation of chemicals but the paying attention to all 5 items with equal credence. I firmly subscribe to the approach of *prevention* rather than *cure* and have proved that preventing an imbalance of these variables goes a long way toward protecting the crop. I am not an advocate of organic growing, but know that the best crops are grown by working with nature not propping it up.

Light on our toes. When it comes to doing the job, our motto is "light on our toes". Large organisations are notorious for being lumbering animals, but our approach is to be quick in response to a crop's need or the weather. As a large company we divide up into departments that specialise. Crop protection is one of the specialised departments. We aim to provide the growing departments with a service covering spraying operations, nutrient requirements, a laboratory service for analysis and P & D identification, compost quality control, and supplies.

My team consists of a crop protection officer, technician, supervisor, and up to 4 spray operators. The team members are very flexible in the times they work and are willing to come in at 5:30 a.m. or stay as late as 9:30 p.m. to get the job done. A sense of concern and urgency is felt by all if conditions are right or the need great.

In the know. One of the important aspects of modern day growing is knowing what is happening. Crop protection in the propagation beds is often influenced by what you know about the crop at any given time. We are constantly looking for ways of improving what we know NOW.

Bed temperatures are controlled by electronic controllers. These can maintain the beds at a far closer tolerance than rod thermostats, as well as monitoring the temperature in the rooting medium within the tray rather than in the bed below. Our units have a temperature meter showing a constant reading of temperature which is also relayed back to the foreman's office. This enables the foreman to constantly review the propagation environment in all six different locations at one time.

Record keeping is an important aspect of our work as we frequently need to be good detectives in identifying a problem. Records are kept covering details of stock plant location, spraying operations prior to cuttings being taken, full daily weather records from our own weather station, details of personnel involved in the cutting production, and compost records of ingredients. All these aspects, as well as many others, help us in protecting the crops under propagation.

Water quality is a constant headache. Our water for propagation comes from a bore hole and is heavily laden with

minerals. Iron at 2.9 ppm and a total hardness of 390 ppm $CaCO_3$ make up a water that naturally blocks nozzles and covers plants with a brown deposit in two weeks. To overcome this we have installed a three stage water treatment plant. The iron is first oxidised by a manganese dioxide filter, and the calcium and magnesium carbonates are removed in an exchange column water softener. Because the Ca and Mg are exchanged for sodium we have a reverse osmosis unit to remove the sodium. This leaves us with a water that is free from harmful minerals, has a neutral reaction, and is biologically pure. Checks on the rooting medium help us to be aware of water quality.

One foot on the ground. It is very easy for a large company to have its head in the clouds and forget that much of our life goes on 6 in. below the ground or pot surface, out of sight. We, therefore, have a firm commitment to foster the "growers" in the company. With departmentalisation and large scale task-oriented operations, it is easy to forget our responsibility to the crop, and the people who are "where the rubber meets the road".

The people in direct control of the crop are our most valuable asset, particularly when it comes to crop protection. In December we held a one-day seminar for all managers and foremen on modern crop protection systems and methods. We invited the best people in their field to come and speak to us. A Health and Safety divisional chief, ADAS Regional Ornamentals Adviser, National ADAS Weed Specialist, and Senior Technical Officer from ICI Midox. The seminar was held off the nursery in a local Country Club and everything was provided free to the delegates. This has helped the people who handle the plants to understand more about the way herbicides work, and has reduced the aura surrounding "nasty chemicals". The differences between residual, contact, systemic, and persistent modes of action were all explained. This made a significant contribution to our crop protection on the nursery.

We also encourage a group of people from different departments to look at any aspects of nursery efficiency. They are formed into what we call The Nursery Action Team. This, too, has helped in high-lighting where improvements in crop protection are needed.

Winning the assistance of our workforce is seen as a major asset of crop protection.

The willing worker. One of the means of being light on our toes is by the productive use of a computer. I stress the productive use because I am a firm believer in making the

computer do what you want — never the other way round. I have built up a series of programmes that will provide the truth at the speed of light and upon which we can make sound decisions. We have a large main-frame computer that handles all the important facilities of the company, but my faithful friend is a desk top micro. We have herbicide tolerance of over half of our plant genera with 8 different residual herbicides. By keying in the genera we can see instantly which herbicides are safe. We can then group our plants according to herbicides, a major efficiency factor in spraying. The production of spraying instruction sheets is by a computer and it works out the amount of water, chemical, the number of journeys, and the time it will take us. Planning a day's work can be a little more accurate. I haven't yet found a way of controlling the weather with it though!

Budgeting a year's crop production costs is also possible. By combining historical and projected data, a pattern of expenditure can be produced. This data is then used in part of the annual analysis of costs. By allocating costs to different crops and apportioning them together with labour, we can very quickly arrive at a price per square metre of a crop's protection costs.

Prevention is better than cure. It costs us 19 pence per square metre per year to carry out a full crop protection programme on a container bed. It is important that we get the best value for money from it. We are constantly looking at new ways of improving it and monitoring its performance. We have found that the best approach is to go for prevention rather than cure. To this end we have produced a programme that is routine and goes on whether the problem exists or not. We apply both a systemic and contact fungicide hoping to attack both those diseases which are subcutaneous and those caused by spores alighting on the leaf. Leaf spots, sooty moulds, and mildews are all targets for that system. We have been using MBC generators in general and carbendazim, in particular, for over 8 years now, and I am beginning to feel nervous about resistance. Therefore I am looking closely at prochloraz as the substitute. As well as the spray programmes, a compost incorporated fungistat is included to reduce the incidence of the water-borne phycomycetes like *Phytophthora* and *Pythium*. Chlorothalonil is also added to protect the newly-potted plant from *Rhizoctonia*. I am a strong believer in tank mixes and have added many products together in the past. The new legislation will no doubt make life more difficult for us in many ways, but we will strive to comply. When a specific disease occurs we will spray against that with a different product from the routine one.

Spray programmes.

Pesticide Programme. (Routine treatments every 3-4 weeks)

Spray aphid control products	H.C.H. Permethrin
Spray leaf spot fungicides (systemic & contact)	carbendazim
.....	dithane
Spray mildew control products (contact)	bupirimate
Spray powdery mildew control products	chlorothalonil
Specific Treatments:	
Heleborus leaf spot	carbendazim + maneb
Glomerella on phormiums, heathers, etc.	carbendazim + maneb
Violet root rot on *Kniphofia*	captan dust+Benlate
Iris borer	Dursban on larvae
.....	Rovral on wet rot
Rusts on geranium, *Trollius*, hollyhock	bendonil
Nematodes on various (leaf tip & stem)	Nemfos+Temik
Paeonia blight	*Benlate*
Wilt diseases on asters	carbendazim
Phytophthora cinnamomi	Fosetyl aluminum
Rhizoctonia	Rovral
Pestalotiopsis	prochloraz
Root aphids	Diazinon
Red spider mites	Childion

Herbicide programme.

Growing over 5,000 different plant cultivars on the nursery may be a sales asset, but from a crop protection point of view it is a nightmare. This nightmare is epitomized in the herbicide selection. We have started to group plants according to herbicide tolerance. This has the advantage of simplifying spraying by the large machinery we use. This works well in container areas but we have not yet extended it to the open field, particularly when planting is dictated by weather conditions or stock availability. Given time I believe we will have achieved the greater degree of coordination necessary by preplanning the planting order.

Never too old to learn. We are constantly looking at new ways and new products in order to improve our crop protection. Research station results are very important to us, but we do not rely only on them. We also look at various other things that are of importance to us, not covered by the National

Institute and E.H.S. levels. We are currently interested in extended cold storage of plants and ways of improving winter hardiness by a closer control of nutrition. This is in addition to herbicide screening and other control products. The changes in funding of research in the future is something which will make us look closely at where we get the best value for money, in-house or at a national level. The expansion or contraction of these facilities in therefore under current review.

A pencil in your hand, not a sprayer. How long is a piece of string? I can't answer that question, but I do know where it starts. Crop protection starts by sitting down with a pencil, not a sprayer in your hand! As growers, we know what problems to expect and when they arrive, and are not pushed into crop protection. We strive to be one step ahead. Observation of the weather helps in identifying pending problems such as: aphids after 5-7 days of warm moist humid atmosphere; red spider mites after dry and warm weather for 2 weeks. The Mills and Beaumont period warnings are good reminders for fungal disorders like the mildews and some leaf spots. Wet autumns increase the likelihood of red core, and when controlled-release fertilizers respond to low temperatures like this year's, the addition of liquid feed is necessary to maintain conductivity levels.

We aim to protect the crop from a controlled position. It may seem non-productive to sit down in the winter and work out many of the aspects I've covered but we have learned that it pays off in the end. We have targets in our crop protection programme that we can aim at: labour profiles, chemical costs, and capital requirements. It is said that strategy does not win the immediate battle, but it wins the war. Spending time in planning our crop protection is proving to pay off on the bottom line.

PROGRESS WITH DISEASES AND DISEASE CONTROL

JOHN EVANS[1]

Agricultural Development and Advisory Service, Government Offices, Coley Park, Reading, RG1 6DT

The temperatures and humidities maintained during propagation are favourable for the development of a wide range of pathogenic fungi. These can reduce very substantially the number of cuttings which produce vigorous, healthy root systems. This paper reviews the fungal diseases most important

[1] Regional Plant Pathologist

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during propagation. It also describes measures for their control.

The origin, age, and location of mother plants and various cultural factors such as nutrition, pruning, and irrigation regimes used, all influence the microflora of cuttings and their susceptibility to disease. Fungi most commonly isolated from decaying cuttings submitted to the ADAS Plant Clinic at Reading are listed below:

Common causes of fungal decay in cuttings of *Azalea, Calluna, Camellia, Chamaecyparis, Erica,* **and** *Juniperus:*

Botrytis	*Glomerella*	*Phomopsis*	*Rhizoctonia**
Colletotrichum	*Monochaetia*	*Phytophthora**	*Thielaviopsis**
*Cylindrocarpon**	*Pestalotiopsis*	*Pythium**	

Some of these fungi are soil-borne (* above) and can be introduced in contaminated compost. Others the so-called water moulds, e.g. *Pythium* and *Phytophthora*, may arrive in the irrigation water. All can be harboured by mother plants and are frequently carried into the propagation unit on cuttings. Thus, the process of producing high quality stock must begin with the selection and maintenance of healthy mother plants.

Mother plants. Ideally mother plants should originate from clonally selected material and be free of major diseases. Where clonal selections are unavailable then the health of any alternative should be verified as far as is possible. This need is now well recognised as is the necessity to establish special isolated stock beds on "clean" land, and their treatment with a rational programme of pesticides to protect against pests and diseases. The programme adopted for any stock area will depend on the subjects grown and their susceptibility to disease. The identification of likely disease problems is essential in formulating a programme of fungicide use for mother plants. Some diseases are readily identified because they produce easily recognisable symptoms. Good examples are: discrete leaf spots produced by *Septoria* (on *Hebe*); *Phyllosticta* (on *Viburnum*); and *Monochaetia* (on *Camellia*). Affected shoots can be pruned out and the remainder treated with a fungicide.

Some fungal pathogens, e.g. *Cylindrocarpon, Pythium,* and *Rhizoctonia* are harboured by mother plants usually without obvious symptoms yet are responsible for extensive losses during propagation.

It is usually worthwhile treating mother plants with broad-spectrum fungicides to reduce inoculum of pathogenic fungi. Fungicide protection is especially important prior to taking a batch of cuttings. Fungicides like benomyl (Benlate), carbendazim + maneb (Delsene M, w.p. formulation), and a

manganese formulation of prochloraz (Octave) are useful in this context. Treatment immediately after removal of cuttings is also worth considering to protect cut surfaces of mother plants against fungal invasion. Flexibility is an essential component of the fungicide programme. Unexplained symptoms should be checked for disease and the programme adjusted to take account of any new development.

Propagation. Fungicide treatment of mother plants reduces but does not eliminate fungal inoculum. Further treatment is usually warranted during propagation. For a fungicide to be of use during propagation it needs to have a fairly wide spectrum of activity. This is essential because the industry produces such a wide range of plant species, each having its own microflora of fungi and bacteria. The successful fungicide also has to be safe in that it has no deleterious effect on rooting.

Trials during recent years have been designed to evaluate the benefits of fungicides as pre- and post- insertion treatments. The most comprehensive exercise of this sort was conducted by Dr. P. Smith of the Glasshouse Crops Research Institute. She determined the efficacy of fungicides during the propagation of four cultivars of hybrid *Rhododendron*. Initially she identified the microflora of cuttings and found that 39% were contaminated by *Cylindrocarpon destructans*, 16% by *Pestalotiopsis sydowiana*, and 8% by *Botrytis cinerea*. The cuttings were immersed in suspensions of a range of fungicides and stem bases dipped in IBA hormone powder before insertion in a 50% peat: 50% grit rooting medium. This was then drenched with the same fungicide. Cuttings were covered with polythene sheeting and the base temperature maintained at 20°C. Cuttings were assessed 3½ months later. The following results were obtained:-

(i) *Cylindrocarpon destructans* was the main cause of decay.
(ii) Prochloraz (Octave 50% w.p. at 0.5 c.p./litre) or benomyl (Benlate 50% w.p. at 1 g c.p./litre) when applied to both cuttings and compost gave the best control of decay, the lowest incidence of C. *destructans* and the highest percentage of rooted cuttings. They were superior to captan (Captan 50% w.p. at 2 g c.p./litre)
(iii) Carbendazim + maneb (Delsense M 10% + 64% w.p. at 0.5 g c.p./litre) gave results similar to benomyl but was inferior to prochloraz.
(iv) Benomyl was not effective when applied only to cuttings. Similar trials have been conducted on cuttings of ericaceous plants (*Calluna*, *Erica* and *Daboecia*), and of *Juniperus* under mist. Prochloraz manganese (Octave 50% w.p. at 0.5 - 1.0gc.p./litre), gave good results in both instances. Iprodione (Rovral, 50% w.p. at 0.5g c.p./litre) on erica-

ceous subjects, and benomyl on all subjects except *Daboecia* also improved the percentage of well-rooted cuttings. In these trials, species of *Pestalotiopsis Botrytis, Phomopsis, Fusarium* and *Glomerella* restricted the rooting of untreated plants.

In the series of trials neither *Pythium* nor *Phytophthora* were a problem. These fungi are sometimes a cause of decay in the propagation unit. *Pythium* is more commonly found than *Phytophthora*. Where *Pythium* is recovered from decayed roots it may be the primary cause of damage, or secondary in so far as it is invading roots weakened due to adverse growing conditions. Nutrient imbalance, high pH, or poor drainage of the compost can all predispose roots to invasion and decay by *Pythium* spp.

Pythium and *Phytophthora* are often introduced in contaminated irrigation water. This is especially a risk where mains water is stored in an uncovered tank prior to use or where growers are forced to make use of non-mains supplies. Recent joint work by ADAS and G.C.R.I. has shown that surface water can be freed of water moulds by chlorination. Two parts per million of free chlorine for a minimum exposure period of one minute is sufficient to kill the motile spores (zoospores) of *Phytophthora cinnamomi*. Surface water often requires coarse filtration to remove suspended organic matter prior to chlorination. The chlorinated water needs to be stored in a covered tank to prevent re-contamination before use for irrigation.

On nurseries where there is a recurring problem with *Pythium* or a high risk of *Phytophthora*, fungicide treatment of the compost may be necessary. Fungicides with label recommendations for control of these fungi are listed below:

In Compost or as a Drench

etridiazole - AAterra W. P., furalaxyl - Fongarid, 25 wp

As a Drench

propamocarb hydrochloride - Filex

fosetyl aluminum - Aliette (effective against *Phytophthora* but does not control most species of *Pythium*)

Recommendations for the control of diseases during propagation are listed below:

— Maintain a high standard of hygiene in the propagation unit
— Encourage growth with a well balanced and drained compost

— Use clean uncontaminated water
— Identify target diseases
— Dip cuttings and drench the compost with a fungicide, e.g. prochloraz, benomyl, or captan
— Repeat drenching sprays at 14 day intervals alternating fungicides to minimise the risk of fungicide resistance
— Avoid trimming leaves of large-leaved subjects, e.g. *Camellia* and *Rhododendron*; (cut surfaces rapidly become invaded by wound pathogens notably *Monochaetia*, *Botrytis*, and *Pestalotiopsis*).
— Where necessary consider the use of etridiazole or furalaxyl to protect against *Pythium* and/or *Phytophthora*

Two specific diseases are worthy of mention as they are currently troublesome:

(a) **Rhododendron powdery mildew.** Symptoms may be apparent throughout the year but are most obvious from June onwards. They appear as faint yellow blotches on the upper surfaces of leaves. As leaves age these blotches may develop a purple margin. With some *Rhododendrons* e.g. 'Seta' the purple margins appear early and the lesions turn brown or purple to resemble a leaf spot. Occasionally in very shaded situations a white powdery fungal growth develops on upper surfaces. Usually, however, this sparse growth is more common on the lower sufaces of leaves.

The disease spreads rapidly when mild, humid weather coincides with a growth flush in early to mid-summer. Powdery mildew was first recorded on outdoor rhododendrons in the U.K. in 1980. It is now widely distributed in southern and eastern counties of England and has spread as far distant as Cornwall, Gwynedd, and Argyll. Severe attacks can defoliate susceptible species, e.g. *R. abeconwayi*, *R. griffithianum*, *R. ponticum*, and *R. cinnabarinum*. Many hybrids are also susceptible.

If only a few rhododendron plants are affected by powdery mildew it is probably wise to remove and destroy them. If, as is more likely, infection is widespread remove worst affected shoots and deploy a regular programme of fungicide sprays. The fungicide should be applied at 7 to 10 day intervals when growth is rapid and conditions favour the disease; at 14 to 21 day intervals at other times. The programme should continue until temperatures fall during October or early November. Imazalil (Fangaflor) and triforine + dimethylformamide (Funginex) have label recommendations for control of this disease.

(b) **Botrytis grey mould:** *Botrytis* is probably the most com-

mon fungal pathogen on ornamentals.

It is an increasing problem on many nurseries causing leaf spot and die-back symptoms. Grey mould is especially a problem on thin-leaved evergreens grown under protection during autumn and winter. In the past, *Botrytis* has been well controlled by the use of fungicides but this is now less successful due to the occurrence of fungicide-resistant strains. The fungicides* available for control of *Botrytis* on various ornamentals are listed below:

Group 1: Benzimidazoles, e.g. benomyl - (Benlate); Carbendazim-Focal Flowable

Group 2: Dicarboxamides, vinclozolin - (Ronilan); iprodione - (Rovral)

Group 3: Pthalonitriles, chlorothalonil - (Repulse)

Group 4: Dithiocarbamates, thiram zineb captan

* all fungicides listed are not necessarily recommended for hardy or ornamental nursery stock.

Fungicides from other groups, e.g. dichlofluanid (Elvaron) and prochloraz (Octave) are currently being evaluated for *Botrytis* control on hardy ornamentals.

ADAS surveys have monitored the extent of fungicide resistance in *Botrytis* taken from protected ornamentals. Survey results have shown that resistance to the benzimidazole (mbc) fungicides increased between 1980 and 1984 but that resistance to the dicarboximide materials has increased even more dramatically. Many isolates of *Botrytis* from nursery stock in South East England during 1984 and 1985 exhibited resistance to both groups of fungicides, thus limiting choice of effective materials.

Guidelines for Control of Botrytis

— Avoid damage which provides an entry point for *Botrytis*
— Remove and destroy any dead or dying plants and senescing leaves which provide an ideal substrate for *Botrytis*.
— Avoid as far as is possible conditions of high humidity (over 93% R.H.) by ventilation, Sub-irrigation is preferable to overhead watering.
— Where resistance is suspected, contact ADAS for advice on the use of alternative fungicides to benzimidazole and/or dicarboximide materials
— Where resistance is not yet a problem, risk of it developing is reduced by alternating fungicides from different chemical groups.

This paper has attempted to highlight some of the current disease problems of hardy ornamentals. It shows that there are many threats to the health both of mother plants and cutting

material. Within the scheme of things the prophylactic use of fungicides correctly integrated into the production system can substantially decrease crop losses and improve quality and health of those that survive.

ALPINES AND HERBACEOUS PLANTS FROM SEED PRODUCED IN LOW COST FILM PLASTIC STRUCTURES

J. G. FARTHING[1]

Lee Valley Experimental Horticulture Station, Ware Road, Hoddesdon, Herts

Herbaceous and alpine subjects can be produced in fully ventilated low cost film plastic structures and will fit into the schedule of the traditional bedding plant producer. The material can be satisfactorily grown in these structures without heat although hardening off and control of growth by growth regulants may be necessary. The production of herbaceous and alpine subjects from seed has been part of the "Bedding Plant Programme" at Lee Valley EHS for the last four years. The objective set was to establish sowing schedules which would fit in with the traditional bedding plant season. Also to establish new subjects which may have not been grown by the traditional bedding plant producer.

Structures. The experiments were carried out in prototype 5 m side and end ventilated film plastic structures, all single clad with 150 micron UV inhibited EVA polyethylene. These structures are more fully described in the Station Leaflet "Low Cost Plastic Structures for Vegetables, Flowers, and Nursery Stock Production". An additional aid to seed germination and summer establishment has been the use of an internal thermal/shade screen which is fully described in Station Leaflet No 24. This screen can easily be replaced by a shade screen only.

A side "baffle" at floor level to approximately 20 cm as shown in Figure 1. This has helped in the reduction of the "edge effect" commonly found in single span side and end ventilated film plastic structures. The skirt successfully redirects the air flow above the plant material but does not adversely affect the ventilation capacity of the side ventilation. In addition, during winter, in periods of driving snow and rain, the outside rows of plants nearest the ventilation skirt were protected.

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[1]Deputy Director

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J. G. FARTHING[1]

Lee Valley Experimental Horticulture Station, Ware Road, Hoddesdon, Herts

Herbaceous and alpine subjects can be produced in fully ventilated low cost film plastic structures and will fit into the schedule of the traditional bedding plant producer. The material can be satisfactorily grown in these structures without heat although hardening off and control of growth by growth regulants may be necessary. The production of herbaceous and alpine subjects from seed has been part of the "Bedding Plant Programme" at Lee Valley EHS for the last four years. The objective set was to establish sowing schedules which would fit in with the traditional bedding plant season. Also to establish new subjects which may have not been grown by the traditional bedding plant producer.

Structures. The experiments were carried out in prototype 5 m side and end ventilated film plastic structures, all single clad with 150 micron UV inhibited EVA polyethylene. These structures are more fully described in the Station Leaflet "Low Cost Plastic Structures for Vegetables, Flowers, and Nursery Stock Production". An additional aid to seed germination and summer establishment has been the use of an internal thermal/shade screen which is fully described in Station Leaflet No 24. This screen can easily be replaced by a shade screen only.

A side "baffle" at floor level to approximately 20 cm as shown in Figure 1. This has helped in the reduction of the "edge effect" commonly found in single span side and end ventilated film plastic structures. The skirt successfully redirects the air flow above the plant material but does not adversely affect the ventilation capacity of the side ventilation. In addition, during winter, in periods of driving snow and rain, the outside rows of plants nearest the ventilation skirt were protected.

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[1]Deputy Director

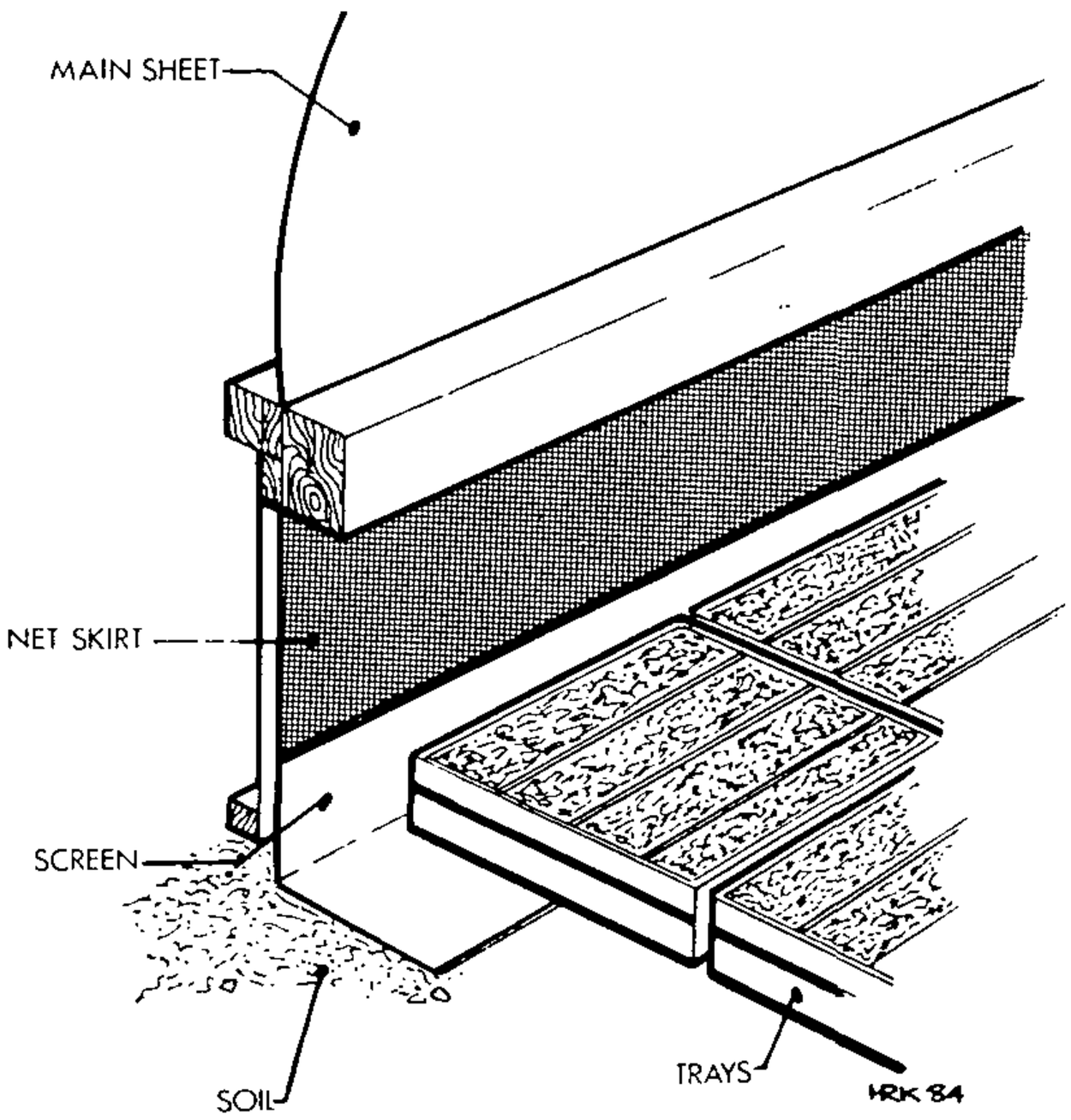

Figure 1. Side "baffle" screen from floor level to approximately 20 cm. to help reduce the "edge effect".

Compost. The compost used in the trials from 1981 to 1985 has been based on 75% medium grade peat, 25% coarse grit plus:

Fertilizer	grammes/ 10 litres	Fertilizer	grammes/ 10 litres
Ammonium nitrate	4	Ground limestone	24
Potassium nitrate	8	Magnesium limestone	24
Superphosphate (18%)	16	Fritted trace elements (WM 255)	4

This compost has given us good growth and compact plant material with the subjects in the trials. It also looks attractive as a compost for alpines with the larger particles of grit. The mix was altered for acid-requiring subjects where a lower pH was necessary, by reducing the lime content (omitting the ground limestone).

THE TRIALS

Direct seeding. This was examined but the variability of germination of herbaceous and alpine seed makes this method of production into the final container uneconomic.

Sowing of two seeds per station helped but still did not

give an acceptable plant stand and also created another operation (singling seedlings) later in the production cycle. The most successful of the subjects examined was hollyhock; delphiniums, though small-seeded and of variable germination, could be direct-seeded very easily into modules. Further work is necessary for improvement of seed germination in herbaceous and alpine subjects before the production by direct seeding of these plants can be considered a viable proposition. Direct seeding of small modules at present offers the best chance in this production system.

In the early trials, sowing schedules were established for production in fully ventilated side and end ventilated film tunnels. This is from setting out to point of sale and can be seen in Table 1.

Table 1. Sowing schedule for spring sales.

Species	Date sown	Species	Date sown
Alyssum montanum	8 Sept	lavender	11 Aug
A. saxatilis	18 Aug	*Leontopodium alpinum*	11 Aug
Aquilegia	17 July	lupin	25 Aug
Armeria	11 Aug	lupin	28 July (direct)
Aubrieta	23 Sept	Pansy	11 Sept
calliopsis	21 July	Polyanthus	2 July
canterbury bell	27 July	Polyanthus	21 July
chives	15 Sept (direct)	*Primula auricula*	2 July
Delphinium	28 July	pyrethrum	2 Sept
Erigeron	21 July	*Saxifraga* mossy types	17 July
Geum	4 Aug	*Sedum*, mixed species	4 Aug
hollyhock	30 July (direct)	sweet william	21 July

Schedules. Several methods of production in the film plastic structures were examined:

1. Full ventilation from pricking out to sale.
2. Modified ventilation (not ventilated in extreme weather conditions, i.e. driving snow/rain and sub-zero conditions.)
3. Outside-grown—without protection.
4. Sown in January within a heated structure at a minimum temperature of 10°C until sale.

The results from these trials indicated Method 1 gave us the most acceptable plant material. Methods 2 and 4 gave plants which were softer and required more hardening-off prior to sale. In some cases there was also a need for growth regulants. The habit of the plants was changed, which was not a desirable feature. It was only in the case of primulas that an

advance in flowering (10 days) was achieved in the modified ventilation tunnel (Method 2).

The crop grown without protection (Method 3) produced substantially later plants. Heavy winter rainfall leached plant nutrients very quickly from the compost. With this method especially, it was essential to liquid feed very early and it is even doubtful then whether a controlled release fertilizer would eliminate the necessity to liquid feed early in the spring prior to sale.

The major labour problems with the production of herbaceous plants under film plastic structures was cleaning the crop of foliage which had died down over the winter period. This is a very labour intensive operation. Late sowing and growing in a heated tunnel (Method 4) produced very soft plant material which needed growth regulant application and considerably longer weaning periods. These growth regulant treatments with Alar at 5000 ppm and chlormequat (Cycocel) at 3000 ppm had in some cases the effect of altering plant habit, e.g. in the case of *Alyssum saxatilis*. This appeared as a change in leaf shape from lanceolate to globose. With most subjects the application of Alar made the foliage a darker green and also compacted the plants. With chlormequat the typical marginal leaf chlorosis was to be seen. The severity of this chlorosis can be seen in Table 2:

Table 2. Leaf chlorosis from application of Cycocel.

Moderate	Severe	Slight
fennel	*Delphinium*	*Geum*
pyrethrum	*Aubrieta*	*Alyssum montanum*
Dianthus		*Erigeron*
Alyssum saxatilis		canterbury bell

Thus with the heated crop it was concluded plants could be produced from a January sowing but this would necessitate growth regulant treatment and additional movement for weaning off. These operations would increase the production costs and would not be compatible with the traditional bedding system and would also compete for labour.

Markets. The establishment of a market is a very important factor in the production system of both alpine and herbaceous plants. It is essential that a market be established before the crop is grown. There is, however, a safety factor in the production system for herbaceous plants that the traditional bedding plant crop does not have. One has the ability to pot on from the 15-cell packs to larger containers, for example, 1 litre poly bags or 1 litre square pots in order to produce a plant for the late summer or autumn sales. These could be sold in

flower which may encourage impulse buying in the garden centre. The cost of the extra labour for potting, the container, and the compost is fairly minimal. Again the market is limited and an outlet should be established for the product.

Alpine trials. A trial examining the effect of capillary watering on sand beds compared with traditional watering by hand indicated problems could occur with overwatering of alpines on sand beds. Considerable rooting through also caused problems at marketing. The rooting through was cured with the use of gloquat at the standard rate and did not cause any phytotoxicity on the subjects that we were growing. The species we examined were:

*Anenome pulsatilla**
*Aubrieta deltoidea [A. leichtlinii]**
Saxifraga umbrosa
'Elliot's Variety'
Cerastium 'Yoyo'
Alyssum saxatilis
Arabis 'Snow Drop'
Saxifraga, mossy hybrids
Aster alpinus 'Dunkle Schone'*
*Dianthus alpinum**
*Leontopodium alpinum**
Arenaria montana
Lychnis alpina
Gentiana septemfida

* The most promising subjects

The examination of other species of gentian has not revealed any suitable type which flower uniformly, quickly, and profusely enough in a small pot or pan. This subject must have great potential for impulse sales in the May period in garden centres.

Other uses. An extension of the bedding plant producers' season using herbaceous and alpine subjects in hanging baskets and pots was examined and attractive arrangements were obtained for a spring display by mixing the plants with small bulbs.

It is necessary to educate the public to accept this new line and perhaps another outlet will have been created.

A PLANT INTRODUCTION SCHEME FOR NEW AND RECOMMENDED PLANTS FROM BRITISH COLUMBIA, CANADA

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During 1981 the Plant Introduction Scheme of the University of British Columbia Botanical Garden (P.I.S.B.G.) was initiated by an executive committee consisting of representation from the British Columbia Nursery Trades Association (B.C.N.T.A.) and the British Columbia Society of Landscape Architects (B.C.S.L.A.) (1). The structure and objectives of the P.I.S.B.G. program was documented by Roy L. Taylor, former Director of the Garden (2).

The aim of this paper is firstly to relate some of the important criteria the Botanical Garden has subsequently experienced for the program to be successful and, secondly, describe the plant releases made available to the 15 participator nurseries within the P.I.S.B.G. program.

Evaluation Panel - Final Plant Selection Procedure. The 30-member evaluation panel, representing the wholesale and retail nursery industry, landscape architects and contractors, and parks boards have met annually to evaluate selected plants. The panel is asked to review some 12 to 15 plants established within different components of the Garden and complete a questionnaire relating mainly to the plants' market potential, uses the landscape, and ease of production (Figure 1).

Following the subsequent analysis of the questionnaire, the five-member introduction and release sub-committee then determines the final choice of plant. The number is reduced to 2 to 3 plants per year as experience has shown that a major reason why many introduction programs have failed is because too many plants were released at one time, resulting in the plants being rarely taken up by the nursery industry.

Test Sites. At the time of release for each introduction the information provided to the industry is based on the plant's performance (normally a minimum of 5 years) at the Garden. The 6 test sites across Canada and the 3 test sites across the United States provide a diverse range of hardiness zones for the plant. The information in the evaluation test site is returned to the Garden and, when appropriate, is released to the nursery and landscape industries through newsletters. How-

ever, it is important to appreciate that the information cannot always be conclusive due to the relatively small number of plants being evaluated at the test site and the degree of cultural care which the test site is able to offer.

Figure 1. Plant selection for PISBG program by the evaluation panel at the Botanical Garden, University of British Columbia, Vancouver.

Publicity. For an introduction program to be successful it is essential that funds are set aside for publicity. Publicity is the responsibility of both the research establishment and the nursery and landscape industries. The Garden provides at cost one-page coloured fact sheets which both illustrate the plant and document information as to market potential, use in landscape, propagation, and culture. Large coloured posters have been printed for use in retail outlets. Through the Garden's staff involvement with the media, incorporating television, radio and newspaper columns, the public is kept informed of the plants and encouraged to purchase them at their local retail outlet. A special picture-tag label has been produced for each plant which each participator nursery is required to use for sales to retail outlets. This enables the homeowner to identify easily plants which have been released from the program.

The Garden has been very fortunate in being invited to participate with the B.C.N.T.A. at nursery trade shows across North America — these have included shows in Ontario, California, Oregon, and Idaho. These large trade show exhibits highlight the P.I.S.B.G. program and the released plants.

Public Plantings. Written into the contract with the participator nurseries is a clause which permits the sale of plants for a public landscape project prior to the date of public release. The public site has to be approved by the introduction

and release sub-committee of the P.I.S.B.G. program. This pre-release enables established plantings to be initiated at an early stage so that landscape architects, contractors, and municipalities can evaluate the effect created by massed plantings of P.I.S.B.G. plants.

Funding. To enable the P.I.S.B.G. program to commence the Garden has been very fortunate in obtaining financial support through matching grants from the Science Council of British Columbia and the Devonian Group of Charitable Foundations, Calgary. Participator nurseries also financially support the program through purchase of the 500 to 1000 mother plants of each introduction and the royalties paid to the Canadian Ornamental Plant Foundation (COPF). Royalties on recommended plants are processed directly by the Garden and not through COPF.

Future Releases. For the continuation of a successful plant introduction program it is essential that there are plants online for at least the next 3-4 year period.

The Garden has now commenced its own plant breeding program to ensure continuating of P.I.S.B.G. material. Through its world-wide contacts, the Garden is continually searching for potential material of new and recommended plants. It is important that Botanical Gardens do not just use their collections as collectors items and not collect with no overall goal in mind. A plant for an introduction program must have a wide appeal in its market potential and use.

It would be foolish to think that every introduction will be successful, because it will not. At the time of public release, market trends may well have changed since the plant was initially selected by the evaluation panel or unforeseen problems may have been experienced with the plant's commercial production.

Released P.I.S.B.G. Plants [C.O.P.F. registered, except Microbiota decussata]

Documented below are outline descriptions of the plants currently released to participator nurseries for general release in 1985 and 1986. Also summarised are their uses in the landscape and their method of propagation.

(1) *Genista pilosa* 'Vancouver Gold' (Vancouver gold broom)

This excellent selection was found by the late Mr. E.H. Lohbrunner in Victoria, British Columbia, and was subsequently acquired and named by the UBC Botanical Garden. This low, spreading shrub eventually attains a height of around 30 cm and a spread of 1 m. During May it produces a

mass of bright golden flowers (Figure 2). Besides its habit and flowers, another asset is that, unlike *Genista pilosa* seedlings, it does not produce a mass of seed pods. Following flowering the dead flowers quickly become covered by the new vegetative growth.

This plant should be sited in full sun on a well-drained soil. It is particularly suited as a colourful ground cover or as a specimen plant. Probably hardy for climates to USDA Zone 5.

It is readily propagated from semi-hardwood cuttings around 7.5 cm (3 in.) in length from July through to October. Rooting hormone is not necessary. It lends itself readily to direct sticking.

Figure 2. *Genista pilosa* 'Vancouver Gold'

(2) *Arctostaphylos uva-ursi* 'Vancouver Jade' (kinnikinnick or bearberry)

This selection was made by the late Mr. E.H. Lohbrunner, Victoria, B.C., and then acquired and named by the Botanical Garden. This plant was chosen as there was a need for the B.C. nursery trade to grow a locally selected clone which rooted readily, had good flowers, vigorous habit, and performed well within the landscape site. Currently nurseries were relying on local wild collections for cuttings which subsequently performed irregularly.

The leaves are bright green during the early spring, the stems bear fragrant clusters of attractive pink flowers. At the Garden it has been more tolerant to leaf spot pathogens, mildew, and galls than other forms grown in the collections. Since its release, this selection has already been planted up in some major landscape sites within British Columbia. Probably hardy to USDA Zone 4.

It is ideal for direct sticking and over 90% success is achieved by taking cuttings from July to January and applying 0.8% I.B.A. in talc.

(3) *Rubus calycinoides* 'Emerald Carpet' (Taiwan creeping rubus)

This clone arose from collections made for the Garden at elevations of around 2900 m in Taiwan. This rapid-growing evergreen spreads 30 cm per year. The attractive bright green leaves have a marbled texture. The white flowers borne in June are inconspicuous (Figure 3).

This ground cover provides an alternative to ivy in many sunny and shady locations. If winter damage occurs, it should quickly regenerate the following spring.

Propagation can be carried out the year round as nodal or internodal cuttings. Rooting hormone is not necessary. It is an ideal plant for direct sticking.

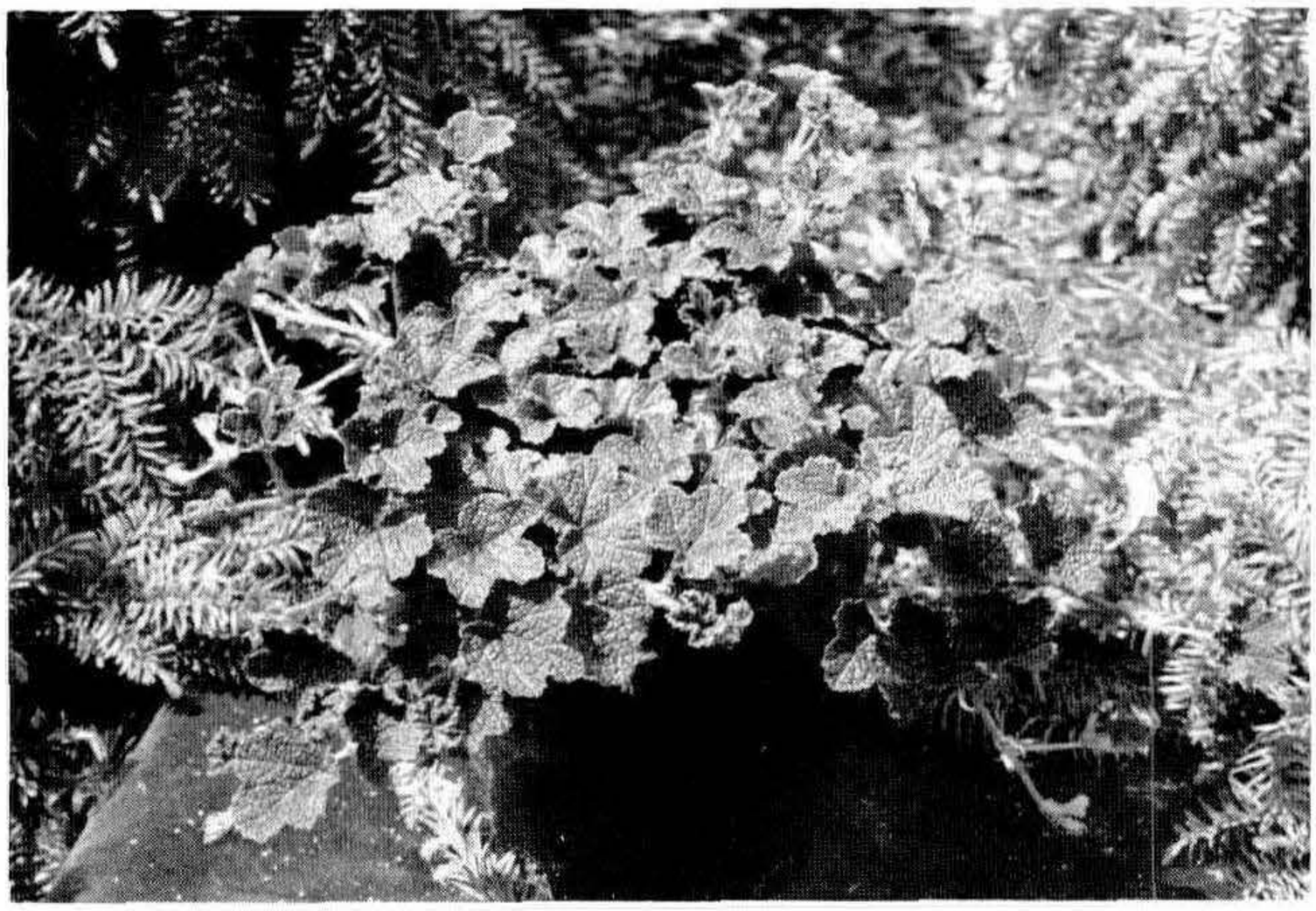

Figure 3. *Rubus calycinoides* 'Emerald Carpet'

(4) *Viburnum plicatum* 'Summer Snowflake' (double file viburnum)

This selection was obtained by R.F. Michaud, Surrey, B.C. from wild collections in Japan and was subsequently acquired and named by the Botanical Garden.

This deciduous cultivar reaches a height of 2 m and spreads to 1.5 m. A large flush of very attractive flowers arises in May and then continues to flower throughout the summer. A secondary flush appears during late September-early October. An added ornamental feature is the dark red-purple shades of the fall leaf colour (Figure 4).

This compact cultivar is an excellent garden or landscape plant for both sunny and shady sites — some light shade being best.

It is readily propagated by softwood cuttings using 0.3 to 0.5% I.B.A. in talc during the summer — optimum period being mid-July and August. Rooting later than this means that the cuttings are less likely to overwinter successfully. It readily lends itself to direct sticking. It is important that rooted cuttings are not potted until the new spring growth occurs, otherwise losses are likely to occur.

Figure 4. *Viburnum plicatum* 'Summer Snowflake'

(6) *Anagallis monelli* 'Pacific Blue'

This form was selected for its intense gentian-blue coloured flowers, also for its use as a ground cover, bedding plant, and for planting in patios and in hanging baskets. Although it is a short-lived perennial (around 3 years) it can be treated as an annual — particularly in colder climates. It is readily rooted from softwood cuttings. Rooting hormone is not necessary. Hardy to U.S.D.A. Zone 8.

(7) *Microbiota decussata* (Russian or Siberian cypress) UBC Clone #12701

This conifer originated in Siberia in 1921 and was received by the Trompenburg Arboretum in Holland during 1968. This will be introduced as a recommended plant for the

B.C. nursery trade as it offers a very viable alternative for junipers in cold localities. Hardy to U.S.D.A. Zone 2 (possibly 1).

The clone chosen for the P.I.S.B.G. program came from material sent by Royal Botanic Garden in Edinburgh. It will not be given a cultivar name unless it is sufficiently distinct from current material available.

It has a low, spreading habit attaining a width of 3 to 4 metres. During the summer the attractive fern-like foliage is bright green while during the winter it attains a coppery-brown colour.

It readily roots from cuttings taken from August to January. During the preparation of the cuttings 2.5 cm of the previous year's wood should be retained at the base of the cuttings. Rooting is improved with 0.8% I.B.A. in talc or a liquid preparation.

LITERATURE CITED

1. Macdonald, A.B. 1983. British Columbia establishes new plant introduction program. *Amer. Nurs.* 158(6):45-49.
2. Taylor, R.L. 1984. University of British Columbia Botanical Garden Plant Introduction Scheme — an opportunity for a new relationship between nurseries and the public garden. *Proc. Inter. Plant Prop. Soc.* 34:121-125.

HANDLE WITH CARE

ANDY HEWSON

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The object of my paper is to relate my observations concerning the materials handling and work organisation aspects of plant propagation.

We may naturally think of materials handling and mechanisation in connection with field and container production of hardy nursery stock. In the context of plant propagation these aspects are often considered less important than subjects such as propagation environments, improving the rootability of our cuttings, fogging or mist systems, treatment of cuttings, rooting media, or direct sticking. Perhaps I could suggest that materials handling and work organisation are equally important if we are to make maximum use of our expensive propagation facilities and our labour resources. At the moment labour costs represent in the region of 25 to 30 pence in every

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pound worth of stock leaving the nursery gate.

Adequate forward planning together with careful attention to work organisation and handling aspects will result in smoother work flow reducing delays due to bottlenecks and double handling. This will increase work output while reducing labour and materials input movement adds only to the cost of your production and will not increase the value of your stock.

To set the scene here are a few facts:

The British nursery stock industry handles over 100 million containers per year.

In a work study exercise conducted on one nursery it was found that in order to grow a plant taking two years to reach saleable size, the cutting or plant was handled 95 times. By studying work methods, physical energy can be conserved and wastage reduced. Some examples of this are the carefully thought through bench layouts for potting and preparation of cuttings, the siting of materials to reduce travelling distances, and avoiding running with empty pallets in addition to the use of pallet systems to move large numbers of plants or heavy materials.

To illustrate these points I would like to look at a typical everyday work situation common to many nurseries whether they produce nursery stock, pot or bedding plants, or even vegetable transplants.

For example, take the small scale potting operation of placing rooted cuttings taken from trays into small liner pots. Firstly, it is essential that adequate forward planning is made to ensure that the operation runs smoothly and efficiently. This is done by identifying the objectives of the task. What are we trying to achieve? What is the timescale for the job? How many liners are to be potted? When do we intend to start? How does the task fit in with the other work in the propagation calendar?

During the planning operation it is essential to identify the priorities. For instance, which crops, if any, should be handled first, deciduous items before evergreens and some deciduous subjects before others? Some items may be required for sale before others. Assess how many plants are to be potted, the time available, and from this estimate the labor requirement employing sensible working targets. I will illustrate this by the following example:

— Production figure- 200,000 liners
— Liners ready for potting April 1st and the work must be completed work by May 1st. This is 22 working days.

200,000 ÷ 22 days = daily potting requirement of 9090 pots.

— A realistic potting target per person per hour is 400 pots.

9090 ÷ 400=23 man-hours required each day in order to complete the potting of 200,000 liners by May 1st.

Having set the objectives and identified the priorities, I now structure the approach to achieve the potting target. It may be decided to employ three full time staff, each for eight hours per day, or perhaps, alternatively, six part time staff in 4-hour shifts. The latter I would suggest is more effective, particularly with repetitive and monotonous work of this type. People working for 8-hour shifts will tend to work with peaks and troughs, probably with a less than acceptable output at the end of the day. Choose staff carefully, set targets, monitor regularly, and consider piece rate payments.

Analyse the structure of the job and where possible, break it down into its component parts, viz:

(i) Preparation of rooted cuttings for potting, knocking out and grading.

(ii) Transport to the potting area

(iii) Potting, counting, labelling, and checking.

(iv) Transport to growing area.

(v) Standing down the potted plants.

It will be observed that every component part involves plant or materials handling to a greater or lesser degree. Much of this will occur at stage iii. It is here with careful planning most of the savings in time and labour can be made.

Consider the work place layout: The positioning of benches, roller conveyor, pallets, compost, access points, trays, pots, and plants all will require careful forethought. Use scale drawings in order to plan a smooth operation well in advance of the task. This will save valuable time later on.

People who are comfortable and relaxed in their work will be more efficient and operate more effectively, therefore one must provide adequate heating and light.

It will be observed that in order to reach the work potting target in the example given earlier, 23 man-hours potting must be achieved each day. This implies that uninterrupted potting must take place. To achieve this a person should be employed in order to supply the potters with all necessary materials. It then becomes the sole responsibility of that person to ensure that workers are continuously supplied with pots, plants, compost and labels. This principle should also be applied to other

nursery operations such as the preparation and handling of cuttings and bench grafting.

One should consider the use of mobile potting benches for the "in situ" handling of plants. These can be easily constructed from conventional trailers and they make the system far more flexible, reducing overall handling considerably. They are especially useful where plants are to be returned to the same standing ground area from where they were taken.

Careful thought should be given to the selection of containers for handling. Pots should fit snugly into tray systems with the minimum amount of wasted space. Similarly trays should be fitted neatly onto trailers or pallet systems where these are used. Trailer specification is important. For example, the height for ease of loading and offloading and the length and width for maximum carrying capacity bearing in mind maneuverability. Tiered trailers present another option to raise carrying capacity still further.

The benefits of a good handling system will be eroded if access around the nursery is poor. Routes should be as direct as possible and the road surface even and solid. Concrete roadways initially represent a high capital outlay but in the long term will save money. It makes sense to plan well ahead and allocate a proportion of the capital budget to the purpose, perhaps constructing a section each year in order to spread the cost.

I have discussed at length materials handling and work organisation but I think we should consider also the handling of people. This is an aspect of which we are not perhaps the best exponents.

Good labor management requires time and effort. It is easy to become caught up in the sophistication of the latest propagation techniques and the more technical aspects of our work at the expense of neglecting people. Impressions from my own limited experience lead me to consider that the motivation and welfare of our staff is something we need to think more about. Do you express an interest in people's welfare, work conditions, training, and safety. Are you a good listener? A little thought goes a long way and a reliable staff will respond to being thoughtfully considered. Labour is not a low cost component of the production budget so it is our own interest to make the most of what we have.

PROPAGATION OF SOME TROPICAL AND OTHER FOREST SPECIES

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The tropical pines, *Pinus caribaea* Morelet and *Pinus oocarpa* Schiede are important tropical forest plantation trees. They are particularly fast growing and will tolerate poor soil. The timber can be used for poles, sawn, pulped, or used for resin production. These species seed profusely and in natural conditions reproduction is entirely from seed. Clonal propagation in forest tree species is becoming more widely practised as techniques for rooting cuttings improve; research is in progress with micropropagation. A spectacular increase in productivity has already been achieved through exploitation of the potential available in tree to tree genetic variation.

The work discussed here aims to increase the yield of propagative material from selected clones of these species by treatments with cytokinin and other growth regulators, followed by improved techniques of micropropagation, stem cuttings, and grafting.

Bud induction on ortet (parent plant). The main problem with vegetative propagation of pines is the limited quantity of suitable cutting material produced by the ortet. Constraint has been a severe restriction to progress. This is a limiting factor in the specialised application of the techniques. Aging of the ortet is also a problem because rooting ability declines severely before a tree is large enough to exhibit its economically important traits.

Synthetic hormones, as used successfully at Wye College by Whitehill and Schwabe (8) on *Pinus sylvestris* were applied to *P. caribaea*. Decapitated 2½ year-old seedlings, were used in this study to induce interfascicular shoots.

The treatments applied were:

a) BAP, 200mg/litre. (BAP = benzyladenine)
b) BAP, 200mg/litre + TIBA, 50mg/litre. (TIBA = triiodobenzoic acid)
c) TIBA, 50mg/litre.
d) BAP, 100mg/litre.
e) GA_3, 50mg/litre. (GA_3 = gibberellic acid)
f) BAP 100mg/litre. + GA_3 50mg/litre.

These were made up in a wetting agent, 3% glycerol containing 0.0125% Tween 20 for all treatments.

The seedlings were sprayed to run-off at 5-day intervals

for one month. New interfascicular buds appeared within 18 days from the first application of BAP, 100 ml/litre. These also developed more quickly than those in the other treatments. Gibberellic acid ultimately stimulated production of longer shoots but they were fewer in number and bud development was inhibited.

Rooting of cuttings and needle fascicles. The induced buds were left to grow out into shoots large enough to provide cutting material. This material was used for a further experiment to determine the best size of cutting. Shoots were graded into small shoots (less than 50mm in length), medium shoots (50 to 80mm), and large (80 to 125 mm) Cuttings were prepared with a small heel of the main stem and the lower needles were stripped.

Hormone treatments were applied to promote rooting. An application of IBA (0.8%) in talc was compared with IBA 2500 ppm +IAA 250mg/litre in 50% ethanol as a quick-dip. The cuttings were kept under mist, arranged in eight randomised blocks. The base temperature was set at 30°C and air temperature was maintained at 20 to 30°C giving a temperature within the containers of 25°C. Analysis of variance showed that both rooting and the number of roots were increased by the application of 0.8% IBA in talc, especially so with larger cuttings.

This indicates that a larger amount of clonal material can be produced from a single plant of *P. caribaea* simply by inducing interfascicular shoots with BAP sprays. To ensure successful rooting, shoots should be selected which are at a minimum of 50 mm. in length.

Since this trial, studies have been made on the application of similar treatments to *P. oocarpa* using one-year-old seedlings of six different provenances. In certain provenances of *P. oocarpa* basal coppice shoots are produced naturally. These are physiologically juvenile and will provide good cutting material. In addition mature trees will produce coppice shoots after felling and while the main stem is in normal active growth.

The overall cutting material yield is therefore provided by a combination of apical shoots, basal coppice shoots, and needle fascicles in varying extents. Apical shoots and coppice shoots are taken as normal stem cuttings, using 0.8% IBA in talc either inserted under mist or, more recently, good results have been achieved by rooting cuttings under polythene. This system used an insulated propagation bench with basal heat incorporating a pulse-ratio controller to maintain a temperature of 25°C. in 50:50 washed silver sand and perlite rooting medium.

Needle fascicles can also be rooted successfully. The best results were obtained in trials with a basal dip of Synergol at 2500 ppm. Rooting is possible but the percentage take is not yet good enough to be considered an economic method of production. Although, if it were, a vast amount of propagation material would be available. Another obstacle is that, although a fascicle can root, very few go on to produce an apical bud, therefore little further growth is achieved beyond rooting.

To overcome this problem trials have been run using applications of BAP singly or in combination with TIBA and Alar (dimethylaminosuccinamide) to 1, 3, and 5-year-old seedlings of both *P. oocarpa* and *P. caribaea* to encourage fascicles to produce an apical bud. Treatment of the current year's growth has shown promising results, especially with BAP.

This material has been used for propagation experiments both by direct rooting and micropropagation, the latter since December, 1984. The explant material has included apical tips from coppice shoots or the mainstem, needle fascicles, and buds induced by BAP application.

The same media as used successfully by David, et al. (1,2,3,4,5), for *Pinus pinaster* have been chosen. Four stages of media are required. In addition to the shoot elongation medium, activated charcoal is included at 20 g/litre plus de-proteinised coconut water at 10 ml/litre. Coconut water is included following the suggestion of Konar and Singh (7) who obtained good results with this in studies of *Pinus wallichiana*. Results so far with *P. caribaea* and *P. oocarpa* show that better elongation has been achieved by including coconut water.

Induced mainstem buds and induced fascicle buds from ortets sprayed with BAP and Alar were transferred directly onto elongation medium. This omits the bud induction stage of the medium. Interestingly, buds take the same time to be induced *in vitro* as they do on the ortet. This is 18 to 20 days for the ortet and 21 days on agar.

A small trial was conducted to find out whether bud induction of fascicles *in vitro* would be increased by priming the ortet with BAP before transferring the fascicles to the bud induction medium. The results showed that the percentage bud induction of fascicles from an ortet primed with BAP was 78%, compared with only 40% bud induction in fascicles from an untreated ortet.

Preparation of the needle fascicles for micropropagation involves selection of material from the treated current year's growth when they are strong enough to withstand handling. They are carefully excised with a scalpel close to the stem and the papery sheath is removed to aid surface sterilisation. Sur-

face sterilisation of *Pinus* is successful, using 0.1% mercuric chloride for one minute followed by three 1 min. rinses of sterile distilled water. Once inserted into the bud induction medium they are kept under continuous light at 28°C, while on the shoot elongation medium they are kept at 25°C with a daylength of 16 hours at 2000 lux followed by eight hours dark at 21°C. These conditions also apply to apical tip material.

Etiolation of induced buds. Etiolation of BAP-induced buds may be an alternative method of developing this material for propagation. Comparisons of black polythene with double layers of 2 mm Netlon mesh to shade trees with induced buds have been made. Further work is required on this subject. However, the best results at present are from using double layers of Netlon.

Grafting of *Pinus caribaea* and *Pinus oocarpa*.

Grafting of *P. caribaea* and *P. oocarpa* is used with some success in forest nurseries in the areas of tropical afforestation as the natural environment provides perfect warm and humid conditions. A disadvantage is that more demand is made on clonal material for scions. *P. oocarpa* and *P. caribaea* are graft-compatible, coppice shoots being a useful source of scion material.

This year we obtained a license to import scion material for grafting to the field laboratory at Wytham. The scions were collected from selected trees in Zimbabwe and consisted of coppice shoots and shoot tips from the current year's growth. The scions were kept fresh by wrapping them in wet muslin inside cool boxes and they showed no signs of deterioration on arrival. Grafting took place within 48 hours of collection in Zimbabwe. A cleft graft was used, secured by Rapidex ties. Each graft was enclosed in a polythene bag to maintain humidity and a brown paper bag over this to ensure complete shade for each graft. The understocks we are using are a combination of 5-year-old *P. caribaea* seedlings and 1-year-old *P. caribaea* and *P. oocarpa* seedlings, pot-grown at all times under glasshouse conditions. The percentage take this year is 70%. It is hoped that this grafted stock will provide suitable material for micropropagation and we aim to form a British clone bank of selected trees which could then be returned to the tropics of afforestation. This work is at a preliminary stage of development and it is in cooperation with Dr. Richard Barnes of The Unit of Tropical Silviculture of the Commonwealth Forestry Institute in Oxford.

***Picea sitchensis* — Sitka spruce.** There is an immense interest in Sitka spruce at present for afforestation in Britain. The Foresty Commission and the private sector aim to produce

a combined output of one million plants of selected clones per year by 1988. Breeding this species over several years has resulted in the selection of particularly promising clones. Production from cuttings has been accepted as uneconomic but it is now considered essential to exploit the potential of selected trees. Cuttings from superior stock ultimately provide an increased yield of cuttings of elite trees which will outweigh any initial increased costs of production from cuttings compared with seed production.

This year the methods mentioned previously to induce interfascicular buds to *Pinus spp.* were applied to Sitka spruce. From March the 2-year-old seedlings were kept under glasshouse conditions with supplementary lighting of 16-hours using florescent warm white lighting. Temperatures were maintained at 15 to 20°C. In this trial all resting buds were recorded and each branch numbered; the tips of each branch were pruned back. A spraying programme began at the beginning of May, with applications at five days and on five occasions.

The results were recorded in mid-June this year. The best results were from using BAP at 200 mg./litre (Table 1). With this treatment buds were also induced at the base of each branch and clusters of buds appeared at the tips of pruned shoots. There was also a dramatic difference in bud size with the application of BAP at 200 mg./litre these being 4 to 5mm in diameter at the first recording after treatment compared with 2 mm average size for the control and other treatments.

Table 1. Results of the effect of BAP, ALAR, and TIBA on *Picea sitchensis* to induce buds.

Growth regulator	*Untreated* Mean number buds /branch	*Treated* Mean number buds /branch	*Difference* between mean number of buds
1. Control.	1.18	3.97	2.79
2. BAP + ALAR + TIBA	6.95	8.77	1.82
3. BAP + ALAR	6.11	8.29	2.18
4. BAP	1.40	6.02	4.62

Treatment rates:
1. No treatment
2. BAP, 200 mg/litre + TIBA 50 mg/litre + Alar 500 mg/litre
3. BAP, 200 mg/litre + Alar 500 mg/litre
4. BAP, 200 mg/litre

At the present, size and number of shoots in this treatment is also the greatest, but development needs to be assessed again at a later date. This work will be repeated on a larger scale to allow fuller statistical analysis of what have so far been very encouraging results. Cutting material can be increased on Sitka spruce by hedging, being pruned back in

late autumn and again lightly the following spring. For abundant new growth the hedges can be shaded to induce etiolation. This will provide seasonal cutting material, whereas an alternative system of treating trees with BAP under cover may produce cutting material throughout the year.

SUMMARY

1.) *Pinus caribaea* and *Pinus oocarpa* respond to treatments of BAP on 1, 2 and 5-year-old seedlings to induce interfascicular buds.

2.) Induced buds can be used for:

a.) Micropropagation explants; this allows the first stage medium to be omitted.

b.) The induced buds can be etiolated into elongated shoots for cuttings.

3.) Needle fascicles also respond to treatments of BAP on 1 and 5 year-old seedlings and will form an apical bud for elongation *in vitro*.

4.) Cuttings from basal coppice shoots and etiolated shoots from induced buds root well with 0.8% IBA in talc under polythene with basal heat.

5.) Because micropropagation of gymnosperms is a slow process and rooting *in vitro* is difficult quicker techniques of reproducting clonal material could be:

a.) Etiolation of induced buds on the ortet for cuttings.

b.) Elongation of induced buds *in vitro*, followed by subsequent rooting as cuttings in sterile medium using conventional methods.

6.) *Picea sitchensis* responds to BAP 200 mg/l sprays on 2-year-old seedlings to induce a higher yield of potential cutting material — but further work is required.

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HALF-HARDY PERENNIALS

IVAN DICKINGS

Notcutts Nurseries Ltd. Woodbridge
Suffolk. IP12 4AF

Half-hardy perennials are a much neglected range of plants which I think should be more widely grown. The variation in habit, flower colour, and foliage is quite considerable. They always create a lot of interest in my garden and visitors are continually asking where they can obtain them. At the moment, there are only a few specialist nurseries who grow them in a reasonable range. It was the difficulty in obtaining these plants which originally prompted me to collect them in the hope that the company which I work for would make them available through their garden centres, and I am pleased to say that this is now happening. We now sell some kinds as spring and summer bedding plants in 9 cm pots.

There are people who, when told that these plants are only half hardy and will probably die during the winter, dismiss them outright, but the same people are quite happy to spend considerable amounts of money each spring on annuals and geraniums. All of these plants are very useful for planting between newly-planted shrubs to give a display while the shrubs are getting established. They can be planted with established plantings to give a longer period of interest, and they can also be used as bedding plants. They also look very good when planted in pots, troughs and urns, adding colour to the terrace or patio.

Most of the plants are very easy to propagate from cuttings taken during late summer and these are ready for sale the following spring. The following plants are not hardy in my part of the British Isles but, no doubt, in some more sheltered, warmer parts of the country they are perfectly hardy. Below is a list of some of the species which I have grown in my own garden during the past 4 to 5 years:

Helichrysum petiolatum: A vigorous plant with wooly, heart-shaped

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Helichrysum petiolatum: A vigorous plant with wooly, heart-shaped

grey foliage. Very useful for tubs and baskets.

Helichrysum petiolatum "Limelight": This does very well in shade and semi-shade and is most effective when planted in a tub. The foliage is a very bright lime yellow.

Helichrysum petiolatum "Variegatum": Yellow variegated foliage, but not very showy.

Helichrysum angustifolium [*H. microphyllum*]: Although this has very small grey foliage, the plant is quite vigorous. This has survived a winter when planted under the eaves of the house and has flowered the following spring, but the flowers are not very attractive and the plant gets a bit scruffy.

Helichrysum populifolium: A very vigorous plant with large grey leaves and conspicuous yellow flowers. Good if a large area is available.

Lotus berthelotii: A most interesting plant, with filigree grey leaves which cascade over a pot or tub. It is also very useful for ground cover. If the plant is kept in a pot and over-wintered in a frost-free greenhouse, you will be rewarded with a plant the following spring, covered in bright red long pea shaped flowers.

Argyranthemum foeniculaceum [*Chrysanthemum anethifolium*]: A very useful plant for bedding or planting in tubs. It also makes a very good pot plant for a cool greenhouse where it will flower continuously during the winter. It has fine glaucous foliage and single white flowers, and grows to 3 ft in height.

Argyranthemum frutescens [*Chrysanthemum frutescens*] "Jamaican Primrose": This is the best of the *frutescens* cultivars. It makes a large bush 2 to 3 ft high, covered in large single butter yellow flowers, which show well against the dark green foliage, all through the summer until frost in the autumn. Another attribute of this plant is that the cut flowers last many weeks in winter.

Verbena 'Lawrence Johnston': Bright red flowers and trailing habit.

Verbena 'Silver Anne': Flowers pink, fading to near white. Large flower clusters with a slight scent.

Verbena 'Sissinghurst': Smaller flowers than the two previous cultivars, but they are carried on long stems. The flowers are magenta in color.

All the verbenas mentioned above, are mat-forming and are suitable for either pot culture or growing in the open ground.

Heliotropium arborescens: The cultivar is unknown but it is a very old one with mauve flowers having an overpowering scent. The original "Cherry Pie".

Cosmos atrosanguineus: A very choice plant from Mexico with dark maroon flowers having a delicious scent of hot chocolate. This plant forms tubers like a dahlia, which can be lifted and stored for the winter, and for taking cuttings in the early spring. Alternatively, cuttings can be taken in late summer and kept just ticking during the winter, and potted in the spring. This is not the easiest plant to propagate by conventional means, but I believe it is now being done by micropropagation, so it should now be more widely available.

Felicia amelloides 'Variegata': The bright variegated foliage makes a good contrast for the single blue flowers.

Felicia amelloides 'Santa Avita': This is a much more vigorous plant than the variegated form, but still with very bright blue flowers.

Osteospermum 'Buttermilk': All osteospermums have large single flow-

ers with coloured reverse. O. 'Buttermilk' has cream-yellow flowers with white base, and biscuit reverse. It is erect growing.

Osterospermum 'Cannington Roy': Purple, fading to white centres with purple reverse. Prostrate growing.

Osteospermum ecklonis 'Prostratum': White, with pale mauve reverse. Prostrate.

Osteospermum 'Whirleygig': The base of the petals have been crimped, making the end of the flowers spoon-shaped. The flower is white with a blue disc and mauve reverse. Erect growing.

Osteospermum jucundum: This osteospermum is perfectly hardy and should not be included in this list, but I cannot let this opportunity pass without mentioning it. It is mat forming and is covered with mauve flowers in early summer and has a smattering of flowers all through the summer. I have had it in my garden for five years and it is looking very fit and healthy.

HORTICULTURAL TRAVELS IN POLAND

MICHAEL L. DUNNETT

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In September, 1984, I was invited to Poland to give a paper at a symposium on hardy nursery stock organised by the Warsaw Branch of the Society of the Horticultural Engineers and Technicians. Whilst in the country I was lucky enough to be able to visit several research stations, botanic gardens, and commercial nurseries both privately and state owned. This short but comprehensive visit gave me an opportunity to have a look at several aspects of ornamental horticulture in Poland.

The conference turned out to be a truly international gathering of both nurserymen and research workers involved in nursery stock production. Delegates attended not only from England but also Holland, Czechoslovakia, Hungary, and of course many from Poland. Unfortunately due to lack of simultaneous translation it was impossible to assimilate accurately the contents of the many conference papers.

My first experience of practical horticulture was when we visited what our Polish host called his garden. In England we would call these areas allotments. A short car journey from the centre of Warsaw brought us to some 200 to 300 acres of land which was neatly divided in 300 square metre plots. The owners of these plots grow vegetables and fruit for their own consumption. Many had a chalet on their allotment which is used for weekend accommodation. In addition to food crops many allotments were attractively planted with a wide range of perennial and annual ornamental plants. The garden

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seemed to be a very important part of the economy of the town dwellers of Warsaw, providing not only cheap and fresh fruit and vegetables but also a healthy and constructive leisure activity.

It was obvious from the number of florist shops and flower stalls on the streets of Warsaw, that cut flowers are very important to the Poles. They, like many other inhabitants of the mainland of Europe, give flowers on many occasions. They do, however, have a custom in Poland which I have not come across in any other part of Europe, that is they do not celebrate birthdays as we certainly do in England, but celebrate "Name Days". Each day of the year is dedicated to a different christian name and when the day of the year arrives on which it is your name day — then you receive presents; the most common and traditional presents are cut flowers. This, of course, gives a great deal of support and buoyance to the cut flower market.

I visited one research station where the production of gladiolus corms was being undertaken and 8½ hectares of these plants were cultivated each year for this purpose.

I was interested to see what amenity plantings were being undertaken in Poland. Compared with England, Holland, or Germany there was very little. A certain amount of street tree planting had been done in Warsaw but this was very spasmodic. Species I saw used included *Acer platanoides, Acer pseudoplatanus, Fagus sylvatica,* and *Fraxinus pennsylvanica.* One interesting thing I noted was that large trees were labelled with a little metal tag on their main trunks. This tag stated that the tree was a natural monument. This very simple procedure I believe could be sensibly copied in the U.K. where we often take for granted some of our mature trees.

There were experiments being carried out in some of the research stations into the growth habits and rate of growth of certain indigenous plants, in particular *Juniperus horizontalis.* The Poles find this plant an excellent hardy ground cover.

Hardy nursery stock was produced both as container and field grown (bare root) plants. I saw both types of production on private nurseries and also on much larger state owned establishments. You cannot go to Poland without noticing the severe shortages of basic horticultural commodities, many of which we take for granted in the United Kingdom. For example bamboo canes seem to be missing completely. The Poles, being very innovative people, were using various ways to overcome these shortages. For bamboo canes they were cutting branches from hedgerows and using these as a very adequate substitute.

The mixture of pots which I saw was quite incredible, ranging from the best rigid containers through hand made polythene bags to clay pots and second hand cups.

Nearly all composts were based on a mixture of loam with either bark or peat added as an extra. A 2 to 1 loam/bark mixture was the most common. In many cases the loam was unsterilised and, in several instances, had been used for a previous crop. For example, on one nursery, I saw compost which had been originally used for the production of carnations as cut flowers.

The use of slow-release, resin-coated fertilisers was non-existent. The standard fertiliser was a product called 'Florovit'. I was unable to determine what this consisted of, but was informed that a small amount was added to the initial compost and then several top dressing were given during the course of the season.

The range of plants grown in containers was quite considerable, bearing in mind the very low temperatures that are experienced in Poland over the winter — 35°C being quite common. The range consisted of many conifers, ericas and numerous deciduous shrubs, such as *Forsythia*, *Spiraea*, *Philadelphus*, and *Berberis*.

Little research has been conducted into the production of plants in containers, although Warsaw University and several other research establishments are starting to undertake various research programmes. High on the list of priorities is finding resistance to winter damage, and ways in which plants can be grown in containers avoiding being killed by low winter temperatures. As far as I was able to ascertain no results had been forthcoming from this research and growers were still plunging plants to avoid damage over-winter.

Some excellent high quality plants were produced in the open ground. I saw extensive crops of maiden roses being grown for export to Sweden, and also many commoner type of shrubs such as *Ligustrum*, *Tamarix*, and *Cornus* produced to high quality. In addition, a certain number of trees are produced in Poland but I saw very little of their production.

In addition to having both an enjoyable and informative visit I was able to forge closer links with ornamental growers and research workers from several Eastern European countries. I.P.P.S. is now sending both "The Plant Propagator" and the "Proceedings" to representatives in Poland, Hungary, and Czechoslovakia. In return we have received catalogues and other interesting information on ornamental horticulture from these countries. This material is kept in the G.B. & I. Library. Finally, I would like to thank my host — Szczepan Marczynski

— for the help and hospitality which he extended during my visit.

INFLUENCE OF SEED WEIGHT ON THE EARLY GROWTH OF *QUERCUS SUBER* L. SEEDLINGS

J.L. GARCÍA VALDECANTOS

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Apartado 8111, Madrid, Spain

Abstract. The relationship between seed weight, time of maturation, and early growth of *Quercus suber* seedlings have been studied in order to establish their relative importance. The lengths attained by seedlings obtained from seeds harvested in September, November, and January were recorded during their first year of life. The results show that the main factor is harvest time and not seed weight. Therefore, further integrated research must be done, including as great a number of factors as possible.

REVIEW OF LITERATURE

Different authors, with different viewpoints, have studied the relationship between seed weight and early growth of seedlings, with not always consistent results.

Wrześniewśki, in a series of papers (8,9,10) establishes the differences in the ratio dry matter in the embryo to dry matter in the megagametophyte, its hydration level, and respiration rate, as well as the imbibition process in seeds of *Pinus sylvestris*, belonging to different weight classes. He concludes that medium-sized seeds are the most favourable and that the growth conditions of seedlings are mainly the result of the conditions of seed development in the mother organism.

Larson (4) did not find an actual influence of the seed weight of *Pinus ponderosa* on either the germination rate, the germination percentage, or seedling growth.

Robinson and van Buijtenen (7) consider there is a correlation between seed weight of *Pinus taeda* and certain morphological characteristics which were related to seedling size at 5, 10, and 15 years.

Working on the same species, Dunlap and Barnett (2) showed that there was a strong influence of seed size on early growth.

Likewise, Keiding (3) points out that the height of one-year-old plants of *Tectona grandis* depends on its seed weight.

Belcher, et al. (1) think that the size of the seed does not show a clear influence on the growth of *Pinus caribaea*.

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REVIEW OF LITERATURE

Different authors, with different viewpoints, have studied the relationship between seed weight and early growth of seedlings, with not always consistent results.

Wrześniewśki, in a series of papers (8,9,10) establishes the differences in the ratio dry matter in the embryo to dry matter in the megagametophyte, its hydration level, and respiration rate, as well as the imbibition process in seeds of *Pinus sylvestris*, belonging to different weight classes. He concludes that medium-sized seeds are the most favourable and that the growth conditions of seedlings are mainly the result of the conditions of seed development in the mother organism.

Larson (4) did not find an actual influence of the seed weight of *Pinus ponderosa* on either the germination rate, the germination percentage, or seedling growth.

Robinson and van Buijtenen (7) consider there is a correlation between seed weight of *Pinus taeda* and certain morphological characteristics which were related to seedling size at 5, 10, and 15 years.

Working on the same species, Dunlap and Barnett (2) showed that there was a strong influence of seed size on early growth.

Likewise, Keiding (3) points out that the height of one-year-old plants of *Tectona grandis* depends on its seed weight.

Belcher, et al. (1) think that the size of the seed does not show a clear influence on the growth of *Pinus caribaea*.

According to Mikkola (5) the main factor is the provenance of *Pinus sylvestris* and *Picea abies* [*P. excelsa*] seeds, the seed weight being of only secondary importance.

Working on *Quercus suber*, Montoya Oliver (6) found better germination and growth in seedlings produced by heavier seeds.

In our research, we tried to evaluate the influence of seed weight and time of harvest on the growth of *Quercus suber* seedlings during their first year. This idea was suggested by the fact that the cork oak produces three distinct crops each year: the heavier acorns, produced by the end of September, the medium-sized ones — in October-November, which constitute the bulk of the crop, and the smaller acorns, which mature in January.

MATERIALS AND METHODS

The acorns were gathered in September, November, and January at Constantina (Sevilla) Spain.

After discarding any floating acorns, as well as those showing symptoms of disease, or attacks by insects or rodents, three groups of 70 acorns each were formed (Groups 1, 2, and 3).

The respective weights (W) were recorded, and the acorns previously germinated sown in plastic pots in a mixture of peat-sand 2:1 v/v in a controlled environment greenhouse. While the experiment proceeded, the number of acorns in group 3 was reduced to 51 due to an attack by mice.

The heights of the seedlings were recorded 3, 6, 9, and 12 months after planting, L_1, L_2, L_3, and L_4, respectively.

All data were submitted to a covariance analysis and to a mean comparison by means of Duncan's multiple range test.

RESULTS

Table 1 shows the average values of seed weights and heights of seedlings for the three groups. The plants growing from medium-sized and small seeds are the ones which achieve better lengths, the differences being consistent through the whole period. It should be pointed out that the weight difference between the medium-sized and small seeds is greater than the difference between the large and the medium-sized seeds.

In Table 2 the analysis of covariance of the data is given. The statistical significance of seed weight and time of harvest are easily inferred from the values of the tail probability and the regression coefficients.

Table 1. Average values of seed weight (W) and seedling length (L).

	Group 1	Group 2	Group 3
W	8.06 gr	7.75 gr	6.74 gr
L_1	66.96 mm	163.07 mm	212.75 mm
L_2	93.90 mm	306.43 mm	215.78 mm
L_3	138.11 mm	308.00 mm	286.17 mm
L_4	166.61 mm	333.86 mm	305.00 mm

L_1, L_2, L_3, L_4 - 3, 6, 9, and 12 months, respectively, after planting.

Table 2. Analysis of covariance.

Dependent variable	Source	Sum of squares	Degrees of freedom	Mean square	F	Tail prob.	Regression coefficients
	Time	847424.06	2	423712.03	73.40	0.00	
L_1	Weight	280500.57	1	280500.57	48.59	0.00	18.18
	Error	1079540.63	187	5772.94			
	Time	1743704.22	2	871852.11	84.47	0.00	
L_2	Weight	487480.97	1	487480.97	47.23	0.00	23.97
	Error	1930187.09	187	10321.86			
	Time	1432038.26	2	716019.13	45.69	0.00	
L_3	Weight	726652.46	1	726652.46	46.37	0.00	29.27
	Error	2930236.03	187	15669.71			
	Time	1369944.10	2	684972.05	36.92	0.00	
L_4	Weight	837774.77	1	837774.77	45.16	0.00	31.43
	Error	3469366.39	187	18552.76			

However, when we adjust the cell means for the first dependent variable (discarding the influence of seed weight), in Table 3 the trend of Table 1 is stressed. The seedlings developing from the heavier seeds are the slowest growing, contrary to what seemed predictable.

Table 3. Adjusted cell means for the first dependent variable (weight).

Dependent *variable*	*Group 1*	*Group 2*	*Group 3*
L_1	58.48 mm	160.20 mm	228.32 mm
L_2	82.72	302.65	236.31
L_3	124.47	303.39	311.24
L_4	151.96	328.90	331.91

Finally, in Table 4, the comparison of the adjusted cell means shows no statistical differences between the seedlings belonging to groups 2 and 3 after the sixth month, being in all cases higher than those belonging to group 1.

These results are in accordance with those of Wrześniewski (9,10), according to which medium-sized and small seeds are the better ones.

Table 4. Comparison of the adjusted cell means.

Group	L_1	L_2	L_3	L_4
3	228.31	236.31	311.24 a[1]	331.90 a[1]
2	160.20	302.65	303.39 a	328.90 a
1	58.48	82.72	124.47	151.96

[1] Means in the same column followed by the same letter are not significantly different at the 99 percent probability level.

DISCUSSION

As stated above, seed weight cannot be regarded as the only or the main factor in every case. Germination and early growth involve a series of complex biological processes that cannot be summed up by saying "the heavier the seed, the better the seedling".

In respect to *Quercus suber*, and for those of the same origin, the quality of the acorns depends much more on their maturation time (physiological conditions of the mother plant) than on their weight.

This could be related to the better hydration level, as well as optimal embryo-megagametophyte ratio recorded for other species.

It is evident that much more research is needed on this subject, by means of integrated experiences on the many factors involved: provenance of the seed, weight, moisture content, and chemical characteristics of the seed coat, the megagametophyte, and the embryo.

Acknowledgements. The author wishes to acknowledge Mrs. Rosa Calvo, from the Departamento de Cálculo del INIA (Madrid) for her skillful help in the statistical treatment of data.

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PLANT PROPAGATION OBSERVATIONS IN NORTH AMERICA

DANIEL P. ELLIOTT

E.R. Johnson Nurseries, Limited
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I travelled in North America for a two-month period from June to August, 1985, on a Nuffield Farming Scholarship study of nursery management. I visited nurseries in the Virginia, Maryland, Delaware area, Lake County Ohio, and the West Coast from Los Angeles to Vancouver, B.C., Canada.

Propagation, per se, comprised a relatively minor part of my study, but I did have an opportunity to view a wide range of propagation practices.

Climate is an important consideration in choosing a propagation system and almost, without exception, summer temperatures were higher than in the U.K. Spring frosts finished earlier and autumn frosts were later. Mist, both outside and under protection, was the most widely used system and seemed ideally suited to the climatic conditions.

Mist units were controlled by time clocks with a few exceptions, where solar controls were used. The majority of nozzle types were large and applied high volumes of water by comparison with conventional U.K. types. Rooting composts needed to be more open and less water retentive. Various mixtures of perlite, peat, bark, vermiculite, and sand were used in the rooting composts — with perlite being the most widely used ingredient. Combined with high temperatures, the above factors provided excellent humid rooting conditions.

Cuttings were gathered from growing crops. Early potting, continous liquid feeding, and production in large (1, 3, and 5 gal) containers necessitated frequent trimming to produce strong, bushy plants, thus yielding large quantities of cutting material. Stock beds were used in some cases, i.e. with culti-

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vars where trimming was not required, or by specialist propagators without access to growing crops.

Rooted cuttings were generally potted into 3 in. square pots. In some instances handling was reduced by sticking direct into the liner pot and grown on *in situ* after rooting. The use of high volume mist nozzles facilitated subsequent watering of the liners. In virtually all cases liquid feed was applied through the irrigation system.

In general, propagation standards were high, and I was particularly impressed to find a wide variety of ornamental trees, e.g. *Malus*, *Prunus*, and *Acer*, being successfully rooted and grown on from softwood cuttings stuck in June. A limited range of blue spruce cultivars, e.g. 'Fat Albert', were also being successfully rooted from a January insertion.

Fog and cold frame propagation were used to a much more limited extent ffor rooting cuttings. The results from fogging were excellent and it seemed ideally suited to rooting in higher temperatures, although unreliability of the equipment had caused problems with some systems.

I was impressed to find that micropropagation was supplying a considerably wider range of plants to the industry than in the U.K., both from in-house micropropagation departments in large firms and from specialist firms. In addition to the rhododendrons and azaleas that are currently being imported in the U.K. from North America, there was a widening range of micropropagated shrub material coming into the U.S. market. Most were sold rooted and weaned as small plantlets needing potting on into liner pots, with some being sold unrooted in agar medium for subsequent rooting at the host nursery.

My impressions of crops grown on from micropropagation were that their habit, vigour, and quality were at least as good as those propagated by conventional means. I expect that the technique will make further inroads into the U.K. industry in the near future.

In general, I found the range of propagation techniques and systems used in North America very similar to those used in the U.K. Climatic variations accounted for many of the differences from our own systems. Although these differences would have little direct application here, they contributed considerably to my understanding of propagation, and hopefully I shall be able to put this knowledge to good use in the future.

CLONAL PROPAGATION OF *FAGUS SYLVATICA* L. BY CUTTINGS

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Abstract. Cuttings of *Fagus sylvatica* were harvested from 85 one-year-old seed-propagated stock plants and rooted. An important difference in rooting ability of different clones was found. Cuttings harvested in a glasshouse could have about 25 cm of new growth in the first season. In contrast. cuttings harvested from clonal mother stock hedges in the field failed to grow new shoots the first season, overwintered poorly, and had very little new shoot growth after being overwintered.

INTRODUCTION

Fagus sylvatica is commercially propagated by seed. Some selected clones for ornamental planting are propagated by grafting, but the cost of grafting is high and the demand for grafted plants is consequently limited. For forest trees a certain genetic variability is required. From this it follows that seed plants are preferred.

In Denmark it is estimated that 80% of the *F. sylvatica* plants produced are used for hedges and scrub planting. If *F. sylvatica* can be propagated by cuttings by a cheap method it will be worthwhile to select clones with defined genetic quality for this type of planting. For many years there has been a shortage of seed, as the fruiting of *F. sylvatica* varies considerably from year to year. Propagation by cuttings would overcome seed shortage problems.

REVIEW OF LITERATURE

Chalupa (1) had good results with cuttings harvested from 2 to 4 year old seed-propagated plants. Treating the cuttings with indolebutyric acid gave 60 to 76% rooting, Cornu *et al.* (2) succeeded in rooting 80 to 90% of the cuttings harvested from 1 to 5 year old seed plants. *Kobert* (3) harvested cuttings from 25 year old grafted trees and obtained up to 97% rooted cuttings but found however, that it was difficult to overwinter the resulting plants. Spethmann (4) harvested cuttings from 2 to 4 year old seed propagated plants and had 50 to 65% success, but the biggest problem was in overwintering the rooted plants. Of the plants from the first year's experiments Spethmann had 30% surviving, but in the second year only 8%.

MATERIALS AND METHODS

Earlier work by the author (unpublished) emphasized that

it is relatively easy to root cuttings harvested from juvenile plant material. It was therefore decided to focus the experiments on factors influencing the rooting of plant material harvested from very young plants.

F. sylvatica seed from Tolne Skov (a Danish selected seed source) were sown on 1 March, 1977, in pots. The pots were placed in a glasshouse and the plants were grown there until 10 June, 1978. The plants had at this date grown to a height of about 1 m. The plants were numbered 1 to 85; 15 cuttings were harvested from each plant. The cuttings were terminals from side shoots. They were given a quick-dip treatment of 2000 ppm indolebutyric acid in 50% ethanol.

Cuttings were inserted in 5 cm rockwool cubes wrapped in plastic film on 4 sides so that newly-formed roots eventually would have to grow out through the bottom. The rockwool cubes were placed onto a glasshouse bench under a mist system controlled by an electronic leaf. The rockwool cubes were kept at a minimum temperature of 21° C by heating cables.

Rooting of the cuttings was recorded at 6 and 8 weeks after insertion. After the last recording all 15 cuttings of 10 clones with good rooting were potted and grown on in a glasshouse. In June, 1980, 5 clones were selected and planted in the field in stock plant hedges.

In June and August, 1984, cuttings were harvested from the stock plant hedges. The cuttings were inserted in 7 cm pots in a growing medium consisting of 70% peat and 30% rockwool. The pots were placed in a glasshouse bench and covered with clear polyethylene film as well as with a milk-white polyethylene film (50% light transmission.)

Before being covered wth the polyethylene films the cuttings were watered with Orthocid 83. The minimum temperature in the pots was maintained at 21°C. Before insertion, 50% of the cuttings were treated with 2000 ppm indolebutyric acid by the quick-dip method; 8 weeks after insertion the number of rooted cuttings was recorded.

The rooted cuttings from the June experiment were overwintered in a frost-free glasshouse.

On 15 May, 1985, the number of surviving plants were recorded and the plants were transplanted into 10 cm pots.

RESULTS

Selection of easily-rooted clones. The cuttings were recorded as rooted if one or more roots penetrated the bottom of the rockwool cubes at the time of recording. By this method it follows that only cuttings with roots which are long enough to

penetrate the bottom of the rockwool cubes will be recorded as rooted.

By repeating the recording it is possible to collect very useful records. Recording was carried out 6 weeks and 8 weeks after insertion of the cuttings.

Table 1 shows the results obtained. It is seen that 6 weeks after insertion there was a wide disparity in how many rooted cuttings there were in different clones. In 3 clones all cuttings had rooted; 8 weeks after insertion there was still a wide dispersion in percent rooted cuttings of the different clones but on a higher level. No further recording of rooting was done as a rooting period longer than 8 weeks would be regarded as unacceptable by the nursery industry.

Table 1. Rooting of cuttings harvested from 1-year-old seed-propagated stock plants (clones).

Percent rooted	Number of clones	
	Recorded 6 weeks after insertion.	Recorded 8 weeks after insertion.
0	2	1
7	5	1
13	3	3
20	2	2
27	5	2
33	9	5
40	6	0
47	6	2
53	3	5
60	5	4
67	10	7
73	7	12
80	6	8
87	8	9
93	5	10
100	3	14
Total	85	85

For the 10 potted clones the new shoot growth was recorded at the end of the growing season. As seen in Table 2 there were recorded a considerable dispersion in the shoot growth of the clones with the fastest growing clone averaging 27 cm of new shoot growth per plant, while the slowest growing clone averaged only 4 cm of new shoot growth.

In June 1985, the height of the plants in the stock plant hedges was recorded. As seen in Table 3 the clones were very different in their habit of growth.

Clones grown as stock plant hedges. Rooting of cuttings started in 7 cm pots was recorded by carefully removing the

pots from the compost ball and recording the plant as rooted, if roots were visible on the surface of the medium. The rooting of cuttings harvested and inserted in the rooting compost at two dates is shown in Table 4. Data is given for untreated cuttings as well as for cuttings treated with a rooting hormone.

Table 2. New shoot growth at the end of the first growing season; 10 easily-rooted clones.

Clone No.	New shoot growth per plant
8306-06	14 cm
8303-07	27
8303-09	18
8303-15	20
8303-23	24
8303-27	12
8303-35	8
8303-50	14
8303-59	22
8303-80	4

Table 3. Height of clones rooted in 1978 and field-planted in 1980. Recorded July, 1985.

Clone No.	Height
8303-06	210 cm
8303-15	230
8303-27	220
8303-35	290
8303-50	170

Table 4. Percent of rooted cuttings. Recorded 8 weeks after insertion.

Clone No.	Inserted June 17, 1984		Inserted August 15, 1984	
	Untreated	2000 ppm IBA	Untreated	2000 ppm IBA
8303-06	28	60	25	20
8303-15	28	60	32	7
8303-27	82	93	38	40
8303-35	62	84	20	18
8303-50	87	93	60	27
Mean	57	78	35	22

For untreated cuttings harvested in June, it is seen that two clones have rooted sparsely; one clone has intermediate rooting, and two clones have a high rooting percentage. When treated wtih a rooting hormone the two shy-rooting clones more than doubled their percent rooting, while the intermediate rooting clone increased its percentage to a level at which the rooting is commercially acceptable.

For the August-harvested cuttings the rooting percentage is unacceptable for all clones and treatments.

Table 5. Cuttings inserted June, 1984. Results are expressed in terms of the percentage of rooted cuttings surviving by May, 1985.

Clone No.	Untreated	Treated with 2000 ppm IBA
8303-06	32%	27%
8303-15	16	27
8303-27	71	73
8303-35	80	78
8303-50	80	88

Table 5 shows how the cuttings survived the winter of 1984/85. It is seen that the clones which rooted well also survived the winter well, while the clones with low rooting percent to a great extent failed to survive:

DISCUSSION

Chalupa (1) showed that *Fagus sylvatica* cuttings harvested from young stock plants could be easily rooted. Cornu *et al.* (2) and Spethmann (4) also noted good rooting in cuttings harvested from young stock plants. They did not investigate the occurrence of genetic variability in the seed-propagated stock plants.

The present work shows that clonal selection is an important factor in the ability of cuttings to root.

This also shows that overwintering of young cutting-propagated plants of *F. sylvatica* is problematic. This agrees with the work of Kobert (1979) and Spethmann (1982).

From the recorded data it is evident that in *F. sylvatica* there are important differences among the different clones' rooting ability. The variance in rooting ability must be genetically conditioned.

Clonal propagation of *Fagus sylvatica* by cuttings is possible but not yet ready for introduction into the commercial nursery industry.

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CLONAL SELECTION OF HARDY ORNAMENTAL NURSERY STOCK

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Abstract. Recent progress and changes made to the "Clonal Selection Scheme" for Hardy Ornamental Nursery Stock are outlined. Since the project commenced in 1975 eleven subjects have been selected and released to the trade. Over 115 different species or cultivars are currently undergoing assessment and it is planned to increase the rate of release to approximately eight selections per year.

INTRODUCTION

Reports (1,2) in previous IPPS Proceedings have described the initiation and early progress of a U.K. selection scheme for hardy ornamental nursery stock. This paper describes recent changes in the organisation of the scheme (usually referred to as the "Clonal Selection Scheme" or C.S.S.), and lists plants so far selected and outlines plans for a more comprehensive system of assessment in the future.

ORGANISATION OF THE C.S.S.

As a result of reorganisation of research and development by the Agricultural and Food Research Council, work on hardy ornamental plant selection was transferred from Long Ashton Research Station to East Malling Research Station in 1983.

At the time of transfer small changes in the organisation of the C.S.S. were implemented to facilitate smoother running of the scheme and plans were made to extend the aims and objectives of the scheme.

The operation of the C.S.S. is best described by considering the procedures as two sequential stages of selection.

STAGE I

The first stage of the C.S.S. involves the propagation, sorting, and initial evaluation of plant material collected from as many sources as possible. This is followed by the propagation and distribution back to the nursery trade of one or more preliminary selections which, as well as being true to *type*, exhibit superior growth and performance (Figure 1).

Subjects nominated for evaluation. Nurserymen, amenity, and other professional horticulturists and botanists have been invited by East Malling Research Station to provide lists of hardy ornamental tree and shrub subjects which they believe

warrant inclusion in the C.S.S. Of particular interest are economically important subjects which tend to vary in characteristics such as growth or flowering when obtained from different sources. After discussion and approval by a small committee of researchers, nurserymen, and other professional horticulturists (the Clonal Selection Committee) a timetable is drawn up to collect and test the nominated subjects.

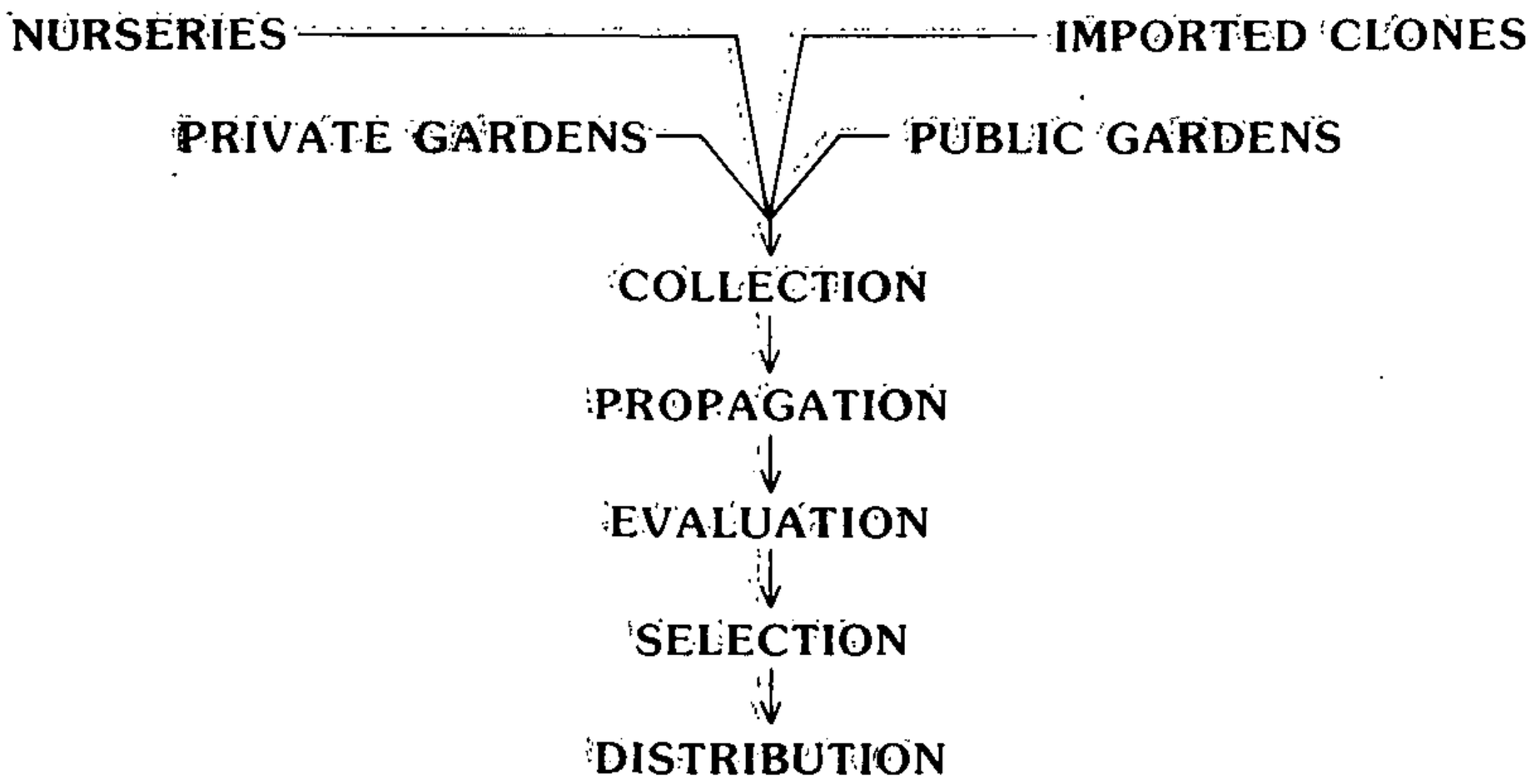

Figure 1. The East Malling Research Station Selection Scheme

Collection of plants. The collection of propagules or plants is undertaken by inviting donation of the nominated subjects from:

Commercial nurseries
Private gardens
National Trust properties
Botanic Gardens
National Plant Collections
Horticultural Colleges
Other Plant Selection Schemes in the UK and abroad
Breeding programmes in the UK and abroad

Currently the majority of material is being donated by sources other than commercial nurseries.

Regional co-ordinators, including ADAS Horticultural Officers, are now involved in ensuring that material is collected and transferred to East Malling as quickly as possible and in a condition suitable for propagation. In the past some consignments of material have been in poor condition on arrival at EMRS with the inevitable result that propagation has been poor. Wherever possible rooted plants are requested as these are less liable to deteriorate in transit and evaluation can be undertaken more speedily.

Propagation. The propagation of material received is carried out using those techniques most appropriate to ensure success. Many plants sent to East Malling as rooted or unrooted cuttings are variable in size and may be received over

several months. Following initial propagation and/or growing-on, it is necessary therefore to repropagate plants from all the sources under standard conditions to ensure uniformity of treatment prior to the commencement of plant evaluation. Although this repropagation procedure delays evaluation it may facilitate the comparison on various methods of propagation, e.g. fogging, mist, and polythene and it has also highlighted the need for research into improved propagation techniques for specific subjects.

Many tree subjects are received as budwood or graftwood and similar problems of variability of scionwood quality, and condition of receipt may, as with cuttings, necessitate subsequent repropagation. A further problem with many tree subjects is that only seedling rootstocks are available. It is of some concern that lack of uniformity in such rootstocks may result in differences in the rootstock influence on scion performance, making comparisons among different scion sources very difficult. Vegetatively propagated clonal rootstocks which would alleviate this problem are currently being sought for several ornamental tree species in research work at East Malling.

Evaluation. The initial evaluation of subjects is carried out in replicated trials planted at East Malling or at one of a number of collaborating centres. The plants are regularly assessed by staff at the trial centres and also by panels consisting of nurserymen, botanists, plantsmen, and consumers.

One of the first and most important facets of evaluation concerns trueness-to-type, i.e. whether the plant is correctly named. This is also one of the more difficult areas as horticulturists, nurserymen, and scientists occasionally differ in their interpretation of correct nomenclature and plant naming. Wherever possible the rules set out in the International Code of Nomenclature for Cultivated Plants (3) are followed; additionally, attempts are made to aid identification by obtaining propagules of the original named plant or an original published description. Colour photographs are taken and pressed herbarium specimens prepared of the selected plants and some of the more interesting variants. Sometimes the International Registration Authority for a particular subject is able to provide information that clarifies identification, but unfortunately, many of the plants currently being assessed are not covered.

Plants identified as being true-to-type are then further assessed on the basis of propagation, establishment, vigour, habit, and aesthetic qualities. The last category obviously varies with the subject studied but usually involves comparisons of leaf, stem or flower colour and abundance.

Distribution. After selection of the best plant from within a trial this plant is used as a nucleus from which stock is propagated at East Malling for eventual return to the contributing centre (or a nominated alternative) for subsequent commercial release.

A list of the plants selected and released to date, together with the primary distributing centres is shown in Table 1 whilst those plants selected in 1985 and currently being built up from a single plant are shown in Table 2.

Table 1. Plants selected and released to date and the primary distribution centers.

Selected Plants	Distribution Centres
Buddleia davidii 'Empire Blue' EM84	Waterers Nurseries, London Road, Bagshot, Surrey
Buddleia davidii 'Royal Red' EM84	Darby Nursery Stock Ltd, Methwold Hythe, Thetford, Norfolk
Cornus alba 'Spaethii' LA79	Darby Nursery Stock Ltd.
Cotinus coggygria 'Royal Purple' EM84	Darby Nursery Stock Ltd.
Cotoneaster conspicuus var. *decorus* EM84	E.R.Johnson Ltd., The Nurseries, Whixley, Norfolk
Forsythia × *intermedia* 'Lynwood' LA79	Wyevale Nurseries Ltd., Kings Acre Road, Hereford
Lonicera periclymenum var. *serotina* EM84	Wellington Nurseries, Brandon Cres. Shadwell, Leeds
Philadelphus × *virginalis* 'Virginal' LA82	Waterers Nurseries
Potentilla fruticosa 'Tangerine' LA79	James Coles & Sons, Thurnby, Leicestershire
Sambucus nigra 'Aurea' LA80	Scott's Nurseries Ltd., Merriott, Crewkerne, Somerset
Weigela florida 'Variegata' LA83	Pershore College of Horticulture, Pershore, Worcestershire

Table 2. Plants selected in 1985 and currently being built up from a single plant.

Euonymus fortunei 'Silver Queen' EM85
Euonymus fortunei 'Gracilis' [*E. fortunei* 'Variegata'] EM85
Crataegus crus-galli EM85
Crataegus laevigata 'Coccinea Flore Pleno' [*C. oxycantha* 'Paul's Scarlet'] 1985
Crataegus laevigata 'Punicea Flore Pleno' [*C. oxycantha* 'Rosea Flore-Pleno'] EM85
Betula pendula 'Dalecarlica' EM85
Cytisus 'Burkwoodii' EM85

Publicity. Now that a significant number of subjects have been selected and are available in quantity from distributing centres, it is intended to publicise the scheme more widely in the trade press. It is hoped that this will generate increased interest in the C.S.S. and stimulate demand for selected plants.

Mature specimens of all of the selected plants will be available for inspection at East Malling whilst selected tree and shrub subjects will be held at Luddington and Efford EHS's, respectively. Demonstration plots containing some of the C.S.S. selections are planted at the Northern Horticultural Society's Harlow Car Garden in Harrogate and similar demonstration areas are planned.

STAGE II

A recent change to the C.S.S. is the proposed introduction of a second phase of the selection process (Figure 2). The best clones, including the selected clone from each trial, will be repropagated for assessment of additional factors of interest to the ultimate consumer. Where appropriate, it is hoped to assess factors such as:

Virus status
Herbicide tolerance
Winter injury
Speed of establishment and ground cover
Genetic stability
Mature characteristics

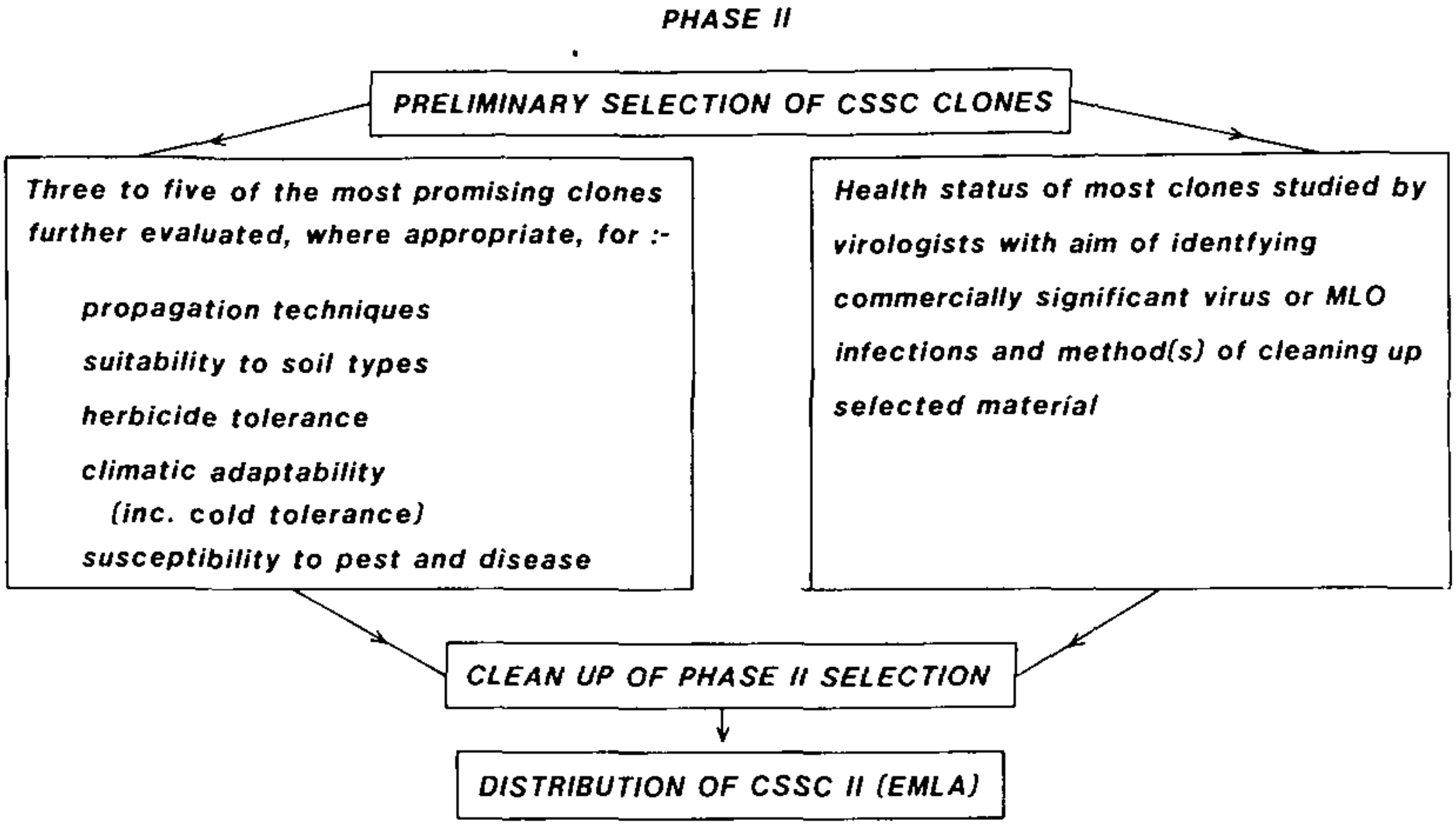

Figure 2. Proposed introduction of a second phase of the selection process.

Freedom from virus. Preliminary testing has already started to determine the virus status of a number of the selected and other superior clones of plants within the C.S.S. using the Double Stranded RNA and other techniques. Unfortunately in most cases little is known of the nature of viruses or microplasmas infecting hardy ornamentals and even less of their effect upon growth and performance. Removal of viruses, using heat therapy or other techniques may not always improve plant quality and much more needs to be known of the influence of these organisms on plant growth and performance

before techniques for obtaining and maintaining freedom from infection can be developed and recommended.

Work at the University of Bath suggests that the selected clones of *Buddleia davidii* 'Empire Blue', *Buddleia davidii* 'Royal Red' and *Lonicera periclymenum* 'Serotina' are free of debilatating viruses.

One investigation currently in progress aims to discover any connection between virus infection and poor propagation (e.g. *Acer platanoides* 'Crimson King').

Many virus-tested cultivars of two species (40 ornamental *Malus* and 20 ornamental *Prunus*) are currently available through the EMLA scheme. However, much of this virus-tested material may be lost under the proposed reorganisation of the EMLA scheme.

Suitability of selected plants for micropropagation. Experiments on fruit species and cultivars have shown that micropropagation may induce juvenility in some plants resulting in increased growth and easier propagation but delayed flowering. Selected plants from the C.S.S. will be micropropagated and their subsequent performances monitored in comparison with conventionally raised material. Selected plants will also be used where appropriate for other micropropagation research such as the genetic manipulation of woody ornamentals to produce new variants and the development of new micropropagation techniques.

CONCLUSIONS

The aim of the Clonal Selection Scheme has remained consistent since its initiation in 1975, that is "to upgrade the general quality of British hardy ornamental nursery stock and eliminate inferior and wrongly named plants". It is hoped that some of the changes outlined in this paper will facilitate the achievement of this objective.

Financed by the Ministry of Agriculture, Fisheries, and Food through their Agricultural and Food Research Council, the Clonal Selection Scheme will continue to depend on the goodwill of nurserymen and others to donate material, serve on committees and selection panels, and provide land for evaluation trials. It is hoped that many members of the industry will continue to give their active support to this scheme.

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ANATOMICAL STATUS AND ROOTING OF *EUONYMUS JAPONICA L.* CUTTINGS

B. BOGDANOV AND P. ALEXANDROV

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The vegetative propagation of the evergreen shrub, *Euonymus japonica* Thunb., plays an important role in the production of decorative material. In Bulgaria this species is grown mainly along the Black Sea coast but it may also be grown in other regions of the country where there is a warmer climate. We are looking for other ways for successful propagation of the subject through rooting cuttings. These are usually taken from one-year-old shoots.

The main task of our study is to analyse the anatomical structure of the current (one-year-old) shoot of *E. japonica* since it has a definite importance for the emergence and forming of the root system of the cuttings with respect to rooting during different times of the year.

MATERIALS AND METHODS

Initial mother plants were 5 and 15-year-old groups of shrubs. The one year old shoots collected from them for anatomical analysis were fixed in FUS. The cuts were performed on Reichert's microtom. The colouring of the preparations is carried out with hematoxilin-eosin. The anatomical observations conducted with the aid of a light microscope on three cuts of the shoots — base, middle, and below the top bud.

Softwood cuttings were cut the middle of each month from a shoot with a length of 8 to 10 cm (three to four nodes) and reducing the leaf mass by about 70%. the cuttings were rooted in cold frames and heated greenhouses in a mixture of washed river sand and perlite in the proportions of 2:1.

RESULTS AND DISCUSSION

During the growing period *E. japonica* forms three flushes of growth. The first is from the middle of March (the bursting of buds) until the second half of May. The second one is from late May until the middle of July; the third one is from the beginning of August until the end of the growing period. The first and the second growth are almost equal but the third is

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more reduced. This is not strong growth and may be destroyed by frost during the winter. The total length of the shoots is about 40 cm.

The investigations show that at the end of the winter the epidermis is clearly outlined around the whole shoot (Figure 1) by a row of cells which have a thickened tangential wall.

Figure 1. Cross section of *Euonymus* shoot before rooting — (1) epidermis; (2) primary bark; (3) phloem; (4) cambium; (5) xylem; (6) medullary rays; (7) perimeduler zone; (8) pith

The primary bark consists of colenchyma and a parenchyma tissue. Under the epidermis there are 4 to 5 rows of thin-walled colenchyma cells filled with chloroplasts. Many of the

parenchyma cells contain tannin; others have big cavities with some of the cells empty. Small intercellular structures are observed. The parenchyma cells of the primary bark are clearly demarked by intercellular spaces. The phloem is without primary fibres, but contains fairly discernible medullary rays.

The cambial zone is clearly revealed due to the activity of the cambium at that time.

E. japonica wood is diffused, porous with vessels, wood fibres, and medullary rays. The vessels are round with five walls and have a mean diameter of about 20 microns. The medullary rays are clearly differentiated, being a single row about 190 microns, situated at intervals of 2 to 6 but most frequently at intervals of 4 rows of wood fibres.

The perimedular zone of the pith is slightly differentiated by 1 to 2 rows of cells. Localised secretory cells are found around the wood.

The pith is composed of large rounded or multiangular parenchyma cells with the presence of starch, mainly near the wood. Large multiangular spaces and a considerable number of large-sized cavities are formed at many places on it.

Table 1. Correlation between the different tissues in the base, the middle, and the top of the one-year-old shoots.

Location of tissue	Pith (microns)	Xylem (microns)	Phloem (microns)	Primary bark (microns)	Height of epidermal cells (microns)
Base	1788	699	151	342	88
Middle	1815	548	137	480	32
Top	1986	206	77	447	27

The data (Table 1) and the investigations show that the one-year-old shoot preserves its epidermal layer and does not develop epiderma. There are no sclerenchyma fibres in the primary bark. The conducting system of the base, middle, and top is not clearly differentiated. At the top the pith is thicker than at the base or in the middle — with bigger or smaller multiangular spaces.

After the appearance of the first 1 to 3 newly formed roots the anatomical status of the cutting (Figure 2) is characterized by an advanced stage of recovery of the tissues of the stem in the area of the wounding. On the periphery of the segment the initial epidermis before cutting is partially preserved but there are no epidermal cells near the place of cutting, i.e. they have degenerated.

The post-cutting phellogen is formed from some colenchyma cells of the primary bark in the sub-epidermal zone.

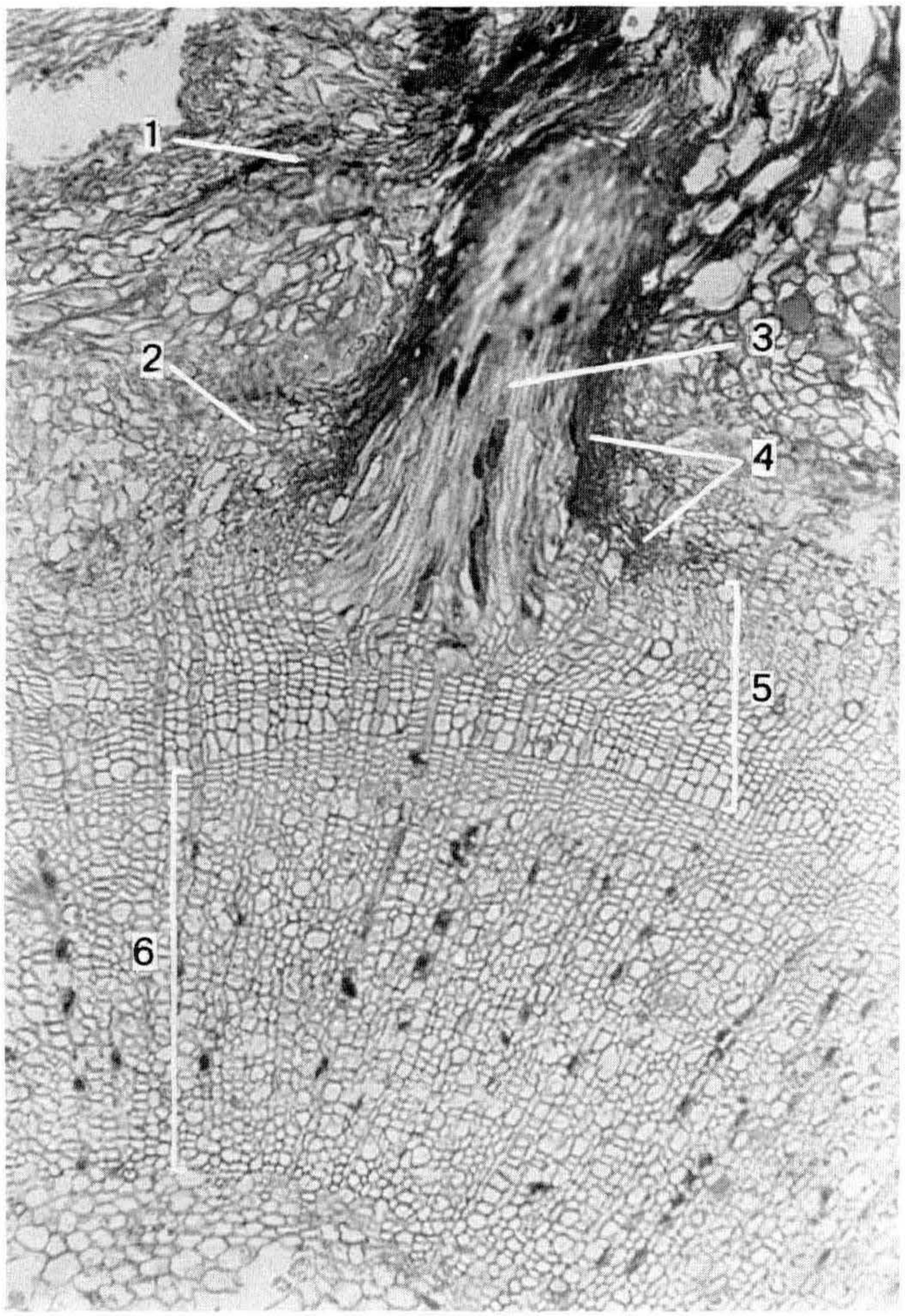

Figure 2. Cross section of euonymus shoot after an adventitious root has formed — (1) primary bark; (2) phloem; (3) newly-formed root; (4) cambium; (5) xylem formed after rooting; (6) primary xylem.

There are 2 to 3 rows of phloem cells. The remaining part of the colenchyma cells degenerate and drop off. The wood, after cutting characterised by a pathological structure is located very near to the peridermal zone. Its cells are tangentially lengthened and convoluted. The medullary rays are rarely formed and are very short. Initial pith rays are found which look twisted and inserted in the pathological wood. The initial pith is bent; its cells are pressed and have a dark brown content. They seem to be connected to the initial wood and are actually dropping off. A regeneration of the cutting's devel-

opment is taking place at this stage which is a bit chaotic in the zone of the callus, but this secures a primary physiological and structural connection which prevents penetration of air in the inner tissues.

The newly-formed roots appear in the cambial zone in the region where phloem and xylem elements are not completely differentiated as well as the increase of the woody tissues which, after planting, is 253 microns. Small bundles of conducting elements are formed at the beginning which gradually group together to form the apex of growth.

The newly-formed roots grow through the primary bark or the callus and tear the covering tissues. It is assumed that the diffused-porous type of the wood of *E.japonica* favours the formation of roots since the cambium cells possess the ability to divide during the whole period of vegetative growth.

The observations show that visible signs for the initial stage of the rooting process appear after the callus formation, about 20 days after planting, root formation (about the 40th day, bud-growing, 50th to 60th day). The rooting proceeds most quickly with cuttings obtained during the months 2, 3, 4, 5, and 6, then at a slower rate — with those cut in the 7, 8, and 9 months, and in an intermediate time — with October and November cuttings.

At an optimal regime for rooting, e.g. a temperature of 20 to 25° C and a relative humidity above 80%, all cuttings develop a good root system and there is a high rooting percentage. The best results are obtained with cuttings taken in March, with 100% rooting: 42 plants have first class roots with 375 cm total length of the root system of one cutting. The most unsatisfactory are the cuttings taken in September with 90% rooting, only 17 plants with first class roots, and 186 cm total length of the root system for one cuttings.

CONCLUSION

E. japonica cuttings manifest high regeneration capacity during the whole period of their annual growth. The rooting proceeds mainly in the zone of the xylem and cambial layer and form after rooting around the cut and in the part of the cutting covered by the substrate. Under the experimental conditions the best results were obtained with cuttings prepared in March.

PRODUCTION OF BARK FOR COMPOSTS

NORMAN STEWART

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Bark appears on trees from the seedling stage, protecting the plant, storing and conducting absorbed salts from the soil to the all-important leaves. Epidermal cells, the precursor to bark, carry out photosynthesis in the immediate post-seedling state, helping the plant to make headway against the many difficulties of its surroundings. In a short space of time the chlorophyll fades to be replaced more and more by the characteristic colour and markings of the firmer and increasingly tough layers of cells we now describe as bark. This layer which can, in mature trees, be quite thick, has been described as "bark, the protector". The latter is the main function against the many enemies from outside which include pests, diseases, and predators of many kinds as well as the natural hazards of tempest and fire. But protection is not complete and defences can be and are breached by endemic problems which, as far as the United Kingdom is concerned, restrict international trade in bark unless it has been fumigated.

Bark used for plant growing in the United Kingdom in composts or mixes is almost entirely softwood. Broad-leaved hardwood trees are not grown in plantations and the bark is usually relatively thin. Softwoods, on the other hand, are grown in plantations throughout the country in numbers large enough to make full scale harvesting possible. In the east of the country pine species grow well — *Pinus sylvestris* (Scots pine), *P. nigra* (Corsican Pine) and *P. contorta* (Lodgepole pine). In the west of England, Wales, and Scotland species suited to the higher rainfall are grown — spruce, larch, and fir.

Planting, management, and harvesting of forest plantations is now big business and at all stages up to date techniques and facilities are used. The Forestry Commission leads the way with a considerable programme of research and development. It was a member of their staff, a Mr. Jack Aaron who, in the 1960's, began trials on bark for plant growing. In the early 1970's it was he who focused my attention as a horticulturist on the commercial possibilities of bark. From these early discussions arose the involvement of Camland in bark. Now the brand name "CAMBARK" is recognised nationally and internationally as a high quality bark product for the growing of plants.

Between 1971 and 1973 Camland carried out a number of trials with a hammer mill product using information from research sources available. It was decided not to follow the popular line and produce a peat-like product but to supply a 100% bark product with defined particles to which the customer would add his own plant growing recipe of nutrients. We realised that we had a geographical advantage with large quantities of all pine bark which is a very slowly degradable product requiring the minimum nitrogen starter. The Regional Horticultural Advisers of the Ministry of Agriculture were kept informed of our objectives, namely a reliable constant product produced by a company respected in the trade for its high standards. Approaches were also made to national and international research and experimental stations. Throughout the years Camland has benefitted from the help and good wishes of many individuals and groups of people and this association still remains firm. By the mid-1970's the product that Camland was producing was of a consistent high quality and its reputation was becoming known. In order to expand, the company sought financial and business assistance and became part of the Gardner Watts Group and the company was re-named Camland Products Limited.

Since the beginning of our work many contacts have been made with sawmills in various parts of the United Kingdom where pine is the primary species and could be separated from others with relative ease. Verbal encouragement was given to sawmills to look at this raw material as a valuable asset, if removed from the timber with reasonable care, stored in a sensible way and kept clean and rubbish-free. It has been a long, slow job communicating our needs to increasing numbers of suppliers. Some have failed to meet our standards and no longer supply us — perhaps they will try again. We only purchase from suppliers who have good material and give good service. We are not happy to find non-bark objects in the raw material — stones (large or small), bolts and nuts, saw blades, engineering tools, etc. Clothing we accept as a soft hazard but it does wrap itself round the machinery causing delays. Damage to pulverising equipment can be very serious and costly. Over the past 10 years we have produced a natural material with admirable qualities and with the versatility which constantly surprises us and will continue to do so.

Turning the pages back to actual bark production, the selected seed of a chosen species is sown individually in multi-cell units in late winter and early spring (the compost used may well be bark-based). The plant is grown on under glass or tunnels and is ready for planting, weather permitting, in the autumn through to the following year depending on

when the quota for that season has been planted, or drought stops planting. Where the ground is suitable, machine planting will take place and will continue until ground conditions make this impossible. In hilly and mountainous areas traditional hand planting is done.

After a period of some 20 to 50 years felling is carried out. The days are long past when trees were felled by axe or two-handled saws, and horses were used to drag the logs from the plantation. Today sophisticated chain saws reduce a 50-year-old tree to ground level in a matter of seconds. The person responsible for sawing lays the logs in a criss-cross fashion trimming off any branches close to the butt. A forwarder machine will pick up some 18 to 20m^3 of logs at a time to be taken directly to the contractors' trucks or trailers. It is at this stage, too, that the same logs may be cut into suitable lengths for further use.

The removal of the bark from the logs can be done by one of two methods: the water tumbler friction method or the much more popular dry ring de-barker method. As the word "dry" signifies, water is not used to soften the bark for easy removal. The water content of the bark of the tree varies, low in summer and autumn, high in winter and spring. In early spring the flow through the sapwood increases in response to plants' requirements for water and nutrients. The moisture content during the active period is about 50 to 55%. Outside these seasons, i.e. late summer, autumn and winter, the moisture content could fall to 25 to 30% and, in very dry seasons, lower than this. Rainfall directed on to the bark of the growing tree has little or no effect on moisture content. The waxy content (suberin) of the corky cells repels the rainwater, though some could be carried in through cracks and crevices of the rough bark.

The dry system avoids any possible loss of chemicals within the bark that could enhance plant establishment and growth. To get the very best from the system the logs should be as regular in cross section as possible and clear of snags — short, stubby remains of branches. The aim is to reduce the amount of wood in the initial raw material before further treatment. The 6 to 7m. lengths of logs are brought into the sawmill yard and are stockpiled or fed directly on to a feed line attached to the de-barker. A cradle conveyor, part of the de-barker, feeds each log into a ring cutter head and is gripped by cogs which pass the now de-barked logs for grading and stockpiling. In the meantime the raw bark is conveyed either for stockpiling or pulverising (granulating).

In Camland we look for quality as well as quantity and

the raw material is collected from a sawmill, wherever that is, and stockpiled at our own depot where we have up-to-date equipment and land for expansion.

The bark is granulated, graded, and matured without additional nitrogen in carefully controlled conditions rendering harmless all phytotoxic chemicals such as an excess of monoterpenes. A small amount of monoterpenes will enhance growth, a large amount will retard, or even kill. A balance must be obtained. Similarly the manganese content must be below 300 ppm or toxicity will arise. Spruce and those other softwoods grown in the west of the United Kingdom where rainfall is high and peaty soil conditions predominate take up large amounts of manganese from the soil. These factors must be taken into consideration before the bark is sold for propagation or for potting or soil improvement.

When Cambark is ready for despatch to the customer the bark will be about three months old. The grades will be standard and consistent and the bark will have a pH of 4 to 5, an all important consideration for compost making.

Why use bark at all? For many years peat had been used but by the mid-seventies, because of mechanical harvesting and the process of mixing, the structure of peat gradually changed and became very fine. This fineness resulted in compaction and waterlogging with all the inevitable results. Even adding sand does not necessarily remedy this situation. Sand is lost in the interspaces and can decrease the air porosity of a mixture. At the time that peat became finer, bark became available in increasing amounts nationally and worldwide and research was begun into its use as an alternative, or as an amendment to peat.

On the continent where peat is scarce, or expensive, bark is marketed as a complete substitute and is processed and broken down to a similar physical consistency to that of peat. In the U.K., in the main, bark is used as an amendment to peat.

To obtain the full benefits of a processed bark for horticulture it must have clearly defined particles which are within certain parameters, depending upon the use to which the bark will be put. Pine bark, such as Cambark produces, has the outstanding characteristic of being resistant to decay and remaining resilient throughout. Rapid decomposition can result in structural loss and alteration of the air/water relationship existing within a compost or mixture. A 25 to 50% addition to peat will bulk up the compost and provide an open structured medium which is well drained, retains sufficient available water for plant growth, and has a good air volume for gaseous

exchange. As no additional nitrogen is added to our pine bark this must be compensated for at the mixing stage of a potting compost. This has the advantage that an early release of nitrogen within the compost will be mopped up by the bark, or leached out because of the free draining properties, preventing scorch occurring. This property is used to full advantage in a propagating mix for rooting cuttings, either as a 50/50 peat/bark mix or 100% bark. Controlled release fertilisers can be used which give a far superior cutting in considerably less time.

No matter how good the compost, growth of the plants is still very dependent on the management and expertise within the nursery. Nevertheless, in order that he may concentrate on growing plants, the nurseryman will want to be assured that the high quality material he buys today can be bought tomorrow and the day after.

Acknowledgements:

Mrs. E.J. Mann and Miss C. Kennedy, Camland Products Limited, 36 Regent Street, Cambridge CB2 1DB, England.

The Forestry Commission, 231 Corsterphine Road, Edinburgh EH12 7AY, Scotland.

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PROGRESS WITH DIRECT STICKING OF CUTTINGS

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Rooting cuttings directly into small containers is not a new technique but with major improvements in propagation techniques in recent years, particularly developments in using fertilized rooting media, it was felt that greater benefits from direct sticking were possible and that the subject needed looking at in greater depth. The work is still in its early stages and the scope of this paper is to preview the background of the improved rooting media, as well as the progress with direct sticking at Efford Experimental Horticulture Station.

Good quality cuttings are an essential start to any production schedule but all too often cuttings, once rooted, become neglected and starved before potting. This results in delayed establishment, slower growth initially, and poorer overall uniformity within a batch of plants which can be reflected in the

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final grade-out at sale. A series of trials and observations at Efford between 1980 and 1984 investigated methods of maintaining (and improving) cutting quality prior to potting. Results were impressive and showed that significant improvements could be achieved.

NUTRITION AFTER ROOTING

The standard rooting medium used at Efford for many years was a 75% medium Irish sphagnum peat + 25% lime-free sharp grit. Use of liquid feed as a means of maintaining cutting quality once cuttings had been rooted and weaned was examined over three successive seasons for a range of autumn struck cuttings held until late spring before potting. Treatments included an untreated control (water only), and feeds containing 50 ppm N + 50 ppm K_2O, or 50 ppm N + 50 ppm P_2O_5 + 50 ppm K_2O, applied every 1 or 2 weeks (depending on frequency of watering).

The magnitude of effects varied with species, but in all cases there was a striking improvement in quality of cutting growth where feed had been given after weaning; establishment and early growth following potting was faster and more uniform than where cuttings had been allowed to starve. These effects were still obvious six months after potting. The N:K liquid feed maintained cutting quality without excessive growth, but the inclusion of phosphate promoted growth in the propagation tray. While this made earlier potting desirable to prevent overcrowding, root activity was such that despite the relatively severe tearing apart required by delaying potting, establishment and early growth was rapid.

One of the problems of liquid feeding over winter was the limited requirement for water and it was easy to waterlog cuttings unless frequency of application was reduced, thus limiting the feed applied. This led to investigation of incorporation of long term formulations of resin-coated controlled release fertilizers in the rooting medium.

NUTRITION DURING ROOTING

1. *Controlled-Release Fertilizers in Peat:Grit Rooting Media.*

The first observation incorporated 1 kg/m^3 of Osmocote 18:11:10 (8-9 months) in a 75:25 peat:grit mix for *Hydrangea* cuttings rooted under mist in the spring. Results were striking — cuttings in the fertilized medium rooting rapidly and foliage remained a dark green with active axillary bud growth compared with the well-rooted but starved, hard cuttings in the unfertilized medium. Work was repeated with summer struck, mist-propagated Japanese azaleas, this time with a 12-14

month formulation of Ficote (Nutricote) 16:10:10 (140).

Results were again impressive with no adverse effects on rooting from inclusion of the fertilizer but a marked improvement in cutting quality by the time they were potted six months after striking. While up to 1 kg/m^3 of either 8-9 or 12-14 month formulations of Osmocote or Ficote proved successful in a peat:grit medium for propagation under mist, caution is needed in their use under polythene covers where leaching is minimal and temperatures often relatively high. Under these conditions fertilizer rates are reduced by up to half, particularly for salt-sensitive species.

2. *Comparison of Rooting Media.*

Following reports of successful use of pine bark for propagation, its use under mist and polythene systems was investigated using a commercial granulated pine bark available in the U.K. (Cambark). The fine grade proved more suitable than the coarser "100" grade, cuttings being easier to insert, better supported, and drying out less rapidly. Mixes of 75:25 peat:grit, 50:50 peat:bark, and 100% bark have been compared, with and without the addition of controlled-release fertilizers.

The 100% bark proved more difficult to manage, holding less water and drying out quickly, particularly after weaning, and while used wtih success on nurseries, at Efford better results were obtained using the 50:50 peat-bark mix. The inclusion of the granulated pine bark produced a marked improvement in rooting and root development and, provided fertilizer was incorporated, produced excellent quality cuttings. Without fertilizer, rooting was still good but top growth suffered and starved more rapidly than in unfertilized peat:grit mixes. Cambark is not composted with nitrogen during its maturing process and consequently has the property of absorbing nutrients after use, particularly nitrogen, a potential advantage in providing cuttings with some safety against excess nutrient release under high temperatures.

3. *Granulated Pine Bark + Controlled Release Fertilizer*

The use of granulated pine bark appears to offer several advantages for use in propagating media: improving structure, increasing aeration (drainage), and allowing safer use of fertilizer incorporation. Other factors may well be involved and need further investigation. Type and rate of fertilizer addition with a 50:50 peat: pine bark mix varies with time of propagation.

Under mist (mainly spring/summer): 1.0 kg/m^3 of 8-9 or 12-14 months formulations of Osmocote or Ficote (Nutricote) have given excellent results.

Under polythene covers (mainly autumn/winter) where

leaching is minimal and temperatures can increase rapidly 0.75 kg/m^3 of the 12-14 month formulations appear reasonable.

The extended release 12-14 month Osmocote 17:10:10, and Ficote 16:10:10 (140), as well as being safer to use than 8 to 9 month formulations, have the advantage of nutrient reserves which help maintain cutting quality until potting. This in turn improves establishment and uniformity of growth in the batch of plants and, with some species, can improve growth, e.g. in *Camellia*, where early branching increased with plants from fertilized rooting media. Even longer term formulations (16-18 month) of coated fertilizers are now being monitored, and higher rates of incorporation than those outlined above look promising, particularly for propagation under mist.

DIRECT STICKING

With the ability of fertilized rooting media to maintain cutting quality over a relatively extended period, one of the main problems of direct sticking was overcome — namely the need to start a feed programme immediately after rooting. Work still in progress at Efford is concentrating on looking at responses of a range of species to direct sticking both under mist and polythene covers with a major objective being that of monitoring, whether a "liner strength" propagation mix could be used without adverse effects on rooting.

1. *Propagation Under Mist*

Hydrangea, used as a preliminary indicator species, was direct stuck into 70 mm pots in various media. As previously, rooting improved in 50:50 peat:pine-bark compared with peat:grit mixes and the inclusion of 1 kg/m^3 of 12-14 month Osmocote or Ficote produced a marked improvement in cutting quality. The work was repeated with a range of vigorous to salt-sensitive species during the summer of 1984, but increasing rates of fertilizer up to 2 kg/m^3 (plus 1.2 kg/m^3 magnesium limestone and 0.3 kg/m^3 Fritted Trace Elements (WM 255) were included.

All species rooted equally well whether direct stuck in 70 mm pots or seed trays, but cutting quality and early growth improved with direct sticking where competition for available nutrients was less. Overall, results were better in peat:bark than peat:grit mixes and cutting quality improved with increasing fertilizer. This was to be expected with the vigorous species (*Hypericum* × 'Hidcote', *Forsythia* × 'Lynwood') but it was encouraging to see species normally considered salt-sensitive responding in a similar manner (Japanese azalea and *Viburnum burkwoodii*). This improvement was not just foliage

colour, but increased stem thickness and active leader and axillary buds which produced well-rooted, small liner plants direct from propagation. No problems were encountered by using the 2 kg/m^3 rate of fertilizer in the peat:bark mixes, but rooting of camellia was reduced where it was used in the peat:grit mixes.

2. *Propagation under Polythene Covers.*

Following the success with direct sticking under mist, work was repeated over the autumn/winter period under polythene covers. Under these conditions it quickly became evident that salt-sensitive species were not doing well in fertilized peat:grit mixes, particularly at the higher rate (2 kg/m^3) — when deaths occurred. Inclusion of bark in the media improved rooting, but rate and type of fertilizer were important since there was evidence that too high a rate of 12-14 month fertilizer (2 kg/m^3 Ficote 16:10:10 (140) could be damaging to sensitive species (Japanese azalea). The same rate of the 16-18 month formulation of Osmocote, however, proved safe.

As with the summer propagation, direct stuck cuttings were a better quality than those from seed trays — but time of potting is important to obtain the greatest benefit from this improved propagation. The earlier the potting of slow-growing species, or those with distinct growth flushes, the better the growth by the end of the season. A delay in potting of the more vigorous species was not so detrimental, their growth rate enabling them to "catch up" on the earlier potting.

Advantages of direct sticking include:
— reduced root disturbance
— faster growth potential
— reduced handling

Its success will depend upon:
— species which guarantee a high rooting percentage.
— correct rooting media/fertilizer combination.
— availability of space.

The potential for direct sticking of cuttings appears considerable, its use having been extended by the development of fertilized peat: pine-bark rooting media, which have the ability to maintain cutting quality without adversely affecting rooting, which leads to improved growth.

Trials are continuing looking at rate and type of controlled-release fertilizer as well as inclusion of phosphate, lime, and fritted trace elements, and the proportion of bark needed in the mix. The potential for direct sticking in "liner mixes" looks promising from preliminary results, but more work is needed before recommendations can be formulated.

Use of a 16-18 month formulation, (Osmocote 16:9:9 + 3 MgO) needs further investigation. This has a slower rate of release than 12-14 month materials and can therefore be used more safely at higher rates and lasts over a considerable period.

The disadvantage of the extra space required for direct sticking may require a change in the propagation system, so the use of fog and gantry systems are already under consideration.

Increased Number of Cuttings per Pot.

Poor utilization of space resulting from propagation failures can be reduced by increasing the number of cuttings per pot. This will reduce propagation losses, produce faster growth rates and quality plants for earlier marketing. An adequate stock area will be essential to provide the increased number of graded cuttings required, and correct pruning schedules in the stock area will be important. A wide range of species has been successfully propagated with increased cuttings per pot, including those in the following categories:

Ground cover species: (*Hedera*, *Hebe*, *Hypericum*, etc.)

Easily-rooted "amenity" species: (*Senecio*, *Forsythia*, *Weigela*, etc.)

Slower growing species: (e.g. *Elaeagnus pungens* 'Maculata')

Higher value species: (azalea, *Pittosporum*)

Poor branching species: *(Camellia)*

Hedging species: *(Ligustrum, Griselinea)*

Trials with this technique are on-going, comparing 1, 2 and 3 cuttings per pot. While 3 cuttings/pot produces excellent quality plants, 2 cuttings per pot have given good results and reduces the strain on available stock. The initial work was with 70 mm pots, but current trials, as well as looking at size and type of fertilizer incorporation, are also examining direct sticking into 1 litre containers under fog and under mist systems.

COMMERCIAL ASPECTS OF DIRECT STICKING OF CUTTINGS AT HILLIERS

BRIAN E. HUMPHREY

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Abstract. "Direct sticking" is defined as the insertion of a cutting(s) into an individual receptacle. Direct sticking into a liner, intermediate, or final pot may be appropriate. By blending pine bark with blends of different grades of peat to which controlled release fertilizers (C.R.F.) are added, a medium with an air filled porosity (A.F.P.) of 20% or more can be obtained and good nutritional status achieved. This is able to serve as a combined rooting/growing medium. The choice of receptacle (container) size is dependent upon the final objective of producing rooted material. Advantages of this system include quicker and higher quality plant production. Disadvantages involve the higher input required at the propagation phrase.

Definition of terms. What is normally understood by the term, "direct sticking", is the insertion of an unrooted cutting or cuttings directly into an individual receptacle. This enables the rooted material to be subsequently handled without being shaken apart and reduced to a bare root or semi-bare stage before potting off or planting out.

To some growers direct sticking implies the insertion of one or more cuttings directly into the container into which they are to be sold. It may, therefore, be appropriate to add to the term an explanation of the type of container into which the cuttings are placed, e.g.:
— direct sticking into liner pots/cells/blocks.
— direct sticking into intermediate pots.
— direct sticking into final pots.

Rooting/growing media. As long ago as 1959 Peter Vermeulen in a paper to the IPPS recognised that new developments in compost additives had made the concept of a rooting/growing medium much more feasible than previously. Further understanding of the factors and materials which affect crucial features such as porosity and aeration, and the provision of appropriate levels of nutrition have all helped in the development of suitable media for rooting cuttings and allowing them to be subsequently grown on in the same medium.

Because larger containers have better internal drainage and aeration characteristics, the use of rooting/growing media has been more commonly seen in these. Small "cells" and "liner pots" require that more emphasis be placed on rooting rather than on growing medium aspects. In general, the use of synthetic materials to produce blocks and the finer-textured peats compressed into blocks or plugs, have not provided an

answer to the rooting problems associated with the whole range of difficult-to-root species grown on the nursery.

MEDIA USED AT HILLIERS

(1) Physical Ingredients

(a) *Containers up to and including 8.5 × 8.5 cm square or diameter.*

At present we use pure fine Cambark, which is pine bark pulverised to produce particles from dust to ¼ in. diameter. To this is added controlled fertilisers according to the guidelines shown in Section 2.

For ericaceous subjects Hilliers use a mixture of 50% Cambark 100 (pine bark produced to give approximate particle size within the limits ¼ to ½ in. in diameter), and 50% peat. The peat is a blend of coarse grade Irish and very fibrous Finnish peat (Finn Fibre). This mixture gives an A.F.P. normally in excess of 20% or more commonly 22 to 23%, as measured by the A.D.A.S. method.

It seems likely that in the future Hilliers may increasingly use the bark:peat mix rather than pure fine bark for all species. The addition of peat appears to aid the production of a heavier quality liner and makes subsequent culture easier, especially if the containers of rooted plants are not potted on quickly. The big advantage of 100% bark is that no mixing is required before filling the containers.

(b) *Containers of 9 × 9 cm (square or diameter) and above up to 3 liters.*

Into these are always placed mixtures of bark and peat fortified with C.R.F. Because of the better aeration characteristics of the larger containers Hilliers use a blend of somewhat finer grade peats than mentioned previously, up to 40% of the total peat content being medium grade Irish or Scottish peats. The addition of finer peats means that subsequent culture of the plants is made even more easy, the mixture being reasonably well-buffered and having good moisture retention properties.

Recently Hilliers have added polyacrylic gels (Broadleaf P4) to the mixture to further enhance aeration and moisture holding. The normal medium used at Hillier's now comprises:

40 to 45% Cambark 100, plus
55 to 60% peat blend, comprised of:
40% Scottish peat, 30% coarse Irish, and 30% Finnish Fibre

The exact proportion of bark:peat is adjusted according to

the propagation system (coarse mist vs. fog), the time of year, and the species.

To the above is added 1 to 1.75g of pre-hydrated Broadleaf P4 per cubic metre of the bark:peat mix.

In all cases containers are filled by mechanically trickling the rooting/growing medium into them. No further firming is carried out before insertion of cuttings. In practice this means that cuttings inserted in the summer/autumn of year one need some topping up by late spring of year two unless, as is usually the case, they are potted on.

(2) **Addition of controlled-release fertiliser (C.R.F.)**

The factors considered when adding C.R.F. are:
a) Percentage of bark
b) Length of time cuttings require to take root.
c) Whether or not artificial bottom heat is used.
d) Conditions under which rooting takes place, i.e. fog or polythene, etc.
e) The season at which the propagation takes place.

The C.R.F.s used are Osmocote (16:9:9), 16 to 18 months formulation, and Ficote 140 (17:10:10), 12 to 14 months formulation. Because the release patterns of these products differ and because their release is influenced by different factors they are normally blended in varying proportions according to the guide-lines as follows:-

With or without bottom heat, summer -

Fast rooting: early nutrient requirement, bottom heat unlikely to be significant as temperatures are high throughout. Use high proportion of Ficote.

Early autumn - rooting somewhat slower but affected by bottom heat. Higher proportion (say equal) of Osmocote. Without bottom heat, higher proportion of Ficote to make up for slower release.

Late autumn - rooting is slower, with or without bottom heat; with bottom heat, little Ficote or too much nutrient released too soon. Without bottom heat, more Ficote to make up for slower release.

General Rates of C.R.F. to Apply:-

100% bark

Summer	2.25 Kg/cu.m
↓	
Late autumn	1.05- 2Kg/cu.m

(Bottom heat→cold)

50:50 bark:peat
Summer 2.25 Kg/cu.m
↓
Late autumn 1.00 - 1.05 Kg/cu.m
(Bottom heat—cold)

Note: in the case of 100% bark mixes the C.R.F. is applied to the base of the pot only, before filling the pot.

Pot Sizes. Normally 7.5 × 7.5 cm. pots are used as the main "liner pot" for direct rooting. Into this, containing pure fine Cambark, or the 1:1 peat:bark mix mentioned, is inserted cuttings of some species and cuttings of virtually every genera grown by Hilliers.

Rooting results have been equal or better than results achieved by conventional rooting into boxes or beds. By inserting more than one cutting into the liner pots, 95% + rooting can be ensured for virtually all species. Cuttings of the difficult species, e.g. deciduous azaleas and *Syringa vulgaris* cultivars are still stuck in boxes in the conventional way. Then 9 × 9 cm and 1-litre pots are used as an "intermediate" pot, that is, something for growing an extra heavy liner before final potting. This container, filled with the rooting/growing medium is used to produce a wide range of species but especially some of the flowering shrubs such as *Potentilla, Philadelphus, Weigela, Buddleia*, etc.

Finally, 1½, 2, and 3 litre pots are regarded as the pots from which the plants are sold directly. The smaller sizes are normally used as an Amenity Grade whilst 3 litre pots can produce Garden Grade plants. *Buddleia* is the most commonly used species for direct cutting insertion into 3 litre pots. Three vigorous cuttings of *Buddleia davidii* cvs. inserted into 3 litre pots in mid-July will be good quality saleable products by the following April. *Cornus alba* 'Sibirica' or *C. alba* 'Spaethii'LA 79' normally requires until the following autumn to produce saleable plants.

All plants rooted into rooting/growing media require supplementary feeding in the spring following rooting. This can be supplied as Sierrablen, Glasgro granular compound fertilisers, or a liquid feed, according to the grower's particular circumstances.

Advantages of Direct Sticking:

1. Highly suitable for container production
2. Avoids root damage/disturbance
3. Saves labour in overall production
4. Produces a saleable plant substantially more quickly (up to one growing season saved)
5. Can produce better quality plants

6. More flexibility in subsequent handling/potting-on procedures
7. Possible reduction in disease, especially in propagation phase
8. Higher percentage out-turn of saleable plants from initial number of receptacles produced.

Disadvantages of Direct Sticking

1. Substantially more propagation facilities required (× 3 to × 15)
2. More labour involved at propagation phase
3. Materials cost higher at propagation phase
4. Care in nutrition (feeding) required
5. Care in spacing to maintain quality
6. Rooting-through can be a problem
7. Because of the high A.F.P. final pots dry out readily
8. More winter protection required the first winter

VEGETABLE PLANT RAISING USING SPEEDLING TRANSPLANTS

JOHN COOLEY

Modular Transplants
Springfield Nursery
Pick Hill, Waltham Abbey, Essex

My objective as a plant raiser, is to enable my customer, the intensive vegetable farmer, to reduce his unit cost of end product; for example, a crate of cauliflowers. In order to do this, the system I use has to be economical but, above all, has to give a high percentage yield of uniform, marketable produce which brings the unit cost down.

Traditionally, vegetable growers have direct-seeded into their fields, or thickly sown in one field or greenhouse then pulled the plants and transplanted them into their final position in the field.

When I became involved in plant raising, growers were starting to use the first form of module — the peat block — which was having some success, especially with lettuce. This technology had come from Holland where the system was well developed, albeit mainly for glasshouse growers. Production of peat blocks in Holland was highly mechanized and was a large industry. However there were disadvantages in this system when used by outdoor vegetable growers in the U.K. mainly because of the slow development of roots into the field soil and the peat block's inability to re-wet if it dries out.

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On looking around for alternatives, we found the "Speedling System" in the United States. This had been developed for the outdoor grower and had eliminated many of the peat block's disadvantages. The peat block had been developed for the glasshouse grower with his ability to control the environment.

The heart of the "Speedling System" is the tray the plants are grown in and, more specifically, the shape of each module or cell (Figure 1). The tray is about 1 × 2 ft and has differing numbers of cells, with as many as 595 cells in our mini-cell tray. The cell is the shape of an inverted pyramid and, when the seed germinates, its roots are guided by the corners and shape of the cell to the large drainage hole. As the cell has no bottom, as in a flower pot for the roots to run around, the roots grow out of this drainage hole and, because the tray is supported off the floor of the greenhouse with a good flow of air under it, the roots die in the dry air. This process is called "air pruning" and it releases the dominance of the root, allowing a number of secondary roots to develop. This process is repeated with each root that grows out of the cell and results in a root system with a large number of young, vigorous roots mainly on the outside of the module, ready to establish into the field soil. This system avoids root balling as the roots are not allowed to run around the base of the module as in a flower pot, and results in more rapid establishment.

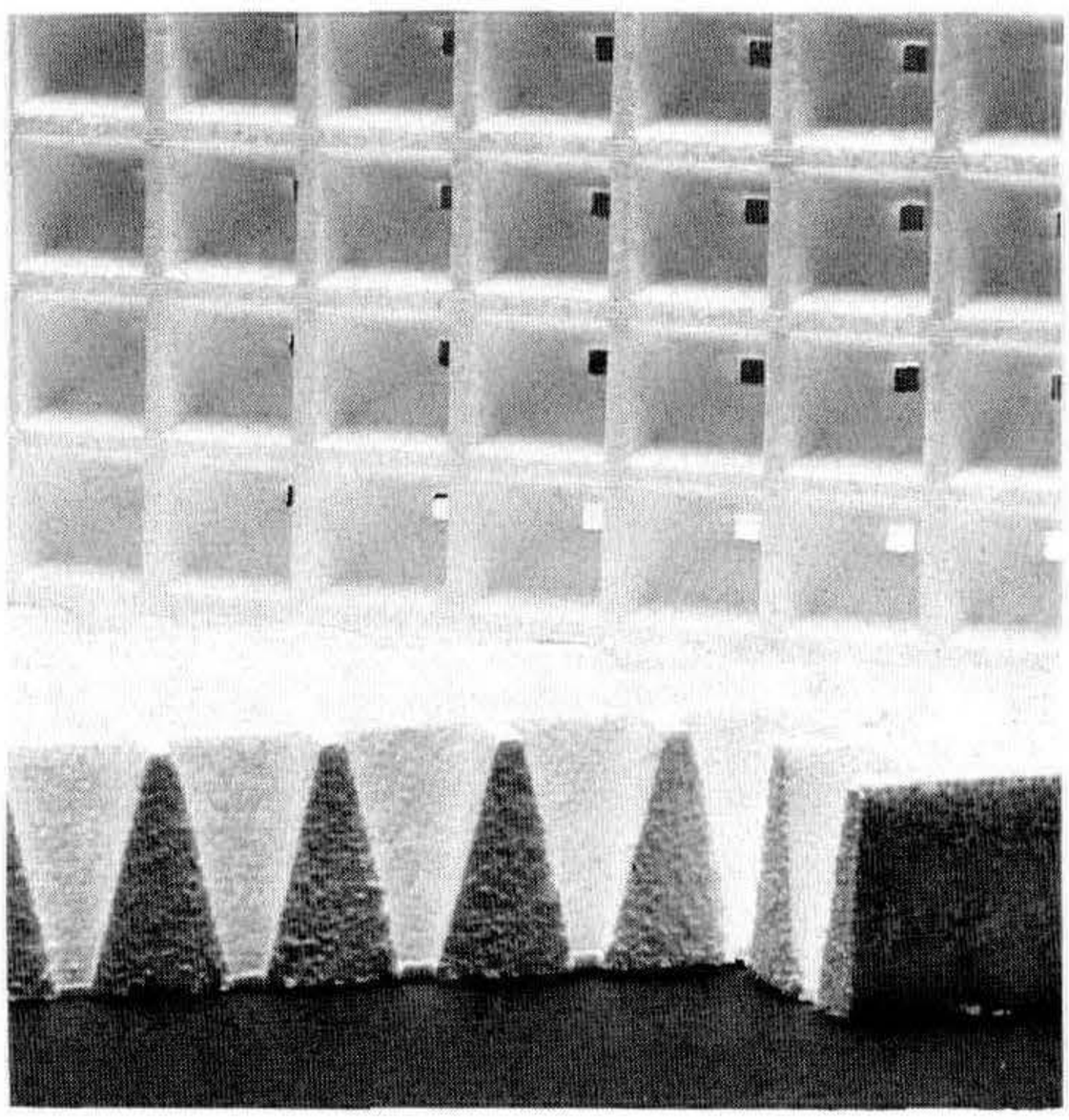

Figure 1. Speedling System trays. *Above.* View looking into tray. *Below.* Side section showing inverted pyramid shape of cells.

The "Speedling System" has now been adopted in many countries and we in the U.K. have, perhaps, been a little slow

to adopt this method, possibly because of the peat block's presence. This initial slowness has, however, been made up for by the now rapid uptake, with probably over 1 billion vegetable modules being planted in 1985.

On our nursery, the first process is the compost mixing, tray filling, and seeding which is all done in one line, and has an output of over 1 million cells per day. We mix our own compost with a low nutrition and the incorporation of vermiculite. The trays are then palletized, "cling filmed," and moved into a germination room, where the temperature is controlled to create the ideal environment for seed germination.

After the appropriate length of time the trays are laid out in the greenhouses on benching of a good working height which allows air to pass under the trays. In order to water the trays and keep each cell with the same moisture content, one needs a very uniform method of applying water, especially as each cell is unconnected to its neighbour and above the ground, so there is no water movement at all. To achieve the desired accuracy, we use a moving gantry, which waters in a band fashion moving across the entire greenhouse and applying water very accurately — and certainly a lot more accurately than spraylines or sprinklers.

Once we have this ability to apply the water accurately, it also gives us the scope to control plant growth by feeding through the gantry and only applying little nutrients at a time in such a way that one gets the type of growth desired, which is strong and stocky. This contrasts strongly to the peat block where the plant gets excessive nutrients which are not controlled, hence growth is often weak and soft.

The result of this method of growing is a plant that has strong foliage, that will stand up to the rigours of the transplanting shock, and also will pass through the planting machine in a trouble-free manner. The roots are so trained that in a very short period a large number will grow out into the field soil and gain water and feed from the field rather than from the module. In short, we are trying to grow a plant which is suited to its ultimate environment and the rapid establishment into this environment.

Our range of plants produced is fairly large, but the most important crops are brassicas (cauliflower, brussel sprouts, calabreze, chinese cabbage, cabbage, etc.), lettuce, and leeks.

In the U.S.A., where plants have to travel a long distance, they are pulled out of the tray and placed into cardboard boxes and shipped to the farm. In the U.K., we send the growing tray to the field and here the trays are placed in a

palletized racked bin, which permits easy handling by forklift. These bins are taken to the field and then the trays are placed on the planting machine. Some plants are planted in the field by hand, but mainly they are put in by a machine of some sort.

The slowest machines are the traditional planters as used for the old bareroot plants; these plant about 1500 to 2000 plants per row per hour. However, much faster machines which have been designed specifically for planting the module are now available. Our sister company specialises in the sale of propagation equipment and sells such a planter, which is capable of planting at 3000 to 3500 plants per row per hour, with a less skilled workforce than the older machines. The plants are simply taken from the tray, which is held on a rotating carousel, and placed into one of a series of moving cups, which at the appropriate times opens and drops the plant into a shoe, which is travelling through the soil. At the correct time for the plant spacing, the plant is pushed out of the shoe by a kicker mechanism, which places it into the soil, hopefully green side up.

The plant is then suddenly and instantly taken from the protection of the greenhouse and its neighbors in the tray, into what is often a hostile and demanding environment and it is then that the plant raising and the system itself are tried and tested.

To date, we have been happy with the results and, as illustrated by the use of the system, so have the farmers. For example, with cauliflowers, the farmer gets between 80 and 99% establishment, as opposed to 30 to 90 percent with bare-root plants. Furthermore, the plants are more uniform and crop over a shorter period, thus allowing the farmer to pass over the field fewer times. We are looking to improve the system in many ways but, in principle, feel we have the correct system for our specific application.

ROOTING OF CUTTINGS IN RELATION TO THE PROPAGATION MEDIUM

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Abstract. Results relating the rooting of cuttings to the physical structure of the propagation medium are often inconsistent. Experiments reported here suggest that gaseous diffusion proceeds relatively freely through the bulk of conventional propagation media and also, that diffusion of oxygen down through the aerial portion of the cutting to its base could supply most of its needs. However, water films both within and around the base of the cutting can obstruct the free passage of oxygen to developing root initials. The subtlety of this influence precludes any obvious and consistent relationship between rooting and the volumetric air and water contents of the media. Practical guidelines for using media, based on consideration of the type of cutting, season, and propagation system are suggested.

INTRODUCTION

Our usage of propagation media for rooting cuttings is based on accumulated practical experience rather than on a sound understanding of the principles involved. Unfortunately, trials of different media often give varied or even opposed results because many other factors interact to determine whether cuttings will root satisfactorily.

Results from a useful trial comparing the rooting of five species in five different media are shown in Figure 1. It is evident that the influence of the rooting medium can be substantial but the best medium differs between species. Even with related cultivars in the same genus, divergent results can be obtained in different media (Figure 2).

It has frequently been supposed that the optimal requirements for rooting cuttings can be specified in terms of the physical characteristics of the medium. However, consistent guidelines have failed to emerge using this approach. Matkin (6) concluded that a rooting medium should have around 20% of its volume as air-filled pore space, which is consistent with Puustjarvi's (8) suggestion that a minimum air content of 15% is required. O'Dell and Stoltz (7) on the other hand found that three woody ornamental species gave an average of 91% rooting in media with only 1% air-filled porosity and Gislerod (3) found that 3.8 to 7.5% volume of air was necessary for rapid rooting of *Poinsettia* in small propagation blocks. Part of this discrepancy may originate from the disparate methods used to measure the physical chacteristics of the medium and also to the widely different propagation systems employed. Nevertheless, it also suggests that our understanding of the principles involved in use of propagation media is far from complete.

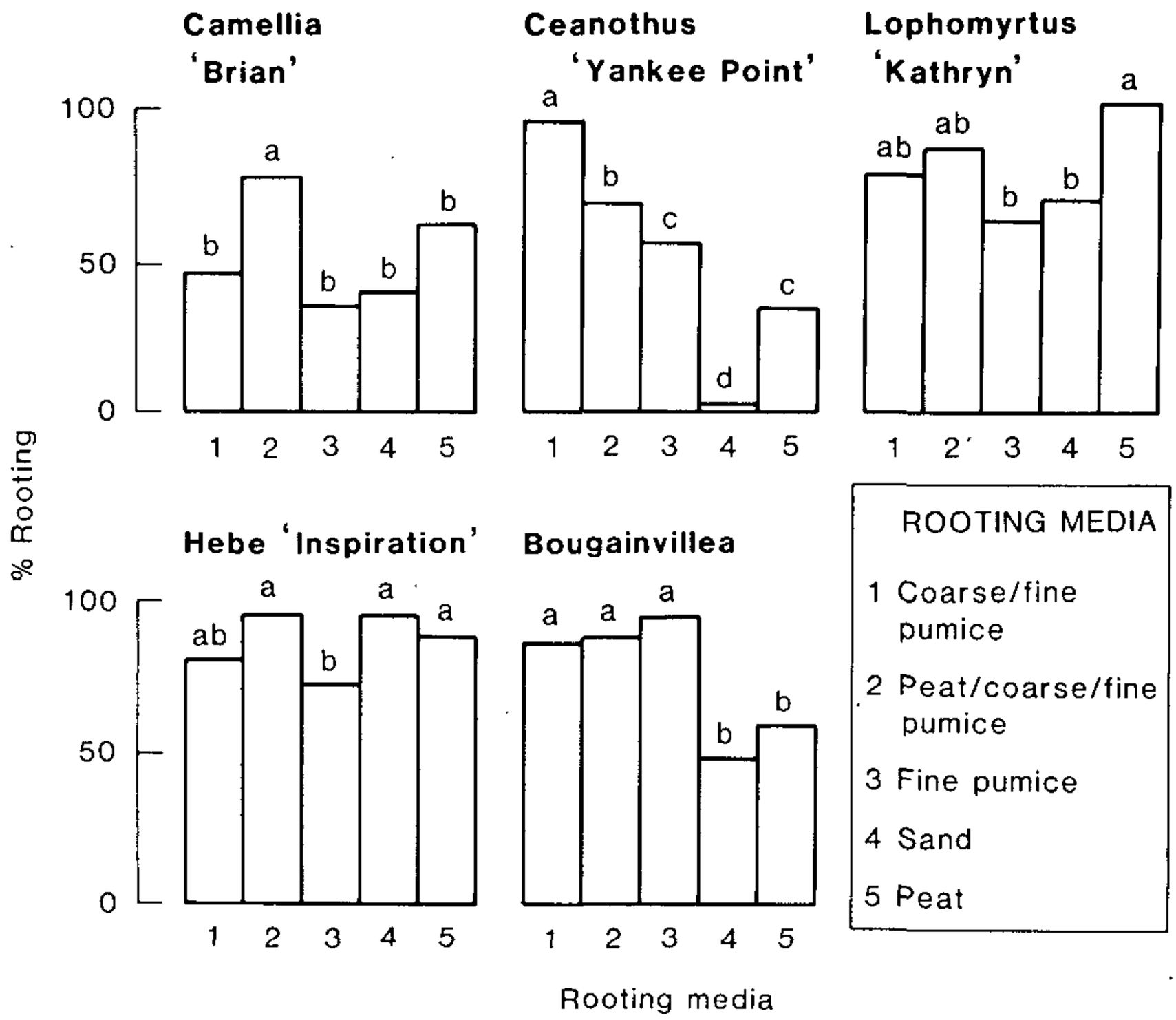

Figure 1. Rooting of cuttings of five different species in five media. Data from the Ann. Rep. New Zealand Nursery Research Centre. 1984.

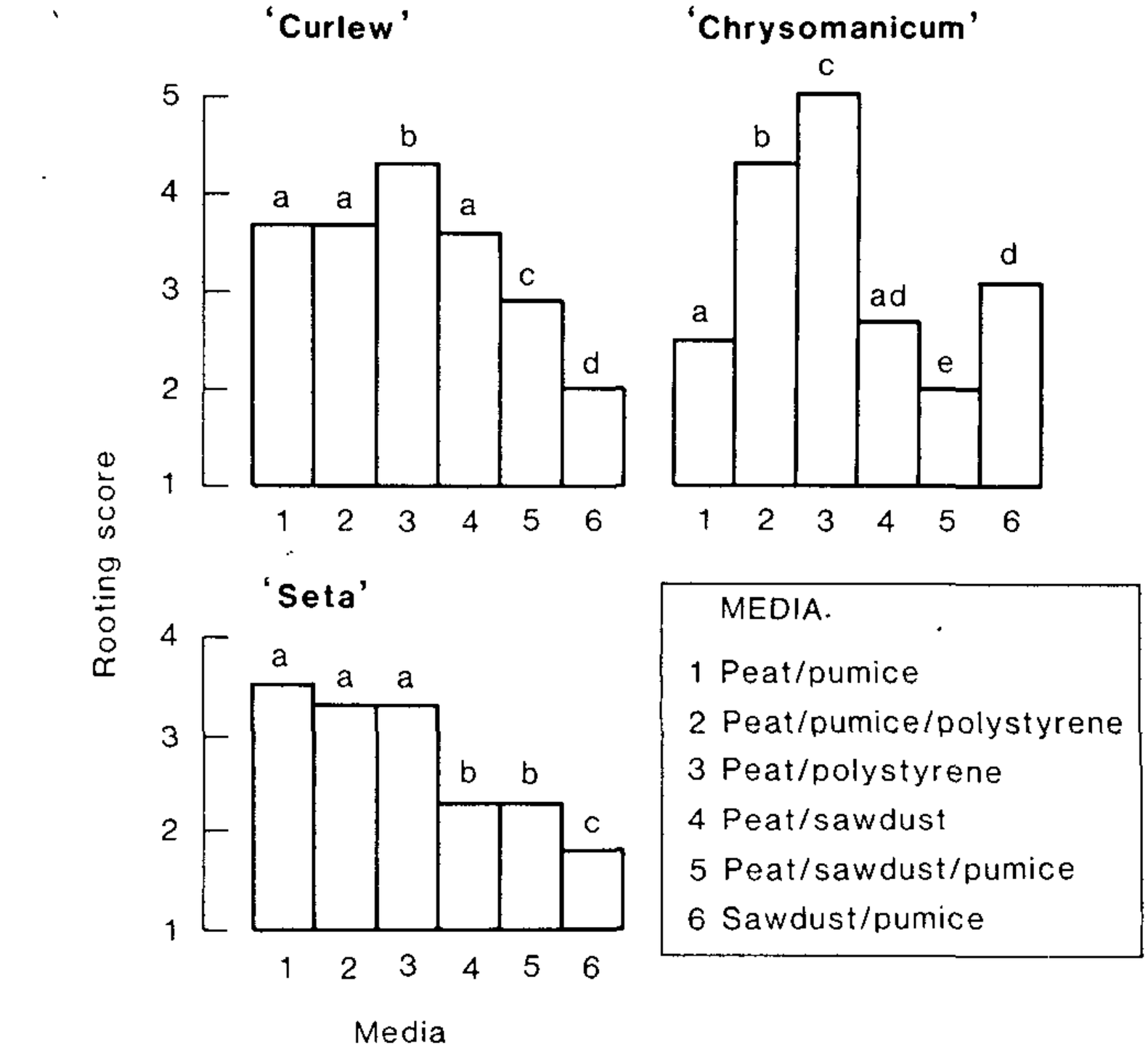

Figure 2. Rooting of three rhododendron cultivars in six media. Data from the Ann. Rep. New Zealand Nursery Research Centre. 1978.

PRINCIPLES

A rooting medium serves three essential functions: it provides, 1) support for the cutting, 2) water, and 3) aeration — i.e. oxygen to support the intensive metabolic processes in root formation. The provision of sufficient water to prevent wilting is a prime requirement. Measurements of the rates of water uptake by cuttings placed in media with successively increasing volumetric water contents showed a simple linear relationship between rate and percent water (4); i.e. from the point of view of supplying water to the cutting, the wetter the medium the better. However, the more water filling the pore space, the less air, and it is important to achieve a suitable balance between air and water contents.

The actual requirement for oxygen in the rooting process and the ability of the medium to provide it have seldom been studied except for attempts to relate rooting to measured air-filled porosities in different mixes. The discrepant results from such comparisons have already been referred to. In ecological and field-crop studies some detailed and quantitative treatments of aeration have been undertaken (2) and their application in our context will be discussed later.

Oxygen can reach the base of the cutting by two routes, i.e. through the medium, or by diffusion down through the tissues of the cutting itself. Quite a wide range of cuttings will root if placed with their bases in water and, since oxygen diffusion through water is 10,000 times slower than through a gaseous medium, we can assume that the latter route, through the cutting, is important in these cases. The Russian horticulturist, Komissarov (5) explored a system of rooting cuttings in water as a viable production method. Out of 30 species tested, 20 gave an almost equal percentage rooting in water as in sand.

This paper reviews the results of a series of experiments and measurements conducted over several years in an attempt to understand the relationship between root initiation and the air/water balance in the medium. Because of space limitations, full experimental details cannot be given in every instance.

OXYGEN SUPPLY

A conventional rooting medium has an open structure to give easy drainage and to facilitate gaseous diffusion. Rapid diffusion of oxygen through the bulk of a peat-grit (equal volumes) propagation mix was demonstrated by including oxygen-generating calcium peroxide (1% by volume) at mixing. The oxygen content of the medium was sampled at 8 min. intervals by withdrawing 0.5 ml samples by syringe, from a 1

ml porous chamber buried in the medium. This sample was then injected through a silicone rubber septum into a stream of nitrogen flowing through a Taylor Servomax, paramagnetic oxygen analyser, to give an instantaneous measure of oxygen concentration.

Results (Figure 3) showed that calcium peroxide released sufficient oxygen when in contact with the moist medium to raise the internal oxygen concentration to 27% by volume, within 8 min. of mixing. Thereafter, the concentration fell rapidly through diffusion, to reach normal atmospheric levels within an hour.

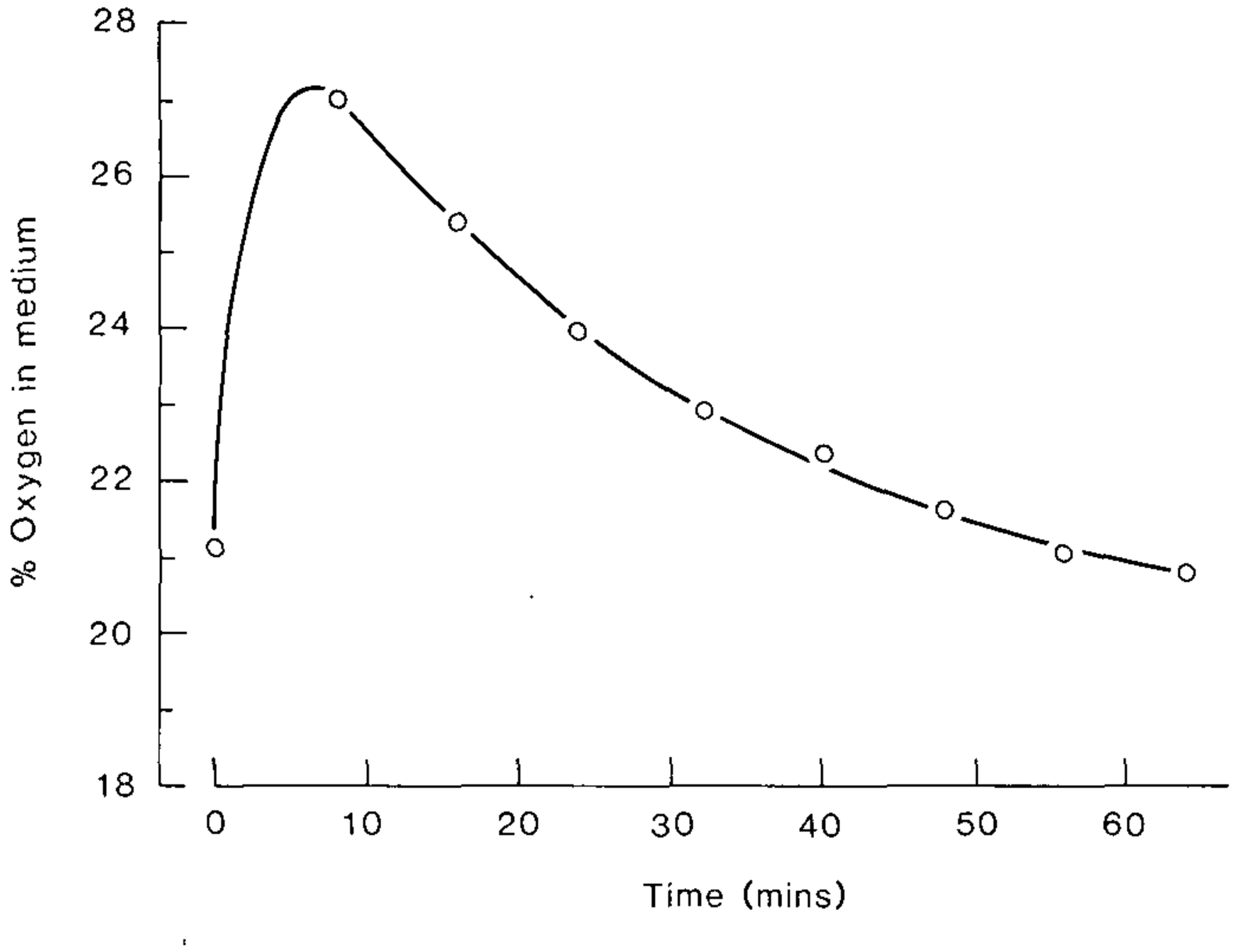

Figure 3. The time course of changes in the oxygen content of a 1/1 peat/grit medium containing 1% of oxygen-releasing calcium peroxide.

Similar methods were used to demonstrate oxygen diffusion from the atmosphere down through the tissues of the cutting to its base. Cuttings were inserted, "gas-tightly", through the rubber stopper of a glass specimen tube (75mm long × 25mm diameter) and the whole retained in an atmosphere of pure oxygen for up to 3 hours. The base of the cutting just touched a water surface in the tube. The stopper also contained a septum through which 0.5 ml samples of the internal atmosphere of the tube could be withdrawn for analysis. The oxygen concentration within the tube, after a set time, indicated the relative ease of oxygen diffusion through the tissues of the cutting. Seven replicate cuttings of each species were used and the measurements repeated on two days.

Table 1 shows close agreement between the duplicate daily measurements and significant differences among species.

Conifers were apparently more porous to diffusing oxygen than were broadleaf evergreens, though cutting bases of both groups were clearly able to receive oxygen by this route. Taken together with the demonstration of free oxygen movement through the medium it is, at first sight, difficult to see how short cuttings in an open mix can suffer serious oxygen deficiency. However, judged from practical experience, difficulties do arise and it is important to understand their origin.

Table 1. Oxygen diffusion through cuttings[1]. Listed in decreasing order.

Species	Percent oxygen	
Chamaecyparis thyoides 'Ericoides'	39.0	37.8
Chamaecyparis lawsoniana 'Pembury Blue'	36.2	33.8
Juniperus chinensis 'Plumosa Aurea'	37.3	35.8
Cupressocypariis leylandii	29.1	28.2
Ilex aquifolium 'Argentea Marginatum'	28.2	28.6
Nothofagus dombeyi	26.5	24.4
Garrya elliptica	21.3	23.6
SED	3.5	

[1] See text for description of method. A high value indicates rapid diffusion. Each figure is the mean for 7 cuttings, measured after 3 hours.

WATER SUPPLY

The importance of ensuring that tissues within the cutting remain turgid is evident when different propagation systems are compared and changes in water content are measured. Figure 4 illustrates a comparison of rooting in conventional open mist, polythene-enclosed mist, and a non-misted, shaded polythene tent. The change in water content of the cuttings

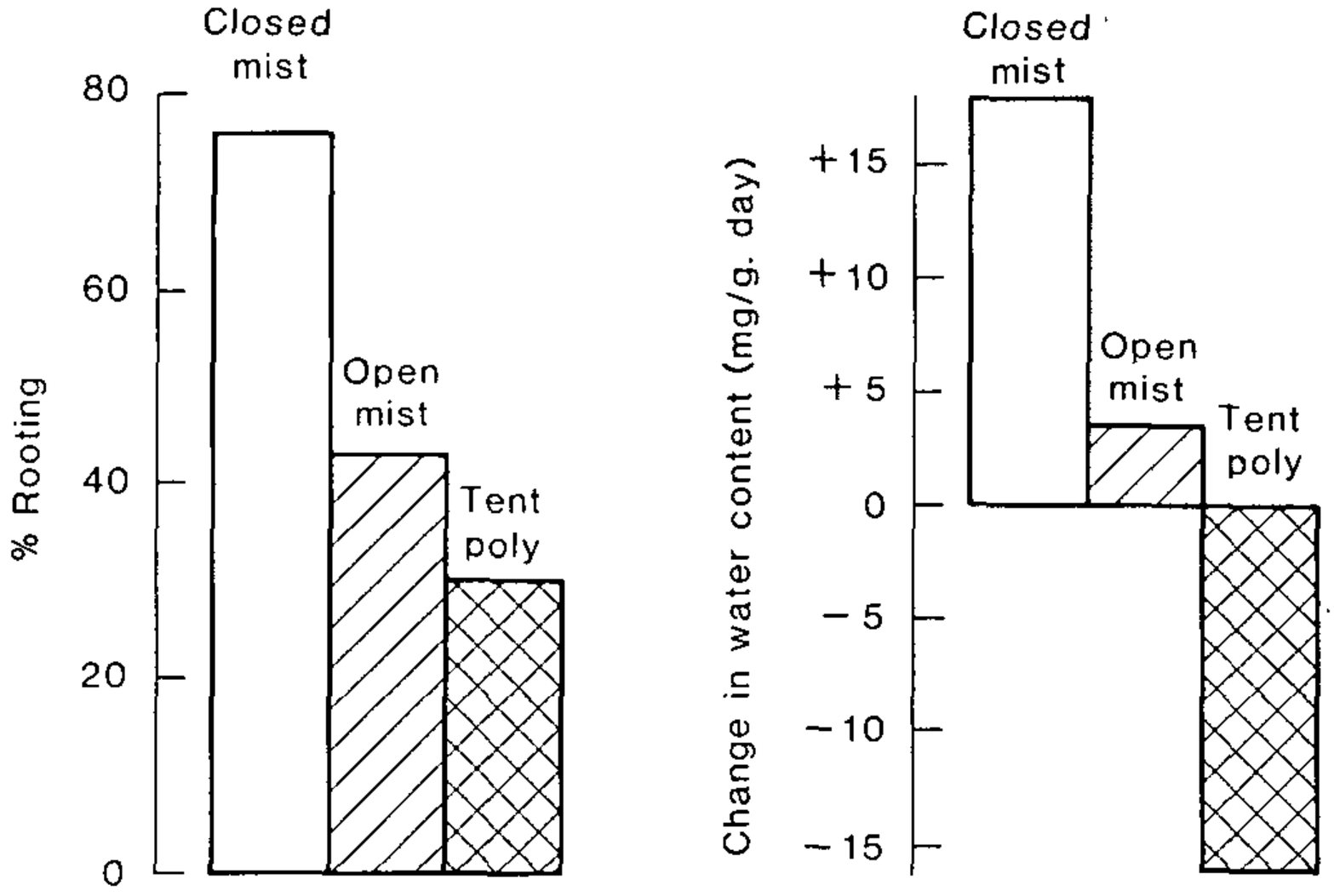

Figure 4. Mean rooting percentages for summer cuttings of six species in three different propagation systems, in relation to measured changes in cutting water content.

over a three week period following insertion (and before any rooting had occurred) was measured by appropriate sampling, drying, and weighing. Subsequently, rooting was scored as soon as it had occurred to a reasonable percentage in the best system — enclosed mist. Misted cuttings gained water from the time of insertion whereas non-misted cuttings lost water. The correspondence between rooting and the relative abilities of the three systems to conserve the water status of the cuttings is clear.

Tissue water content is determined by the balance between water loss from the leaves and water supply through the cutting base. As noted above, water uptake by cuttings is directly related to the volumetric water content of the medium. In summer conditions with soft cuttings, it is possible to demonstrate a positive relationship between rooting success and the water content of the medium. Figure 5a records the results of an experiment where cuttings of *Fuchsia magellanica* 'Nana Gracilis' were rooted in three media composed of peat (Irish, medium grade) and grit (Chichester, 5mm) in volumetric ratios of 1/3, 1/1, and 3/1. These were placed on sand beds with water tables held at 4 different depths below the pots (down to 100mm), to maintain 12 different water contents in the media. The soft cuttings clearly benefited from wet media. However, in winter conditions with harder cuttings, the reverse relationship can be shown and the importance of balancing the need for air and water is then most evident.

AERATION

It is only occasionally possible to demonstrate a positive relationship between the volumetric air content of the medium and rooting. Figure 5b presents such a result for cuttings of × *Cupressocyparis leylandii* 'Castlewellan' propagated in 1/1 peat (Irish, medium)/perlite (supercoarse), maintained over 6 water table treatments to achieve a range of air contents. The correlation is perhaps less than impressive and, in any case, since the percent air and percent water are inversely correlated for any one medium, it is not possible to say whether high air content or low water content promoted better rooting.

In a further experiment where cuttings of *Cryptomeria japonica* 'Elegans' were propagated in 5 different media under a non-misted polythene tent during winter, rooting was inversely related to the volumetric water content of the medium but showed little correlation with air content (Figure 6). This suggests that "poor aeration" may owe more to an excess of water at the base of the cutting than to the overall air-filled porosity. Water films at the base could perhaps restrict oxygen diffusion at this very localised level, even though the bulk of

the medium is well aerated.

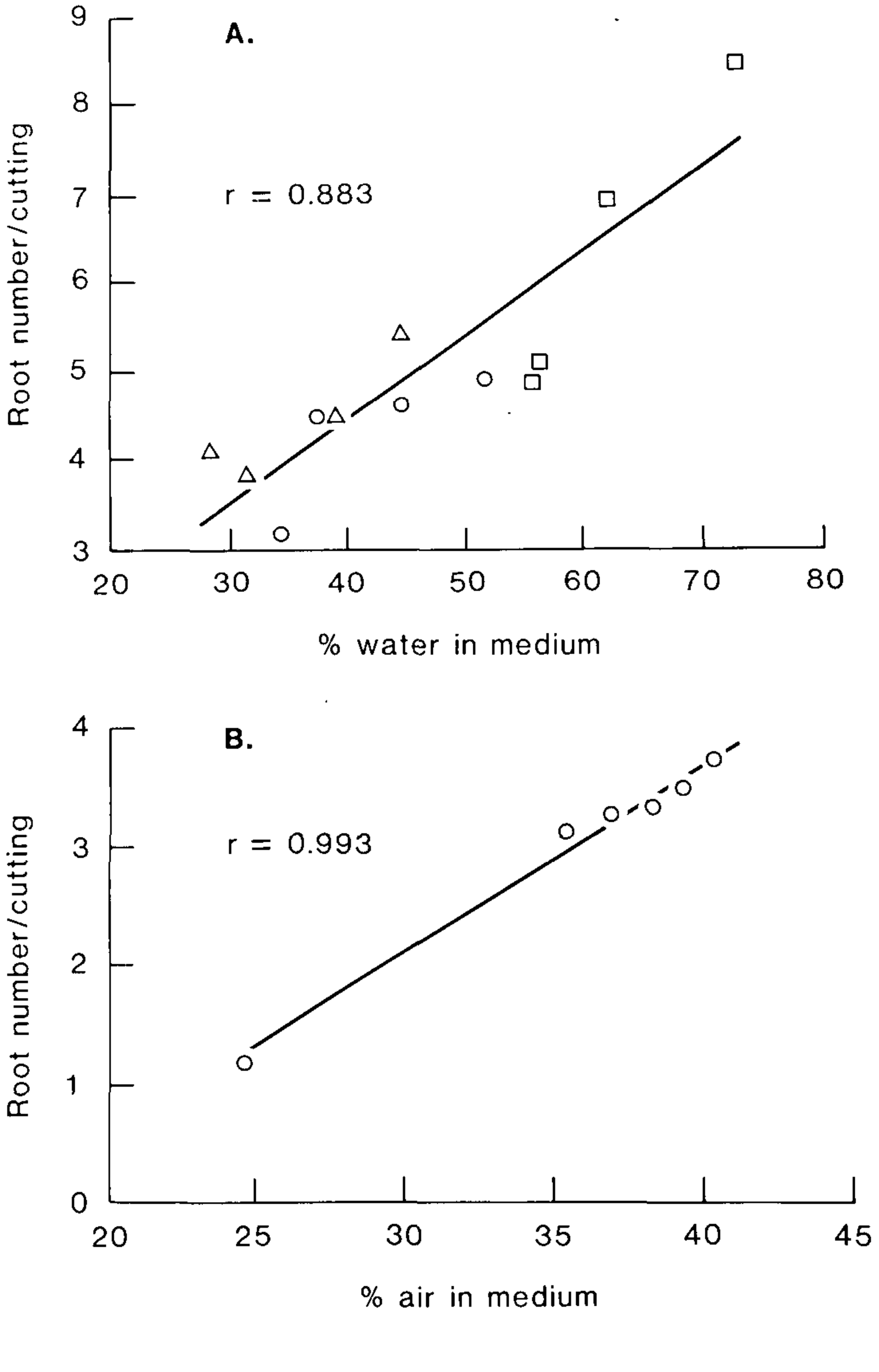

Figure 5. (A) The relationship between rooting cuttings of *Fuchsia magellanica* 'Nana Gracilis' and the volumetric water content of the medium. (△=1/3, ○=1/1, □=3/1 mixes of peat/grit over 0, 50, and 100 mm water tables or freely drained.)
(B) The relationship between rooting of cuttings of × *Cupressocyparis leylandii* 'Castlewellan' and the volumetric air content of a 1/1 peat/perlite medium, (differences again obtained by varying water table heights).

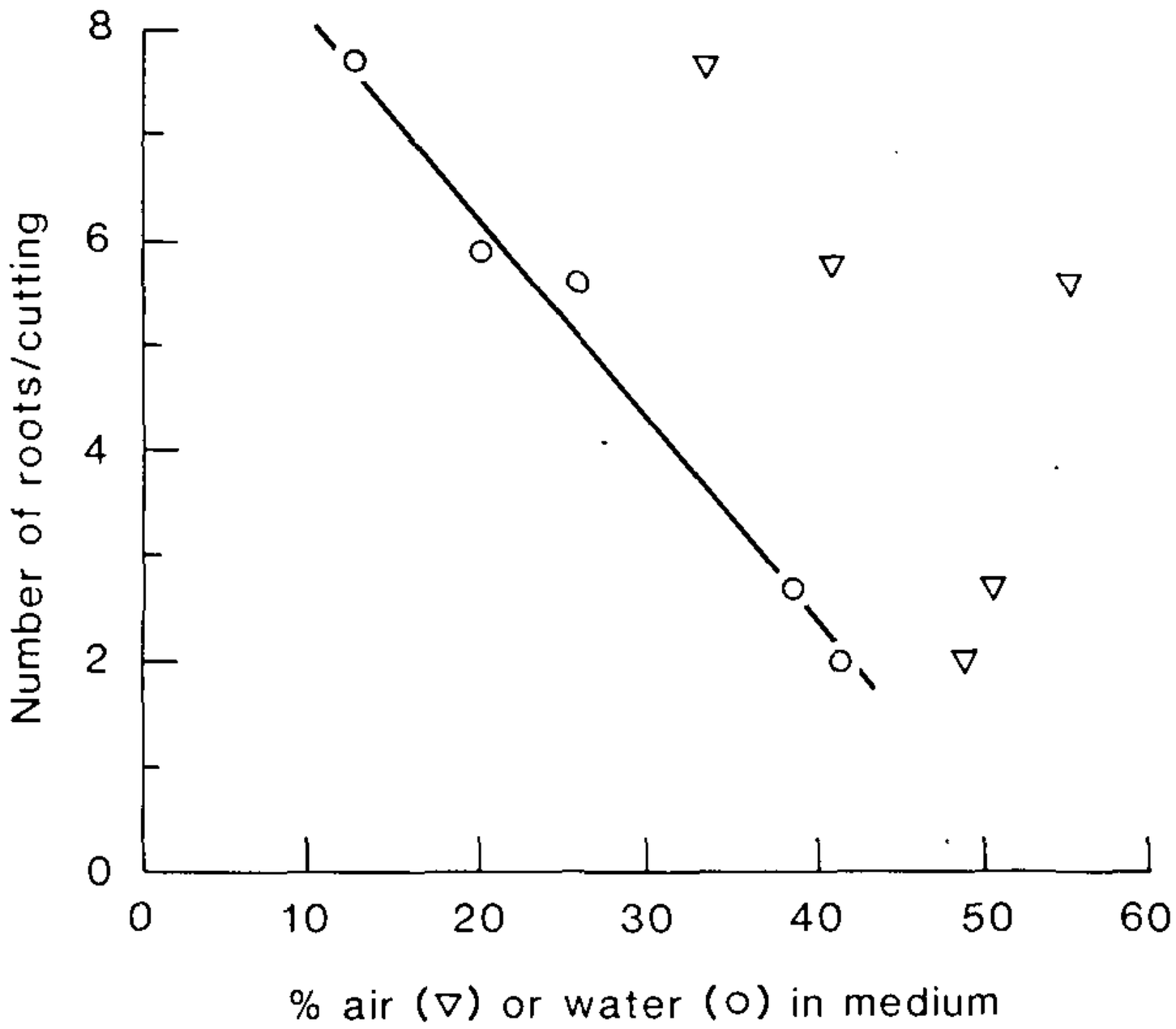

Figure 6. Rooting of cuttings of *Cryptomeria iaponica* 'Elegans' in relation to the volumetric water and air contents of five different media. r= −0.947 and −0.199, respectively.

Such observations are not entirely confined to conifer cuttings in winter conditions, though conifers do seem to be particularly sensitive to wet media. Cuttings of three broadleaf evergreen species, *Philadelphus* 'Burfordensis'. *Buxus sempervirens* and *Ulmus pumila* 'Hansen' propagated in a densely fogged polythene enclosure gave similar results. A pneumatic fogging nozzle (Sonicore 052H) was located at one end of a 8.5m × 1.7m × 0.9m (height) clear polythene enclosure constructed over the propagation bench. The operation of the nozzle was controlled by a timer operating for 60 sec. on and 75 sec. off in sequence to give a persistent, visible fog. The volumetric water content of a 1/1 peat/perlite rooting medium varied from 38% near the nozzle to 32% at the opposite end. Even this narrow range appeared to have a substantial effect on the rooting of the three species (Figure 7). Poor rooting close to the nozzle was associated with a greater gain in water by the cuttings over the first three weeks following insertion (see Figure 7).

However, when two coarse, well-drained media — pine bark and grit — were used, the variation in water content along the length of the enclosure was much reduced, but the positional effects on rooting still persisted (Figure 8). In these instances neither the volumetric water nor air contents of the bulk of the medium related to the rooting performance. Close to the nozzle, cuttings frequently showed damage and decay at

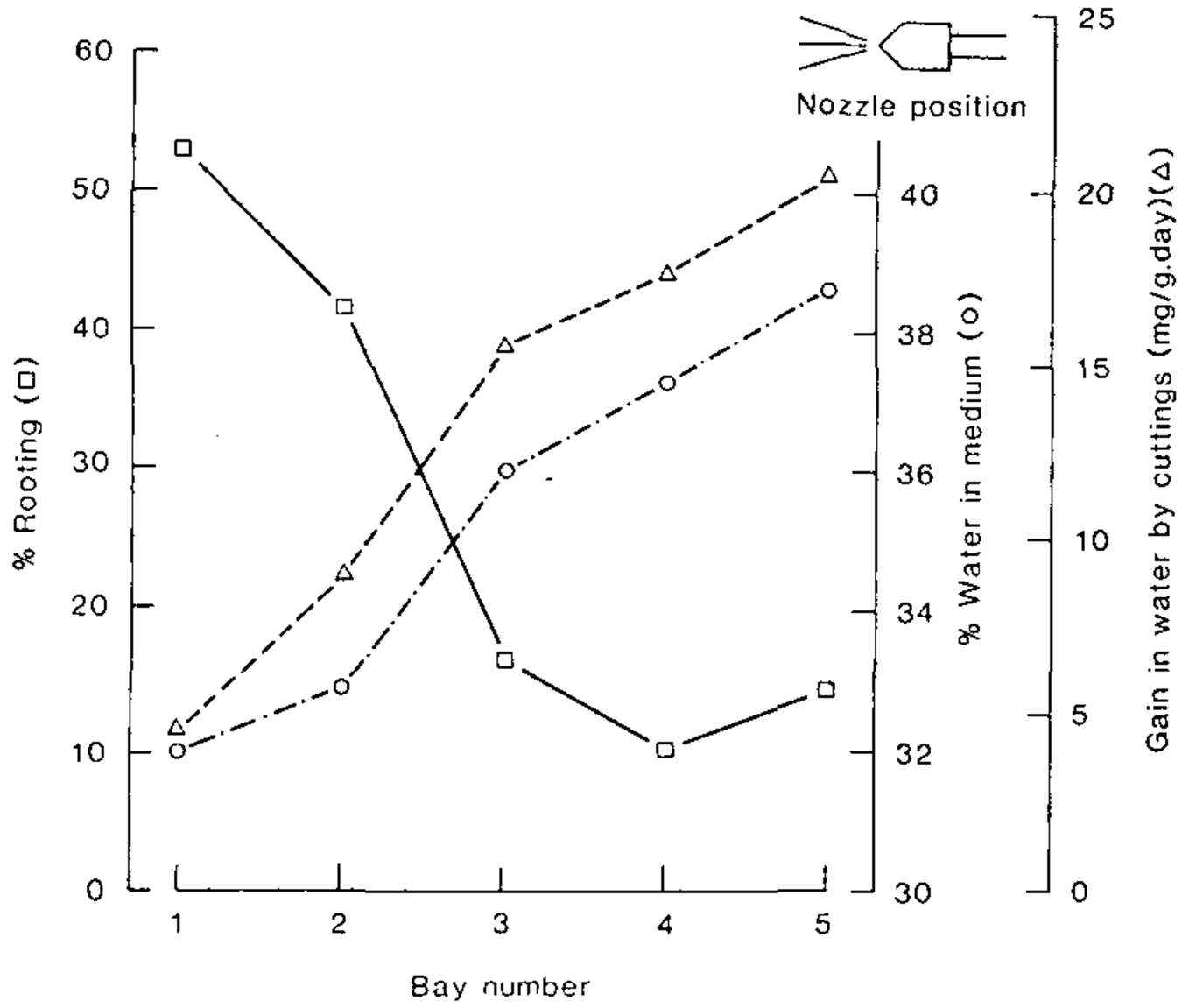

Figure 7. Variation in rooting in relation to distance from a fogging nozzle. (Each bay is 1.7m long). The volumetric water content of the medium and the water gain by the cuttings are also shown. Data are means for three species.

their bases (scored here on a 0 to 5 basis, for zero to most severe damage — Figure 8): weight changes in the cuttings were not measured in this experiment.

Finally, changes in the water content of cuttings inserted in a fine, pine bark medium and positioned along the fogged enclosure were measured (by weighing) over six weeks. Further cuttings were left in place until rooting had occurred. The species used was *Chamaecyparis lawsoniana* 'Ellwoodii'. Fresh and dry weight changes were followed in the basal 15 mm and in the remaining top portion of the cuttings. The pots of cuttings were either protected by an additional polythene "umbrella" supported 100 mm above them to prevent direct fall-out of fog droplets onto the cuttings and medium, or they were left uncovered. This achieved a range of "wetness" of the cuttings and media along the enclosure.

The rooting which occurred showed no clear relationship to either the volumetric water or air contents of the bark medium. However, a close inverse correlation was observed between the final root score and the water gain (i.e. change in fresh weight - change in dry weight) in the basal 15 mm of the cutting during the first six weeks from insertion (Figure 9). Calculations showed that this water gain amounted to as much as 29% of the total volume of the basal segment, sufficient to easily fill most of the intercellular spaces and reduce oxygen diffusion very substantially. Rooting was not related to water changes in the top of the cutting.

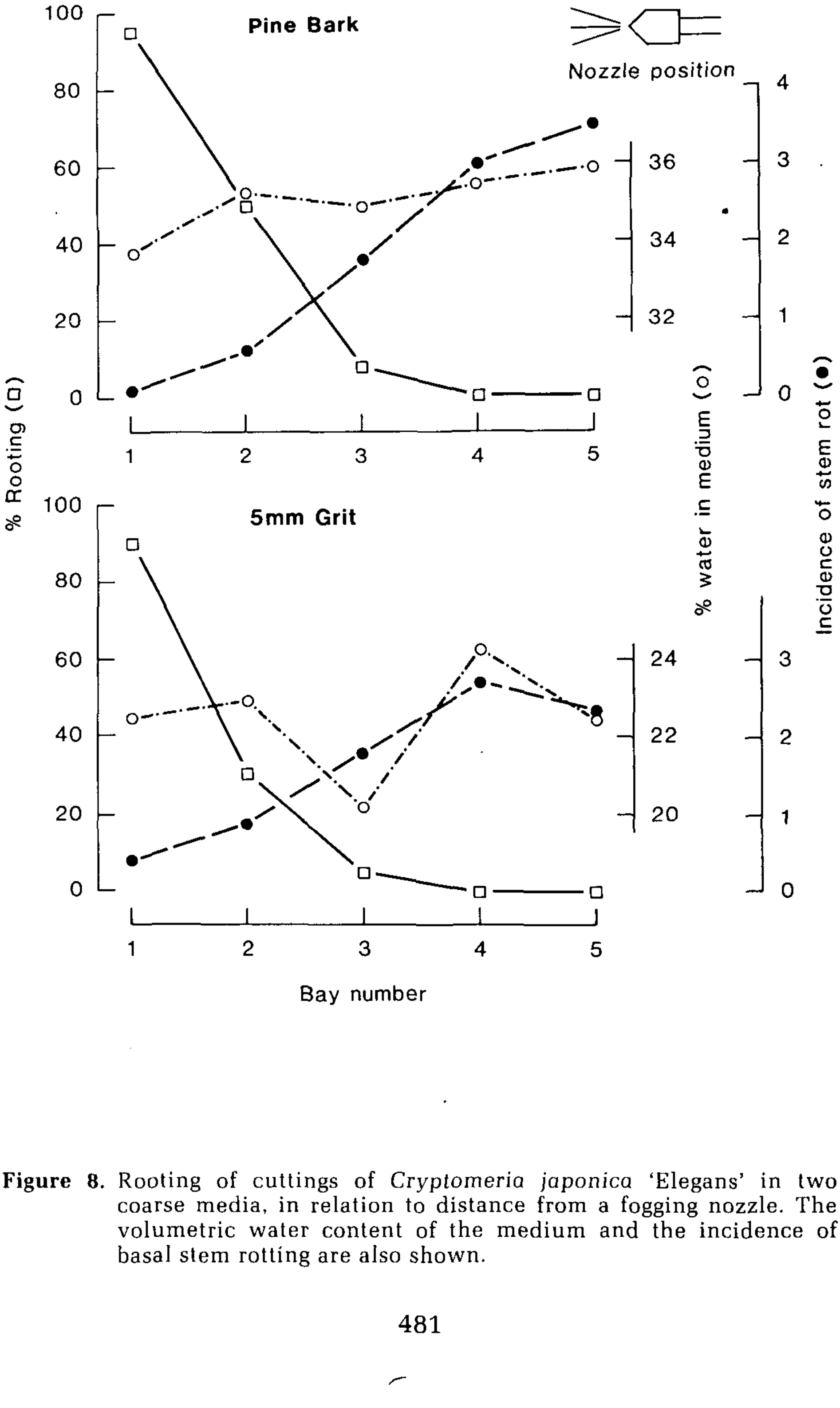

Figure 8. Rooting of cuttings of *Cryptomeria japonica* 'Elegans' in two coarse media, in relation to distance from a fogging nozzle. The volumetric water content of the medium and the incidence of basal stem rotting are also shown.

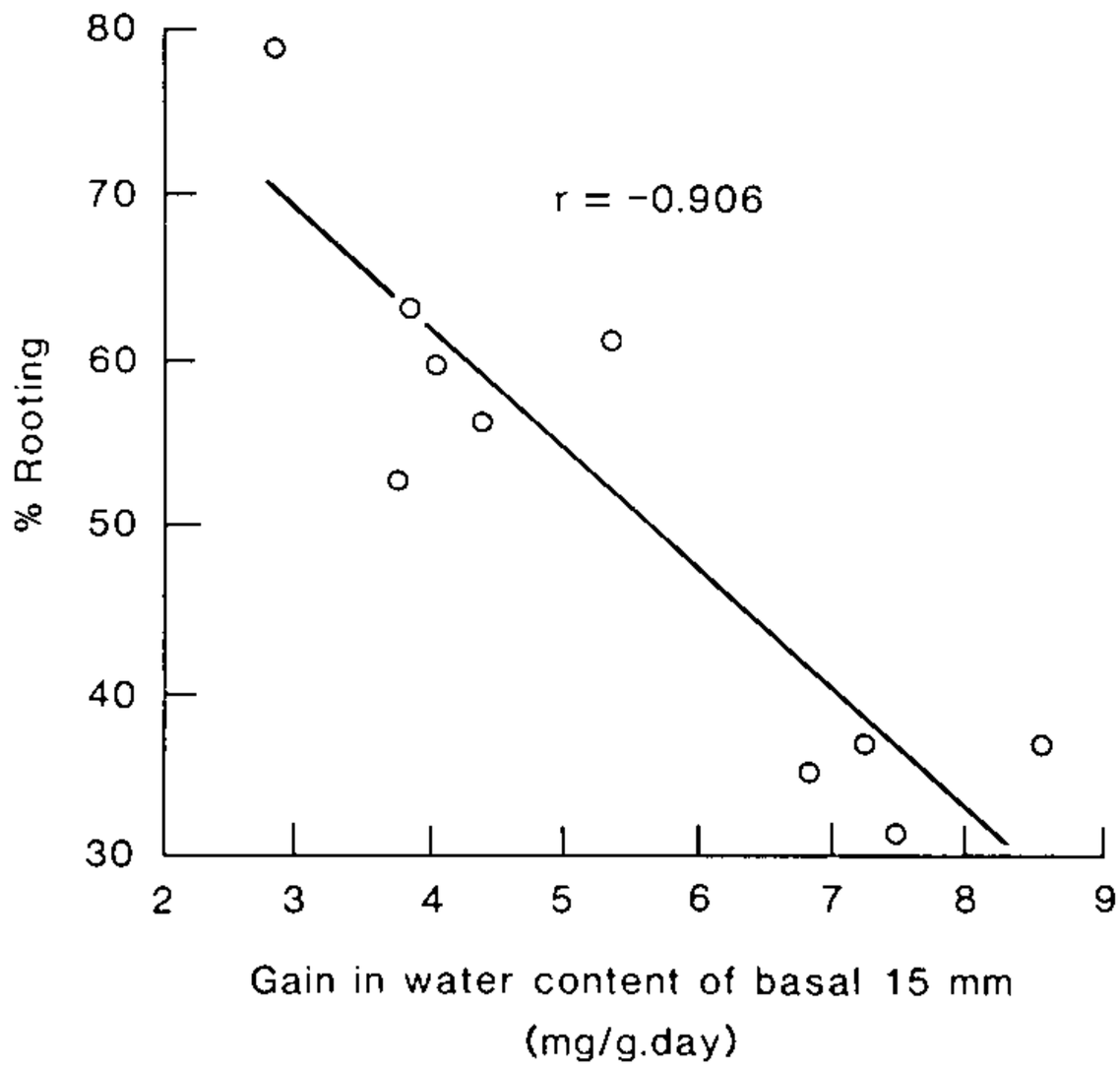

Figure 9. Rooting of *Chamaecyparis lawsoniana* 'Ellwoodii' in fog, in relation to the gain in water by the basal 15 mm of the cuttings.

DISCUSSION

In the foregoing experiments, evidence is presented that gaseous diffusion through the bulk of conventional propagation media proceeds relatively freely and that the base of a cutting can, at least initially, receive oxygen by internal diffusion downwards from the exposed top portion.

With reference to this diffusive pathway from the top, Armstrong (2), presents an equation for assessing the maximum length of stem (1, in cm) which could be supported entirely by longitudinal oxygen transport through the tissues, if it were inserted in an anaerobic medium:

$$1=\sqrt{2\ D_e\ C_o/M}$$

1 depends on C_o, the oxygen concentration in the air (273×10 g cm^{-3} at 20°C). D_e the effective diffusivity of oxygen in air which consists of the diffusion coefficient (0.201 $cm^2\ s^{-1}$ at 20° C), multiplied by a fractional factor relating to the gas-filled porosity of the stem (e.g. 0.04), and M, the respiratory oxygen consumption within the tissues (e.g. 1×10^{-7}g $cm^{-3} \cdot s^{-1}$). With these values inserted, 1 is 6.6 cm. In practice, few cuttings are inserted more than about 3 cm deep so that on the basis of these speculative calculations, the aeration route through the cutting could normally provide much of the cutting's oxygen requirement.

The question of oxygen supply *via* the rooting medium is more complex. While equations have been formulated to de-

scribe this pathway in soils (2), the requisite biological data are lacking for our situation and this precludes any full quantitative assessment. For example, organically-based propagation media must present an active oxygen sink in themselves but quantitative information on respiration in peat or bark-based rooting media is sparse. Similarly the relative importance of diffusion through the cut stem base, the lenticels or the stem cuticle is unknown.

We have observed that whilst the propagation medium can have a marked effect on rooting, there is only occasionally any clear correlation between rooting and the volumetric air content of the medium (Figure 5b); the relationship between rooting and water content can be positive (Figure 5a), negative (Figures 6 and 7) or entirely absent (Figure 8). In cases where wetter media give poor rooting, it is striking that only a small change in the volumetric water content can have a large effect (Figure 7 and more specifically, Figure 8). Poor rooting is often associated with a large gain in water by the cuttings themselves (Figure 7), most notably in the basal portion (Figure 9).

The implication is that water, in both the rooting medium and within the base of the cutting itself, can present a major diffusion barrier, (remembering that oxygen undergoes a 29-fold drop in concentration at an air/water interface and diffusivity of oxygen through water is 10,000 times lower than in air). Waterlogged cutting bases in some species show evident damage (e.g. Figure 8), which may result from anoxia within the tissues. The time course of changes in hydration of the bases of cuttings have, surprisingly, seldom been studied.

Recognition of the possible significance of small changes in water film thicknesses within the cutting and medium, suggests a reason for the apparently disparate results which are common in the literature relating rooting to the physical structure of the medium.

PRACTICAL CONSIDERATIONS

The rooting media used on most nurseries consist of an organic and a mineral component. The organic component — commonly peat — is used because of its large total pore space and its ability to hold water. Bark, sawdust, leaf mould, sphagnum moss, or rice hulls have also been used. The mineral component is used to increase the proportion of large, air-filled pores: sand, grit, pumice, scoria, perlite, vermiculite, polystyrene, clay granules, or rockwool are commonly employed. The mineral component should be sufficiently coarse and used in sufficient quantity to ensure that it does more than fill in the pore spaces between the peat aggregates; e.g. the air-filled

porosity of our peat/perlite mixes does not improve substantially until the proportion of perlite is increased to around 75%. Fine sand is inappropriate for a rooting mix and a coarser grit is desirable.

From the foregoing, it will be evident that there can be no single, "ideal" mix. It will depend upon the type of cutting, time of year, climate, other characteristics of the propagation system and unfortunately, even the weather. Practical suggestions are summarized in Table 2 and explained further below.

Table 2. Suitable rooting media

Good, all-purpose:		
	1/1	Medium grade peat/coarse perlite (or 5 mm grit), (or fine (<8 mm) bark)
Better (same materials, varied proportions):		
	1/3 for:	winter conditions, or mature cuttings, or "wet" systems
	3/1 for:	summer conditions, or soft cuttings, or "dry" systems

A good, all-purpose medium is obtained using equal proportions of medium-grade peat and a coarser amendment such as coarse perlite, 5 mm grit, or bark. However, it is sensible to vary the proportions according to the type of cutting, season, and the propagation system involved.

Soft, immature cuttings with broad, actively transpiring leaves require a medium with a high water content, i.e. with a large proportion of peat, especially in summer conditions. Harder cuttings in winter transpire less and benefit from a fast-draining, more open structure. A "wet" propagation system calls for an open rooting medium: thus a polythene-enclosed mist system, a densely fogged house, propagation under "contact" polythene (where the sheet is wrapped directly over the trays of cuttings), and dull conditions, all require an open medium. Relatively "dry" systems, such as a polythene tent without mist, or open mist in summer, benefit from the use of a medium with more water, i.e. a greater proportion of peat. Sensible variations, within these almost self-evident guidelines, can be achieved through varying the proportion of peat from 75% down to 25% of the total volume of the mix (Table 2). It is unfortunate that our present level of knowledge precludes more specific recommendations.

MINERAL NUTRITION

Most cuttings contain sufficient reserves of nutrients to initiate roots. It is not generally necessary and indeed can sometimes be harmful (1) to add fertilisers to rooting media.

Once rooting has occurred, the provision of a dilute liquid feed maintains root and top growth and is often beneficial. Recently, the practice of incorporating controlled-release fertilisers (e.g. Osmocote, Ficote, Nutricote) in the medium has been recommended. Such coated fertilisers release their nutrients slowly and largely avoid damage to sensitive new root tips which standard chemical fertilisers can cause. For example, Efford Experimental Horticultural Station has recommended the incorporation of up to 1 kg/cubic m of an extended release, coated fertiliser into a medium containing equal proportions of peat and bark. With other mixes, lower levels may be safer.

Acknowledgements. Thanks are due to R.L. Jinks, Dr. R.I. Grange, and Dr. W. Armstrong for their helpful discussions. Technical assistance was provided by Mrs. C. Deans, Miss E.A. Solti, and Miss L. Holt.

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TECHNICAL SESSIONS

Tuesday Morning, December 10, 1985

The thirty-fifth annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:00 a.m. in the Ballroom of the Biltmore Plaza Hotel, Providence, Rhode Island.

PRESIDENT SAVELLA: Good morning members of the Eastern Region of the International Plant Propagators' Society and guests. On behalf of the Eastern Region Board, I welcome you to our 35th Annual Meeting here in Providence. Your program chairman, Elton Smith, has put a very informative program together for you and I hope you all take a very active part in the meeting.

At this time I would like to turn the meeting over to your program chairman, Elton Smith.

ELTON SMITH: Thank you, Len and good morning. I think we have an excellent program and I hope you will take an active part in it and ask questions. The moderator for this morning's session is Dr. Paul Read.

ETIOLATION AS A TOOL FOR ROOTING CUTTINGS OF DIFFICULT-TO-ROOT WOODY PLANTS

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Abstract. The stockplant pretreatment techniques of etiolation and banding were used with success in the cutting propagation of 13 woody ornamental species. Each pretreatment alone was noted to have a significant effect on rooting while the combination of the two resulted in optimal rooting in most trials. An alternative banding method has been developed, using reusable adhesive bands of Velcro, which allows for the addition of root promoting chemicals as a part of the banding procedure. Substantial improvements in rooting response were obtained in a number of species previously considered difficult to root.

INTRODUCTION

The etiolation of stock plants as a pretreatment to cutting propagation involves growing shoots in the absence of light. The etiolated shoots, which result from this treatment are typically chlorotic, possess smaller leaves, longer internodes, and are more succulent than their light-grown counterparts (5).

Banding of shoots as a stockplant pretreatment refers to wrapping an opaque material, usually black plastic tape

around that part of the shoot that will become the base of the cutting. Banding may be applied early in the growth of a light-grown shoot, and would properly constitute blanching, or may be used in conjunction with etiolation to maintain an etiolated zone at the base as the rest of the shoot is permitted to green-up. The goal of these stockplant pretreatments is to obtain stem cuttings with basal tissues that have developed in the absence of light. In this way these techniques are similar to the well known propagation techniques of air layering and stooling (12).

The techniques of etiolation and banding were first combined by Gardner (3), for use in apple propagation. Recently, much work has been done with these techniques at the East Malling Research Station, Kent, England. Their research with M.9 apple rootstocks and other woody species has shown that 80% shade or more produces shoots which root significantly better than light-grown controls (7,8,9). This permits the use of ventilated shading materials instead of black plastic, reducing temperature and humidity build-ups under the covers that can stress the etiolated shoots and promote disease (7,8,9). This also results in cuttings which are stronger and larger than those grown in complete darkness (4). The use of etiolation and banding at East Malling involves erecting shade enclosures as bud-break commences, and leaving the cover in place until shoots have elongated to a length sufficient for banding (8 to 10 cm) (11). Banding is applied at this time and left in place as the shoots green up (4).

Several decades of work, on a variety of plant materials, have soundly established the benefits which may be obtained using etiolation and banding as stock plant pretreatments to cutting propagation of apple (2,3,7,8,9), hibiscus (6), lilac (10), pistachio (1), and linden (7).

RESEARCH OBJECTIVES

In our earlier work with the banding of woody ornamentals we used black plastic tape as the banding material. During that process we became aware of a number of drawbacks to the use of this material. Plastic tape is difficult to use in that small pieces of the sticky tape must be cut and handled carefully in the process of banding. Furthermore the tape has been observed to unwind in a number of instances, allowing light to impinge upon the etiolated stem tissues. Finally, the degree to which the etiolated stems must be handled, both in putting on and removing plastic tape, can result in damage to the stems, which are by nature of being etiolated very delicate. In beginning our present research we sought a banding material which could be quickly and easily applied, necessitating as little

handling of the etiolated shoot as possible. Hence we have modified the banding technique to make use of a reusable adhesive banding material commonly known as Velcro. This opaque banding material excludes light in the same way as tape, but may be more easily applied and removed. Furthermore, the unique adhesive nature of the material permits the application of root promoting chemicals as a part of the banding process.

MATERIALS AND METHODS

In our present work, the techniques of etiolation and banding were used alone or in combination, as pretreatments to the cutting propagation of a number of woody ornamental species which are listed with their rooting responses in Table 1.

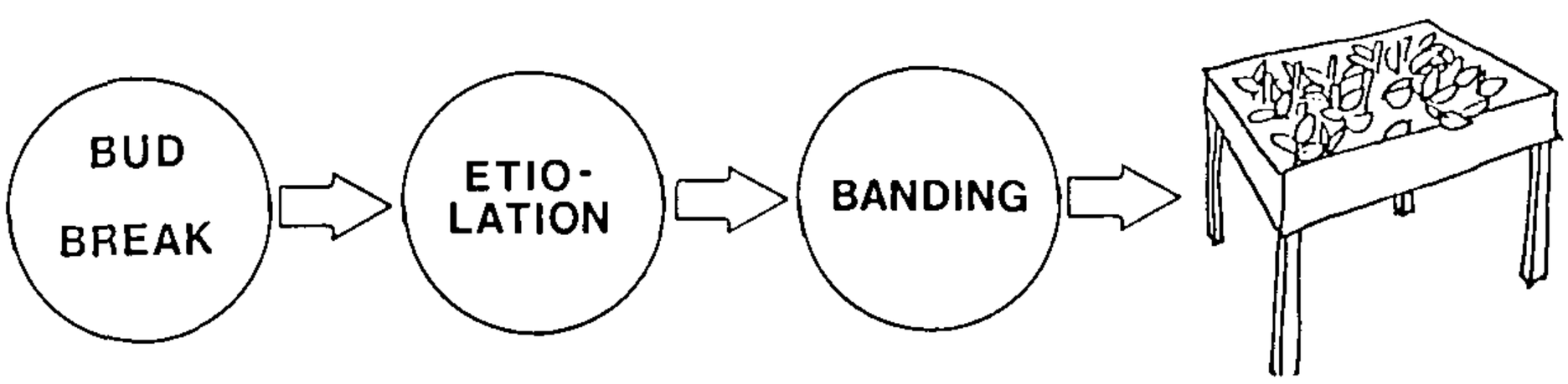
The procedure of etiolation involves erecting a black cloth covered structure over the shoots to be etiolated at the time of bud break and prior to the appearance of leaves. The structure is left in place, excluding light from the developing shoots, until the shoots have elongated enough for bands to be applied (2 to 5 in.). The progress of shoot elongation may be determined by visual inspections made briefly every couple of days. This does not appear to compromise the benefits of etiolation (11). At the time that etiolation is completed the banding material is applied to the base of the etiolated growth. Caution must be exercised at this point because etiolated shoots, lacking protective pigmentation, are susceptible to sun scorching. It is our practice to apply the banding material and then replace the shading cover partway. This allows the entry of a small amount of light. Over the course of one week the cover is gradually rolled back or lifted, allowing shoots to green up. After one week or so the shoots will tolerate exposure to full sunlight; however, the speed with which shoots adjust to higher light levels varies among species. The technique outlined above is presented graphically in Figure 1.

Hormone may be applied with the Velcro band at the time that the shoot is banded. In the present work we used Hormodin 3, a talc preparation containing 8000 ppm IBA. The hormone is applied to the band by pressing an opened band into a layer of the hormone. Excess hormone may be tapped from the band before application to the stem. The hormone laden band is then pressed firmly onto the stem, forcing the hooks of the band into the succulent stem tissues. Wounding of the stem occurs at this time.

After 4 weeks the cutting is made by severing the shoot from the stock plant, just below the band. The band is removed, and the cutting is then placed in the propagation mist

bench for rooting. Before sticking, the cuttings were treated with a talc preparation of 4000 ppm IBA and 25% Captan fungicide. In our research we used a rooting medium of perlite, peat, and white sand (2:1:1 v:v:v). The cuttings received bottom heat of 25°C and incandescent lighting was used to maintain a 16 hour photoperiod.

Figure 1. Etiolation and Banding as Stock Plant Pretreatments



1) Shade placed over shoots before leaves appear, and left in place until shoots reach 2″ to 5″.

2) Shade removed gradually over 1 week.

3) Banding applied when shade is first removed, and bands left on for 4 weeks as shoots green up.

4) Cuttings made just below band. Band removed before cuttings are placed in the propagation bench.

RESULTS

The rooting results for each trial presented here represent 4 treatments which were applied to the stock plants before the cuttings were made. The four shoot treatments were:

(1) light grown and not banded (control);

(2) light grown and banded with Velcro plus hormone;

(3) etiolated and not banded; or

(4) etiolated and subsequently banded with Velcro plus hormone.

The rooting responses of 22 trials, representing 13 species, are presented in Table 1. Information on stock plant age and disposition, and the time allowed for rooting in the propagation bench have been included.

The results show that in 16 of the 23 trials the combination of etiolation and banding resulted in the greatest increase in rooting response. The rooting responses may be grouped into those which responded primarily to etiolation, and those which responded primarily to banding. In the former category we have the shoots taken from a 10-year-old hedge of *Carpinus betulus*, young plants of *Castanea mollissima*, seedlings of *Quercus palustris*, and a 30-year-old hedge of *Q. robur*. Responding more to banding were shoots taken from either seedlings or a 30-year-old hedge of *Carpinus betulus*, a 30-

year-old hedge of *Corylus americana* 'Rush', 6 cultivars of *Syringa vulgaris*, and 3-year-old seedlings of *Pinus strobus*. Shoots from stock plants of *Q. coccinea*, on the other hand, required both pretreatments for a rooting response.

Table 1. Effect of etiolation and banding stock plant pretreatments on the percent rooting of 14 woody ornamental plant species

	Percent rooted[1]				
	Light grown		Etiolated		
Plant	No band	Velcro + hormone	No band	Velcro + hormone	Rooting time (weeks)
Species:					
Acer griseum 1 yr old seedlings	7	12	14	34	4
A. griseum 30 yr old trees	0	0	0	5	4
A. saccharum 1 yr old seedlings	47	64	65	86	2
Betula papyrifera 1 yr old seedlings	51	65	71	100	2
Carpinus betulus 1 yr old seedlings	0	63	5	94	2
C. betulus 10 yr old hedge	19	65	96	92	2
C. betulus 30 yr old hedge	14	52	37	72	2
Castanea mollissima 4 yr old seedlings	0	0	44	100	
Corylus americana cv. Rush 20 yr old hedge	4	83	0	87	4
Pinus mugo 3 yr old seedlings	41	64	–	–	12
P. strobus 3 yr old seedlings	29	79	58	83	12
Quercus coccinea 1 yr old seedlings	0	0	0	46	4
Q. palustris 1 yr old seedlings	31	24	50	44	4
Q. robur 1 yr old seedlings	36	70	53	58	4
Q. robur 30 yr old hedge	0	9	27	36	4
Q. rubra 2 yr old seedlings	37	50	29	35	4
Syringa vulgaris 4 yr old potted shrubs					
'Belle de Nancy'	28	65	21	38	5
'Charles Joly'	0	51	26	63	5
'Charles X'	20	70	45	79	5
'Michel Buchner'	21	79	43	83	5
'Mme. Lemoine'	10	10	21	83	5
'Pres. Grevy'	17	48	35	42	5

[1] Twelve or more cuttings used per treatment. Replicated 3 times when the availability of shoot material permitted.

We observed in nearly every case in which stems were banded with Velcro plus hormone, that the area under the band was swollen by the time the bands were removed after 4 weeks. Moreover, in two of the species, *Betula papyrifera* and *Carpinus betulus*, visible root primordia formed under the band on the stock plant. Cuttings made from these pre-rooted shoots rapidly developed root systems in the propagation bench. This response was noted previously in etiolated and banded apple shoots by Gardner (3) and Howard (8).

DISCUSSION

In the present research the stock plant pretreatments of etiolation and banding yielded very favorable increases in rooting response of a wide range of difficult-to-root woody ornamental plant species. Considering that these trials were the first attempts using etiolation and banding with the majority of these species, the results are especially encouraging. It is anticipated that continued work using these techniques on the same species will result in impressive increases in rooting response. The results obtained with several of these species represent, to the best of our knowledge, the best rooting responses yet achieved. Notably: *Carpinus betulus* (96%), *Castanea mollissima* (100%), *Q. coccinea* (46%), *Q. palustris* (50%), and *Q. rubra* (50%).

It may be recommended, based on this work and the works of previous researchers, that the use of etiolation and banding as stock plant pretreatments to cutting propagation will result in substantial increases in rooting response. In a number of species it appears that the response to one of the treatments alone, i.e. etiolation or banding, may be sufficient to warrant the use of only that stock plant retreatment. For example, the work of a number of researchers on the cutting propagation of apple has indicated that for that species etiolation is about twice as effective as banding in promoting rooting, though the combination of the two pretreatments always resulted in the optimal response (2,3,7,8,9).

The technique of etiolation and banding is especially useful for the propagation of particularly difficult-to-root species, where the value of the propagules warrants the moderate cost of the material needed to etiolate and band the stock plants. It also represents a viable alternative, we believe, to other, more expensive and labor intensive propagation techniques, such as grafting. Etiolation and banding may be applied on any one of a number of scales, from single branches to entire hedges, and even small potted trees. Furthermore, the components involved: the shade enclosure and reusable adhesive bands, are

easily obtained, and may be recycled indefinitely, with a minimum of preparation.

Reusable Velcro adhesive bands represent an improvement over plastic tape in that (1) they are easier to apply and remove, (2) they are reusable, (3) and they serve an added advantage in permitting the application of root promoting chemicals while simultaneously wounding the area of the stem in which we hope adventitious roots will form.

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PETER VERMEULEN: Do you have a list of plants that were not responsive to your technique?

BRIAN MAYNARD: *Acer rubrum* was not, but all treatments gave easy rooting. *Tilia cordata* also did not respond but work at East Malling showed positive results with that plant.

JOHN SMUGULA: Is the length of etiolation important?

BRIAN MAYNARD: We like the shoots to be long enough so that the shoot tips are not damaged during banding. Probably 2 to 5 in.; however, we have let them go longer.

ART DE WIT: What was your propagation procedure?

BRIAN MAYNARD: We put them in a medium of peat: perlite:sand (1:2:1, v/v/v) under mist and with an extended photoperiod.

MIKE DODGE: I tried the technique after Nina's talk last year but got into trouble when I took the cover off. The shoots just dried up. What did I do wrong?

BRIAN MAYNARD: You have to gradually remove the cover and it is best to start on the north side. You need to get the feel of your own individual plants and environmental conditions.

SEED TREATMENTS TO ENHANCE GERMINATION

JOERG LEISS

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Seedlings are an important source of planting stock for nursery production and, in our case, over 200 species of both coniferous and deciduous plants are seeded. Most kinds of seeds will germinate readily, especially when fall-seeded, and I will not concern myself with them. Instead, I will address the problem seeds, those that have given us poor or no germination in the past, and describe the treatments that we use to produce seedlings of consistent quality and size required for field and understocks production. A number of reasons can be advanced for poor germination, such as, embryoless seed, dried out seed, impermeable seed coats, seeds that have not fully ripened, seeds exhibiting various internal dormancy problems, and last but not least, a reliable seed supplier who supplies fresh seeds in good condition. It is still a good idea to pick as much seed yourself as possible to avoid some of the above problems.

Before any treatment is attempted — as a matter of fact before seeds are collected, a cutting test is conducted to check for the presence of well developed embryos. It has been our experience that during stressful growing conditions, seeds are often devoid of embryos even though the seed coat looks perfectly normal. *Carpinus caroliniana, Liriodendron tulipifera, Rhus typhina* are prime examples of plants that show this problem.

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Seed propagation is a fascinating and challenging way of propagation that can often be unpredictable. The treatments

and procedures described below make seed propagation a little more predictable, however, they are in no way complete and we are always trying to improve our germination percentages. Our treatments have evolved over many years and new ways to stimulate the germination of difficult seeds are being tried.

HARVEST TIME

Many seeds lose their ability to germinate unless harvested and sown at a certain seed developmental stage. Below are listed some examples:

Acer saccharinum — Sow as soon as ripe in June.

Aesculus glabra — Sow when ripe in September because the seed deteriorates quickly.

Cotoneaster — Seed from fruit picked green often germinates the first year; sow August-September.

Daphne mezereum — Pick, stratify, or seed beginning of July; often germinates in September.

Quercus alba and related white oak species — Root emergence often starts on the tree; fall sow in October.

Quercus (red oak species) — If they cannot be fall-seeded, store moist and cool.

Tilia americana — Will germinate nearly always if picked before the seed coat and wing turns from grey to brown; sow in early September.

Tilia cordata — Will germinate if picked before seed coat turns brown. Seed kept moist and planted by the middle of October will always germinate the following spring. If seed dries it has to be stratified to restore moisture and break dormancy, and requires one more season to germinate. The resulting seedlings are inferior to seedlings germinating the first spring following ripening.

Viburnum carlesii and *V. lantana* — If seeds are picked on coloring in early August before the fruit coats are soft and black, many seedlings will emerge the following spring. Many viburnums need warm stratification for development of the radicle followed by cold stratification to break dormancy in the epicotyl.

POSTHARVEST TREATMENTS

1) **Water Soak.** Many seeds not protected by a fleshy covering often lose moisture to the extent that soil moisture is not sufficient to restore enough moisture in the seed for germination, especially in well-drained sandy soils.

To restore moisture and bring the seed up to its maximum imbibition capacity, we soak seeds in water for a period of 12

to 36 hr. The procedure is to cover the seed with water in a pail or plastic bag, equal amounts of seed and water, and leave them for the specified period. It is normal to see the seeds swollen and little free water left. Some seeds benefit from water of 80°C to remove waxy coatings. Seeds of the following plants are treated with a water soak:

Acer palmatum — 24 hr before sowing.

Acer rubrum — 24 hr before sowing (fresh seed); northern seed will benefit by 30 days cold stratification at 1°C.

Corylus — 36 hr or until shells are moist inside.

Cornus kousa — 24 hr soak before planting.

Cercis canadensis — Some seeds will swell, the rest can be treated with acid.

Larix — 24 to 36 hr before sowing.

Rhus typhina and *Robinia* — Soak in 80°C water and let cool for 24 hr.

2) **Acid Treatment.** Concentrated sulfuric acid (94%) is used in a non-corrosive (plastic) vessel. Sufficient acid is poured over the seeds to cover them. The mixture is stirred until the time specified has elapsed. It is wise to periodicially check the progress of seed coat digestion by washing and examining small samples of seeds.

When the specified time has elapsed, or seeds are sufficiently scarified, the acid is poured off and the seeds cleaned with running water. This treatment will scarify the seed coat and make it water permeable.

3) **Stratification to Keep Seeds Moist.** One type of stratification treatment is only to keep seeds moist until sowing. *Prunus* species, which fall into this group, will go dormant if they dry out and not germinate for one full year. The stratification medium must be moist.

4) **Warm Stratification.** Seeds of a number of species require a warm stratification before planting. Examples of this are the following:

Euonymus europaeus — We can accelerate or make possible seed germination by after-ripening for 8 to 10 weeks at 18°C. *Euonymus euorpaeus* seed will normally lay dormant for one additional season.

Ginkgo biloba — Seeds of this plant will not germinate at all when harvested locally unless after-ripened for 8 to 10 weeks at 18°C. Following warm stratification seeds are stored at 0°C until the middle of May when soil temperatures are sufficient for germination and danger of frost is past.

Halesia carolina — Seeds of the Carolina silverbell should

be after-ripened for 3 months at 18°C. They can then be seeded or kept stratified for one full year while being subjected to cold, warm and cold treatments. Seedlings will emerge in the summer of the second year after harvest. There are from 2 to 4 seeds in each drupe.

5) **Cold Stratification.** Cold stratification at 1 to 4°C for a minimum of 30 to 60 days is necessary for seeds of certain species. Included in this group are: *Abies concolor, Chaenomeles, Fraxinus americana, F. pennsylvanica, Malus, Pinus strobus, Rosa multiflora, R. rugosa* and *Sorbus.*

6) **Cold, Warm, Cold Stratification.** Plants having seeds falling into this group include the following: *Cornus alternifolia, C. mas, Cotoneaster, Crataegus* except *C. cordata, Fothergilla, Hamamelis, Rosa canina, R. rubrifolia,* and *Taxus cuspidata.* They usually require one year outside.

FUNGICIDE TREATMENTS

This procedure is used for two purposes. First is for the protection of the emerging seedling from damping-off fungi and the second is as a bird repellent.

Our procedure is to use a plastic bag of large enough size to hold at least twice the volume of seeds. We then moisten the seeds with a sticker by shaking the bag until all seeds are moist. Our sticker is Dow "Methocel" used at 4%. Then sufficient fungicide is put into the bag and shaken until all seeds are covered with a good fungicide coat. It is much easier to add both sticker and fungicide as needed than starting with too much sticker. If done properly seeds come out individually coated and nearly dry. The fungicide we use is Captan.

CAMERON SMITH: *Cercis canadensis* seeds this year have a lot of wax on the seed coats. We have had very irregular results with the sulfuric acid treatment. We have tried hexane and acetone to remove the wax before acid treatment. If you leave the seed in long enough to get all the seeds etched, some will be over-etched and acid will get into the embryo. Do you have any suggestions?

JOERG LEISS: Coatings on some of the seed is water soluble and those are the ones damaged by the acid. We soak our seed first, take out the swollen seeds, and treat the others with acid. This problem also happens with *Gleditsia triacanthos.*

RALPH SHUGERT: Forget the acid treatment. Put the seeds in hot water at 140 to 160°F. It is a lot safer and cheaper.

TOM MCCLOUD: Any suggestions for treating bayberry seed with the wax covering?

JOERG LEISS: We rub the seed coat off first. We tried other treatments such as acetone but they did not work. Just

rub the seed between two pieces of wood.

FRANK GOUIN: Have you tried vinegar or tannic acid instead of sulfuric acid?

JOERG LEISS: Vinegar is a weak acid; however, sulfuric acid is not dangerous if handled properly.

RALPH SHUGERT: What is your treatment for *Taxus cuspidata*?

JOERG LEISS: Our seed is imported from Japan. We receive the seed by the end of January, treat with Terrachlor, and combine with an equal amount of moist sand and peat medium. The mixture is packed in shallow boxes, placed outside, and left until the spring two years following. Therefore 1986 seed will come out in the spring of 1988. You give them a cold, warm, then cold cycle before spring planting. You cannot speed it up.

PHOTOPERIODISM IN WOODY PLANTS AND ITS SIGNIFICANCE TO PLANT PROPAGATION AND PRODUCTION[1]

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Woody perennial plants which have developed in temperate regions have evolved intricate mechanisms to allow survival, competition, and reproduction. This has led to complicated, sophisticated mechanisms for starting and stopping growth at the appropriate times for best survival and growth. One of these mechanisms is the ability to sense the gradual seasonal changing of daylength or photoperiod that occurs because of the tilt of the earth's axis and its orbit around the sun. The higher the latitude the greater daylength changes between winter and summer. These photoperiod changes and their effects on flowering of greenhouse crops are reviewed in Post (35).

There are several early reports and reviews of woody plants responding markedly to daylength or photoperiod (12,25,36,43). One of the first of these in our Society was by Waxman (42). Nitsch (31), in his classic review, modified Chouard's (8) criteria and separated plants into response groups to photoperiod (see Table 1). He also listed as many

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woody species with photoperiodic studies as he could find and fit them into his classification groups. Numerous species that Nitsch listed have question marks as to their photoperiodic growth response group. This paper will offer explanations for the question marks and the significance of photoperiod for selecting and producing woody perennial plants in light of these explanations.

The first reason for conflicting reports regarding the photoperiodic classification of certain species reported by Nitsch (31), is that seedlings may respond to photoperiod differently than larger plants with more defined growth patterns. In addition to photoperiod, seasonal influences become important as the plant ages. The second and more significant reason is due to the phenomenon of photoperiodic ecotypes in a species. This has been recently studied extensively and has great significance not only to the production of woody perennial plants, but also to which ones to produce.

Seedlings vs. older plants. The vegetative growth response to increased photoperiod seems to be more active in seedlings than older plants. Hanover, *et al.* (18) found that newly germinated seedlings and one-year-old plants of *Picea pungens* grew continuously under 24 h days, but plants three or more years old formed terminal buds and ceased elongation after 4 to 6 weeks in the same light regime. Heide (20) reported that in *P. abies* longer photoperiods were needed for continuation or resumption of growth in second-year plants than for maintenance of uninterrupted growth in first-year seedlings. Junttila (24) observed that in *Salix pentandra*, smaller seedlings were less responsive to short days and formed a terminal bud when growth ceased, but large seedlings stopped growth sooner and aborted the shoot tip. Older plants of this species would form aborted shoot tips even under continuous light.

The maximum vegetative response to extended photoperiods depends on the absence of other limiting factors. If temperature, soil moisture, fertility, or any other growth factor is limiting, then a rapidly growing seedling can age prematurely and start responding to photoperiod in a different manner. This author (29) has had small tissue culture derived *Rhododendron* micropropagules, which are analogues to seedlings, stop growing because of a momentary stress period due to lack of watering in the greenhouse under long days. This changed these plants from an A response to a B response under Nitsch's classification in Table 1.

Photoperiodic ecotypes. An ecotype of a species is a genetic change that allows a group of plants of a species to adapt and compete favorably in a new environment (9). Woody plants in particular are likely to develop ecotypes because of

their heterozygous genetic makeup and mechanisms to ensure cross-pollination. If the plants colonizing a new environment show major genetic rearrangements and major changes in outward appearance, then a new species or subspecies can be recognized. In many instances the outward changes are minor, but a plant's physiological response to the environment is altered. Development of ecotypes is a way of colonizing new areas by a species, and many woody perennial species have developed considerable ranges by this process (see Little, 26).

Table 1. Photoperiod and vegetative growth response of woody plant species classified by Nitsch (31).

Plant response	Class	Examples
I. Long days prevent the onset of dormancy		
1. Short days cause dormancy		
a. Long days cause continuous growth	A	*Weigela, Populus*
b. Long days cause periodic growth	B	*Quercus, Rhododendron*
2. Short days do not cause dormancy	C	*Juniperus, Thuja*
II. Long days do not prevent dormancy onset	D	*Buxus, Syringa*

One of the changes in physiological response of major survival value to a plant species is the response to changes in daylength in the environment. This genetic change allows a species to colonize different latitudes or different altitudes by new photoperiodic ecotypes. The growth responses of interest here are the induction of growth cessation, bud maturity, and dormancy by shortening days in the autumn. This phenomenon was reported by Weiser (45) to be necessary for the first stage of hardiness induction of *Cornus sericea*. Hummel, *et al.* (23) found that *C. sericea* plants of ecotypes from 65°N and 62°N underwent this first stage hardiness induction at a shorter night (longer day) than those collected from 42°N latitude. This was under genetic control as shown by crosses being intermediate in response. Donselman and Flint (10) reported that both stages of hardening, the first stage being induced by short days, increased more rapidly in northern than in southern sources of *Cercis canadensis*. Aronsson (2) found photoperiod was more important than temperature in the fall hardening of *Pinus sylvestris*. Although other factors may be important for some geographic hardiness of other species (1,3,15), plants in Nitsch's class A or B would probably be hardened by shortening days in the autumn.

Several studies have measured the response of ecotypes from several latitudes and their growth response to photoperiod (4,11,15,17,27,34,39,40,46), although hardiness was not tested. The photoperiod at which growth stopped generally decreased with decreasing latitude. Trees with extensive southern latitude ranges may reach a point where vegetative growth does not respond to photoperiod. This was found for

Liquidambar styraciflua by Williams and McMillan (46) and *Taxodium distichum* by Flint (personal communication).

Heide (19) in a major study of *Picea abies* from five different latitudes found major interactions of temperature, photoperiod, and latitude in the critical photoperiod for growth of seedlings. The growth response at lower temperatures to increased photoperiod was not as strong as higher temperatures; i.e., the critical photoperiod for growth was increased at lower temperatures. Pauley and Perry (32,33) collected seeds of *Populus trichocarpa* from several latitudes and grew them at Weston, Massachusetts. The growth cessation in the fall was correlated with the latitude or daylength and frost-free season of the native habitat. They further found this character was under multigenic control as F_1 hybrids from a north-south cross were intermediate to their parents in growth cessation at the latitude of Weston, Massachusetts.

Altitude can also play a major role in photoperiodic ecotype response. Harborg (17) and Heide (19) reported that critical photoperiod for growth response of Scandinavian trees and shrubs was longer for seed sources from a high altitude than those from a low altitude at the same latitude. McCreary, *et al.* (28) reported a similar response for Douglas fir although the latitude also varied slightly with elevation.

Photoperiod and plant production. The response of plants to photoperiod and photoperiodic ecotypes has several important ramifications in the production of woody plants for the landscape. This phenomenon is primarily important in seedling production, but can be an important consideration in clonal propagation, particularly with the newer micropropagation techniques. The photoperiodic considerations can be divided into two areas — selection of native plant sources, and methods of accelerating production.

Selection of plants to be propagated. The selection of seed source is very important for those plant species that have native ranges over several degrees of latitude and considerable changes in altitude at the same latitude. At higher altitudes fall freezing temperatures occur earlier. There have been several papers showing the importance of seed source for production of woody plant species out of their native region. Heit (21) in an early paper before this Society, and Flint (14) later, state that consideration of seed source is second only to which species to propagate. However, the sale of seedlings by seed source, except for a few species, is hard to find in nursery catalogues. Plant material manuals tend to stress species, clones, and maximum hardiness range and say little about ecotypic or geographical variation. An important exception is

by Flint (16) who gives a range of hardiness in his plant descriptions.

An example of importance of seed source is illustrated in the production of Douglas fir for Christmas trees in central Illinois as Heit (22) had earlier found in New York State. Dr. Jokela, of the Forestry Department, University of Illinois, had planted several trees from Arizona and New Mexico seed sources that grew rapidly compared to other local trees of unknown sources. Several seed sources also were obtained from Dr. Widemoyer, Department of Forestry and Horticulture, New Mexico State University, and grown in Urbana, Illinois. The growth of these trees proved markedly different, as shown in Table 2. The seed source trees from lower elevations grew twice the height of some of the others, although considerable variation was noted even within a seed source of good growth. The superior growth of some of these trees was due to growth later into the summer: the classic photoperiodic ecotypic response.

Table 2. Seeds from several sources in Arizona and New Mexico started in a greenhouse in deep tubes and grown with incandescent lights from 12 p.m. to 4 a.m. and seedlings grown in a bed for two summers (height of seedlings measured at the end of the second summer).

State	National Forest	Ranger District	Elev. (ft)	Growth (cm[1])	Size range (cm)
AZ[2]	Kaibab	North Kaibab	8,800	13.7 ± 4.4	8-20
NM	Carson	Canjilon	9,800	15.5 ± 5.3	6-28
AZ	Coconino	Unknown	8,000	21.0 ± 6.1	9-32
NM	Santa Fé	Las Vegas	8,100	21.1 ± 4.2	13-30
NM	Santa Fé	Santa Fe	Z 730[3]	23.5 ± 5.8	5-36
AZ	Apache-Sitgreaves	Chevelon	8,500	24.0 ± 10.2	13-49
NM	Carson	Jemez	7,600	24.7 ± 7.6	5-39
AZ	Apache-Sitgreaves	Unknown	8,000	25.1 ± 5.2	18-33
AZ	Apache	Black River	7,700	26.9 ± 8.2	6-43
NM	Gila	Reserve	Z 180[3]	29.7 ± 11.3	11-60

[1] Mean growth of 36 plants ± standard deviation of the mean.
[2] AZ = Arizona; NM = New Mexico
[3] Seed collection zone; elevation unobtainable.

Another example of seed source importance is *Liquidambar styraciflua* (sweet gum). There appears to be considerable variation of hardiness in the local sweet gum trees during the unusually cold winters that central Illinois has had the last few years. Numerous trees have died-back and some were killed to the ground, while numerous other trees experienced no damage. This is possibly related to seed source, although this is difficult to prove. These trees are 20 to 40 years old and came from various local nurseries which obtained seedlings

from a variety of sources. There are several ways to solve this problem. First, seed could be collected from the northern-most latitude in the Midwest or from even hardier local trees and grown by local nurseries or contracted to a seedling grower. Another alternative is to choose several of the better local trees and micropropagate them (37) as superior central Illinois clones.

Photoperiod and plant production. Numerous nurseries are using extended daylengths to produce large, rapidly-growing seedlings which are reported to survive transplanting better. Hanover, *et al.* (18) have reported anywhere from 0 to 800% increase in growth of seedlings in a greenhouse using continuous light, high moisture and fertility, vs. normal seedbed-grown seedlings. Tinus (38) grew seedlings of several seed sources of Douglas fir and Englemann spruce in a greenhouse and found growth increased from 50 to 600% depending on the latitude of collection and photoperiodic treatment. Witte, *et al.* (47) have reported in past Society *Proceedings* responses of several woody species but sweet gum and European white birch did not respond. They may not have had the proper photoperiodic ecotype of these species (46).

Both light type and duration may have a major influence on production response. Cathey and Campbell (5,6) found that woody plants were most sensitive to incandescent light of five vision lighting sources tested. Tinus (38) found a variation in response of photoperiodic ecotypes to maximum daylength with some ecotypes of Douglas fir and Englemann spruce doing better with 21-h days than 24-h days. All ecotypes did even better if they received a light break of one minute out of 15 throughout the dark period (cyclic lighting (7) or flashlighting (43) and incandescent light at 270 lux was more efficient than cool white fluorescent light at 950 lux for this response. It would appear from this and other studies that incandescent light would be the best light source for obtaining continuous vegetative response, and flash lighting (43) would save on energy cost for the accelerated greenhouse production of photoperiodically responding woody plant seedlings or micropropagules.

SUMMARY

Nitsch's photoperiodic class of a woody species can vary with the ecotype or even between seedlings and older plants. The continuous vegetative growth of seedlings of many woody species under extended days can be used to produce accelerated seedlings or micropropagated plants and save considerable time in the seed or transplant bed. The length of day or photoperiod is the strongest controlling force of many woody

plant species with native ranges into the higher latitudes. Photoperiodic ecotype has to be considered when deciding on the length of photoperiod necessary for accelerated production of particular species. To obtain a seed source for maximum growth and hardiness in a specific location, photoperiodic ecotypes must be considered for plant species with native ranges in several latitudes or different altitudes at the same latitude. Care should be taken to match photoperiod and first frost to the area where the plants are to be grown if local hardy seed sources are not available.

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COMPANION GRASSES IN NURSERY PRODUCTION

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We at Forrest Keeling Nursery are involved in our third year using companion grasses as an integral part of our field-grown seedling production program. Introduction of selective grass herbicides has rendered this program a valuable asset to seedling production.

Primary reasons for using companion grasses at Forrest Keeling have been: erosion control; stabilization of mulching materials; prevention of crusting of mulch materials; and protection from a number of spring weather conditions including torrential rains, desiccating winds, and late spring frosts.

GRASSES USED AND THEIR CONTROL

After experimenting with several grasses we have determined the best two for our program are annual rye grass for summer and fall-seeded nursery crops and oats for spring-seeded nursery crops. It is important to note that fall seeded oats, as historically practiced in the nursery industry, fail to

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correct the crusting condition. In addition, fall seeded oats give no spring protection because they are killed during the winter and leave only a few remnants by spring when protection is vital. Conversely, annual rye grass, being a winter annual, begins growth and offers the protection needed.

In open field seedling production, the most critical spring period occurs at the time of seedling emergence and continues until true leaves appear and seedlings are able to fend for themselves. At our nursery in northeast Missouri, this critical period lasts about 30 to 45 days and normally ranges from early April through mid-May. This particular time span presents precarious weather conditions including late spring frosts, torrential rains, and high desiccating winds usually in combination with low humidity. Any of the above conditions are capable of completely decimating an emerging seedling crop. Our use of companion grasses has added a major safety factor during this critical production period.

Managing the use of companion grasses has been made possible by the introduction of a number of selective grass herbicides. Our program currently is designed around the use of the herbicide Poast. It allows us to kill the companion grass at exactly that stage of growth when it converts from a protection crop to a competition crop. Poast gives us a near perfect grass kill with no apparent injury to any of our 80 kinds of deciduous tree and shrub seedlings.

SPRING SEEDING WITH OATS

Spring seeding of nursery crops presents an entirely different situation than summer or fall seeding and necessitates a need for a different approach to the use of a companion crop. A faster germinating companion crop is needed that will create a microclimate that gives quick protection to the germinating tree and shrub seedlings. We have found oats to be our best spring companion crop. Oats give us immediate and almost complete seed germination and thus provides protection when most needed.

Oats are seeded with a Gandy air flow seeder directly on our prepared seedbeds at the time we sow our nursery crop. We feel a density of 10 to 15 oat plants per square foot gives optimum protection. To achieve the desired density we seed at a rate of 20 seeds per square foot. The entire production field, including pathways, turning areas, and all other open areas is seeded.

SUMMARY

The use of companion crops has proved to be an asset to our overall seedling production program. The use of oats seed-

ed in spring has filled an important gap in our companion crop program. This is particularly noteworthy because historically oats have been used as a fall protection crop in nursery production. The availability of new selective grass herbicides has opened a host of beneficial uses for this old "standard" companion crop.

CHARACTERIZATION OF THE ROOT-PROMOTING ACTIVITY IN WILLOW EXTRACTS[1]

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Abstract. Using the mung bean rooting test, fractionation, and chromatographic techniques, attempts were made to identify and characterize the nature of the root promoting substances in crude and partially purified willow extracts. Clarified extracts increased the rooting response in comparison to crude extracts. Rooting activity was greater in extracts from plant materials collected in winter months than in those of the summer months. There was a positive correlation between root number of mung bean cuttings and total phenol content in seasonal willow extracts. Water extracts or their fractions showed greater root promoting activity than those of ethylacetate counterparts. The results suggest that water soluble phenolic and indolic compounds are major root-promoting substances in willow extracts.

INTRODUCTION

Kawase (15) obtained strong root promoting activity on mung bean (*Phaseolus aureus*) by applying centrifugal diffusate of willow (*Salix alba*). The diffusate was strongly synergistic with indoleacetic acid (IAA) in inducing rooting of mung bean cuttings. Kawase (16) also extracted with water, rooting substances from *S. alba* similar to those found in the centrifugal diffusate. He suggested that the willow extracts contained large amounts of endogenous cofactors, as yet unidentified, and the right balance of hormone and rooting substances capable of improving rooting. Water-soluble substances from many

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woody plants were found to promote rooting when tested on mung bean (17). Root-promoting activity of willow extracts applied to cuttings of certain woody species also has been observed by other researchers (18,21,22).

This study attempted to identify the willow rooting substances and to elucidate the nature of their activity. In this context a systematic series of experiments using mung bean rooting tests under controlled environmental conditions were conducted with willow extracts. The willow extracts were clarified or subjected to progressive steps of greater purification and selected extracts or fractions were analyzed for the presence of phenolic and auxinic compounds.

MATERIALS AND METHODS

Mung bean test. The rooting test described by Kawase (15) was used. Mung bean cuttings, each 7 to 9 cm long with a 5 cm long hypocotyl, a 2 to 3 cm long epicotyl, and a pair of primary leaves, were obtained from seedlings germinated and grown in growth cabinets under 24°C and 18-hour photoperiod (400 lux of incandescent light). Cuttings were incubated for 7 days in 7 × 2.5 cm glass vials containing rooting test solutions or extracts that were maintained at 15 ml by daily addition of distilled water. Tests were conducted in growth cabinets supplied with 14,000 lux of light (25% incandescent and 75% fluorescent in wattage). Rooting activity was evaluated by recording the number of roots longer than 1 mm on each cutting (15). Experiments were arranged in a randomized complete block design with one to three main factors and with four replications per experimental treatment unit (glass vial), each with six cuttings.

Crude and clarified extracts. Crude extracts (aqueous slurry) were prepared by adding various amounts of ground, freeze-dried powder from willow (S. *alba* var. *tristis*) twigs, and the mixture shaken at 275 strokes per min for 1 h at 4°C to minimize possible enzyme reactions. The optimum concentration of crude extract was determined from a series of concentrations between 0 (distilled water) and 75 mg of willow powder per ml of distilled water. Concentrations of extract greater than 75 mg/ml were not tested because of the pasty consistency of such mixtures.

Crude extract (7.5 mg/ml distilled water) was clarified by filtration through Watman No. 1 filter paper (filtered extract) or by centifugation for 15 min at 4°C at 10,000 rpm in an automatic refrigerated centrifuge (supernatant extract). The residue of the supernatant extract was re-extracted with 10% methanol (residual extract) (13). The rooting activity of crude and clarified extracts were tested in comparison with distilled

water. Tests also were conducted on supernatant extracts derived from willow twigs collected at monthly intervals over a one-year period. The contents of total phenols were determined in these extracts using the colorimetric method of Swain and Hillis (24).

Fractionated extracts. Willow powder was extracted and partitioned with water, methanol, and ethylacetate (EToAc) according to the method of Jalal (14). These steps are outlined in Figure 1. When fractions F and G were each passed repeatedly through a 50.0 cm × 2.8 cm chromatographic column of Sephadex LH-20 at a flow rate of 5 ml/8 min at room temperature using methanol as eluent, five methanol-soluble water sub-fractions (F_{W1} – F_{W5}) and seven methanol-soluble EToAc sub-fractions (F_{E1} – F_{E7}) (Figure 1) were detected by spectrophotometry of the eluates (14). Each subfraction was subjected to ascending one- or two-dimensional thin layer chromatography (TLC) and subsequent qualitative tests for IAA, indole groups, and phenolic compounds (12,29). The EToAc sub-fractions also were analyzed for total phenols, as previously described. All extracts, fractions and sub-fractions (Figure 1) were evaporated to dryness *in vacuo*, taken up with distilled water to a concentration equivalent to 7.5 mg of willow powder per ml of distilled water, and subjected to mung bean rooting tests.

RESULTS

Crude and clarified extracts. Concentrations of crude willow extract between 1 and 75 mg/ml (Figure 2) increased the rooting response of mung bean cuttings in comparison with distilled water; the optimum concentration was 7.5 mg/ml. This result was confirmed using filtered extract at concentrations between 0 and 10 mg/ml (data not shown). In comparison with crude extract yielding 25.1 roots per mung bean cutting (Figure 3), clarified extracts (supernatant, filtered, or both) yielded 46 to 52% more roots; the 10% methanolic residual extract was slightly promotive in rooting activity.

The root-promoting activity of seasonal supernatant extracts fluctuated greatly during the one-year period (Figure 4), increasing between October and November, decreasing thereafter until January, and increasing to a peak in April. There was a rapid decrease in rooting activity between May and June, followed thereafter by a progressive but sharp rise in activity. The mean response between October and April (35.6 roots/cutting) was considerably higher than that between May and October (22.5 roots/cutting). Similar seasonal trends in mean root number and total phenols contents analyzed in the supernatant extracts (Figure 4) showed a correlation coefficient of $r = 0.658$ ($P<0.05$) between the two variables.

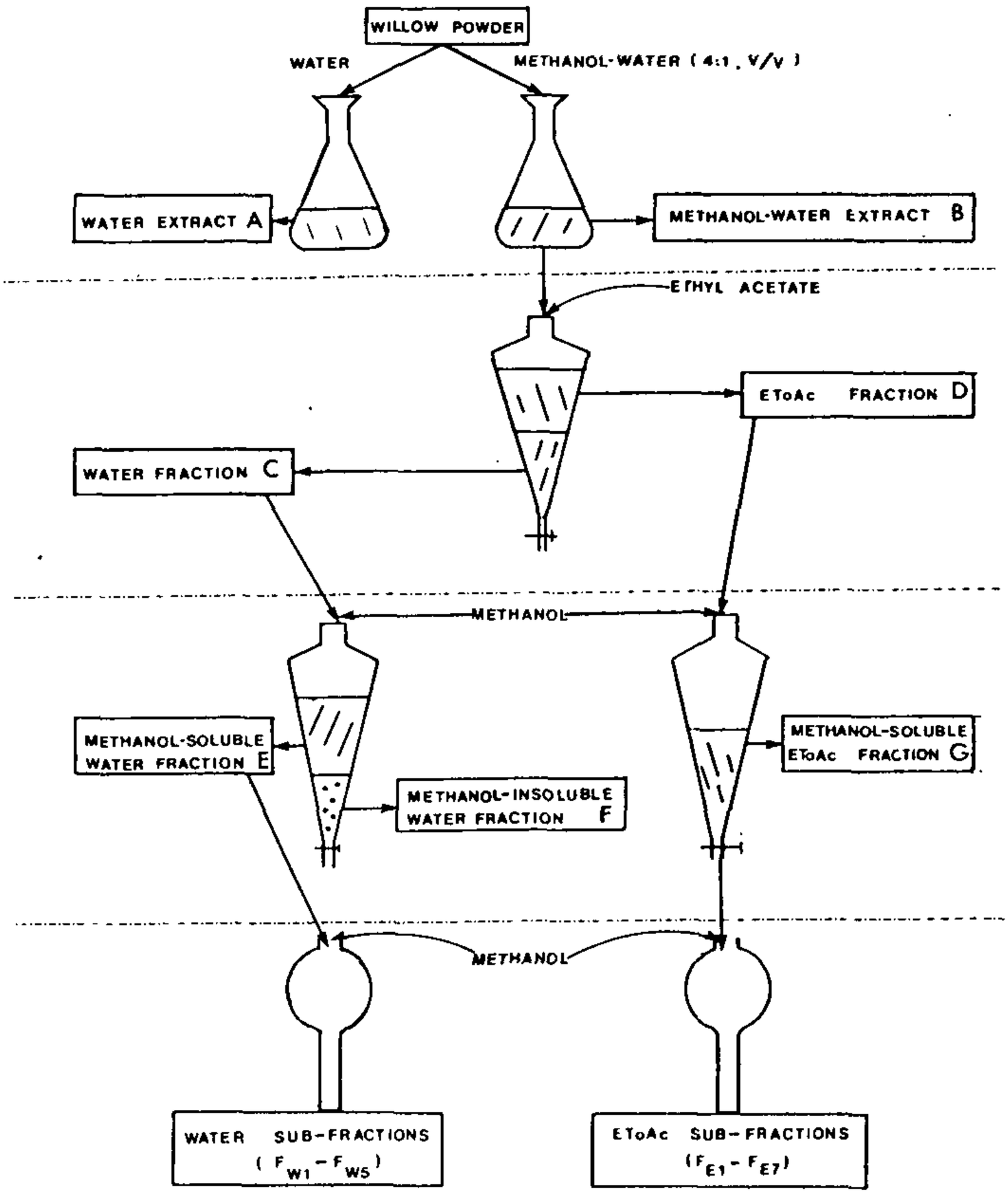

Figure 1. Steps in the extraction and fractionation of willow extract.

Fractionated extracts. All extracts and fractions (Figure 1) showed significant root promoting activity, except EToAc fraction D and methanol-soluble EToAc fraction G. The five methanol-soluble water sub-fractions (F_{W1} to F_{W5}) (Figure 1) showed consistently high root promoting activity with indole group detected in the F_{W1} sub-fraction only (Figure 5A). Of the seven methanol-soluble EToAc sub-fractions (F_{E1} to F_{E7}) (Figure 1), sub-fractions F_{E1}, F_{E2}, F_{E5} and F_{E6} showed low to moderate root promoting activity, while sub-fractions F_{E3}, F_{E4} and F_{E7} were slightly inhibitive (Figure 5B). Similar to the F_{W1} sub-fraction (Figure 5A), indole group also was detected in the F_{E2} sub-fraction (Figure 5B). IAA was detected in the F_{E3}, F_{E4} and F_{E5} sub-fractions (Figure 5B). Phenols were detected in all F_W and F_E sub-fractions but were not clearly separated by TLC to yield quantitative results.

DISCUSSION

Rooting cofactors have been found in many plant species (8,20,26). Using the mung bean bioassay, Hess (13) obtained

from methanolic extracts of easy-to-root, juvenile form of *Hedera helix* and red-flowering *Hibiscus rosa-sinensis*, four root-promoting substances, cofactors 1, 2, 3 and 4. Three of these cofactors were found to be soluble in water (10). Hess (13) also showed that chromatograms from hard-to-root, mature *Hedera* and white-flowering form of *Hibiscus* either lacked these cofactors or contained smaller quantities. Kawase (15,16,17) found four water soluble promotive fractions in willow extracts. Hess' cofactor 1 and Kawase's most active fraction 1 had a similar Rf value of 0 to 0.1. Similarly, Thurman and Street (25) and Britton *et al.* (5) found the strongest zone of growth promotion of other plant extracts to be located at low Rf values of 0.1 to 0.2. In the present study, water extracts or their fractions showed greater root-promoting activity than those of ethylacetate counterparts (Figure 5). The most active water-soluble sub-fraction, F_{W1}, was the first one to be eluted (Figure 5A), suggesting that F_{W1}, Kawase fraction 1, Hess cofactor 1, Thurman and Street Zone 1 and Britton *et al* Zone X are similar or closely related. Thurman and Street (1960) characterized the substance responsible for Zone 1 activity to be the indole compound, tryptophan. Other researchers also detected the presence of indole compounds, including tryptophan, 3-

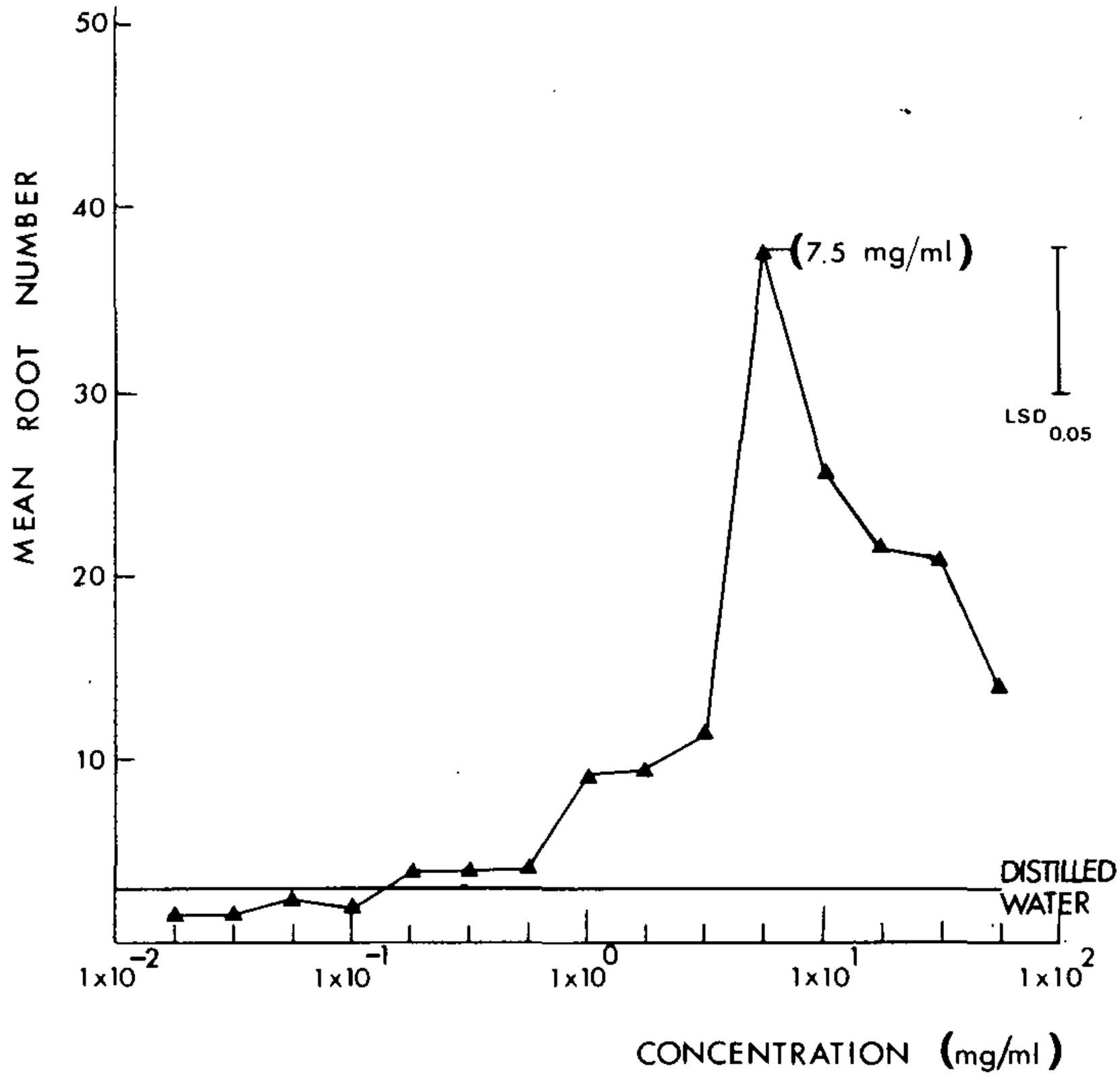

Figure 2. Mean root number for mung bean cutting in response to a series of 16 concentrations of crude willow extract.

indolepropionic acid, s-methyl indole, and 3-indoleacetonitrile in plant extracts and demonstrated their high root-promoting activity (2,11,28). Limited evidence showed that the rooting activity of the EToAc sub-fractions was concentration-dependent suggesting that each sub-fraction has its own balance of rooting promoter:inhibitor and thus its own optimal concentration.

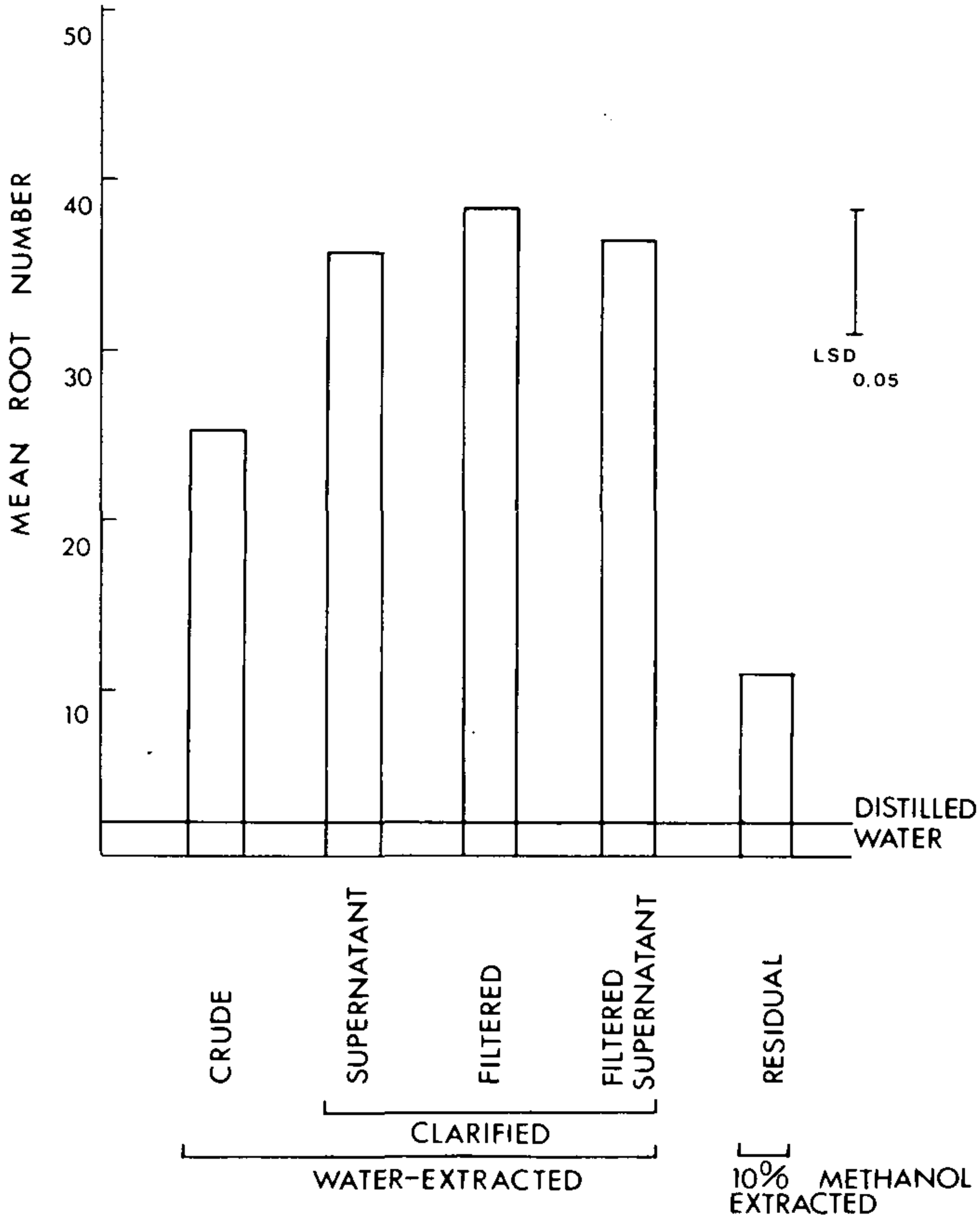

Figure 3. Mean root number per mung bean cutting in response to crude and clarified willow extracts.

Similar to the study of Richer-Leclerc and Chong (21), greater root-promoting activity in willow extract was observed during the winter months (Figure 4). Higher root-promoting activity in winter months has been attributed to the accumulation of rooting cofactors in the stem after leaf drop (23), or to the accumulation of inhibitors such as abscisic acid which interacted with endogenous auxin to promote rooting (1,6). Vieitez and Pena (27) found that rooting activity of acidic S. *cinerea* [syn. S. *atrocinerea*] extracts was lowest in the sum-

mer months (June to August) and related seasonal rooting activity of the extracts to amounts of endogenous IAA. Kikuchi *et al.* (18) and Lamphear and Meahl (19) reported no relationship between seasonal changes in rooting ability of cuttings of *S. kariyanagi*, *S. bakko*, *Taxus cuspidata* 'Nana', and *Juniperus horizontalis* 'Plumosa' and seasonal rooting activity of water-soluble substance(s) in extracts of these species.

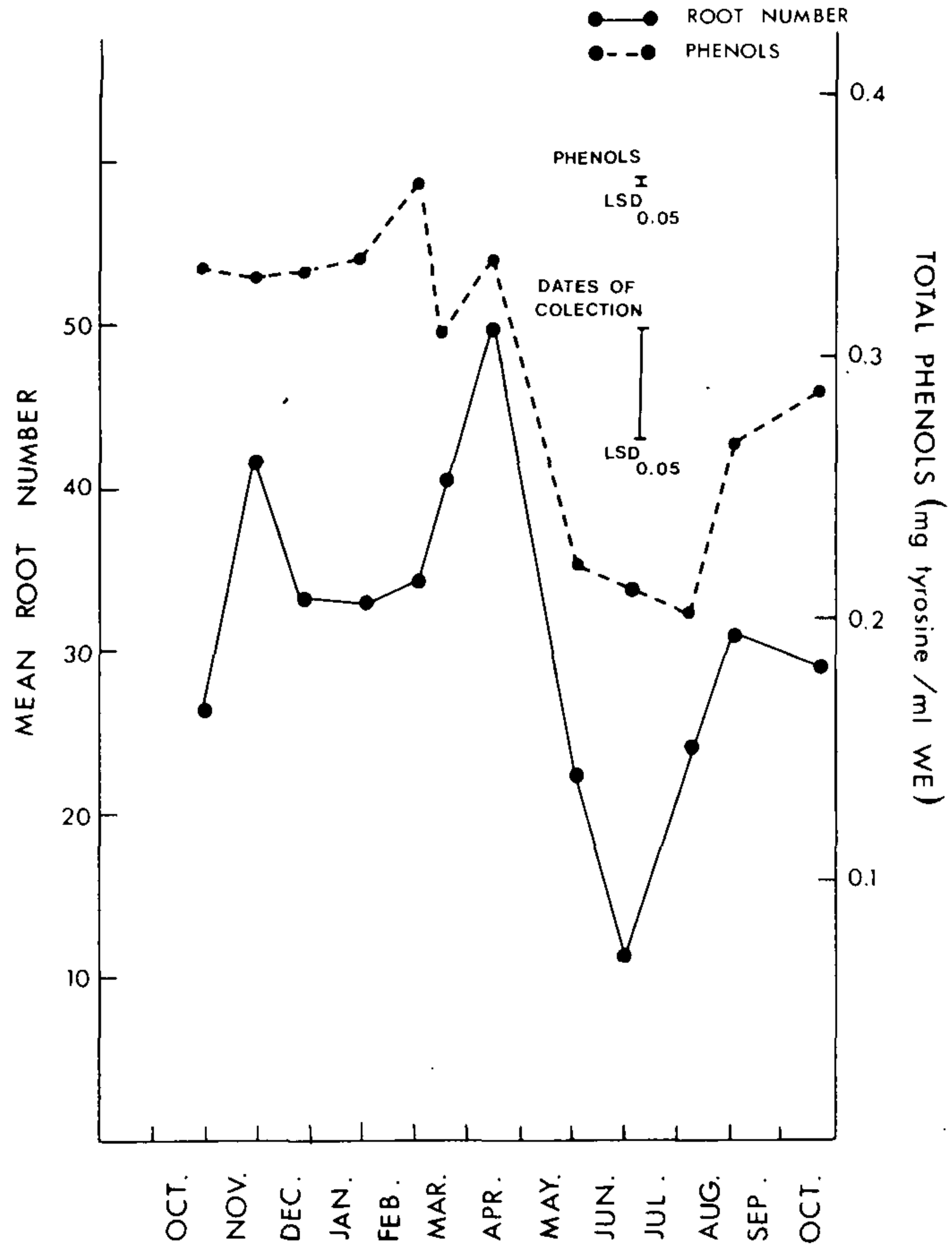

Figure 4. Seasonal rooting activity and total phenol content of clarified supernatant extracts from willow twigs collected at monthly intervals over a one-year period.

Bassuk and Howard (3) found a strong correlation between an abundant phenolic (phloridzin) and seasonal rooting of cuttings. Cortizo (1981) related a high level of phenols in stems in winter to low meristematic and hydrolytic enzyme activity of the plant. Forrest (9) observed similar seasonal trends in total and o-dihydroxy phenol content as in the present study and

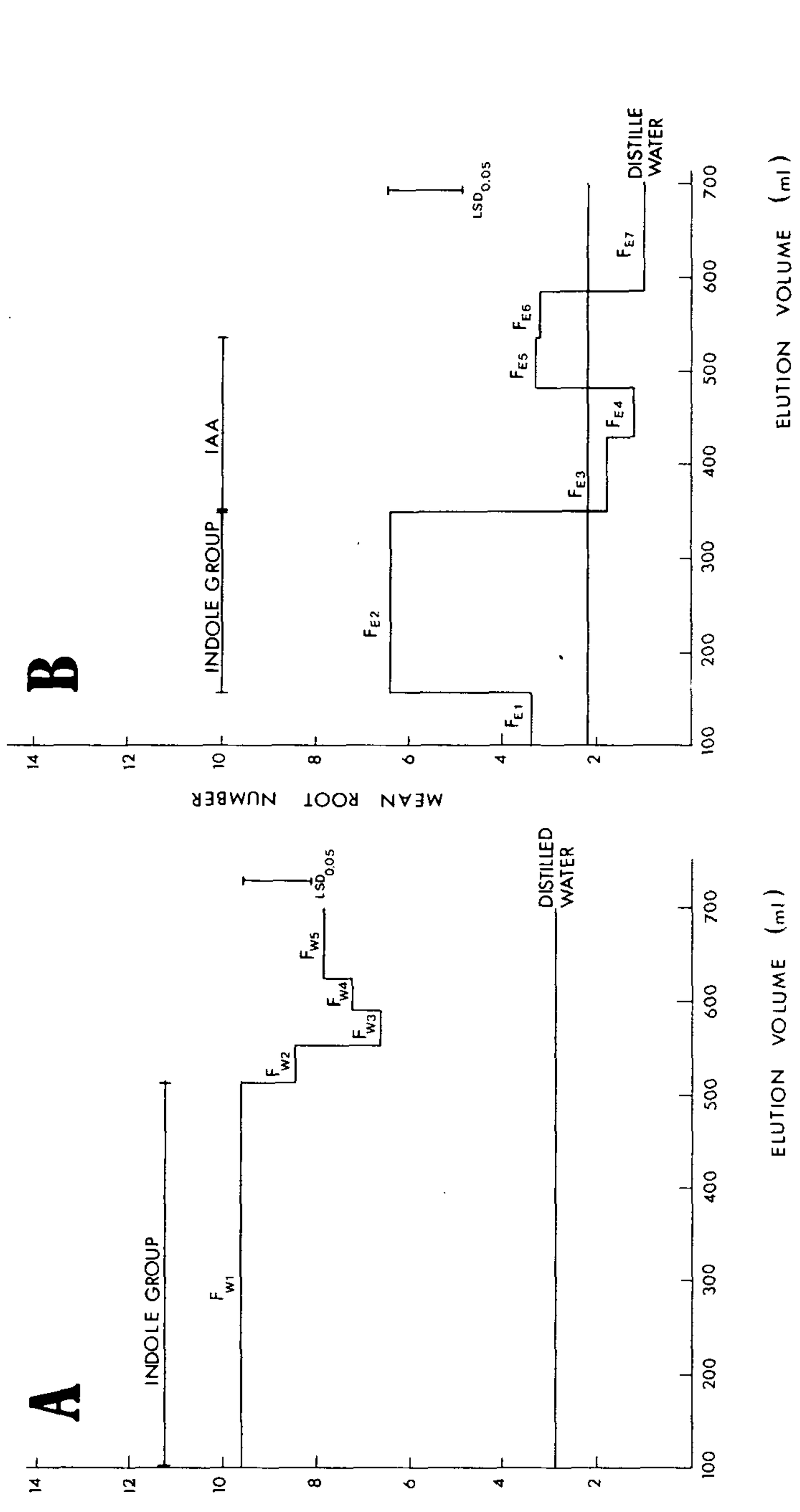

Figure 5. Mean root number per mung bean cutting in response to (A) five water sub-fractions, F_{W1} - F_{W5} and (B) seven EToAc sub-fractions, F_{E1} - F_{E7}.

related their presence to state of lignification of the tissue. Although the phenol nucleus has been reported to act synergistically with an indole nucleus to induce rooting (11), the role played by phenolic rooting cofactors remains controversial (4).

Evidence of the present study confirms that the willow rooting substance(s) is in effect a complexity of substances (21). The activity of these substances appears to be attributable primarily to the presence of phenolic and indolic compounds which are most prevalent in the water fraction; activity is altered by prevailing environmental and/or physiological conditions.

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ROOTING SOFTWOOD CUTTINGS OF MATURE *BETULA PAPYRIFERA*[1,2]

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Abstract. One-node cuttings from current shoots of six 18-year old *Betula papyrifera* trees were collected on 5 dates and treated with indolebutyric acid solution (IBA) 5-second dip at 0, 2000, 4000, 6000 and 8000 ppm. Three trees produced over 40% rooting over all dates compared to 12% or less for other trees. Cuttings from mid-shoot had higher rooting percentages than basal or apical cuttings except on the last two dates when apical cuttings had higher percentages. Three indices of maturity, which were stem length, stem diameter and leaf number, showed a linear growth pattern throughout the sampling period with no distinct change related to the time for best rooting. IBA concentrations of 4000 and 6000 ppm resulted in the highest rooting percentages for most trees on most dates of collection.

INTRODUCTION

Rooting birch by cuttings has been considered difficult (2,7). However, some reports cite success with standard nursery practices. Hares (6) reported rooting in England with basally wounded cuttings on August 18 and September 1, using 2000 ppm IBA as a 5 sec. dip. Cuttings of several birch species rooted best when the last leaf on the cutting reached full size and the last bud was not fully matured (1).

Considerable variation in rooting has been reported among clones of birch species (5) and among clones of other species (3,9). Our preliminary studies during the summer of 1983 showed variation from 0 to 88% rooting of *Betula papyrifera* cuttings from 5 different trees of seed-bearing age. Cuttings made in mid-June using 3000 ppm IBA (0.3%) in talc gave better rooting than 1000 ppm (0.1%). In mid-July, quick dip in 2000 ppm IBA solution gave better rooting than 1000 ppm. One-node cuttings rooted as well as multi-node cuttings in our preliminary study, as with *Acer rubrum* (8).

The effect of cutting date, IBA concentration, and tree-to-tree variation in rooting cuttings of seed-bearing paper birch is presented here.

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MATERIALS AND METHODS

Current-year shoots from 18-year-old *B. papyrifera* trees were collected on 5 dates during the summer of 1984. These trees were seedlings of a local provenance growing in the White Mountain National Forest at approximately 290 m elevation near Bartlett, New Hampshire. Trees were thinned to a pure stand of 2500 plants per hectare when they were 8 years old and fertilized in 1974 with 3600 Kg/ha dolomitic limestone, 400 Kg/ha N, 200 Kg/ha P, and 100 Kg/ha K. Five uniform trees selected for sampling ranged from 9.2 to 11.2 cm DBH and one tree was 14.7 cm DBH. Trees were considered mature, being approximately 8 m tall and bearing seed.

Shoots were collected from randomly selected quadrants in the upper one-third of the tree crown. They were placed in polyethylene bags on ice in an insulated chest and transported to Burlington, Vermont where they were prepared as cuttings and stuck within 24 hr of collection.

On collection dates, cuttings from each of 5 shoots were randomly assigned to the 5 IBA treatments. From each shoot, 1-node cuttings were made and kept in serial order. Wounds 1-cm long were made through the cambium on one side of the cutting base. Each cutting consisted of a node with attached leaf at the top and subtending internode with the basal cut made above the next node. Leaves over 4 cm wide were trimmed to remove the terminal one-half of the leaf.

The basal 1-cm portion of cuttings were dipped into IBA solution for approximately 5 seconds at 0, 2000, 4000, 6000 or 8000 ppm (50% ethanol). Cuttings were stuck 1 to 2 cm deep in 5 cm-deep flats of a 1:1 mixture of perlite-vermiculite and placed in the University of Vermont glass greenhouse under intermittent mist controlled by Mist-A-Matic device.

Cuttings were arranged in a randomized block design with 30 tree-IBA treatments (6 trees, 5 IBA treatments per tree) randomly assigned within each of 5 blocks. Cuttings of each shoot were serially ordered in a row. The number of cuttings from shoots was variable depending on the number of nodes. There were more cuttings per shoot on subsequent sampling dates.

Considerable variation in the stage of shoot development occurs in different locations due to climatological and latitude influences. Since maturity of shoots on a given date may vary in different regions, identification of some stage of maturity may be a better index of when to take cuttings than date. Shoot diameter, shoot length, and number of leaves over 4 cm wide were recorded as objective indices of maturity.

Flats were removed from the mist after 5 weeks to harden

off the cuttings. Rooting was evaluated 6 weeks after sticking; cuttings were considered rooted if they had one root at least 1-cm long. In addition, rooted cuttings were given a quality rating of 1 (poor) to 5 (excellent) based on number and length of roots.

RESULTS AND DISCUSSION

Rooting percentages differed among the six trees for all dates (Figure 1). Trees 3, 5 and 6 had rooting percentages of 43, 46, and 49 respectively, over all dates while trees 1, 2 and 4 had only at 8, 9, and 12 percent rooting, respectively.

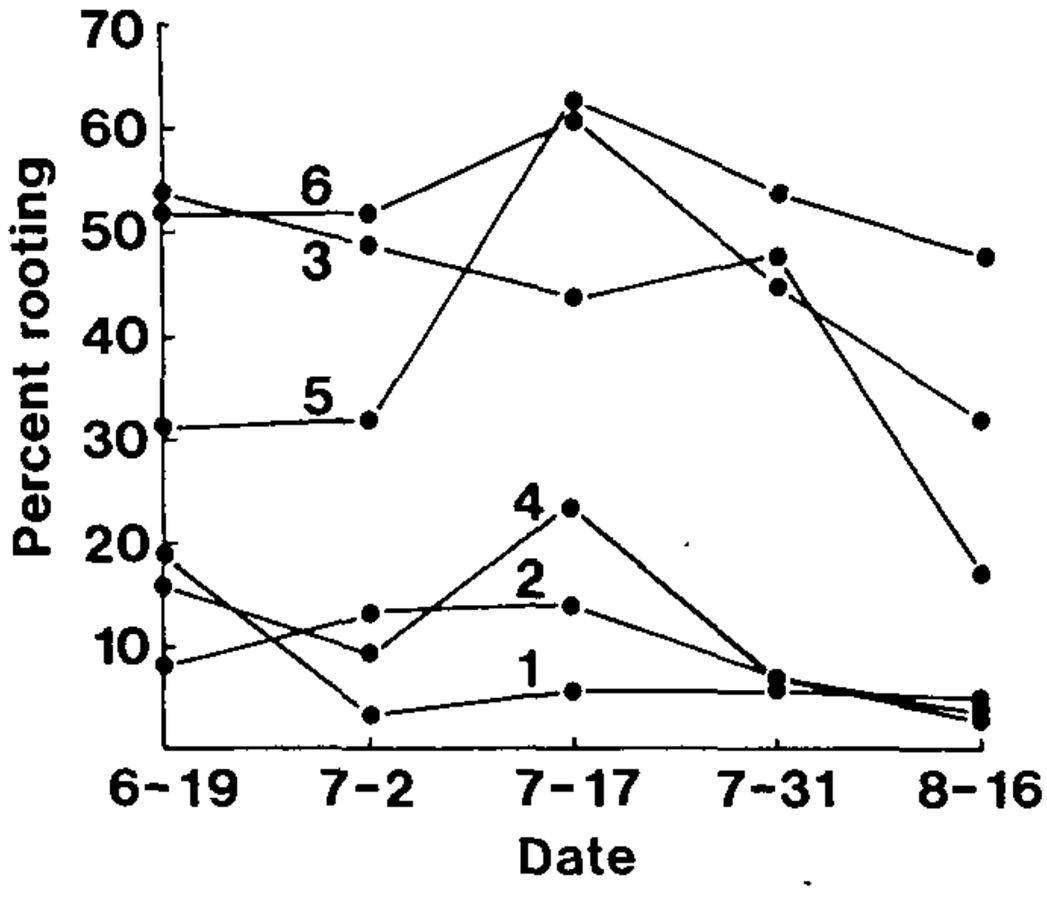

Figure 1. Percent rooting for 6 *Betula papyrifera* trees for 5 cutting dates — 1984. Means of cutting from 25 stems.

Mid-stem cuttings generally had better rooting on the first three dates than basal or apical cuttings (Table 1). Apical cuttings had as high or higher rooting percentages than mid-stem cuttings on the later dates (July 31 and August 16). This could be a function of the increasing maturity of apical shoots when cuttings were made.

The three indices of maturity, shoot diameter, shoot length, and number of leaves, showed a steady increase throughout the sampling period (Table 2). In general, rooting of cuttings collected over an 8 week period appeared to be unrelated to any change in growth. The only apparent relationship between shoot development and rooting was the better rooting of apical cuttings stuck on August 16 using 4000 to 8000 ppm IBA (Table 1). By this time most shoots had set terminal buds and ceased terminal growth.

Figures 2 and 3 show the contour representation of the relationship between the mean percent rooting, IBA concentrations, and date of cutting. Each contour line connects the cutting dates and IBA concentrations which give the same predicted percent rooting.

Table 1. Effect of cutting location within shoot and IBA concentration on percent rooting[1], of *Betula papyrifera* shoot cuttings on 5 dates in 1984, composite of 6 trees.

Date and location on stem	IBA concentration (ppm)				
	0	2000	4000	6000	8000
June 19					
Basal	10.3b	30.0b	24.1b	30.0b	36.7a
Mid-shoot	27.7a	43.4a	59.1a	50.0a	40.8a
Apical	3.4b	16.7b	10.0b	13.3b	13.3b
July 2					
Basal	3.3b	6.7b	26.7b	16.7a	30.0a
Mid-shoot	18.0a	40.6a	44.3a	35.1a	36.7a
Apical	3.3b	20.0b	13.3b	16.7a	33.3a
July 17					
Basal	10.0b	23.3b	13.3b	23.3b	13.3b
Mid-shoot	28.0a	47.4a	52.1a	49.6a	37.5a
Apical	0b	23.3b	33.3b	33.3b	40.0a
July 31					
Basal	6.7a	20.0a	33.3a	30.0a	10.3a
Mid-shoot	15.2a	40.8a	39.0a	28.2a	24.3a
Apical	13.3a	36.7a	43.3a	40.0a	26.7a
August 16					
Basal	0a	6.7a	0b	13.3b	0b
Mid-shoot	10.8a	15.2a	24.3b	24.5b	16.2b
Apical	13.3a	23.3a	53.3a	43.3a	33.3a

[1] Percents of all trees. Percents in a column on a date followed by the same letter are not significantly different at the 0.05 level by proportion separation (4).

The lettered lines in Figure 2 show how to read the graph. For cuttings taken on July 2, horizontal line AB connects the date to the rooting percentage of 35%. This was the highest rooting percentage averaged over all trees. The vertical line BD shows the lowest IBA concentration to give 35% rooting. Vertical line CE shows the highest concentration of IBA that was effective in rooting 35% of the cuttings. For July 2, horizontal distance axis DE gives the range of IBA concentrations (4200 to 6000 ppm) most effective in rooting cuttings.

On July 31, using the same procedure, A′B′ and A′C′ predicted the limits on the 35% contour line. The vertical lines B′D′ and C′E′ predicted the range of IBA concentrations of approximately 2800 to 7000 ppm IBA which resulted in 35% rooting on that date.

A 60% rooting percentage was predicted for the trees with the highest rootability (trees 3, 5, 6) during a 5-week period from early July to mid-August (Figure 3). Optimal IBA concentrations for the mid-point of this period (approx. July 25) ranged from approximately 3500 to 7000 ppm. For earlier or later cutting dates, a narrower range of IBA concentrations gave optimal rooting.

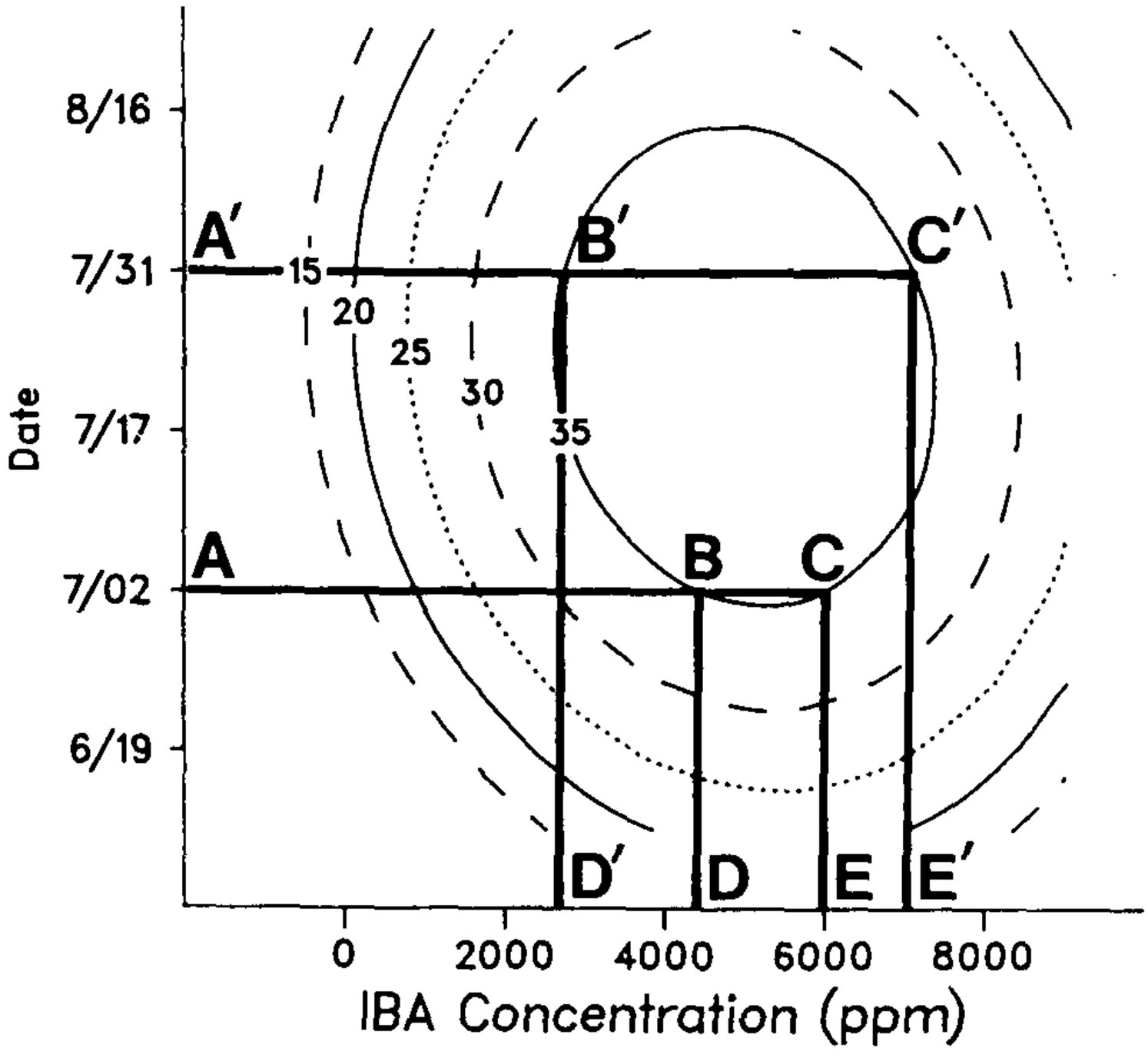

Figure 2. *Contour plots of the effect of IBA concentration and date of cutting on percent rooting of Betula papyrifera cuttings from six trees — 1984.*

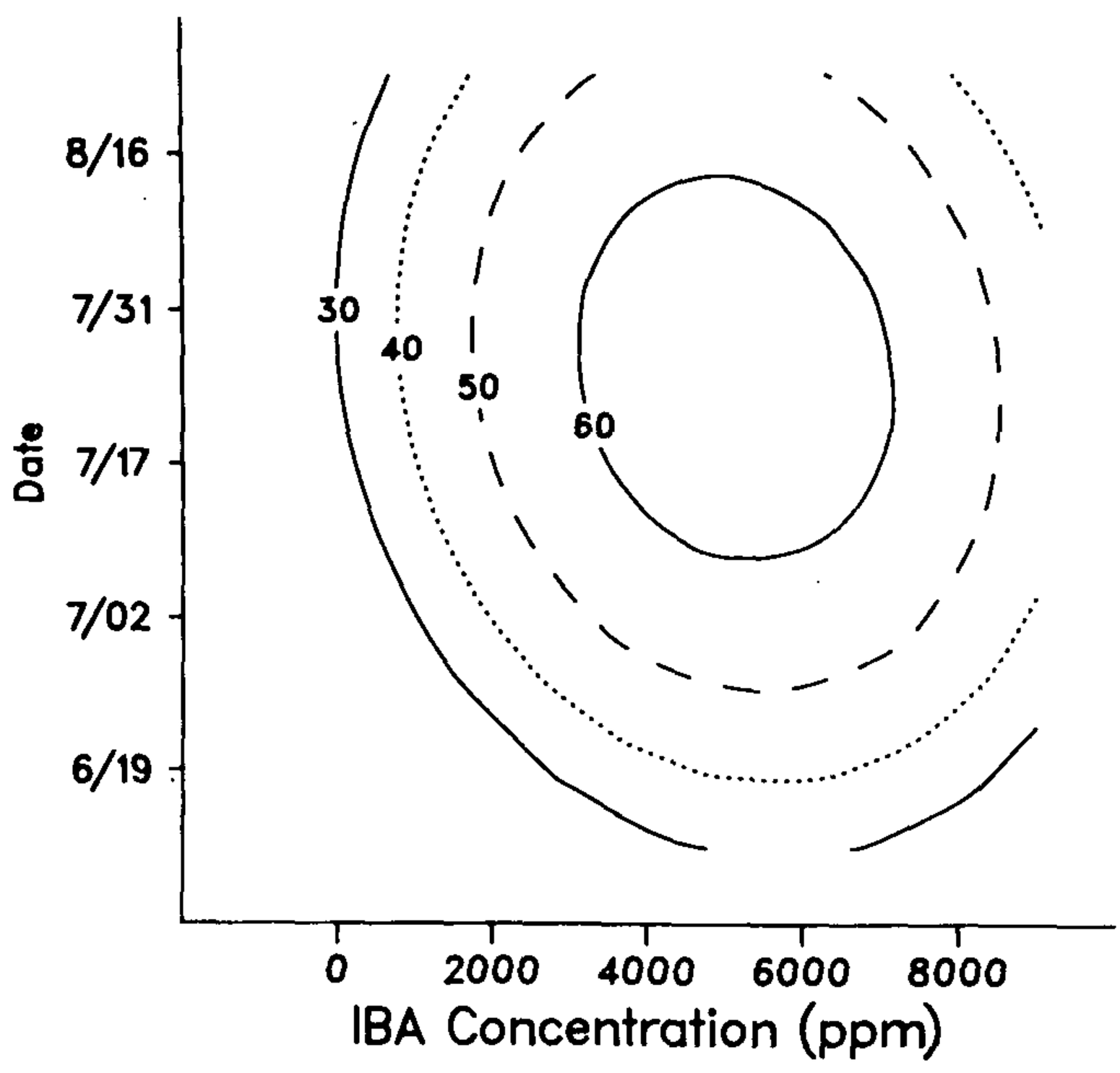

Figure 3. Contour plots of the effect of IBA concentration and date of cutting on percent rooting of *Betula papyrifera* cuttings from the trees showing good rooting percentages — 1984.

Date of collection (maturity) and IBA concentration for rooting birch cuttings were not highly critical in these studies. Optimal rooting over all IBA treatments for trees with over 50% rooting was predicted from July 7 to August 16 (Figure 3) when shoot diameter increased from 0.28 to 0.45 cm and leaf number increased from 4.9 to 11.0 (Table 2).

Table 2. Shoot diameter, shoot length, and number of leaves on *Betula papyrifera* shoots[1] used for cuttings on 5 dates — 1984.

Date	Shoot diameter (cm)	Shoot length (cm)	Number of leaves[2]
6-19	0.30 ± .06	18.9 ± 5.4	3.7 ± 1.1
7-2	0.28 ± .06	16.0 ± 5.8	4.9 ± 1.3
7-17	0.35 ± .07	31.7 ± 9.2	7.8 ± 1.5
7-31	0.38 ± .08	35.9 ± 11.7	9.0 ± 1.9
8-16	0.45 ± .12	44.3 ± 13.9	11.1 ± 3.9

[1] Means and standard deviation of 150 stems, 25 each from 6 trees.
[2] Number of leaves wider than 4 cm on current-season shoots.

Root quality ratings were highest for trees, dates, and IBA concentrations giving highest percent rooting (data not shown). Root quality ratings were not significantly correlated to stem diameter, shoot length or number of leaves.

While cuttings of some trees showed substantial rooting, subsequent lack of growth and survival was a problem. The leaves of most cuttings deteriorated during rooting. Leaves abscised when cuttings were removed from mist. Cuttings were potted and fertilized weekly with 20-20-20 at 150 ppm of N after rooting, but few new shoots developed even in the presence of 16-hr days effected with artificial lighting. More than 50% of the rooted cuttings died within 2 months of potting.

Survival of rooted birch cuttings may depend on forcing new stem growth simultaneously or subsequent to root formation. This has proven necessary for first year survival of many hard-to-establish trees from rooted cuttings (7).

In an attempt to improve survival, Osmocote 20N-6P-11.6K (14-14-14) at 2.65 kg/m^3 (4.5 lb/yd^3) and fritted trace elements (Peter's 555) at 62.47 gr/m^3 (1/4 tsp/ft^3) were incorporated into the perlite:vermiculite rooting medium. Two-node cuttings taken July 2, 1985 were subirrigated with the basal 1 to 2 cm of media submerged in tap water. No mist or overhead irrigation was applied, but cuttings were shaded for 1 week following cutting. Cuttings from 2 of 5 trees made significantly more shoot growth than unfertilized cuttings (Figure 4). Further studies are planned to establish the benefit of slow release fertilizer.

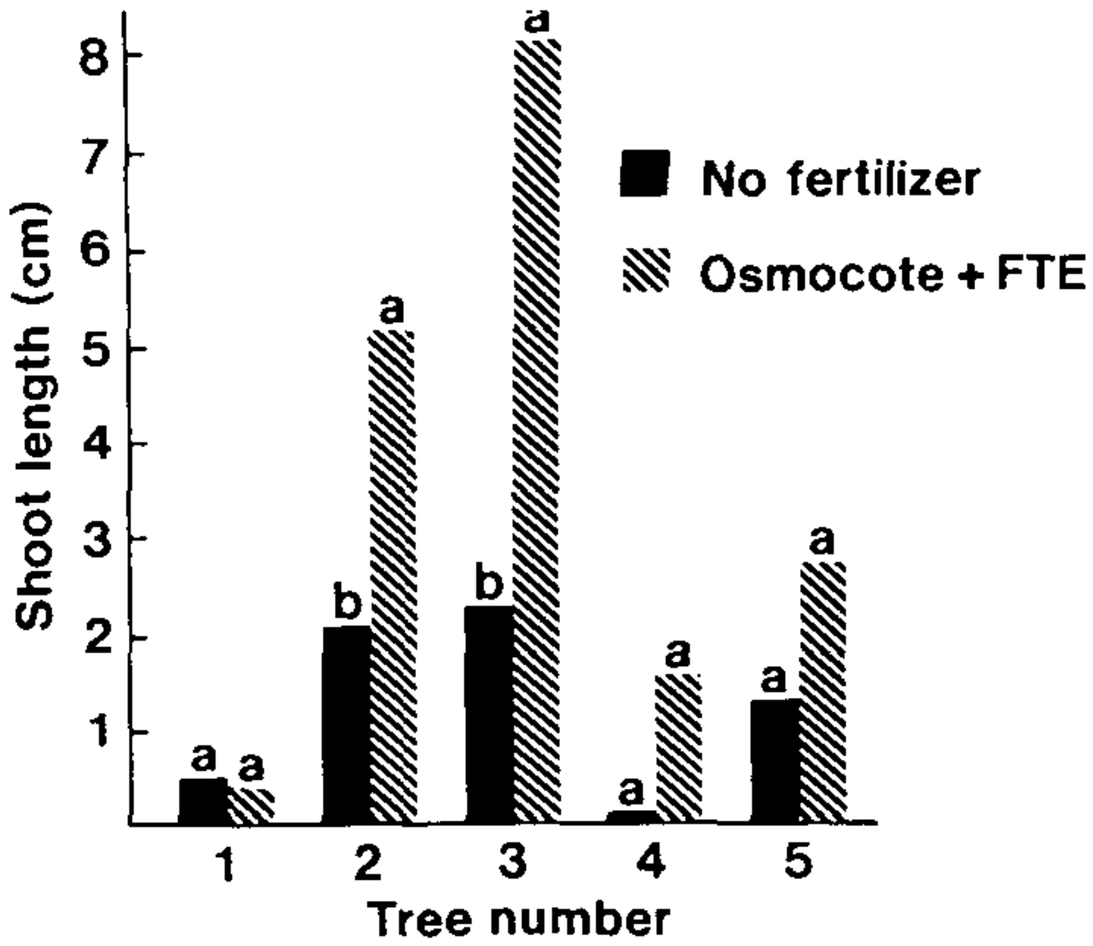

Figure 4. Effect of Osmocote (14-14-14) and fritted trace elements in rooting medium on shoot length of rooted cuttings 8 weeks after sticking. Comparisons for each tree with the same letter are not significantly different at the 0.05 level.

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OVERWINTER SURVIVAL OF NEWLY-PROPAGATED STEM CUTTINGS OF CERTAIN DECIDUOUS WOODY PLANTS

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INTRODUCTION

Stem cuttings of deciduous woody plants such as *Acer*, *Cornus*, *Hamamelis*, *Magnolia*, *Prunus*, *Rhododendron*, and *Viburnum* root satisfactorily but either do not survive the first winter or die after spring bud break (1,2,3,4,8,11,14). Inadequate carbohydrate levels to sustain plants during the winter or to support bud break in the spring have been postulated for the overwintering problem (1,11). Shoot growth following rooting improved survival of some species (1,3,4,8), supposedly by carbohydrate replenishment (1,11), but in other studies it had no effect (3,11,19).

Studies have been inconclusive as to the effect of fertilizer applications on cold acclimation. Fuchigami and Weiser (5) reported that plant health and carbohydrates may not be as important for development of vegetative maturity and cold acclimation as plant nutrition and cessation of growth. *Salix purpurea* grown without nitrogen, phosphorus, or sulfur resulted in early growth cessation and early onset of vegetative maturity. Vegetative maturity occurs just prior to the increase in plant cold hardiness (15). Cold acclimation begins at the time of growth cessation (6,20).

The objective of this study was to investigate the effects of cutting time, nitrogen, photoperiod, and shoot growth on survival of newly propagated terminal stem cuttings of *A. palmatum* 'Bloodgood' and *Cornus florida* 'Rubra'.

MATERIALS AND METHODS

Terminal stem cuttings of *A. palmatum* 'Bloodgood' and *C. florida* 'Rubra' were taken at Angelica Nurseries Inc., Chesterville, Maryland. Cuttings momentarily were submerged in water, wrapped in moist burlap and plastic, and placed in flats in the shade. At the University of Maryland, College Park, Maryland they were submerged (a few seconds) in water, rewrapped in burlap, and stored overnight at 4°C.

Cuttings were cut to lengths of 20 cm for *A. palmatum* and 15 cm for *C. florida*. Basal leaves on the cuttings of both species were removed so 4 fully expanded leaves remained. Surface area of *C. florida* leaves was reduced by one third. Four 2.5 cm long vertical basal wounds through the cambium

were made with a razor blade on both species. The bases (2.5 cm) of the cuttings were dipped in water and then a talc powder preparation of 1 H-indole-3-butanoic acid at 20,000 ppm (Hormo-Root 2; Hortus Products Co.) or 4,000 ppm plus Thiram at 15% active ingredient (Hormo-Root B; Hortus Products Co., for *A. palmatum* and *C. florida*, respectively. Cuttings were placed in wooden flats containing moistened medium of equal parts coarse grade perlite and sphagnum peat (v/v) and rooted under intermittent mist.

Rooted cuttings (roots ca 2.5 cm) were transplanted into 10.2 cm square pots (0.5 liter) in a medium of 3 parts sphagnum peat and 2 parts coarse perlite (v/v) amended with 7.5 g fritted trace elements #503 (Peters Fertilizer Products, W.R. Grace & Co., Fogelsville, Pennsylvania), 300 g dolomitic limestone, 80.9 g of ON-19.2P-OK, and 71.2 g of ON-OP-41.5K per 50 liters of medium. Potted plants were returned to the propagation house and misted twice daily for 1 week, then grown in the greenhouse under polypropylene shade fabric (33% light reduction) until 21 September. The greenhouse remained open and unheated until plants were moved outdoors into an open coldframe on 24 November.

Experiment I. The purpose of this experiment was to determine if nitrogen, photoperiod, shoot growth, and type of storage affected overwintering. In 1981, *A. palmatum* and *C. florida* cuttings were taken on 18 June and rooted. At transplanting, half of the rooted *A. palmatum* cuttings had a terminal leaf and petiole detached to expose the subtending bud and promote apical growth (21). Following acclimation, *A. palmatum* from each treatment and *C. florida* were divided between natural day (ND) and long day (LD) (18 hr day continuation from 100 W incandescent bulbs placed 2 m apart and 1.1 m above plants, 9 μmols s^{-1} m^{-2}) photoperiods. Plants were given a constant feed of either 0 or 200 ppm of NH_4NO_3 (N). The ND and LD treatments were continued through 30 October. A completely random design was used within photoperiods. Plants were moved outdoors on 16 November to receive freezing temperatures.

Overwintering storage treatments were begun on 18 December and included microfoam (0.6 cm thickness; Dupont Company, Wilmington, Delaware) covered plants in a cold frame covered with a sash. Plants under microfoam were watered and tipped on their sides before covering. Air temperature changes under the microfoam were recorded every 5 days using a maximum-minimum thermometer until plants were uncovered, set upright, and watered in the spring (10 March 1982). On 10 May data were collected on the number of plants surviving (one active shoot).

Experiment II. The purpose of this study was to determine if combinations of ammonium (NH_4) and nitrate (NO_3) nitrogen equaling 200 ppm nitrogen influenced overwintering. Propagation of terminal stem cuttings from current season's growth of *A. palmatum* 'Bloodgood' and *C. florida* 'Rubra' in 1983 was carried out as described in Experiment I according to the schedule in Table 1. Early season cuttings of *A. palmatum* taken in May and of *C. florida* taken in June consisted of expanding shoots. Late season cuttings of *A. palmatum* taken in June and of *C. florida* taken in July consisted of fully expanded shoots. A shoot was considered expanding if the terminal shoot tip had unfolding leaves, and expanded if leaf unfolding ceased and terminal and lateral buds were set.

Table 1. Dates of cutting harvest, transplanting, and fertilizer application.

Plant	Group	Cutting harvest	Transplanting	Start of fertilization
Acer palmatum 'Bloodgood'	1	May 19	June 29	July 14
	2	June 16	July 18	July 28
Cornus florida 'Rubra'	1	June 16	July 18	July 28
	2	July 11	August 18	August 25

Combinations of NH_4 and NO_3 (Table 2) were applied to each plant (ca 100 ml of solution) once a week at 200 ppm according to the schedule of Table 1 through 27 October 1983. Water was provided until run-off as needed between N treatments.

Overwinter storage in the cold frame was started on 20 December 1983. Plants were overwintered under microfoam as described in Experiment I. Air temperatures were recorded under the microfoam every 5 days until uncovering on 7 March 1984. Media pH were measured on 20 December 1983 of all treatments.

Data were collected on the number of living plants after winter storage (16 May 1984). Plants were rated as dead if external and internal root and stem necrosis was observed.

Table 2. Ammonium and nitrate sources used to equal 200 mg/l of nitrogen.

Treatment (milligrams/liter)		Nitrogen source (grams/liter)			
NH_4^+	NO_3^-	$Ca(NO_3)_2 \cdot H_2O$	NH_4NO_3	$(NH_4)_2SO_4$	NH_4Cl
0	0	0	0	0	0
50	150	0.84	0.29	0	0
100	100	0	0.57	0	0
150	50	0	0.29	0.24	0.19
200	0	0	0	0.47	0.38
0	200	1.68	0	0	0

RESULTS

Experiment I. Overwinter survival was optimum for rooted cuttings of *A. palmatum* and *C. florida* which did not receive N and grew the previous season (Table 3). Those without N and without previous season shoot growth had high survival, but less than plants with shoot growth and not given N. Poorest overwintering occurred on both species which were given N and failed to grow prior to winter storage. Plant dieback following bud break in the spring occurred on both species, but in no detectable pattern (data not presented). No detectable patterns of overwinter survival were related to previous season photoperiod treatments.

Table 3. Percentage of *Acer palmatum* 'Bloodgood' and *Cornus florida* 'Rubra' cuttings surviving overwinter.

			Nitrogen (ppm)			
			0		200	
			Photoperiod[z]			
Plant	Propagation time (Month)	Shoot[y] growth	LD	ND	LD	ND
Acer	June	with	100[x]	100	92	86
		without	88	80	8	13
Cornus	June	with	98	—	66	—
		without	93	88	9	17

[z] ND-natural day length; LD-18 h of light as a day continuation.
[y] After transplanting.
[x] Data collected on May 10, 1982. Values based on 20 to 105 plants.

Experiment II. Survival after overwintering of *A. palmatum* and *C. florida* was maximum when there was no N application the previous season (Table 4). Losses increased on plants receiving N applications as the amount of NH_4 increased compared to NO_3. A higher percentage of plants with shoot growth survived compared to those without. Plants from the later cutting dates had the lowest survival rate.

The average daily minimum and maximum temperatures during winter storage were 0.4° and 19.5°C, respectively. The highest recorded temperature was 30°C while the lowest was −11°C. The pH of the growing medium ranged from 6.3 to 5.7 with no clear trend relating to N treatment.

DISCUSSION

Similar patterns of overwinter survival were observed for *A. palmatum* and *C. florida*. Plants not given N had greatest survival, those with shoot growth receiving N slightly less, and plants without shoot growth plus N had poorest survival. This influence of N resembles cold acclimation responses reported previously for *Viburnum plicatum* f. *tomentosum*, *Cotoneaster*

divaricatus, and *Forsythia* × *intermedia* (10,16). Growth cessation must occur for cold acclimation to begin (6,20). Application of N during the growing season induces late season shoot growth and delays onset of vegetative maturity (5). This may be due to the promotional role of N in protein synthesis (5). Since cold hardiness increases following vegetative maturity (15), plants with delayed vegetative maturity would remain susceptible to cold injury. Nitrogen in our experiments likely delayed vegetative maturity and cold acclimation which resulted in reduced winter survival.

Table 4. Percentage of plants surviving overwinter in response to previous season nitrogen, propagation date, and shoot growth.

			N-form	ppm N					
Plant	Propagation month	Shoot growth	NH_4 NO_3	0 0	50 150	100 100	150 50	200 0	0 200
Acer palmatum 'Bloodgood'	May	with		100[z]	97	100	77	46	97
		without		100	55	88	20	0	44
	June	with		100	100	100	90	100	92
		without		86	41	36	18	0	24
Cornus florida 'Rubra'	June	with		100	67	85	74	29	74
		without		100	0	0	0	0	—
	July	with		100	45	65	0	0	30
		without		91	0	0	0	—	0

[z] Mean of 30 plants.

The prolonged application of NH_4 as a N source for higher plants may disrupt various aspects of metabolism leading to physiological and morphological disorders and death (7,9,12,13). However, some plants grow better with NH_4 than NO_3 as the sole N source (17,18). The data from the present study illustrate similar patterns of plant survival between *A. palmatum* and *C. florida* after overwintering in response to propagation date, shoot growth, and N form. Substantially more plants survived increased levels of NH_4 if plants were propagated early season and shoots grew after rooting. This suggests that NH_4 sensitivity exists in these plants but that seasonal climatic conditions such as temperature or light or the physiological state of the plant, depending on propagation date, may be interacting to create this sensitivity.

The results of the present study clearly suggest that newly rooted plants of *A. palmatum* and *C. florida* are sensitive to NH_4 and NO_3 nitrogen. However, this sensitivity varies throughout the season of propagation in response to the physiological state of the plant and/or climatic conditions. Future studies should investigate the role of temperature and light duration and intensity on their interactions with plant metabolism leading to physiological and morphological disorders. Also, the time of application and the concentration of N being

applied in relation to propagation date should be investigated. Nitrogen fertilization of newly rooted cuttings of *A. palmatum* and *C. florida* should be avoided in the year of propagation until its role is better understood.

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DICK WOLFF: Just a comment on Dr. Stimart's paper. We have found that nitrogen applied late in the season is a killer with *Acer palmatum*. We store our rooted cuttings over winter at about 35°F for two winters because of some stem splitting we have encountered.

MIKE DIRR: Another comment on Dr. Stimart's paper. I have a student who is just finishing research and looking at many of the same things you are. We find that those plants that do break bud have significantly greater quantities of carbohydrate and also overwinter in greater proportion than those that do not.

DENNIS STIMART: I might also add that if you can give short days, you can override the stage 1 cold acclimation with a late season application of ammonium nitrate. How that relates to carbohydrate balance in the plant I do not know.

PRE-SEASON PROPAGATION

BRIAN M. DECKER

Decker Nursery
6239 Rager Road
Groveport, Ohio 43125

At Decker Nursery we have added a new propagation season to our schedule. This is a spring propagation of softwood or semi-softwood cuttings prior to our usual June, July, or August propagation. Our goal is to produce cuttings of high demand species, rooted directly in cell pacs, ready for container production within 4 to 8 weeks after propagation.

Our method of preseason propagation begins with the propagation medium. This mix is two parts pine bark, two parts styrofoam or its equivalent, and one part sand. Good drainage is the most important factor in this mix; however, it must also serve as a growing mix that will hold together as a root and soil plug.

The propagation containers are sheets of 72 count cell pacs held in a plastic tray. This size cell pac seems to work best for two reasons. First, the cost averages out to less than 0.5 cents

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per plug. Secondly, the small soil volume is quick to fill with roots, thus producing a solid plug faster.

The hormone used is not critical as the species we have tried are easily rooted. Similar excellent results have been achieved with Hormodin #2 or Woods 1:10.

The cuttings themselves are of two different categories. The earliest cuttings we call semi-softwoods. These are cuttings of last year's growth that are just beginning to leaf out. These are produced usually in early to mid-April. The bulk of the production, however, are true softwood cuttings. These are gathered between mid-April and the end of June. Both types of cuttings are stripped of lower leaves, treated with hormone, and stuck into a cell pac.

The care of the cuttings is typical for softwoods. They are placed in a propagation bench in a greenhouse. Heat is applied on cold spring nights. Misting is done by two methods; hand misting as needed for cloudy, cold days, or timed misting for sunny days. Great care is taken to avoid over-misting, as decay can easily develop.

After the cuttings are lightly rooted, the misting is greatly reduced and they receive half-rate liquid fertilizing. This continues until the root system is extensive enough to hold the soil plug intact.

The potting of preseason plugs usually begins in late May. The plastic pots, either one or 2-gal size, are filled, positioned, and watered in advance. A pointed 5-foot wood stake of 1½ in. diameter is used to poke a hole in the medium of each pot. The plant plug is removed from the cell pac, inserted into the hole, and firmed. The pots are then watered and shaded. After 10 days the shade is removed. The plants are also fertilized with Osmocote and treated with Ronstar herbicide. The critical factor in this whole process is that the cuttings have never experienced potting shock, either as a cutting or in the container potting stage.

The development of this method began in the spring of 1984. We were already direct-sticking cuttings in cell pacs for two years during our usual summer propagation. However, due to both an increase in demand and overwintering losses during 1983 and 84, we found ourselves in need of liners for container production. We experimented with approximately 5,000 mid-May softwood cuttings of various species such as *Potentilla*, *Spiraea*, *Euonymus*, *Cotoneaster*, *Forsythia*, and *Ligustrum*. We were amazed at the growth over the summer. By fall we had sold approximately 1,000 plants, shifted 2,000 to 2-gal containers, and overwintered the rest for spring 1-gallon sales.

We expanded our experimentation in the spring of 1985 to earlier semi-softwood cuttings. We used a high peat content rooting mix but developed some stem rot problems. Overall, however, the results were favorable and justify more attempts next spring.

The bulk of our spring propagation remained true softwood cuttings. The results were very satisfactory and the growth of the plants over the summer has been consistent with 1984 results.

In conclusion, this method of preseason propagation has many benefits. First, we are able to rapidly increase production of a new cultivar by taking additional crops of cuttings in one season. Second, we can reduce start to finish production time on some species. Third, we lessen risk by overwintering large plants instead of small cuttings. Finally, we produce a crop that finishes usually in late spring, after the shipping of normal sequence plants. This allows us to offer a more consistent product.

JIM SAMPSON: Is there any hardening off after coming out of the mist?

BRIAN DECKER: The critical factor is that after potting the rooted cuttings are always shaded and that gives them about a week to get moving.

DALE HENDERSON: Was your material forced or was it outside spring growth?

BRIAN DECKER: The timing was a little deceiving this past year because of the early growth. All the cuttings came from container stock overwintered in white poly houses.

CHARLES HILDERBRANT: Did you use any bottom heat?

BRIAN DECKER: They were propagated in a greenhouse that we use for our hardwood propagation. We propagate in flats so we were able to move things such as junipers out of the house. The heat was the normal setting we use in our greenhouse. There may have been some bottom heat on the colder nights.

Tuesday Afternoon, December 10, 1985

The afternoon session was convened at 2:00 p.m. with Peter Orum serving as moderator.

ROOTING DECIDUOUS SOFTWOOD CUTTINGS IN PLUGS

DALE G. DEPPE

Spring Meadow Nursery
Grand Haven, Michigan 49417

Spring Meadow Nursery produces 2¼ in. potted liners for resale to other growers. We have been growing potted liners for four years and currently grow ¾ million plants per year. Over 90 different kinds of plants, mostly deciduous, with a few broadleaf evergreens are grown. The system we use, rooting cuttings in a plug tray and transplanting to 2¼ in. pots, was designed to provide our customers with the most uniform plant possible. The system is clean and neat, easy to work with, easy to mechanize, and allows for maximum production from unskilled labor. I hope this paper gives you an idea of how we do it.

PLUG SELECTION

There are many different types of plug trays now on the market. Most of them are not suitable for rooting cuttings. Some are too shallow or small. Those made of heavy plastic are too expensive, while the light plastic types cannot be carried around. Each time a new idea comes along, the price goes up. We tried plugs with ribs and ridges, small drain holes, large drain holes, and ones that are round, square, and even paper. We were not convinced. None of these new generation types was better than the old bedding plant flat and molded insert.

Our selection for rooting cuttings was a 10-20 R8 flat with an 8-12 insert. This gives us 96 cells or plugs that are 1½ × 1⅛ × 2¼ in. deep. Each plug has a slight taper for easy plant removal and enough depth and volume for excellent rooting. The 8-12 insert is used only once and then discarded. By using a new insert for each crop, we maintain a very clean environment. The flat is not used again in propagation, but is used later when the plugs are potted up. The cost for each 96 cell or plug insert is 17 cents — a real bargain when compared with other types of plugs trays.

MEDIUM

The medium used for propagating is standard for all 90 kinds of plants. It provides good drainage, aeration, and water holding capacity. It also has enough nutrient holding capacity to keep the cuttings actively growing while rooting. Equal amounts of commercially bagged Peat-lite mix and coarse horticultural grade perlite are combined with 6 lb. Osmocote (19-6-12) per yard are mixed in a drum type mixer. The medium

is mixed moist, but not wet. When filling plug trays by hand, be careful not to pack the medium down.

CUTTING WOOD AND STICKING

Cuttings are taken as soon as possible in the spring from greenhouse grown 2¼ in. potted liners. Most of our potted liners will have two batches of cutting wood cut from them before being sold in May. Cutting wood not available from liners is taken from field stock plants in early summer. Timing is not as critical when cuttings are taken from greenhouse-grown plants because the cutting wood is growing rapidly and is very soft.

Cuttings are 3 to 5 in. long depending on the kind of plant. The cuttings are cut directly above a node and the lower leaves are removed. This leaves the internode for sticking and allows the next set of leaves to hold the cutting upright in the medium. Cuttings are very soft and wilt quickly, therefore, we handle them carefully to avoid any damage. Before sticking, cuttings are quick-dipped in Wood's hormone. A 1 to 20 dilution is used. Very little hormone is needed because of the soft condition of the cutting wood.

One cutting is stuck in each cell which yields 96 cuttings per tray. The whole process of cutting, sticking, and transferring to mist takes less than 30 min. Our crew is expected to do between 750 and 1200 cuttings per man-hour depending on the kind of plant.

ROOTING STRUCTURES

Greenhouses are 30 by 96 ft quonset type poly houses. Every house has a 3 ft wide cement walkway in the center and is connected to all other houses by cement walks. Misting houses are covered with clear poly and a 50% shade saran cloth. Ventilation in the summer is achieved by cutting holes in the poly as needed. Each misting house also serves as a growing house after the mist system is removed.

After covering the floor with perforated black plastic, a mist system is set up using brass Spraying System ¼E 10 (ten) nozzles. These nozzles are mounted on 24 in. risers at 5 ft. intervals. They also have a large hole to reduce clogging, but spray a medium type mist at 60 lb pressure. The system is operated by a Phototronics timer. Misting varies from 4 sec./8 min. to 6 sec./32 min. depending on weather conditions. Plug trays are placed on top of an inverted empty flat for drainage. Each misting house will hold 130,000 plugs.

CULTURE

Flats of cuttings are placed under the mist as soon as possible. Twice a day, newly stuck cuttings are lightly watered by hand. We have no fungicide program and have used only two pounds of Benlate in 4 years. Tables, flat carts, and tools are cleaned each day. Trays used for transfer of cutting wood are replaced with new trays. Traffic is limited in the misting houses in order to keep contamination to a minimum.

Soft cuttings taken in early spring begin to root in 2 weeks and are removed from the misting house after the roots have reached the bottom of the plugs. The trays of rooted cuttings are placed in 50% shade saran covered houses for hardening off. Trays are watched carefully and watered automatically twice a day until potted.

POTTING

Our potting medium is a combination of 75% Peat-lite mix and 25% composted pine bark mix. Osmocote (18-6-12) at 10 lb/yd and Micro Max Plus at 10 lb/yd are added during blending in a drum type mixer.

Plugs are potted up into an 804 insert which fits into the same bedding plant flat that was used to hold the plug tray. Each of the 32 cells in the 804 insert is slightly larger than a 2¼ in. peat pot. This size container allows for easy transplanting of the smaller plug, plus it gives ample room for growth.

Rooted cuttings grow very rapidly and need pruning before potting. All plugs are pruned with an electric lawn mower mounted over a roller conveyor. The trimmed cuttings are pulled from the plug trays with a fibrous root system intact. Plugs are graded during pulling, and unacceptable plants are discarded. One plug is placed in each 2¼ in. pot cell of the potting tray. Cells are potted individually at a potting bench by holding the plug upright and filling it with medium. After all cells are filled, the flat is dropped on the potting bench to pack the medium. The tray can then be angled to allow excess medium to slide off. This is a very quick process and easy to do. Our potting crew averages more than 500 plants per man-hour, including picking up plugs, trimming, pulling, potting, and returning the potted trays to the greenhouse.

GROWING CULTURE

Greenhouses are 30 by 96 ft. poly covered quonset houses. Each has a cement walkway for easy carting of flatted plants. Houses are watered automatically using Nelson Whiz heads on 15 ft. spacing. Supplemental heat is provided for early spring growing with Modine propane heaters. During the summer,

the poly coverings are replaced with 50% shade saran cloths for wind protection to keep the potted plugs from drying out.

The potting of all plugs is completed in September which allows new roots to become established before winter. Houses are recovered with double poly in mid-October. New root growth continues until mid-December, even without supplemental heat.

Supplemental heat is not used until approximately mid-February. Potted liners are frozen during the winter with a minimum soil temperature of 25°F. Because of snow cover, the greenhouses hold ground heat very well. When the heat is turned on, a temperature of 40°F is maintained at night. The sun heats the houses to 75°F during the day. As new growth appears, regular liquid feeding begins.

When new growth is about 3 to 4 in. long, we begin taking cuttings again. After the cuttings are removed, the flats are trimmed with the electric lawn mower. This trimming maintains a very compact, uniformly branched liner. Shipping of 2¼ in. potted liners begins May 1st and continues until mid-June.

CONCLUSION

Plug trays have made the propagation system at Spring Meadow Nursery flow from beginning to end. We like trays because they are sterile, in addition to being easy to carry, inventory, root in, and discard. It is a system with nothing left over at the end of the year. I have been in the nursery business for over 20 years and a member of the IPPS for 15 years. Many good ideas have come and gone. I like the plug tray system. If you haven't used it, try it.

DESCRIPTIONS OF EIGHTEEN TETRAPLOID *LOBELIA* CULTIVARS

WRAY M. BOWDEN and ARTHUR J. OSLACH

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R.R. 1
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Since 1940, considerable data on the North American species and hybrids of *Lobelia* sect. *Lobelia* have been published by Bowden (3) and Bowden and Hirao (5). Some of the complex tetraploid hybrids that have resulted are excellent perennials for temperate-zone gardens. The parentage, ancestry, and history of these hybrids have been described by Bowden

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The potting of all plugs is completed in September which allows new roots to become established before winter. Houses are recovered with double poly in mid-October. New root growth continues until mid-December, even without supplemental heat.

Supplemental heat is not used until approximately mid-February. Potted liners are frozen during the winter with a minimum soil temperature of 25°F. Because of snow cover, the greenhouses hold ground heat very well. When the heat is turned on, a temperature of 40°F is maintained at night. The sun heats the houses to 75°F during the day. As new growth appears, regular liquid feeding begins.

When new growth is about 3 to 4 in. long, we begin taking cuttings again. After the cuttings are removed, the flats are trimmed with the electric lawn mower. This trimming maintains a very compact, uniformly branched liner. Shipping of 2¼ in. potted liners begins May 1st and continues until mid-June.

CONCLUSION

Plug trays have made the propagation system at Spring Meadow Nursery flow from beginning to end. We like trays because they are sterile, in addition to being easy to carry, inventory, root in, and discard. It is a system with nothing left over at the end of the year. I have been in the nursery business for over 20 years and a member of the IPPS for 15 years. Many good ideas have come and gone. I like the plug tray system. If you haven't used it, try it.

DESCRIPTIONS OF EIGHTEEN TETRAPLOID *LOBELIA* CULTIVARS

WRAY M. BOWDEN and ARTHUR J. OSLACH

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Canada

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Since 1940, considerable data on the North American species and hybrids of *Lobelia* sect. *Lobelia* have been published by Bowden (3) and Bowden and Hirao (5). Some of the complex tetraploid hybrids that have resulted are excellent perennials for temperate-zone gardens. The parentage, ancestry, and history of these hybrids have been described by Bowden

(1,2,3). The colour plates of Bowden and Hirao (5) illustrate seven clonal selections.

The three gene pools of these complex tetraploids can be stated in taxonomic terms as: *Lobelia siphilitica* L. var. *siphilitica*; *L. cardinalis* L. subsp. *cardinalis* var. *cardinalis*; and *L. cardinalis* L. subsp. graminea (Lam.) McVaugh var. propinqua (Paxton) Bowden cv. Queen Victoria and cv. Illumination. While the original plants were diploid ($2n=14$), the tetraploids ($2n=28$) originated spontaneously in several hybrid populations or the tetraploids were induced by colchicine treatments of diploid plants followed by selfing and selection.

In 1962, I (Bowden) grew a large population of complex tetraploids at Ottawa, Canada. In 1967, 6 selected clones were sent to the Royal Horticultural Society's Garden at Wisley, England. The 6 clones were given the following cultivar names by the Wisley staff: Brightness, Cherry Ripe, Dark Crusader, Greensleeves, Red Plush, and Will Scarlet. In 1978 and 1979, I obtained rosettes of these 6 clones and grew them at Simcoe, Ontario. In 1979 and later, many intercrosses, selfs and backcrosses were made and large numbers of hybrid seedlings were grown. A few of the best clones were selected for testing

Table 1. Characteristics of leaves and stems of 18 *Lobelia* cultivars.

Cultivar	Parentage	Mature stem and leaf colours	Mature leaf-blade width, lower ½ of stems (cm)	Mature plant height (cm)
Brightness (=B)	orig. Ottawa Ont., Canada	green	3.0-5.5	108-136
Cherry Ripe (CR)	orig. Ottawa	green	2.9-4.4	55-131
Dark Crusader (DC)	orig. Ottawa	stem maroon; leaves green and maroon	3.5-4.7	60-84
Greensleeves (G)	orig. Ottawa	stem maroon below, green above; leaves green	3.0-4.2	50-121
Red Plush (RP)	orig. Ottawa	green	3.2-5.0	46-100
Will Scarlet	orig. Ottawa	stem maroon; leaves green and maroon	2.7-4.0	70-89
Simcoe	CR × B	green	3.5-6.0-(7.0)	85-115
Toronto	RP × B	green	3.7-5.4	70-132
Oakes Ames	RP × B	stem maroon to greenish; leaves green and maroon	4.0-6.8	84-139
Mexican Beauty	B × RP	green	3.5-5.8	97-134
Ottawa	B × RP	stem maroon; lvs. green and maroon	3.0-5.5	74-109
Canada	B × RP	green	3.5-5.2	94-130
James Pringle	B × RP	stem maroon; lvs. maroon and green	2.4-4.3	60-104
Ernst Benary	B × RP	green	3.2-4.8	90-136
Leslie Laking	B × RP	green	3.2-5.0	126-153
Monroe Landon	G × DC	green	3.0-5.5-(6.3)	90-157
Hamilton Dwarf	G (selfed)	green, some maroon	2.4-3.9	39-79
Wisley	G × CR	green	3.2-7.7	82-137

and propagation. Bowden (3) and Bowden and Hirao (5) listed some of the cultivar names. In Tables 1 and 2 are presented descriptions of the original six clones from Wisley and twelve of my newer clones. New seedlings and clones are being tested constantly. Bowden (3) classified and described these tetraploid clonal cultivars as *Lobelia* × *speciosa* Sweet (Canadian tetraploid group).

The descriptions of the 18 tetraploid cultivars have been written to conform to the articles and recommendations of the International Code of Nomenclature for Cultivated Plants (1980) and especially the instructions in Article 39 and Rec. 39A. Many kodachrome slides are available in my files. Numerous lobelia specimens listed in my earlier papers have been deposited in the Phanerogamic Herbarium of the Biosystematics Research Institute, Agriculture Canada, Ottawa (DAO).

The morphological characteristics of the 18 named cultivars are listed in Tables 1 and 2. The stems of all these clones are puberulous with dense short white hairs. In the last column of Table 2, the colours of the corolla-lobes were determined from the first edition of the Royal Horticultural Society

Table 2. Characteristics of racemes and flowers of 18 *Lobelia* cultivars.

Cultivar	Length of mature raceme (cm)	Mature sepal colour	Width of flower 3 corolla-lobes (cm)	Colour of corolla-lobes
Brightness	40-74	maroon, some green	3.0-3.5	blood red to orient red
Cherry Ripe	8-61	green and maroon	2.4-3.2	cherry; aged to rose red
Dark Crusader	13-23	deep maroon	2.0-2.3	ruby red; young fls. are redder.
Greensleeves	16-61	maroon	2.7-3.0	blood red to orient red
Red Plush	15-48	green and maroon	2.5-3.0	chrysanthemum crimson
Will Scarlet	19-31	deep maroon	2.5-2.9	blood red to orient red
Simcoe	18-54	green, some maroon	3.0-3.6	blood red to orient red; aged to crimson.
Toronto	20-49	green and maroon	3.1-3.8	chrysanthemum crimson
Oakes Ames	20-57	maroon; some green	3.2-3.6	blood red to orient red
Mexican Beauty	30-47	green	2.9-3.4	cardinal red; aged to chrysanthemum crimson
Ottawa	29-39	green and maroon	2.6-3.2	cardinal red; aged to chrysanthemum crimson
Canada	27-44	green and maroon	3.0-3.3	currant red to blood red
James Pringle	10-45	deep maroon	2.8-3.1	deep cardinal red
Ernst Benary	40-56	green and maroon	2.7-3.3	cardinal red; aged to chrysanthemum crimson
Leslie Laking	48-79	green	2.9-3.2	garnet lake (young); to beetroot purple; aged to deep lilac purple
Monroe Landon	27-59	green and maroon	2.8-3.4	doge purple; aged to royal purple
Hamilton Dwarf	12-20	maroon	2.0-2.8	blood red to orient red
Wisley	26-74	green and maroon	3.3-3.7	blood red to orient red

Colour Chart and the second edition was also consulted. Many of the corolla-lobe colours are the deepest tones shown on the colour charts and sometimes the colours are even more intense than the deepest tones of the charts.

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ALAN BUSH: Do you have any special overwintering techniques or do you receive a lot of snow cover?

ATHUR OSLACH: Our snow cover is not reliable, but in an average winter we will get snow. That is why I prefer not to move the plants in the fall. We mulch with straw in the fall. Put the straw on loose.

MICHAEL DODGE: Have you tried root cutting propagation? You would have more material available to you. Also, why are you not using *Lobelia cardinalis* 'Alba' or *L. syphilitica* 'Alba' to produce your whites?

ATHUR OSLACH: We are not using root cuttings. We have a large number of cultivars and produce them from rosettes. They produce anywhere from 7 to 8 rosettes per plant. We may use root cuttings with some of the better clones in the future. We have been into other colors and are just starting the white program.

PETER DEL TREDICI: I know that the diploid forms are short-lived in the garden; what about the tetraploids?

ATHUR OSLACH: The clones that we are working with, such as 'Wisley', 'Simco' and about 8 or 9 others, do not show the short-lived problem common to the species. We consider hardiness to be a more important problem for us in Canada.

PROPAGATION OF WILDFLOWERS

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The recent resurgence in popularity of herbaceous perennials in this country has prompted many growers to consider propagating native wildflowers for sale. Although many growers probably do not realize it, American natives have been a staple in perennial gardens for years. To name just a few, *Asclepias tuberosa* (butterfly weed), *Baptisia australis* (blue false indigo), the many *Liatris* species (blazing star), *Echinacea purpurea* (purple coneflower), *Lobelia cardinalis* (red cardinal flower) and *Phlox stolonifera* (creeping phlox) are all North American natives that have become so ubiquitous in perennial gardens that they are now thought of as perennials rather than wildflowers.

However, there are many other natives that deserve wider recognition and use by growers. There are two main reasons why more natives are not in greater use:

1) Image — Wildflowers have been looked upon as being only for specialty gardens that contain unusual habitats. With the increasing sophistication of the American gardener this idea is gradually being dispelled.

2) Economics — Although more nurseries are beginning to propagate native plants, the vast majority of wildflowers sold in this country are still collected from the wild. The reason is purely economic. It is almost always cheaper to buy a collected plant for resale than it is to propagate the same plant. Many species need several years to produce a saleable plant, and since there has always been a ready supply from the wild, nurseries have bought from collectors instead of propagating plants themselves. It is somewhat ironic, however, that a nursery that would not balk at propagating a Japanese species for two years before sale, will not consider propagating a native that needs a similar period of time.

Wild collection has often been criticized, and due to destruction of local populations, some states have even enacted laws preventing the export of certain species from their boundaries. Yet wild collection is not a simple issue. I feel that there are a number of common species that could be ethically collected from the wild on a sustained-yield basis without destruction of local populations if only collectors would do so. Other species, many of our native orchids for instance, need many years of growth before they reach blooming size, and

therefore collection of these plants in any number is likely to result in decimation of the population in a short period of time. The decision to collect should therefore be based on three factors: the rarity of the species in its overall range, the local abundance of the species at the collection site, and the length of time the species needs to regenerate the population to its former level after collection.

Faced with uncertainty as to whether the plants they are buying-in to sell have resulted in the decimation of a local population, and in response to the ever-growing public demand for propagated material, a number of nurseries are now beginning to propagate the wildflowers they sell. Propagation assures that no local populations have been destroyed, and selling plants that are propagated rather than collected is becoming a public-relations tool for the nurseries.

There is a wide range of practical (and often conflicting) information available on wildflower propagation. Our program at the New England Wild Flower Society has been geared towards producing economically-feasible propagation methods for the commercial nursery. What follows is a very basic outline of techniques used at our botanical garden, the Garden in the Woods. The methods used are similar to those for other herbaceous perennials, and thus allow wildflowers to be fit in to existing propagation schedules.

METHODS OF PROPAGATION

The first step in commercial propagation of wild flowers is to build up sufficient stock. At this time there is little alternative to buying-in collected material and lining the plants out in growing beds according to their cultural requirements. Once established, these beds will provide material for division, cuttings, and, most importantly, will allow for collection of fresh seed. Seed of many native species is not readily available. Furthermore, fresh seed of many species that is collected and sown while still moist is the best and sometimes the only method of germination.

SEEDS

Seeds of wildflowers tend to fall into two categories. These categories are based on successful germination rather than any published physiological categories. In the first category, seeds of these species must be sown immediately outdoors upon collection. Often included in this group are seeds that ripen within moist berries, seeds of wetland plants, and seeds bearing a small, white aril on their surface. However, there are seeds of other species that, although they appear to ripen in a dry state, should be sown immediately outside in

flats or seed beds or their germination will be delayed for a year or retarded altogether. Seeds of many of the Ranunculaceae, including *Hepatica*, *Coptis*, and *Caltha*, should be collected when ripe and sown immediately outside to remain there through the winter.

However, seeds of most species fall into the second category. These may be collected, dried, cleaned, and stored under refrigeration until the most convenient time for sowing within the existing propagation schedule. I divide seeds in the latter category into two groups:

The first group includes seeds that will germinate immediately upon sowing either inside a greenhouse or outside when temperatures are warm enough. These seeds can be sown outside in early spring or in a warm greenhouse in January. They can also be sown outside in the fall to germinate in the spring if so desired.

The second group includes seeds that need a period of moist-cold stratification in order to germinate. Also, included in this group are a number of species whose seeds may not definitely need a cold period in order to germinate, but whose germination seems to be better if given a moist, cold treatment. Seeds of this group are usually sown outside in the fall to germinate in the spring, but seeds may also be sown in flats and placed in a refrigerator for several months in order to overcome internal dormancy.

CUTTINGS

Many native plants are easily propagated by softwood stem cuttings taken in May, stuck in sand using a weak hormone powder (Hormroot #1, for example) under mist in a warm greenhouse. These will usually root in 3 to 5 weeks without bottom heat, but bottom heat will speed up rooting. Root cuttings are an especially good method for some species, and these are taken either in fall or spring depending upon the species. I usually use sand as a medium to avoid overwatering.

DIVISION

Many wildflowers can be lined-out in field beds and divided each year, or every other year, depending on rate of growth. I lean towards spring division simply because sizing of plants seems easier at that time, but fall division is successful with many species as long as heaving of the soil over winter can be avoided.

TISSUE CULTURE

Rapid conal multiplication of wildflowers is in its infancy, and much research needs to be done with this technique. There are several problems involving this method as applied to native plants. Firstly, many herbaceous perennials are difficult to disinfest, particularly those tissues growing below ground. Secondly the proper media for growth have yet to be defined.

Yet the potential for tissue culture is fantastic. In the case where a species can be propagated economically by conventional methods, it can be used to build up stocks of plants that will later be propagated by more economical methods. However, its real potential lies in its use for species that cannot at the present time be propagated economically by other means. For example, seeds of *Trillium* species normally take two years to germinate and approximately 3 to 5 years further growth to reach saleable size. It is, therefore, a good candidate for tissue culture propagation. Similarly, most of our native terrestrial orchids cannot be successfully propagated at this time, and research in tissue culture of this group is underway.

In conclusion, the following are lists of native plants and their respective propagation methods. Also included is a list of sources on wildflower propagation.

PROPAGATION METHODS FOR NATIVE PLANTS

SEEDS

Seeds of the following species should be *sown immediately* upon ripening. In most cases, the seeds should not be allowed to dry out before sowing. Germination in some species will take two years, even if freshly sown.

Asarum canadense (wild ginger)
Calla palustris (wild calla)
Caltha palustris (marsh marigold)
Clintonia borealis (blue-head lily)
Coptis groenlandica (goldthread)
Dicentra cucullaria (Dutchman's breeches)
Hepatica acutiloba (sharp-lobed hepatica)
Jeffersonia diphylla (twinleaf)
Sanguinaria canadensis (bloodroot)
Stenanthium gramineum (featherfleece)
Stylophorum diphyllum (celandine Poppy)
Trillium species (trillium)
Uvularia grandiflora (merrybells)
Xerophyllum asphodeloides (turkeybeard)

Seeds of the following species will germinate *without any cold treatment*. These can be sown outside in spring or in a greenhouse in late winter. They will also germinate perfectly

well in spring if sown outside in late fall.

Aletris farinosa (colicroot)
Aquilegia canadensis (wild columbine)
Arisaema triphyllum (jack-in-the-pulpit)
Ascelpias tuberosa; *A. incarnata* (milkweeds)
Baptisia australis (blue false indigo)
Chrysanthemum leucanthemum (ox-eye daisy)
Coreopsis lanceolata; *C. auriculata*
Echinacea purpurea (purple coneflower)
Epigaea repens (trailing arbutus)
Erigeron pulchellus (Robin's plantain)
Geranium maculatum (wild geranium)
Helonias bullata (swamp pink)
Liatris cylindracea; *L. punctata*; *L. pychnostachya*
Linnaea borealis (twinflower)
Mimulus (monkeyflower)
Monarda didyma; *M. fistulosa*
Polygala paucifolia (fringed polygala)
Rudbeckia hirta; *R. triloba*
Shortia galacifolia (oconee bells)
Tiarella cordifolia (foamflower)

Seeds of the following species need a period of *moist cold* in order to germinate. Also included in this list are species whose seeds may not definitely need a cold period for germination to occur, but who seem to germinate better with a cold treatment. Seeds of all species in this list can be allowed to dry out before sowing. Sow seeds outside in November or provide three months cold stratification in a refrigerator.

Anemonella thalictroides (rue anemone)
Aruncus diocus (goat's beard)
Aster spectabilis; *A. novae-angliae*
Chelone lyonii (pink turtlehead)
Cimicifuga racemosa (black cohosh)
Cornus canadensis (bunchberry)
Dicentra eximia (wild bleeding heart)
Eupatorium coelestinum; *E. fistulosum*
Gentiana clausa; *G. crinita*
Native grass species — *Andropogon*, *Sporobolus*, etc.
Hieracium aurantiacum (orange hawkweed)
Iris pseudacorus; *I. versicolor*
Lobelia cardinalis (red cardinal flower)
Rudbeckia fulgida var. *sullivantii* (perennial coneflower)
Sabatia kennedyana (plymouth gentian)
Sarracenia purpurea (pitcher plant)
Silphium perfoliatum (cup plant)
Solidago puberula; *S. sempervirens*
Trollius laxus (spreading globeflower)
Vernonia noveboracensis (ironweed)
Veronicastrum *virginicum* (Culver's root)

CUTTINGS

The following species are usually propagated by *softwood cuttings* taken in late May or early June.

Aster species — *A. spectabilis*, *A. novae-angliae*

Chelone lyonii (pink turtlehead)
Chrysogonum virginianum (green and gold)
Eupatorium coelestinum; E. fistulosum
Linnaea borealis (twinflower)
Mitchella repens (partridgeberry)
Monarda didyma; M. fistulosa
Phlox stolonifera; P. divaricata; P. ozarkana
Vernonia noveboracensis (ironweed)
Veronicastrum virginicum (Culver's root)

The following species may be propagated by root cuttings. The proper time to take the cuttings is listed next to the species.

Anemone canadensis (Canada anemone) — spring
Asclepias tuberosa (butterfly weed) — spring
Coptis gorenlandica (goldthread) — spring
Dodecatheon meadia (shooting star) — fall
Stokesia laevis (Stokes' aster) — fall
Viola pedata (bird-foot violet) — early spring

DIVISION

The following species are often propagated by division in either fall or early spring.

Acorus calamus (sweet flag)
Anemone canadensis (Canada anemone)
Calla palustris (wild calla)
Chimaphila umbellata (pipsissewa)
Clintonia borealis (blue-bead lily)
Cypripedium pubescens (yellow ladys-slipper)
Dicentra cucullaria (Dutchman's breeches)
Disporum lanuginosum (yellow mandarin)
Galax urceolata (galax)
Geranium maculatum (wild geranium)
Iris cristata; I. pseudacorus; I. versicolor
Podophyllum peltatum (Mayapple)
Sanguinaria canadensis (bloodroot)
Shortia galacifolia (oconee bells)
Vancouveria hexandra (inside-out flower)

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VOICE: How many cuttings were your getting from the butterfly root?

BILL BRUMBACK: You can cut the root into only a few sections. It used to be thought that you could not move that plant. However, it has been shown that you can cut them up into pieces and they will come back.

VOICE: What are the germination requirements for trillium seeds?

BILL BRUMBACK: Trillium is a two-year plant. Seeds need a cold period so that during the subsequent warm period the root will grow out. You then need another cold period to release the shoot inhibition. The leaf the first year will be a single leaf. By the third year you will see the three-leaf whorl.

PROPAGATION OF HERBACEOUS PERENNIALS BY ROOT CUTTINGS

MICHAEL H. DODGE

White Flower Farm
Litchfield, Connecticut 06759

Why propagate by root cuttings? It is a relatively cheap and simple way to propagate perennials and is the only way to propagate some cultivars asexually. In comparison to propagation by shoot cuttings, it is less costly because root cuttings do not require expensive humidification or misting systems and bottom heat is unnecessary. Many root cuttings will regenerate new plants without any added heat. Most commercially grown perennials are field-grown, mechanically harvested, and shipped bare-root. This facilitates the taking of roots as the plants are being prepared for shipping. For plants with thick, fleshy roots the sticking of roots can be mechanized. This year we installed Bouldin and Lawson equipment that allowed us to reduce the time it takes to stick 20,000 oriental poppy roots from 2 or 3 days to less than one full day. Paper cutters are used to trim soft rooted plants, such as phlox, which saves a considerable amount of time.

There are many plants that produce underground shoots which can be treated in the same manner as root cuttings (Tables 1 and 2). The main difference between the two is that underground shoots have preformed buds or bud initials which produce shoots readily in propagation, whereas roots have to develop buds. Hartmann and Kester discuss root bud development in their book, *Plant Propagation: Principles and*

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Practices (3), therefore I will not elaborate on the physiology and anatomy of propagation by root cuttings.

Source of roots. We use two field-grown sources for roots: 1) saleable plants, and 2) stock plants. Field-grown plants are superior to pot grown plants because in pots the roots are matted and twisted together. It is also difficult to tell in a pot-grown root ball the polarity of the roots.

1) Saleable plants. It has been the standard practice for us to remove a few roots for propagation at the time that plants are being shipped. As this is done with discretion it does not affect the plant in either its appearance or performance. The disadvantages of this method are: a) It slows down the shipping process; b) Not all plants flower the first year from root cuttings, therefore rogues can be propagated without us knowing it; and c) Propagation time is determined by harvesting/shipping times.

2) Stock plants. This has several advantages: a) Roots can be taken when it fits the propagation schedule; b) Rogues can be eliminated before propagation; and c) Some plants produce better roots for propagation from two-year-old plants, such as *Geranium cinereum* 'Ballerina' (2).

We are moving more to stock plants and may eventually only use this technique. We already do this on those kinds of plants that we sell in pots, such as *Anchusa azurea* cultivars and *Cynoglossum nervosum*.

A word of caution when planting stock from a plastic container. It is essential to trim the roots that ring the bottom of the pot, otherwise it will be very difficult to obtain straight roots. Plants from flats, ground beds, or peat pots are a better source.

Types of roots. As far as productivity in handling is concerned, there are two basic types of roots, those with thick fleshy roots, such as, oriental poppy, *Anchusa*, and *Cynoglossum*; and those with soft, flexible roots, such as, *Phlox*. Thick roots can be stuck in a preformed hole, permitting mechanization, while soft flexible roots need to be placed vertically in the soil and the soil brought up against the root.

Polarity. The majority of plants propagated by root cuttings will produce shoots only at the proximal (top) end of the root. The proximal end is the end closest to the crown of the plant. Therefore, it is essential to plant the root with the proximal end up. Otherwise the shoot will try to develop at the end buried in the soil, and if it does not rot before reaching the surface of the soil it will produce a mechanically weak plant which is hard to plant with an automatic planting ma-

chine. Many books on perennials or plant propagation recommend laying the roots horizontally so as to overcome the problem of polarity. We have found this to be impractical and again it is hard to plant a liner which has shoots at right-angles to the root. The practice of making a straight cut at the proximal end of the cutting and a slanting cut at the distal end is also too time consuming. With care and developing a routine of always repeating the same motions, such as always putting roots down in the same direction, the problem of "upside-down" roots can be overcome.

Time of year for taking roots. Many perennials can be propagated from roots at different times of the year. We do most of ours when it is most convenient, that is in the fall as the plants are being dug from the field. We start with oriental poppies in early September and finish with cooler stored phlox in late December or early January. Some exceptions to fall propagation mentioned by Hill (5) are *Primula denticulata* cultivars in March through May, and *Anemone pulsatilla* in June, July or August (6). *Geranium cinereum* 'Ballerina' is propagated at Blooms Nursery in England during February in outdoor frames (2).

Taking roots. When taking roots we remove the roots close to the crown. On a saleable plant we can take 3 to 10 roots without making it unsaleable. The roots are either snapped off or cut off with a sharp knife. Each root length can be cut up into suitable lengths, each section of which will produce a new plant. The second section of phlox roots are much thinner than the first and therefore we group more roots in each cluster. After taking roots we lay them down in a flat taking great care to lay them in the same direction. At this time the flats are put in plastic bags and placed in cold storage at 34 to 38°F until it is convenient to stick the roots. Root pieces can be kept in storage for several weeks without harming them. If storage molds develop we stick the roots immediately. We have not found it necessary to treat with fungicides.

One way to propagate rare plants that can be propagated by root cuttings, without disturbing the root system, is to pot the plant in a narrow pot with a large drainage hole and then plunge the pot in sand. One or more roots will eventually grow into the sand. These roots can be removed for propagation without disturbing the plant (5).

Length of root pieces. Root pieces are usually taken 2 to 3 in. long, although some fleshy roots, such as, *Anchusa*, can be taken with pieces ¼ in. long (5). This is valuable when roots are in short supply. We cut thin roots with a well-sharpened paper cutter. Thick, fleshy roots are fastened in bundles with

rubber bands spaced down the roots to facilitate cutting the roots into even lengths. The rubber bands are removed just prior to sticking the roots and it is at this time that most mistakes are made with putting roots upside down.

Methods for growing root cuttings. 1) *Individual pots.* We use Nu-pot 25's extensively. These are blow-molded pots with tops 2½ in. across and 3 in. deep and a tray to fit the pots. They are very convenient for mechanization. We have used peat pots in the past and we found that Fertil Pot #008 to be the best with Jiffy Pot #425 a fair substitute. Individual pots provide inventory accuracy and enable us to ship some crops directly to the customer with those items that grow too large in field production. Disadvantages of individual pots are the cost of the pot and the need to grow them in a heated greenhouse. It also takes longer to prepare a plant for field planting when it has been pot grown.

2) *Flats.* We have used wooden flats for years, but they break, rot, and need to be disinfected as they carry fungi, bacteria, and liverworts. We are replacing wooden flats as needed with rigid plastic flats. These are expensive initially, however they are unbreakable in normal use, and will eventually be more economical than wooden flats. The advantage of flats is that they are suitable for mechanization. Disadvantages are the initial high cost, the cost of disinfesting the flats, also the need for heated frame or greenhouse space.

3) *Multipots.* These are used extensively by some large wholesale growers for root cuttings. They are space efficient and can be mechanized, but they produce a very tight root ball because of the confined space. We cannot produce the quality of plant we sell with multipots.

4) *Frames.* Heated and unheated frames when used for direct sticking are usually very inefficient in terms of productivity of workers, and the sticking of roots is determined by the weather. They do require less heat than greenhouses, especially when well insulated. Another problem is the need to pasteurize the soil on a regular basis.

5) *Polyhouses.* Direct sticking in ground beds is used extensively at Walters Gardens which is said to be the largest perennial grower in the world. The advantage of this method is that it is a really high volume technique because roots can be packed in closely and the time needed to prepare the resulting plants for field planting is very short. The disadvantages are that ground beds have to be pasteurized and also it is back breaking work sticking roots in the ground.

6) *Field beds.* For large fleshy roots this can be a successful method. We don't practice this technique because we feel

that it is not reliable. New England weather is too unpredictable. A few years ago we had a winter we call the "freeze-dried" winter, where the top few inches of soil became totally void of moisture. This was due to a lack of precipitation, abundant sunshine, 10 to 20°F below zero temperatures and 30 to 40 mph winds. Many long established plants succumbed; outdoor root cutting propagation would have been a disaster.

Composts. One of the keys to successful root cutting propagation is that the compost must be able to hold moisture, but must also have perfect drainage. High nitrogen fertilizers should be kept to a minimum until good shoot and root systems have been developed. Our basic container compost contains per cubic yard the following:

8 cu ft peat moss
8 cu ft #2 vermiculite
8 cu ft coarse perlite
3 cu ft coarse sand
20 lb dolomitic limestone (aiming for a pH of 6.0 to 6.5)
1 lb double superphosphate (0-20-0)
1 lb Micromax trace element mixture.

For oriental poppies we add 3½ lb Osmocote (18-6-12) slow release fertilizer and for most other plants we add 1 pound of potassium nitrate. We add chelated iron to the soil for *Anchusa azurea* 'Little John', as an iron deficiency develops when we use our regular mix.

For outside beds or frames a compost of 3 parts peat moss, 2 parts grit (very coarse sand) and a 1 in layer of pasteurized loam — forked in — has been recommended by Blooms Nursery (2).

Sticking the roots. We try to get the proximal end about ¼ in below the surface of the soil. Roots sticking above the soil will dry out at the tip; this inhibits bud formation. Shoots produced from roots buried too deep will frequently rot before or after they break the surface of the soil. For thin roots we use two or more roots together which produces a larger crown. We have two basic techniques for sticking roots, based on the type of root.

1) Firm, fleshy roots: For either pots or flats we mix the compost mechanically and feed it to a flat-filling machine. The filled trays are passed by conveyor to a mechanical dibbler where holes are dibbled; then the flats proceed along a slow-moving conveyor where workers on either side of the belt put in roots. The holes and the roots have to be uniform otherwise the depth would be unacceptably inconsistent. The flats are stacked on wagons and transported to a growing house.

2) Soft flexible roots: We have not been able to devise a method for mechanizing the sticking of soft roots; only the mixing of the compost is mechanized. Flats are filled by hand, making a row of soil, putting down either clusters of roots against the soil and then putting in another band of soil; this is repeated until the flat is filled. Our fastest workers can stick a flat in six minutes, but an average worker takes 10 to 15 minutes. As we grow about 35,000 phlox a year this way we would really like to figure out a way to mechanize this operation.

Growing environment. 1) *Temperature.* Generally the faster a plant is produced, the warmer the initial temperature. A plant, such as *Catananche*, will produce new shoots in 2 to 3 weeks, whereas, phlox takes 3 to 4 months. We produce fast-growing plants at 50 to 60°F night temperature and 35 to 40°F for slow growers. Those items that are sold directly from a pot to a customer are the faster growing types, and those that are planted in the field are the slower growers.

2) *Watering and fertilizing.* Composts are kept on the dry side and liquid fertilizer is not applied until new roots and shoots have developed.

3) *Pests and diseases.* Roots decay quickly if the soil is kept too wet. If an area of disease starts it can usually be stopped with a drench of a broad spectrum fungicide, such as Banrot.

Aphids are the worst enemy of emerging shoots because they can cause severe distortion of the new shoots. Prevention, with a regular spray program including an insecticide, is recommended.

4) *Light.* Light is unnecessary until the shoots begin to emerge. We frequently stack flats of root cuttings and cover them with plastic when greenhouse space is short. A careful watch must be kept, for once the shoots begin to grow the flats must be spread out. After the shoots emerge they should be placed in bright light to prevent etiolation which weakens the shoots.

What factors control a plants ability to regenerate from root pieces? This was discussed by Heuser (4) at the IPPS meeting in 1977 and is also covered by Hartmann and Kester (3). It appears that it is controlled by hormone concentrations. Cytokinin concentrations at the proximal end have been found to be higher than normal in roots developing buds. Auxins, which are normally found in roots, prevent bud formation and therefore their affects have to be "swamped" by higher cytokinin levels. I am not aware of any studies to find out if cytokinin treatments can stimulate rooting on plants that do

not normally initiate buds. It would be an interesting study for a research organization.

Table 1. Perennials that can be propagated by underground shoots.

Achillea spp.	*Macleaya cordata*
Aegopodium podagraria	*Mentha* spp.
Anthemis spp.	*Monarda* spp.
Artemesia spp.	*Physalis alkekengii*
Asperula odorata	*Polygonatum* spp.
Aster spp.	*Polygonum* spp.
Campanula spp.	*Rodgersia* spp.
Chrysanthemum spp.	*Sanguinaria canadensis*
Convallaria majalis	*Saponaria officinalis*
Coptis trifolia	*Schizostylis coccinea*
Coreopsis verticillata	*Uvulara* spp.
Geranium spp.	*Yucca* spp.
Helianthus spp.	Also many ferns, grasses and bamboos.
Lysimachia spp.	

Table 2. Herbaceous perennials that can be produced from root cuttings.

Acanthus spp.	*Geranium* spp.
Ajuga spp.	**Gypsophila* spp.
Anemone spp.	**Helleborus* spp.
**Arabis* spp.	*Lobelia* spp.
Anchusa azurea	*Matthiola tristis* var. *vallesiaca*
Asclepias tuberosa	*Mertensia maritima*
Brunnera macrophylla	*Morisia monanthos*
**Campanula* spp.	*Papaver orientale*
Catananche caerulea	*Phlox decussata*
Centaurea spp.	**Phlox subulata*
**Crambe* spp.	*Pulsatilla* spp.
Cynoglossum nervosum	*Primula denticulata*
**Dicentra* spp.	*Primula mistassinica*
**Dictamnus albus*	*Scabiosa caucasica*
**Drosera* spp.	**Senecio pulcher*
Echinacea purpurea	*Stokesia laevis*
Echinops spp.	*Symphytum* spp.
**Echioides longiflorum*	**Taraxacum albidum*
**Epilobium angustifolium*	**Trollius* spp.
Erodium spp.	*Verbascum* spp.
Eryngium spp.	*Viola pedata*
Gaillardia spp.	**Weldenia candida*

Those marks with an asterisk (*) have been reported in various lists but I have no experience with them. I am somewhat doubtful that some of these can, indeed, be propagated by root cuttings; however, if I get the opportunity I will certainly try them.

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CLONAL DIFFERENCES IN PROPAGATING CONIFERS

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At the University of Connecticut we have been working on the development of new forms of dwarf conifers. The dwarf plants we develop are not the result of hybridization, but are seedlings obtained from mutations found on various conifers. These mutations, called witches'-brooms, produce seed that yield plants which are 50% normal and 50% dwarf.

We have 20,000 seedlings at our nursery that range in age from 2 to 21 years. Most of these seedlings are from witches'-brooms found on: two *Larix* species, one *Picea* species, one *Tsuga* species, and six *Pinus* species.

Although we could obtain dwarf shrubs by merely grafting scions from the witches'-brooms, we prefer to collect and grow seeds from the brooms. We do this because with seedlings we obtain a highly variable population from which we could select some unique forms.

Although the variation among seedlings obtained from witches'-broom is, most likely, similar to the variation obtained with normal seedlings, the compact growth of the dwarf shrub makes it easier to discern a short-needled plant from a medium or long-needled plant or a blue-green plant from a green plant. Other variations that are not easily noticed on a normal seedling become more obvious on the dwarf. As a consequence, the dwarf shrubs obtained from witches'-brooms offer a wide range of variation in growth patterns.

Our objectives in this project are to select, from these progenies, shrubs that are aesthetically pleasing and different from those currently available. We evaluate them for at least 6

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Our objectives in this project are to select, from these progenies, shrubs that are aesthetically pleasing and different from those currently available. We evaluate them for at least 6

to 10 yeárs and then introduce them to the trade for propagation and dissemination.

Another major objective is to develop methods of rooting these difficult-to-root species. Our current approach is to establish highly select groups of young plants as sources of cuttings. The plants selected must exhibit, by their third or fourth year, growth characteristics that show promise.

Earlier work with white pine witches'-broom seedlings showed excellent rooting of 4 year old plants. On 5 year old plants, however, there was a significant reduction in the percent rooted. By initially taking cuttings from selected young seedlings and by repeating this in subsequent years, i.e. by taking cuttings only from young rooted cuttings, we hope to produce a source of cuttings that will root at fairly high percentages. If we had to wait for the 6 to 10 years required to select a plant to be named, its cuttings would most likely root at very low percentages.

Tables 1 through 7 illustrate clonal differences and, in some instances, progeny differences, on jack pine, white pine, Norway spruce, Canadian hemlock, and eastern larch cuttings rooted under mist.

Cuttings of jack pine (*Pinus banksiana*) were collected on March 16 from four 6-year-old seedlings. All cuttings were treated with 5000 ppm K-IBA and inserted into flats of granular Styrofoam and sawdust (1:1, v/v) or granular Styrofoam and peat (1:1, v/v). Rooting percentages were recorded on July 9.

Rooting was better in the styrofoam and sawdust mixture (Table 1). Clones 23 and 54 had 60% and 80% rooting, respectively, whereas clone number 21 did not root. Subsequently growth of the potted cuttings was fairly rapid and required more frequent repotting than the other pine species.

Table 1. Effect of rooting medium on the rooting percentages of jack pine (*Pinus banksiana*).[1]

	Rooting percent of clone numbers			
Medium	12	21	23	54
Styrofoam and peat (1:1, v/v)	0	0	20	20
Styrofoam and sawdust (1:1, v/v)	40	0	60	80

[1] All cuttings taken from 6 year old plants.

Cuttings from three 4-year-old white pine witches'-broom progenies were taken on December 23 and treated with 4000

ppm IBA in talc and inserted into flats containing supercoarse perlite, Rooting percentages were recorded April 18.

There were differences in rooting percentages not only among clones, but also among progenies from different witches'-brooms (Table 2) Nine of 10 Clinton clones rooted while only 5 of 10 Parsonage clones rooted.

Table 2. Clonal differences in rooting percentages of cuttings taken from 3 white pine (*Pinus strobus*) witches'-broom progenies.

	Clinton witches'-broom clones									
	9	19	29	21	22	23	29	37	46	47
Percent rooted	80	100	100	40	60	40	0	100	100	100
	Parsonage witches'-broom clones									
	1	2	3	4	5	6	7	8	9	10
Percent rooted	0	100	0	0	60	30	0	0	40	40
	Hillsboro witches'-broom clones									
	1		2	3	4	6	8	9	16	45
Percent rooted	0		0	60	50	0	100	60	100	100

Cuttings from six 7-year-old Pomfret Norway spruce witches'-broom clones were collected on January 22 and treated as follows:

a) Submerged for 24 hours in a 10% sucrose solution plus 8000 ppm IBA in talc
b) Submerged in 10% sucrose
c) 8000 ppm IBA in talc
d) Control

Rooting percentages were recorded on May 20 and were highest on cuttings treated with sucrose plus IBA (Table 3). Treatments containing sucrose induced higher rooting percentages than the treatments lacking sugar. There were sharp clonal differences among the six clones.

Table 3. Effects of sucrose and hormone treatment on the percentage rooting of 6 Norway spruce (*Picea abies*) witches'-broom clones[1].

	Percent rooting of Pomfret witches'-broom clones						
Treatment	2	9	14	17	18	20	Avg.
10% sucrose + 8000 ppm IBA	0%	0%	0%	75%	100%	100%	54.8%
10% sucrose	0	0	25	75	75	75	41.6
8000 ppm IBA	0	0	0	50	25	0	12.5
Control	0	0	0	50	0	25	12.5

[1] All cuttings from 7-year-old plants.

All cuttings from forty 7-year-old West Street Norway spruce witches'-broom clones were collected on November 17, treated with 1000 ppm IBA in talc, and inserted into flats of peat and sand (1:1, v/v). Rooting percentages were recorded on March 16.

Clonal differences were apparent with 9 out of the 40 clones having 100% rooting. Thirty-one or 77% of the clones had rooting percentages that were 50% or greater, while 9 or 23% of the clones did not root (Table 4).

Table 4. Variation in rooting among 40 Norway spruce (*Picea abies*) witches'-broom clones[1].

	Rooting percent groups		
	0	50-75	100
Number of clones rooting	9	22	9

[1] All cuttings taken from three year old plants.

Two Canadian hemlock witches'-brooms progenies were quite different from one another. The Woodstock progeny consisted mainly of low shrubs with spreading horizontal branches, whereas the plants of the Hills progeny were oval and had vertically oriented branches.

Cuttings were collected on January 4 from six 5-year-old and from six 12-year-old Woodstock clones. With two-year-old wood at the bases, all cuttings were dipped into a solution of 20,000 ppm IBA in alcohol and water then inserted into flats of peat and perlite (1:1, v/v). Rooting percentages were recorded on May 10. Rooting of most all Woodstock clones was successful when taken from 5-year-old plants (Table 5). Those taken from 12-year-old plants, however, exhibited greater clonal differences and lower rooting percentages.

Table 5. Clonal differencees in rooting percentage of cuttings taken from one Canadian hemlock (*Tsuga canadensis*) witches'-broom progeny.

	Rooting percentage of Woodstock witches'-broom clones					
Clone age (yr)	1	2	3	4	5	40
5	100	100	80	90	70	40
12	0	60	80	40	0	20

All of the clones among the Hills hemlock progeny rooted 100%. The cuttings were collected from nine 5-year-old clones on January 4. With 2- or 3-year-old wood at the base, the cuttings were dipped into a solution containing 20,000 ppm IBA in alcohol and water and inserted into flats containing

peat and perlite (1:1, v/v). Rooting percentages were recorded on May 10.

Table 6. Clonal differences in rooting cuttings taken from one Canadian hemlock (*Tsuga canadensis)* witches'-broom progeny.

	Rooting percentage of Hills witches'-broom clones[1]								
	1	2	3	4	5	6	7	8	11
Rooting percentage	100	100	100	100	100	100	100	100	100

[1] All cuttings taken from 5 year old plants.

Cuttings of eastern larch, *Larix laricina*, were collected from four 8-year-old witches'-broom clones on June 13 and divided into two groups. Group 1 was treated with 10,000 ppm IBA in talc plus captan while Group 2, the control, was treated only with Captan. Both groups of cuttings were inserted into flats containing granular Styrofoam and peat (1:1, v/v). Rooting percentages were recorded on October 27.

Responses to hormone treatment illustrate no significant differences (Table 7). Only one of the four clones had a low level of rooting in both treatments. The results show that eastern larch can be rooted from 4-year-old witches'-broom seedlings.

Table 7. Effects of hormones on the percentage rooting of eastern larch (*Larix laricina*) witches'-broom clones.[1].

	Rooting percentages of Newport witches'-broom clones:			
Treatment	7	15	17	29
10,000 ppm IBA + Captan	50	30	80	40
Captan (control)	60	0	50	70

[1] All cuttings taken from 8-year-old plants.

SUMMARY

It is not surprising that witches'-broom seedlings exhibit so much clonal variation. Because the rooting of most of the conifers discussed here is difficult, it pays to spend the time searching for those individuals which are more easily rooted. Once those seedlings are identified as being good rooting clones, they should be perpetuated by the repeated collection of cuttings from rooted cuttings so as to maintain them as close to the juvenile stages as possible.

Not only will the rooting percentages be greater, but the subsequent growth of the potted cuttings will also be greater

than on cuttings taken from older plants.

WESTERN NORTH CAROLINA HEMLOCK SEEDLING PRODUCTION

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INTRODUCTION

To understand why we grow hemlock seedlings the way we do in Western North Carolina (WNC), you need to know something about us. Although we are nearly as far south as Los Angeles, WNC has nursery production areas in hardiness zones 5, 6, 7 and 8. Such dramatic differences in climate in a relatively small area are due to elevation and slope. Most of our hemlock seedling production is in the Blue Ridge and Smokey Mountains at elevations between 1500 and 3500 feet. Most hemlock field production is in Zone 7 while most seedlings and transplants are grown in Zone 6.

The mountains contribute to regular rainfall, abundant high quality irrigation water and morning fog, almost daily during mid-summer and early fall, in the coves and valleys where we grow hemlock seedlings. Our southern latitudes give us a frost-free growing season from about May 10 to October 10. This very closely parallels the period of active growth for above ground portions of hemlock seedlings. The southern mountains have not been glaciated or inundated so we often are faced with old, weathered clay soils.

Bed Preparation. The standard WNC hemlock seedling production unit is the 400 sq ft (4 × 100 ft) raised bed. Soil samples are taken in mid to late summer. If the production area is in sod or perennial weeds, the area is sprayed with Round-up.

When soil test results return, about a month later, needed fertilizer is broadcast. WNC soils are usually very low in phosphorus, calcium, magnesium, and pH. We like to lime with dolomite to a pH of 5.5 to 6.0 and achieve a calcium to magnesium ratio of about 3 to 1. Occasionally, we are unable to achieve the desired levels by liming. When this happens, we use sulfur to lower the pH, gypsum to raise calcium without raising pH and either magnesium sulfate or olivine to raise magnesium levels. Treble superphosphate (0-44-0) is most often used to raise soil phosphorus levels to the high reading we

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seek. Where soils are too heavy, i.e., they have poor internal drainage, soil amendments such as pine bark are added.

After amendments, fertilizer and lime have been added, soils are subsoiled, plowed and disced, or subsoiled and rotavated to provide the required seedbed. Bed forming equipment is then used to throw a bed about 8 in. high in the center and sloping to a height of 6 in. at the sides. The center of the bed will settle so that beds are nearly level by the end of the first year. Drainage ditches to carry excess irrigation and rainfall are formed at this time. Distance between beds is determined by topography and equipment needs.

Within 2 weeks of bedding, plastic is pulled over the beds and they are fumigated. Most growers use methyl bromide at the rate of 2 lb per 100 sq ft in October or November when it's easiest to obtain the required soil moisture and temperature conditions for effective fumigation. The plastic remains in place until shortly before seed sowing. During the winter, locust stakes are driven along the sides of the bed to support shade in the spring.

Planting. Both northern and southern provenance seed are sown. Northern seeds require at least 60 days stratification while local seeds require 90 days. Few seeds, however, are artificially stratified. During the late January or early February thaw, plastic is removed from beds and seeds are sown by broadcasting at a rate sufficient to achieve a seedling density of 35 to 50 plants per sq ft. Seeds are immediately covered with about ½ in. of Canadian spaghnum peat and beds are compacted using a lawn roller. Black polypropylene shade cloth is next laid on the beds and secured to prevent wind erosion of the peat.

The First Year. In mid-April, about dogwood flowering time, shade cloths are raised to 2 to 4 in. above the bed surface but secured at the soil surface along the edges to prevent bird damage to emerging seedlings. At this time, irrigation begins, with regular light irrigation employed to keep the seeds and peat from drying out. Once seeds have germinated, irrigation time is increased with the days between waterings increased so that seedlings gradually harden off. Adequate rainfall usually occurs so that regular irrigation is not needed until June.

The percent shade employed depends upon elevation and slope. Above 2000 ft, 30% shade is used while below 2000 ft 47 to 55% shade is best. Growers located at near 2000 ft use 30% shade on north or east facing slopes with 47 to 55% shade on south or west facing slopes. Once germination has finished, 10 to 14 days after the first seedlings emerge, the shade cloth is raised to about 2 ft and secured with as little sag as possible.

Supports need to be adjusted during the season as shadecloth stretches.

Four to 6 weeks after germination, the initial nitrogen fertilizer is applied. If the high phosphorus and moderate potash levels sought are already present in the soil, only nitrogen is needed. Our research has shown equivalent response to sulfur-coated fertilizers, ammonium nitrate, and fertilizer solutions. Sulfur-coated, 3-month release complete fertilizers are broadcast at the rate of ½ lb actual nitrogen per 400 sq ft bed, e.g., 21-6-12 is applied at the rate of 2⅜ lb per 400 sq ft. Growers using ammonium nitrate apply it every two weeks at the rate of 0.1 lb actual nitrogen (4.8 oz. of 33.5-0-0) per 400 sq ft for a total of 5 applications.

Granular fertilizers should only be applied to dry foliage. Granules are then swept off foliage with a broom and at least ¼ in. of irrigation water is applied.

Growers using fertilizer solutions feed weekly through their irrigation system. The first application is approximately 50 ppm nitrogen which is gradually increased to 200 ppm by mid-July. Urea (45-0-0) is the most common nitrogen source but many soluble fertilizers are used. Fertigators always irrigate a little first, fertilize, then irrigate long enough to flush the lines and wash any fertilizer solution into the soil.

The last fertilizer application for fertigators and those using ammonium nitrate will be about 6 weeks before the average first frost date to help induce hardening. Depending on elevation, the last application is between July 21 and Labor Day.

Beginning about a month before first frost, both irrigation frequency and duration are reduced in an attempt to slow growth and harden plants. Shade cloth is removed by mid-September in most nurseries but nurseries in warmer areas may wait until as late as October 1. Shade cloth is not removed from the field however. If an early frost threatens, shade is pulled over the bed and irrigation turned on from the time frost starts to form until well after sunrise.

The 1-0 seedlings should go dormant naturally. Even though hemlocks are supposed to withstand −35° F, these small seedlings cannot survive the freeze-thaw cycles of a WNC winter. The regular occurrence of frost heaves make mulching essential to prevent heaving of seedlings and the subsequent desiccation and death of roots. Standard practice has been to apply an organic mulch in late November to early December. The organic mulch is held in place by shade cloth, pea netting, or conifer boughs. Mulch is carefully removed before temperatures warm consistently in the spring, generally

mid-March to early April, depending upon elevation.

We estimate the cost of organic mulch per bed is about $16.00. Organic mulches have many problems, among which are poor moisture control, harboring pests (weed seeds, insects, rodents, and disease), poor light penetration, and labor costs. Research with spun-bonded polymers last winter left us the hope that Reemay, a spun-bonded polyester manufactured by DuPont, may solve some of these problems at a cost of $11.50 per bed. We lost no plants with any of our mulch treatments; however, hemlocks exhibited a yellow frost-burn when uncovered from Reemay mulching. This color change occurred the last week before uncovering. The plants "greened-up" shortly after spring fertilization but were significantly shorter in June. By the end of the season, the stunted plants had caught up (Table 1). We're continuing this work to see if we can manage Reemay to avoid the early season yellowing and growth reduction.

Table 1. Effects of mulch materials on growth of one year old hemlock seedlings.

Mulch material	Height (in.)	
	6/20	10/1
Organic mulch	5.8	13.5
Reemay - 1 layer	4.9	12.8
Reemay - 2 layers	5.0	13.1

The Second Year. When mulch is removed, about half the growers shade their 2-0's. The others leave them unshaded. Shade-grown plants will be a more attractive, darker green color but show no difference in performance otherwise. Growers using shade will keep shade in place until the fall hardening period.

Most growers apply a granular fertilizer at the rate of one pound of actual nitrogen per 400 sq ft before bud break in the spring. Although sulfur-coated fertilizers and ammonium nitrate are still favorites, many growers are using diammonium phosphate (DAP, 18-46-0) at the rate of 5½ lb per 400 sq ft because they feel they get better cool season growth with DAP. Since bud break occurs from late April to mid-May, growers have ample time to fertilize after uncovering before bud break.

Eight to 10 weeks after bud break in lower elevations, 2-0 seedlings are fertigated weekly, or ammonium nitrate is applied every 2 weeks until 6 weeks before first frost.

Pest Management.

Insects. The only consistent insect problem we see is white grubs. Land preparation and fumigation takes care of them with 1-0's. We have had good results with Oftanol and Proxol with fall and spring applications. Diazinon has provided variable results depending on the species of grub and time of application.

Diseases. Second year seedlings, 2-0's, have more disease problems than 1-0's, probably due to the fact that a vigorous bed of 2-0 hemlock seedlings shades itself so that the base of the plants may not dry out for days at a time. Hemlock rust generally shows up as flagging and "rat-tailing" of twigs with the first flush of growth in spring. Ferbam or carbamate sprayed at 10 to 14 day intervals is an effective control.

Aerial *Rhizoctonia* symptoms will usually first show as a roughly circular group of plants turning yellow and appearing to wilt. The circle widens rapidly under warm moist conditions with plants on the interior turning light golden brown and dying. Benlate sprayed at 7 to 10 day intervals with enough pressure to penetrate to the base of the plants and thoroughly coat the surfaces has worked best for us.

Weeds. Weeds are the number one pest of hemlock seedlings. We have done extensive tests to screen herbicides for efficacy and phytotoxicity. We have had damage from Roundup, Surflan 75W, Simazine 80W (Princep) and Goal 2E. We've safely used Devrinol 5G and 50W, Enide 90W, Goal 1.6E, Fusilade, Kerb, OH-II, Poast, and Ronstar 2G.

In WNC, most growers use no herbicide beyond fumigation on 1-0 hemlock. Where weed seed contamination exists prior to seed germination, 1 pint of Goal 1.6E per acre may be used safely until the first seedling hemlock emerges. If weed seed contamination shows after germination, hand weeding followed by Devrinol 50W at 4 to 6 lb active ingredient per acre is used.

On 2-0's Goal 1.6E is used before bud swelling. Any application after mid-April may result in phytotoxicity below 3000 ft. rates vary from 5 pints to 5 quarts per acre with 1 gallon per acre being most common. One gallon per acre gives 10 to 12 weeks of good control. By then a healthy crop of 2-0 hemlocks at 35 to 40 plants per sq ft will out-compete most weeds.

PROPAGATION OF *TSUGA CANADENSIS* CULTIVARS: HARDWOOD VERSUS SOFTWOOD CUTTINGS

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REVIEW OF LITERATURE

According to the literature, the main factors affecting the rooting ability of *Tsuga canadensis*, the Canada hemlock, are the time of year when the cuttings are taken and the type and concentration of auxin used. With regard to proper timing, the literature is ambiguous. Thimann and Delisle (12) had success with rooting both the species and the cultivar Pendula in October and December. Deuber (3) had good success rooting cuttings of the species in November, and Jenkins (9), in reporting the works of nurserymen, variously recommended March, July, December, and August. In 1941, Doran (4) reported success in rooting cuttings from a species plant as well as the cultivars Pendula and Minuta at all times of the year, except early summer. In a later work (5), with the species, he narrowed his recommendation down to any time from mid-August to late January. Swartley (10) recommended February as the optimal time, provided bottom heat was available. In 1984, Swartley (11) modified this recommendation to say flatly that, "the date of taking the cuttings does not seem to be at all critical . . ." Data presented by other authors does not support this lack of specificity. In a 1971 study on an unnamed semi-dwarf hemlock cultivar, Flint and Jesinger (6) came to the conclusion that cuttings taken January through April were comparable with each other and superior to those taken July through October. The author's own research results (2) with 'Pendula' indicated that summer softwood cuttings under mist rooted as well as winter hardwood cuttings, and always better than those taken in the early fall. This paper expands my earlier research to include 8 different clones of *Tsuga canadensis* and focuses solely on the effect of the time of year when cuttings are taken on their ability to form roots.

MATERIALS AND METHODS

All cuttings consisted of wood in its first year of growth, from 2 to 8 months old except for 'Minuta' and 'Pygmaea' which contained 2-year-old wood. The cuttings were taken at 4 different times of the year: 14 July 1980, 1 January 1981, 10 December 1984, and 2 July 1985. In all cases the cuttings were taken and stuck on the same day they were collected. The cuttings varied in length from 1 to 5 in., depending on the

cultivar. Eight different individuals of *T. canadensis* growing at the Arnold Arboretum were experimented with: a species tree (50 ft high), 'Ashfield Weeper' (902-69), 'Bradshaw' (634-48), 'Cole' (12-80), 'Minuta' (1068-62), 'Nana' (507-62), 'Pendula' (1514-2) and 'Pygmaea' (955-70-A). In addition, a 120 year old specimen of Sargent's weeping hemlock ('Brookine'), (1), growing outside the Arnold Arboretum, was used.

The lower third of each cutting was stripped of its needles and was quick-dipped for 5 sec in a 1% IBA solution (IBA dissolved in 50% ethanol). In an earlier study (2) 1% IBA proved to be the most effective concentration for inducing roots and was selected for this study.

Following the auxin treatment, the cuttings were inserted into a rooting medium consisting of fine sand and medium perlite (1:1,v/v). Cuttings taken in July were placed under intermittent mist (2½ sec every 2½ min during daylight hours) in a greenhouse at ambient temperature. Cuttings taken in January were stuck in sealed, polyethylene covered frames in a greenhouse with a minimum temperature setting of 55°F (7). In both cases, mist as well as polyethylene, the cuttings received constant bottom heat of 70°F. The cuttings were evaluated for rooting after 4 months. No attempt was made to rate root systems. The fact that there was little difference in the survival rate of well-rooted versus poorly-rooted cuttings also argued against the value of quantifying the root system.

RESULTS

Only in the case of 'Pygmaea' did the summer cuttings root better than the winter cuttings (Table 1). In the case of the two weeping hemlocks, 'Pendula' and 'Brookline,' the summer and winter cuttings both rooted at 50%. With the other 6 clones the winter cuttings all showed superior rooting.

In attempting to apply these results to nursery practice, it should be kept in mind that the softwood July cuttings were potted up in November and passed the winter in cold storage, while the hardwood January cuttings were not potted up until April and received no chilling period. As a consequence of this different timing, the summer softwood cuttings made excellent growth the spring following rooting, while the hardwood winter cuttings made little or no new growth. These weak hardwood cuttings did not really grow until the second spring following rootings. This confirms the observation of Gray (8), who noted that two-thirds of December-rooted cuttings failed to grow out the following spring. Thus, a difference of six months in the time of taking cuttings resulted in the loss of a full year's growth. The softwood cuttings offer a further ad-

vantage in that they require no supplementary heat, while the hardwood cuttings required an ambient temperature of 55°F as well as bottom heat throughout the winter.

Table 1. Rooting behavior of hardwood versus softwood cuttings in selected cultivars of *Tsuga canadensis*.

Cultivar	Number of cuttings rooted	
	July[1]	January[2]
Control (Species 50 ft. tree)	3/10	6/10
'Ashfield Weeper' (902-69)	8/10	10/10
'Bradshaw' (634-48)	0/10	1/10
'Pendula' ('Brookline' original plant)	5/10	5/10
'Cole' (12-80)	5/10	10/10
'Minuta' (1068-62)[3]	12/20	15/20
'Nana' (507-62)	4/10	10/10
'Pendula' (1514-2)	7/10	7/10
'Pygmaea' (955-70-A)[3]	19/20	17/20

[1] Number of cuttings that rooted out of 10 cuttings stuck 14 July 1980; treated with 1% IBA; placed under mist.

[2] Number of cuttings that rooted out of 10 cuttings stuck 1 January 1981; treated with 1% IBA; placed under polyethylene tent.

[3] In the case of 'Minuta' and 'Pygmaea', summer cuttings were taken on 2 July 1985 and winter cuttings on 10 December 1984. Also, because of the small size, cuttings consisted of 2-year-old wood.

DISCUSSION

When looking at the complex equation of *profitability*, it is important to consider the issue of *survivability* of cuttings along with their *rootability* in deciding when to take cuttings. It may also be that by sticking the softwood cuttings in an outdoor Nearing frame, as the late Don Smith did (11), one might get better rooting results than this author did under mist.

In conclusion, every clone of *T. canadensis* behaves differently and needs to be investigated individually in order to determine the most effective time of year for taking cuttings. The only point that needs to be stressed is that softwood cuttings of *T. canadensis*, and perhaps other conifers, might well prove to be the most economical way to produce healthy plants.

CUTTINGS VERSUS GRAFTS

While most propagators would agree that cuttings are the preferred method of propagation when it comes to dwarf conifers, there are still a number of nurseries that graft *T. canadensis*. A large part of the reason for this is that grafted plants reach saleable size much more quickly than rooted cuttings. While this is understandable from an economic point of view,

it is unconscionable from a horticultural viewpoint, given the ease with which hemlocks can be rooted.

The data in Table 2 shows clearly that hemlocks are no different than apples in that the rootstocks can dramatically affect the height growth of the plant. Grafted plants of 'Cole' were three times taller than rooted cuttings after 4 years, and grafts of 'Nana' were over five times the height of the rooted cuttings after 4 years. This phenomenon has been noted by many propagators in the past, but for dwarf conifers it has seldom been documented with hard data.

Table 2. The effects of cuttings -versus- grafts on the growth rate of *Tsuga canadensis* cultivars (Cole and Nana).

'Cole' (AA 12-80)	
6 grafts (March 1981)	9 cuttings (January 1980)
Av. height (June 1984): 18 cm Av. width (June 1984): 25 cm	Av. height (June 1984): 6 cm Av. width (June 1984): 21 cm
'Nana' (AA 507-62)	
5 grafts (March 1981)	9 cuttings (July 1980)
Av. height (June 1984): 51 cm Av. width (June 1984): 64 cm	Av. height (June 1984): 10 cm Av. width (June 1984): 25 cm

In the case of certain dwarf conifers, then, mutations in the root system may be as much a part of the reason for the slow growth and congested habit as mutations in the shoot system. No doubt, a good deal of the confusion that is endemic to dwarf conifer nomenclature has to do with the differences in appearance that a cultivar can have depending upon whether it was grafted or rooted.

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Thursday Morning, December 12, 1985

The Thursday morning session convened at 8:00 a.m. with Everett Emino serving as moderator.

OVERWINTERING LINERS IN A WELL-WATER HEATED STORAGE STRUCTURE[1]

JAMES R. JOHNSON[2]

Cumberland County Agricultural Extension Service.
R.D. #1, Morton Avenue
Millville, New Jersey 08332

Abstract. A quonset nursery overwintering structure was built using a floor which was heated with 55 to 55.5°F well water as the heat source. The structure was covered with milky-colored, air-inflated polyethylene.

Medium temperatures during two study periods dropped only to 29°F with a typical minimum difference of 2.1° over a normal unheated overwintering structure. Preliminary liner observations showed some benefit with *Euonymus alata* 'Compacta' and *Rhododendron* 'Hino Crimson', but none with *Ilex crenata* 'Hetzii' which was successfully overwintered in both structures.

REVIEW OF LITERATURE

Polyethylene covered structures have been used successfully to prevent desiccation of overwintered nursery stock and reduce temperature fluctuation (1) for many years. The absolute cold that roots experience is also a controlling factor to successfully overwinter plants. In an effort to maintain higher temperatures, the use of air-inflated double milky polyethylene has been shown to be beneficial (5). While killing temperatures for many plants do not occur until 23°F (2), it has been shown that young roots can be injured at 27°F (6). Since temperatures of the growing medium can easily drop below these injury levels even in storage structures, an overwinter-

[1] Supported by a grant from the New Jersey Association of Nurserymen.
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ing house was designed to heat the medium using well-water to heat the floor of the structure (3). This offered some opportunity to protect plants having little root hardiness (4) and also opened the possiblity of overwintering liners.

METHODS AND MATERIALS

A 14 × 96 ft quonset overwintering structure was built at the South Jersey Research Center in Centerton, New Jersey, following New Jersey Plan 153 (Figure 1). A 6 in. bed of crushed stone was placed on the floor of the structure covering a ¾ in. polybutylene pipe network and header system (Figure 2). The pipes were spaced to give 3, four-run loops which terminated in a double-header return system designed to give equal flow throughout the entire network. Water which enters the system and passes through the closest loop must return by going across the house and back again. In a similar manner, water which travels across the house to the last loop will also return across the house. In either case, the length of travel, hence the friction path, is the same giving equal flow to all floor loops. Water was supplied from a 75 ft deep, 4 in. well and returned to a 1¼ in. well 70 ft deep, and monitored with a water meter. Temperatures in the well-water heated storage (WWS) structure, and a similarly constructed normal storage (NS) structure with a crowned, black polyethylene covered (non-heated) floor, were monitored with a Campbell Scientific 21X Micrologger.

Liners were produced in #18 cell trays (10.5 × 21 × 3.5 in.). Each cell measured 3 × 3 × 3.5 in. and they were monitored with thermocouples placed in the center of the cells. The medium was a peat:vermiculite:sand mix (70:25:5, v/v/v), into which cuttings of *Euonymus alata* 'Compacta', *Rhododendron* 'Hino Crimson', and *Ilex crenata* 'Hetzii' were placed. All cuttings were stuck on August 27, 1984, using a quick-dip liquid hormone and placed under an intermittent mist.

RESULTS

During engineering study periods the flow rate in the WWS was 9.3 gpm. The water coming into the WWS was 55 to 55.5°F. The heat loss of the water was 2.5 to 3.0°F and resulted in a heat input to the floor near 12,000 BTU/HR. This was the heat equivalent of about 2.5 gallons of fuel oil per day. The additional cost of the WWS was $2,377 which included a $1,784 well and return. The well could easily be used for up to three houses (25 gpm).

Temperature recordings during 1985 indicated that neither the WWS nor the NS were subjected to temperatures which

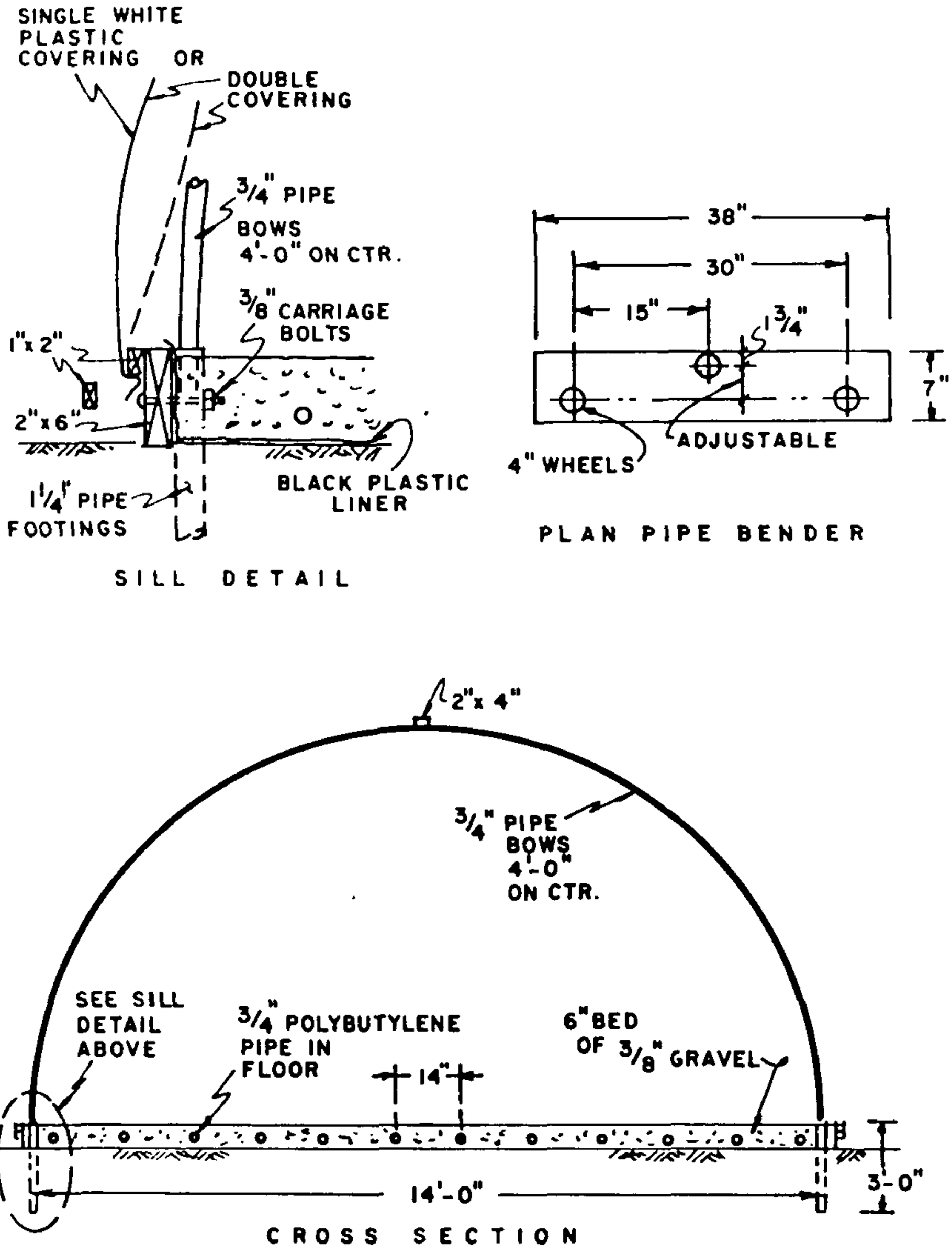

Figure 1. New Jersey Plan 153: Construction details of a floor heated nursery storage house.

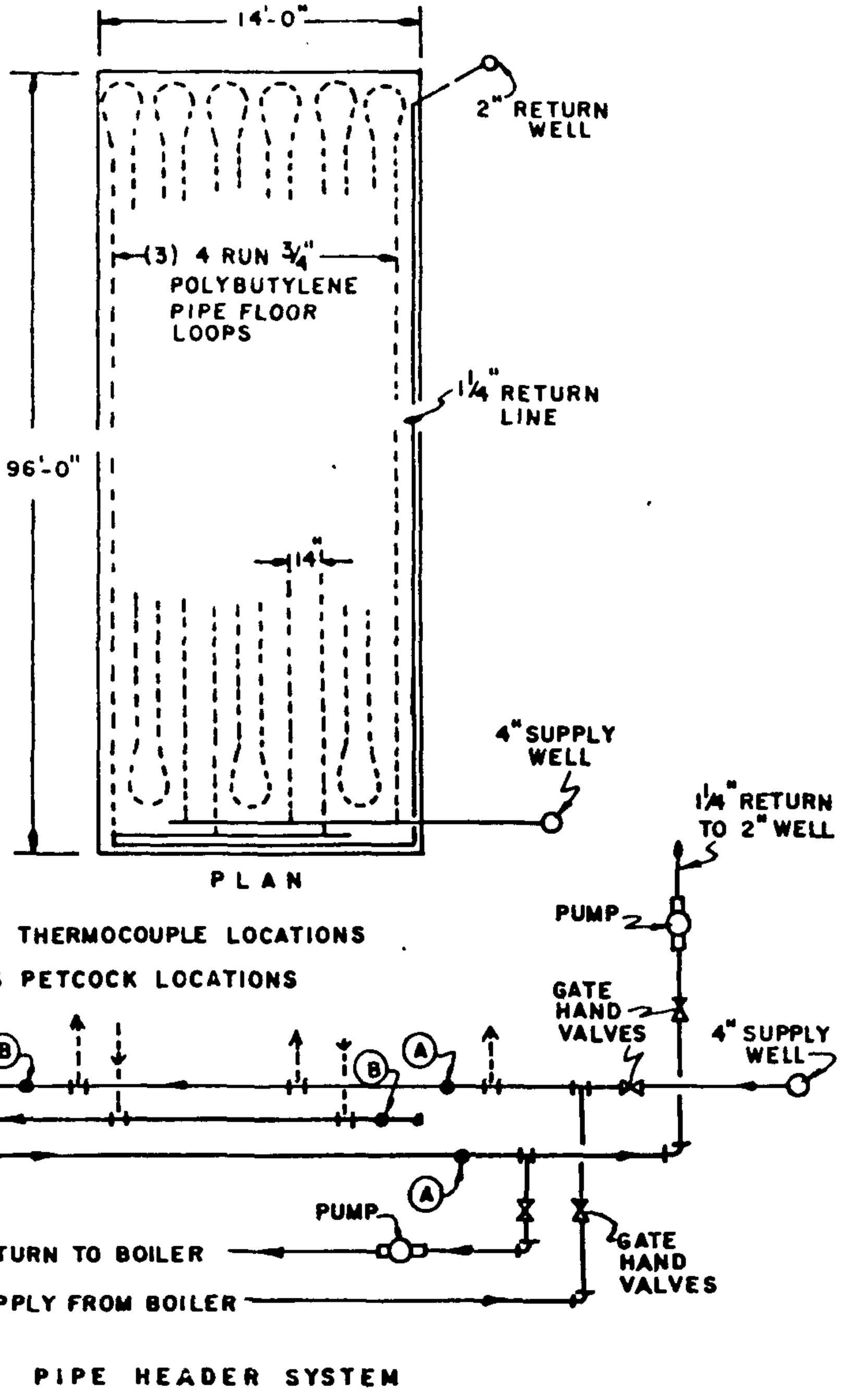

Figure 2. Engineering details for a heated floor incorporating a double-header return system.

caused the medium to drop below 32°F during the monitoring period (Figure 3), while the outdoor temperature dipped to 10.2°F. The medium temperatures in the WWS were never less than 2.1°F. above the NS medium temperature (Table 1), and the time spent at near freezing temperatures was much greater in the NS structure. During observations of two earlier episodes, the NS cells dropped below 32°F 9 hours earlier than the WWS cells. the lowest medium temperature recorded in earlier studies was 29°F when the outdoor temperature was −2°F.

Table 1. Cell temperature differential between a well-water heated storage structure and a similarly constructed normal structure[1].

Average cell difference (°F)	Minimum cell difference (°F)
2.95	2.3
2.67	2.1
4.15	4.1

[1] When temperatures dropped below 33°F.

The liner survival data during the experiment was intended as preliminary information. The liners were evaluated on

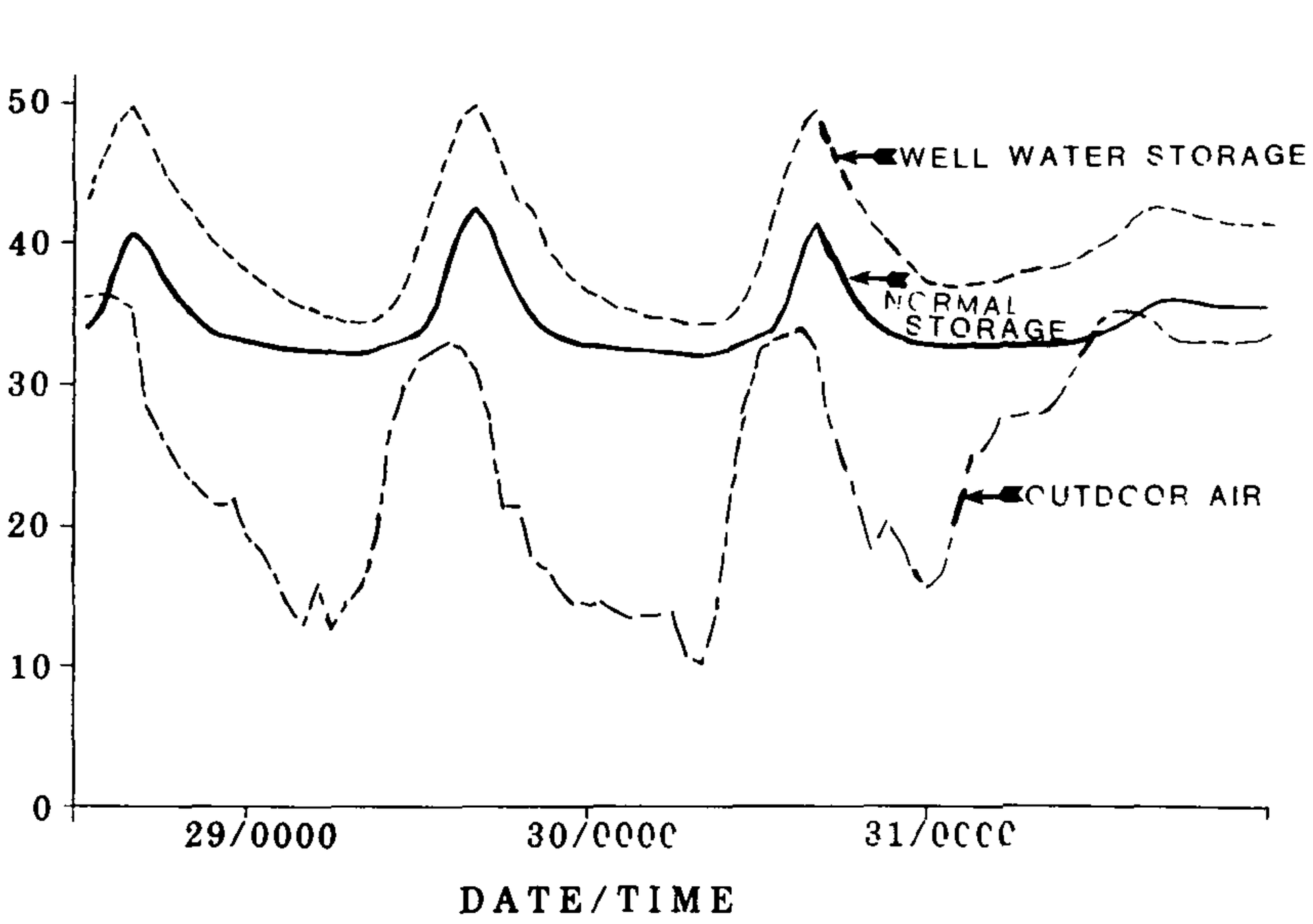

Figure 3. Medium temperatures under winter storage conditions in 3 × 3 × 3.5 in. cells.

May 8, 1985 and showed positive results for *Euonymus* and *Rhododendron* (Table 2), with the *Ilex* surviving well in both structures.

Table 2. Percent liner survival (preliminary)

Liner type	Percent survival	
	Well-water heated storage	Normal storage
Euonymus alata 'Compacta'	82.8 (30)[1]	73.7 (38)
Rhododendron 'Hino Crimson'	85.0 (40)	50.0 (30)
Ilex crenata 'Hetzii'	100.0 (40)	100.0 (40)

[1] Number of Replications

DISCUSSION

Traditional year-round greenhouse structures cost approximately $2.30 per sq ft while the WWS structure cost approximately $1.50 per sq ft (both calculations excluding labor). The 35% savings in the cost of the storage structure may be a feasible alternative to an additional year-round greenhouse if liners can be successfully overwintered.

Although medium temperatures during the study period were not extremely cold, outdoor temperatures dropped to −10°F earlier in the season. Since the medium temperature had dropped to 29°F when the outdoor temperature was −2°F, the liner medium temperature should have experienced colder temperatures. As indicated in Table 2, storage of liners was more successful in the WWS than the NS for the *Euonymus* and the *Rhododendron*, while no differences were detected for the *Ilex*.

The potential for the WWS house as an overwintering structure for rooted cuttings needs additional evaluation. Economically, the structure can be well justified if success in overwintering liners is near or equal to that in greenhouses now used. From early results it does appear that there is benefit from using a floor heated overwintering structure to store liners over a normally constructed storage structure. Furthere research is necessary to determine root hardiness of liners, and overwintering performance.

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PROPAGATION BY ROOT CUTTINGS

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Although propagation by root cuttings generally plays a minor role in the nursery industry, it presents a potential source of readily available material and perhaps should be considered more widely for those species which can be economically and practically propagated by this method. Plants propagated by root cuttings will be true-to-type, except for periclinal chimera plant types which do not reproduce true-to-type. A favorable aspect of root propagation, especially for the manager or foreman, is that it requires little skill to do and can be easily taught. Root cutting propagation will be illustrated by discussing some of our methods employed at Sheridan Nurseries and highlighted by examples of some species propagated.

A year prior to planting a field with root cuttings, it is seeded with a clover cover crop. A relatively sandy soil is preferred. The field is prepared for spring planting by fall plowing, adding required P and K according to a soil test, and cultivating. An application of Treflan (1 to 1½ lb/A) prior to planting helps in maintaining weed control.

Collection of roots presents a challenge. If they cannot be easily gathered from field-harvested plants, then they must be tediously dug from stock plants. Following collection, roots are stored in a barn in boxes containing a mix of composted bark and brick sand (3:2,v/v). Storage in the barn exposes the roots to temperatures which fluctuate from −2 to +6°C. in our area.

In February, after the majority of our grafting is completed, the root cuttings are made. Cuttings, approximately 12 cm in length, are made with a flush cut on the proximal end and an angled cut on the distal end to indicate the correct planting

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PROPAGATION BY ROOT CUTTINGS

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In February, after the majority of our grafting is completed, the root cuttings are made. Cuttings, approximately 12 cm in length, are made with a flush cut on the proximal end and an angled cut on the distal end to indicate the correct planting

direction and maintain the proper polarity. After trimming, the root pieces are placed into boxes, covered with the bark-sand mix, and again stored in the barn until planting.

In April, cuttings are planted with a four-row trencher. The final spacing is at 5 × 30 cm. Planting requires 7 people: 1 driver, 4 planters, 1 tamper, and 1 supplier. Following planting, the soil is tamped down around the cutting and mounded up to cover the tips with a cultivator-packer. A straw mulch helps to retain moisture, control weeds, and keep unwanted traffic out of the beds. The straw is removed when shoots begin to show, usually the beginning of June.

During the growing season, the root cuttings are irrigated and fertilized with 100 lb/A ammonium nitrate. Enide 15W (6.85 lb/A actual) and Dacthal 75W (16.5 lb/A actual) applications help to control weeds. Plants harvested that fall, are graded and either replanted at 15 × 42 in. spacing, potted, or sold.

Some shrubs, perennials, and one tree species are propagated at Sheridan Nurseries from root cuttings. Roots of *Campsis radicans* and *Aralia elata* receive no special treatment. In order to increase the number of takes and the size of a one year plant of *Rhus typhina* 'Laciniata' root cuttings are potted into a mix of bark, peat and sawdust (6:1:1,v/v/v) and placed in a greenhouse at 20°C. In the beginning of June they are potted into a #2 container.

Roots of *Aesculus parviflora* are taken off stock plants in the fall. Cuttings are placed into plug trays containing Vitamix, covered with sphagnum, then placed in a greenhouse at 20°. In the beginning of June are potted into a #2 container.

Prunus × *cistena* root cuttings after treatment with a 0.95% IBA powder, are stored in the barn until the beginning of April. They are then given a 3 to 4 week warm treatment of about 18°C to promote callusing. Cuttings are planted in a polyhouse (15°C), spaced at 2.5 × 5 cm. Once shoots have begun to sprout, they are fertilized with a 20-20-20 formula, at 200 ppm weekly. During the summer, these shoots provide a good source of softwood cuttings. Plants are dug in the fall.

Papaver orientale is propagated in August after the foliage has begun to die back. Cuttings, approximately 3 mm thick and 8 cm long, are placed directly into pots with tips barely exposed. Pots are kept well-watered and shaded in a cold frame. Shoots should be visible in about 4 weeks. Plants are sold the following year. Cuttings of *Armoracea rusticana* are propagated by the same method.

Phlox paniculata cultivars are propagated in the beginning

of October from root pieces approximately 1 to 2 mm thick and 5 cm long. The root cuttings are planted upright in flats of mix, covered with moist sphagnum, then stored in a cool greenhouse (15°C). In January, shoots start to show and the sphagnum is removed. The new plants are watered and fertilized with a 20-20-20 formulation at 200 ppm. Cuttings are moved into plugs and later potted on. *Salvia superba* 'East Friesland' is propagated the same as *Phlox*, however, cuttings taken in late August are planted into a cold frame. *Anemone japonica* root cuttings made in February are kept in the greenhouses like *Phlox*. This is one way to prevent freezing of the stock in most years.

Populus 'Tower' is the only tree presently grown at Sheridan's from root cuttings. At one time the nursery also propagated *Gymnocladus dioicus* this way. These cuttings are made similar to those of *Campsis* and *Aralia*.

At Sheridan Nurseries, we have begun to explore the possibility of propagating, both root and hardwood cuttings in "Spencer-Lamaier" rooting trays. The objective is to produce a strong, established plant with a good root ball which can be readily transplanted.

There are, of course, many other shrubs, trees, and perennials which can be easily propagated by root cuttings. The plants discussed here give a brief outline of our root cutting propagation methods. Extensive lists of plants may be found in past IPPS *Proceedings* or most any book on propagation.

PROPER SELECTION OF PROPAGATION MATERIAL CAN BOOST NURSERY PRODUCTIVITY[1]

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Abstract. Three year height data from a *Betula papyrifera* provenance test was used to show the economic benefits of proper selection of propagation material. The best of 8 commercially available seed sources (number 1306, obtained from Musser Forest and Herbst Tree Seed) averaged 8.3 ft in height vs. 7.4 ft for the 8 commercial source average. The shortest source was 6.1 ft. Based on fall 1985 wholesale prices, planting seedlings from

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source 1306 would have grossed an additional $5.60 per plant or an additional $10.00 per plant compared to the 8 commercial seed source average or the shortest commercial source, respectively. Seedling heights within source 1306 ranged form 6.1 to 11.8 ft. Asexual propagation of the tallest individual within source 1306 would have grossed an additional $20.00 per plant compared with the 8 commercial source average and $14.40 per plant compared to the average of source 1306. By recognizing and exploiting variation among and within seed sources, a nursery manager can realize significant increases in nursery productivity (more dollars per acre per year) without changing current production practices.

INTRODUCTION

One goal of nursery production managers is to produce uniform crops. To them variation is undesirable. However, plant-to-plant variation, if exploited, can increase nursery productivity and return more dollars per acre per year to the business. One means of increasing nursery productivity would be to grow the same quality and size plant material in less time. This work will demonstrate how three types of variations: 1) among seed source, 2) within seed source, and 3) within an individual, can be exploited by progressive nursery managers to increase productivity.

Height measurements taken in a 3-year-old *Betula papyrifera* provenance test will be used to demonstrate among and within seed source variation while the importance of within individual variation to nursery productivity will be demonstrated by data from a rooted cutting experiment.

Among Seed Source Variation. The genetic variation in growth potential among seed sources is documented in a provenance test. In a provenance test seed sources (provenances) from different geographical areas are grown in a common environment so that genetic differences can be detected. A *Betula papyrifera* provenance test was planted at Wooster, Ohio in June, 1983, using 3-month old greenhouse grown seedlings from 43 wild seed sources and 8 commercially available seed sources. The planting has eight 4-tree row plots in a randomized complete block design. The planting was measured in September, 1985.

The height data of the 8 commercially available seed sources at year three is presented in Table 1. Average plantation height was 7.4 ft. The tallest commercial seed source (1306) was 36% taller than the shortest commercial seed source (1302), 8.3 vs. 6.1 ft, respectively, and 12% taller than the 8 commercial seed source average. Using prices from the Lake County Nursery Exchange fall, 1985, wholesale catalog (Table 2) the possible per tree gross can be calculated for the various sources. If a nursery had planted seedlings from seed source 1306 instead of 1302 an additional $10.00 per plant

would be realized (Table 3). A similar comparison between source 1306 and the 8 commercial seed source average would have grossed an additional $5.60 per plant. The increased height growth is the result of the genetically superior seed of source 1306. The appealing aspect of selecting genetically superior seed sources is that no modification of production practices needs to be made, except making adjustments for shorter rotation times. Also, the increased gross would represent a close approximation of net profit as it costs no more to purchase seed or raise seedlings from 1306 as it would from any of the other 7 commercial sources.

Table 1. Three year height of *Betula papyrifera* trees raised from 8 commercial seed sources. Plantation site is Wooster, Ohio. Each value is the mean of 32 trees.

Seed Source	Third year height(ft.)	Percent of 8 seed source (mean)	Percent of seed source 1302 (mean)
1300	7.9	106	129
1302	6.1	82	100
1303	6.9	93	113
1304	7.9	106	129
1305	7.5	101	123
1306[1]	8.3	112	136
1307	7.4	100	121
1308	7.5	101	123
Average	7.4		

[1]Source 1306 was obtained from Musser Forest, Indiana, PA 15701, from seed purchased in fall, 1982, from Herbst Tree Seed, New Fairfield, CT 00812.

Table 2. Costs by height(caliper) of balled and burlapped *Betula papyrifers* plants. Data obtained from 1985 Lake County Nursery Exchange catalog, Perry, OH 44081.

Height (ft)	caliper (in.)	Cost/Plant
6	—	$26.60
7	—	31.00
8	—	36.60
9	1¼	41.00
10	1½	46.50
11	1¾	51.00
12	2	63.75

Within Source Variation. Not all individuals within a seed source were the same height. This tree-to-tree variation is termed, "within source variation" and can also be exploited by nurserymen. Within the tallest source, 1306, individual tree heights ranged from 6.1 to 11.8 ft. If the tallest tree was asexually propagated (thus capturing all of the genetic superiority)

and planted, additional gains could be made. (See "Cautions" section for reason why full phenotypic height might not be achieved.)

If the 11.8 ft individual was asexually propagated (cloned), transferring all of the apparent genetic height superiority to the "offspring", a clonal planting would realize an additional $14.40 per plant compared to planting just seedlings of seed source 1306. An additional $20.00 per plant would be realized if a nursery planted clonal material of the tallest 1306 individual compared to planting seedlings randomly chosen from the 8 commercial seed sources (Table 3).

Table 3. Increased gross return per plant when different constraints are made between propagation sources.

Contrast (seed sources)[1]	Height (ft)	Cost ($)	Differences per plant ($)
1306 vs. 1302	8.3 vs. 61	36.60-26.60	+ 10.00
1306 vs 8 seed source average	8.3 vs. 7.4	35.60-31.00	+ 5.60
Tallest individual within source 1306 vs. 1306 average	11.8 vs. 8.3	51.00-36.60	+ 14.40
Tallest individual within source 1306 vs. 8 seed source average	11.8 vs. 7.4	51.00-31.00	+ 20.00

[1]Seed source 1306 was tallest of 8 commercial seed sources at year three in a Wooster, Ohio, *Betula papyrifera* provenance test; source 1302 was the shortest.

Cautions. Several factors must be considered as every nursery planting seed source 1306 or clonal material from the tallest individual of 1306, might not obtain 8.3 or 11.8 ft tall plants after 3 years.

First the data presented are based on one test site. Seed source by environment interaction may exist. The best source in Wooster, Ohio might not be the best in Wisconsin or Maine. Also, the Wooster planting received excellent care from John Elliot, the farm manager. Less intensive cultural practices would result in reduced growth. Second, the interpretations are based on 3 year results. At the end of 10 years the tallest seed source might not be source 1306. Relative source superiority can shift with time. Third, the genetically best individual within a source might not be the tallest tree in the planting, again due to environmental differences within the Wooster site. The tallest individual in source 1306 might have been in a favorable micro-site and been taller than other individuals within 1306, not for genetic reasons, but for cultural (environmental) reasons.

Finally, significant differences in growth rate and form can occur among individuals within a clone. When long shoots or shoots of *Betula nigra* 'Heritage' are propagated, plants differing in growth rate and form can result, even though they are genetically identical (1). The most likely reason for the difference in appearance can be attributed to plagiotrophic effects, the long term persistance of age, or positional effects.

To realize the full growth potential of the best individual within a source, long shoots must be used as propagation material. Long shoots have been programmed, while on the stock plant, for rapid growth. Long shoots have larger leaves, greater stem caliper, and longer internodes than short shoots.

Propagation of long shoots by stem cuttings can result in plants up to 6 inches taller (28 vs. 22 in.) 125 days after propagation than propagation of short shoots (1). Further, long shoots compared to short shoots need less staking to develop upright growth, produce greater leaf area, and greater root and shoot dry weights.

Stem cutting derived short shoots can be trained into long shoots by vertically staking one shoot and pruning any lateral shoots to a three node length. If done, the transition can be completed within the growing season remaining after propagation, approximately 85 to 125 days. Severe pruning of stock plants will result in the production of long shoot type growth, which can be used for propagation.

In summary, a production manager can increase the return per acre per year by careful selection of propagation material. Selecting the best seed source over the poorest can return up to $10.00 per plant more at the end of three years. Asexual propagation of the best individual within a source can return an additional $10.00 per plant. In order to realize the full growth potential of asexually propagated genotypes long shoots must be selected as propagation material. The increased returns per plant outlined in this paper can be realized without significant changes in present nursery practices.

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SYNTHESIZING PLANT CHIMERAS AS A SOURCE OF NEW PHENOTYPES[1]

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A chimera is a plant possessing two or more genetically distinct tissues. In horticulturally important species, chimeras are manifested frequently by useful or ornamental characteristics. For example, some thornless blackberry cultivars contain epidermal tissue which has genes for "thornlessness", whereas the inner tissue layers can give rise to thorny branches (3). Chimeras for flower or bract color exist in carnations, mums, and poinsettias (9,10,11). In addition, leaf variegation can be caused by green and albino cell genotypes coexisting in a single shoot (4). While variegation is obvious in the leaves, its actual origin is from the cells which give rise to the leaves, namely the "apical initials" of the shoot tip or shoot apical meristem. Most higher plants have a structured shoot tip which contains two or three cell layers, each with a set of apical initials. These layers generally remain independent from each other as the apex continues to produce cells. The layers have been termed the LI (the outermost), the LII (the middle), and the LIII (the innermost). When the cells of a given layer are genetically different from those in the other cell layers of the shoot tip, the plant is known as a periclinal chimera. Other less stable chimeral arrangements can exist, but because of their instability they have not become horticulturally important. It is important to realize that the term "variegation" is not synonymous with "chimera" and that variegation can be caused by factors other than chimerism (4,12). For example, coleus plants, which are popular because they have variegated leaves, *are not chimeras. The entire plant is composed* of cells with the same genetic makeup. However, the genes "tell" the plant the position on the leaf where various pigments should be produced or destroyed. One analgous case in animals is the panda bear. Although the animal is composed of one genotype, dark pigments are produced only in certain body regions. If it were possible to regenerate panda bears from "black cells" and from "white cells", the resulting animals would still appear identical to the original "variegated" panda bear. If, in theory, the bear was actually a chimera, cells from its white body parts would yield white panda bears, and

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[1] Contribution No. 2755, Massachusetts Agric. Exp. Stn., Univ. of Mass. Amherst.

cells from its black parts would yield black panda bears.

With few exceptions, this "regeneration test" holds true for periclinal chimeras in plants. If small tissue pieces excised from the differently colored regions of a variegated leaf are tissue-cultured, and if the regenerated plants still have the same pattern of variegation, the chances are good that the plant *is not a periclinal chimera, i.e., it does not possess a* unique homogeneous genotype in each cell layer. If, however, the white portions of a leaf regenerate white plants and if the green portions regenerate green plants, then the plant is most likely a chimera, and the tissue culture process has separated the chimera into its component cell types. Such a separation is usually undesirable, because it is the chimeral nature of a plant which gives it its unique appearance. Therefore, propagation of chimeras via adventitious shoots rarely result in chimeral "offspring". Fortunately, axillary buds do maintain the periclinal arrangement which exists in the terminal shoot tip. *Therefore, plant chimeras can be propagated by stem cuttings,* leaf-bud cuttings, grafting, or budding.

Most horticulturally important chimeras have arisen spontaneously after a mutation has occurred in one or more cell layers in the shoot tip. Since spontaneous mutations rarely produce desired changes, it would be useful to develop techniques for synthesizing chimeral shoot apical meristems from two known cell types. For example, if the disease resistance of a particular plant was known to be due to epidermal characteristics, it would be beneficial for this epidermis to be "transferred" to less resistant cultivars. It would be possible to create new flower colors if the epidermis of a red-flowering cultivar was "transferred" to a yellow-flowering cultivar.

From a historical perspective, experimental techniques for synthesizing chimeras have been developed in the Solanaceae, where chimeral shoots, i.e. graft chimeras, were forced from the graft unions of grafts between tomato and nightshade. The grafting technique is limited because it is only useful for graft compatible combinations and for species which will form adventitious shoots from a graft-union. The technology of plant tissue culture has yielded a new tool for manipulating chimeral plants *in vitro*. In many species, whole plants can be regenerated from callus cultures or from cell suspensions if the appropriate media are used. Since chimeras can be regenerated from callus tissue that forms at the graft union, perhaps they can also arise *in vitro* from callus cultures composed of two genetically different cell types. This hypothesis has been tested experimentally by several researchers, but the results have been disappointing (1,5). There are, however, a few reports that such a system is feasible (2,7).

In order to develop a reliable procedure for the synthesis of plant chimeras, a model system was tested using two species in the genus *Nicotiana*. The species chosen were *N. tabacum* and *N. glauca*. These species are ideal for studying chimeral synthesis because they are graft compatible, can be easily regenerated from cell culture, and contain the necessary morphological markers, e.g. leaf color, leaf shape, flower color, leaf pubescence, etc., for early and easy identification of periclinal chimeral arrangements.

Two techniques were used to determine if interspecific chimeras could be synthesized from *N. glauca* and *N. tabacum*. The first consisted of reciprocally splice-grafting the two species. After the graft union had healed and scion growth had occurred, the scion was pruned and trimmed away, leaving a thin layer of scion cells above the graft union. Several auxin-lanolin, paste treatments were applied to encourage callus formation. While the auxin encouraged callus formation, it reduced the number of adventitious shoots which arose from the region of the graft-union. Maximum shoot production from the graft union was encouraged by the removal of all axillary buds and adventitious shoots which arose from regions other than the graft union. A few of the shoots produced were chimeras and clearly displayed leaves which were composed of cells of both species. These shoots were propagated by stem cuttings, and eventually two types of periclinal chimeras were obtained. With repeated pruning and asexual propagation, two shoots spontaneously arose and had different chimeral arrangements in their apices. A total of four of the six possible periclinal chimeras now exist. The flowers of these different chimeras are unique and possess some characteristics, e.g. colors, previously nonexistent in the genus *Nicotiana* (6) (Figure 1). Leaf shapes were also unique. Casual observations indicate that certain chimeral arrangements may be resistant to mites and to *Alternaria*, a fungal pathogen which can infect tobacco leaves.

The second technique utilized tissue culture methods and consisted of mixing callus cultures of both species (8). The "mosaic" callus masses were allowed to grow together on callus-induction medium until they appeared to be a single piece of tissue. This tissue was placed on shoot-induction medium. It was hoped that some of the organizing shoots would be chimeral. However, only nonchimeral shoots of each species were recovered. Possibly, the process of shoot formation from a graft union differs from that in cultured callus.

Recently, experiments were conducted to determine if adventitious shoots derived from chimeral leaf tissue would be chimeral or nonchimeral. Leaf discs were removed from the periclinal chimeras and placed on a medium which encour-

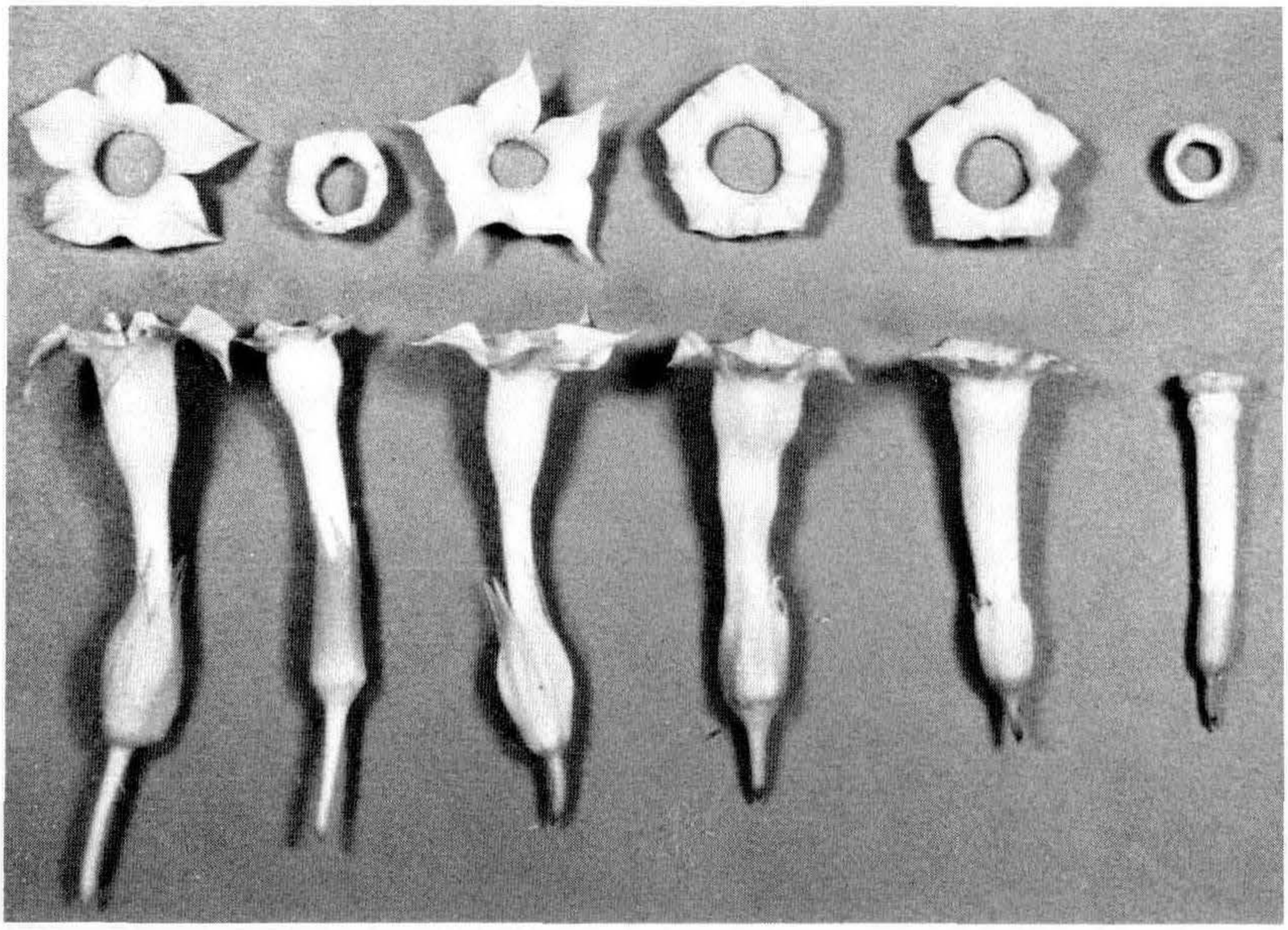

Figure 1. Flowers of *Nicotiana tabacum*, *N. glauca*, and four interspecific chimeras. 1 = Flower from *N. tabacum* with a pink corolla limb, off-white corolla tube. 2 = Flower from G-T-T chimera (actually a *N. tabacum* flower covered by an *N. glauca* epidermis). The flower is bright yellow and the corolla limb is not sharply lobed. 3 = Flower from T-T-G chimera. The flower is pink with an off-white corolla tube and yellow veins. 4 = Flowers from T-G-T chimera. Corolla tube is yellow, limb is bronze. 5 = Flowers from T-G-G chimera (actually and *N. glauca* flower with a *N. tabacum* epidermis). The flower is similar to #4 but the tube is not distorted. 6 = Flower from *N. glauca*, all yellow but not deeply lobed.

aged slight callus formation at the cut edges before the production of shoots. It was hoped that a regeneration scheme such as this would allow shoot formation to proceed quickly, thereby reducing the amount of "unmixing". "Unmixing" is known to occur when chimeral callus is allowed to grow in an undifferentiated state. Large colonies of identical cells will form (1), and this occurrence reduces the chance of recovering shoots organized from two unlike cells. After shoot regeneration, 51 of the 658 shoots recovered were chimeras. In addition, the chimeras did not always have the same appearance, i.e. periclinal arrangement, as the leaf disc from which they originated. These results are encouraging because they indicate that it

is possible to regenerate chimeras from adventitious shoots arising from tissue cultures, and that new types of chimeras can be recovered. As shown in Figure 1, each type of chimera can result in a unique phenotype. These new chimeras can be propagated by stem or leaf-bud cuttings and will rarely produce nonchimeral shoots.

CONCLUSIONS

The unique nature of many chimeral plants can make them valuable additions to horticulture. While plant breeding remains the strongest force in the development of new cultivars, the synthesis of chimeras may result in phenotypes which cannot result following conventional breeding. Yet, a greater understanding of shoot formation *in vitro* must exist before synthesis of chimeras in tissue culture will significantly contribute to the addition of valuable chimeral cultivars.

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FOG PROPAGATION — AN UPDATE

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Early attempts at high humidity propagation involved the natural humidification of enclosed chambers which contained the cuttings to be rooted (1). High temperatures during sunny weather and inadequate means of temperature control were frequent reasons for propagation failure (1). The concept of high humidity propagation was advanced during the 1940's by V.T. Stoutemyer of the U.S Plant Introduction Garden at Glenn Dale, Maryland. He supplemented natural humidity with mechanically-produced fog to minimize the effects of solar heating which lowered the humidity during the day. Because high humidity required frequent care by trained personnel and often produced unpredictable results, intermittent mist surpassed high humidity for commercial propagation use. Research was begun in 1974 to solve the problems of high humidity propagation and thus improve it for commercial use. After 4 years of work, the modern concept of ventilated high humidity propagation was developed. This concept solved many of the original problems of high humidity propagation but existing humidification equipment was inadequate for commercial propagation.

Tobacco humidification equipment (Agritech, Inc., Raleigh, NC) was modified to emit a centrifugally-produced fog and it became an acceptable propagating system (2). Since that initial introduction, two additional types of humidification equipment have been introduced: high pressure and vortex-produced fog systems. In the relatively short period of 11 years, ventilated high humidity propagation has been conceived, tested, introduced and accepted as a commercially viable alternative to intermittent mist for propagation.

The ventilated high humidity concept of propagation provides a convenient means of controlling temperatures during propagation. Humid air around the cuttings prevents evaporative cooling which promotes solar heating of the propagation medium. Excess solar heat is removed through the air surrounding the cuttings. Forced air circulating among the cuttings and exhausting of heated air from the greenhouse have made this a very effective means of regulating the air temperature around the cuttings. When this means of temperature control is exceeded by summer heat, shading of the greenhouse is implemented.

The smaller droplet size produced by humidifiers as compared to mist reduces the amount of water applied to the propagation medium. Improved temperature control and saturation of the propagation medium are features of ventilated high humidity propagation that have added to its appeal for propagating plants. Other advantages of ventilated high humidity propagation that increase its feasibility for commercial propagation are its portability and easy adaptation to the popular plastic film-covered quonset-style greenhouse.

Two of the four manufacturers of humidification equipment produce humidifiers that are reasonably light and relatively easily removed from one greenhouse to another. One (Agritech, Inc.) is suspended from a support frame or from the greenhouse superstructure while the other (Humidifan) pivots within its own frame. The remaining two humidification systems (Mee Industries and Atomizing Systems, Inc.) are stationary, much like the intermittent mist systems.

The advantage of mobility is that it permits nursery growers to propagate in any available greenhouse or to use the humidifers for other purposes. The use of ground level propagation and the suitability of quonset enclosures further increase the versatility of an otherwise quite rigorously defined nursery operaton.

Water immersion of cuttings.

In addition to being a commercially acceptable means of propagation, ventilated high humidity propagation has become valuable for research. Because cuttings can be maintained in a healthy condition for longer periods of time, smaller differences due to treatments can be measured with less variation. Because of this, a treatment designed as a control in an immersion pretreatment experiment produced unexpected results. In an experiment in which water was used as a solvent for chemicals, water alone produced earlier root initiation when compared with non-immersed cuttings. The significance of this phenomenon was first studied with poinsettia *(Euphorbia pulcherrima)* cuttings and later with a honeysuckle *(Lonicera xylostoides)* 'Clavey's Dwarf'), rose *(Rosa multiflora)* and Heller's holly *(Ilex crenata* 'Helleri').

Eighty, 6-in. terminal cuttings of field-grown poinsettia stock plants were immersed in 5, 25 and 35°C water for 0, 3, 6 and 12 hours and the 5 cuttings of each treatment were stuck individually in one-gallon containers with a coarse sand medium. Each container was placed in a greenhouse humified with Agritech humidifiers. After 3½ weeks, each cutting was evaluated for root initiation.

Poinsettia cuttings immersed in water for 3 hours initiated

roots earlier than cuttings that had not been immersed or which had been immersed for longer periods of time (Figure 1). Because of early root initiation, these cuttings produced more and longer roots in the same period of time required for the remaining cuttings to begin root initiation.

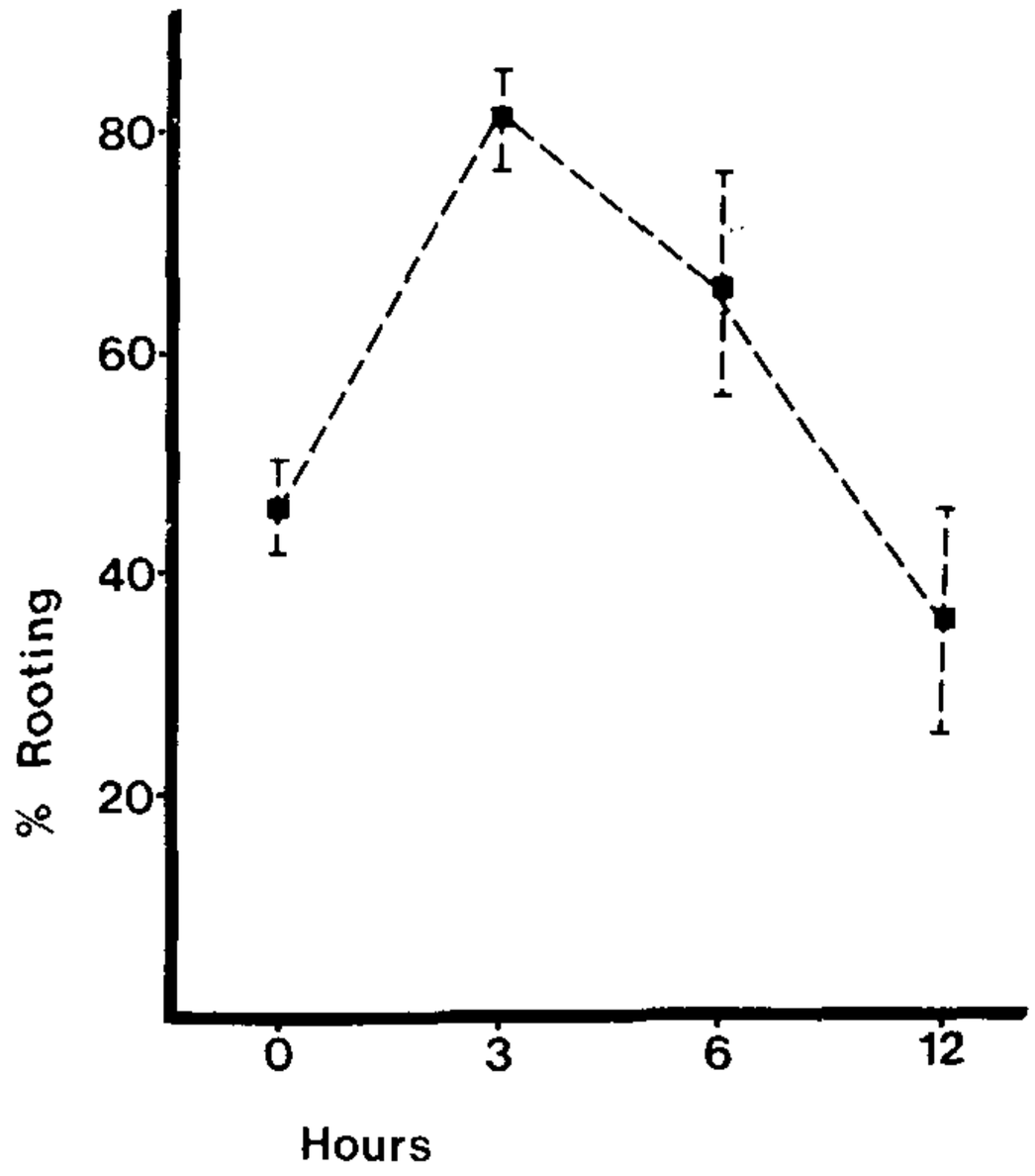

Figure 1. The percent of poinsettia cuttings which rooted after immersion in water for varying lengths of time and propagation for 3½ weeks.

The temperature of the immersion water was also observed to be important. Figure 2 shows that 80% of the cuttings rooted early when immersed in room temperature (15°C) water as compared to 70% when immersed in cooler (5°C) water and 55% when immersed in warmer (25°C) water. When this research was applied to other species the results were variable.

One year later, the effect of water immersion on root initiation was retested using 20 cuttings each of poinsettia, honeysuckle, rose, and holly. Ten cuttings of each species were immersed for 0 and 3 hrs. in room temperature tap water (approximately 20°C) and treated as previously described but in a paired comparison.

After 3 weeks, cuttings were evaluated for root initiation and number of roots. A cutting in a pair was considered superior if it was rooted, when both were rooted, if it had a total root length greater than its companion (Figure 3). All the immersed cuttings of honeysuckle were superior to non-immersed cuttings and 70% of poinsettia and rose cuttings were superior. Holly required an extra week of propagation time to produce similar results. When the experiment was repeated

using poinsettia, honeysuckle, rose, holly, and 'Blue Rug' juniper (*Juniperus horizontalis* 'Blue Rug'), holly and juniper failed to produce better rooting as a result of immersion.

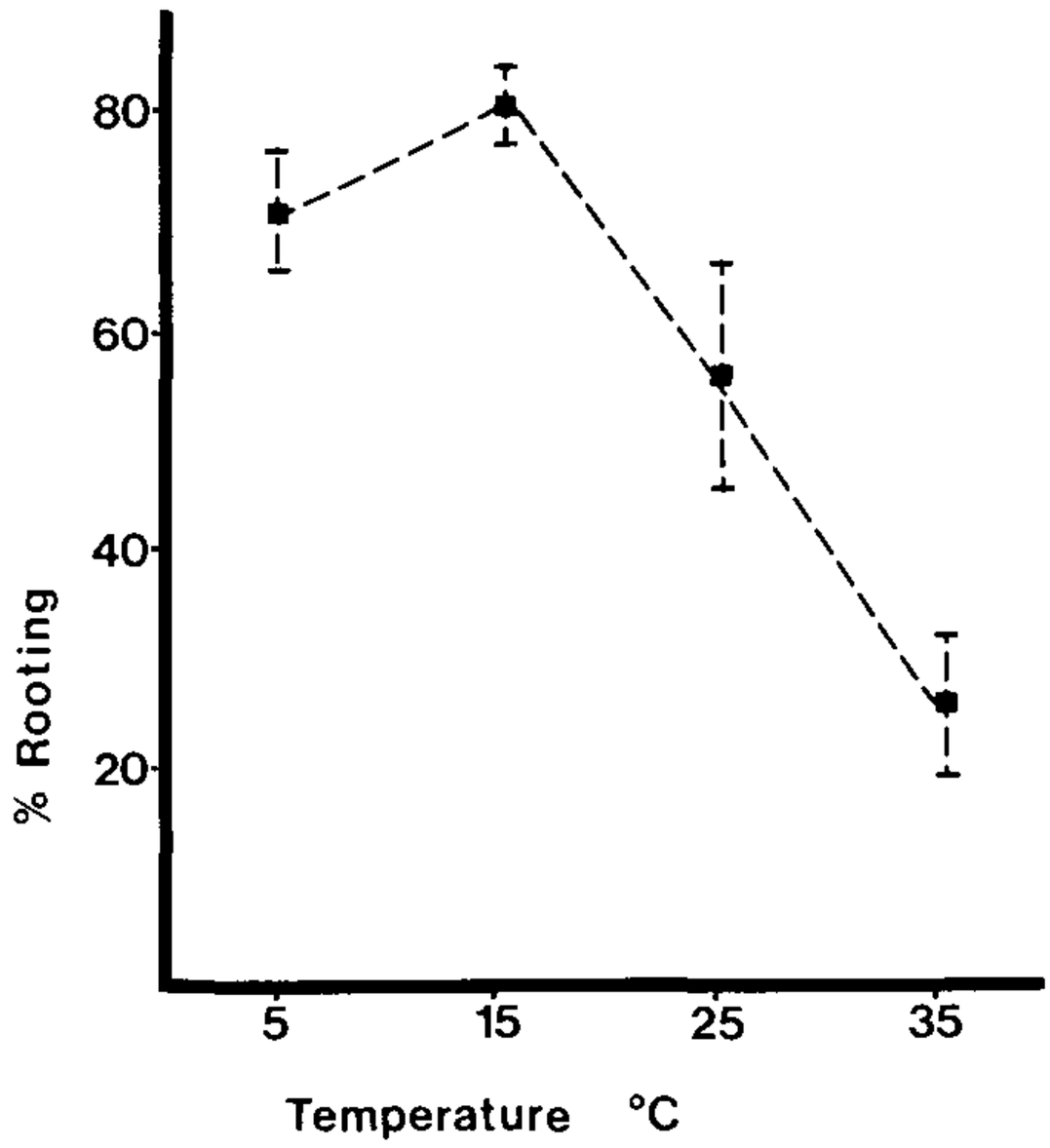

Figure 2. The percent of poinsettia cuttings which rooted after immersion in water at 4 temperatures and propagated for 3½ weeks.

Figure 3. The percentage of superior-rooted members of ten immersion (3 hr.) (solid bars) vs. non-immersion (cross-hatched bars) pairings.

These results show that early root initiation from immersion in water is a reproducible result for poinsettia, honeysuckle, and rose. The variable response of holly and nonresponse of juniper indicate that all the conditions for a favorable response may not be understood or that some species may be unresponsive.

Ventilated high humidity propagation appears to have promising commercial applications for propagation, and immersion, at least for some species, may be a beneficial pretreatment for early rooting of cuttings.

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RICHARD WOLFF: Just a comment on Dr. Milbocker's paper. We took cuttings of Japanese red maple this past year from plants that were well hydrated from irrigation. Those cuttings rooted 100% as usual. We also took cuttings from our tree farm. We had a drought this past summer and did not hydrate the cuttings from the tree farm and the percentage fell back to 50%. We came to the conclusion that the hydrated trees gave us better rooting.

IMPROVING MEDIA AERATION IN LINER AND CONTAINER PRODUCTION

DALE M. MARONEK, DANIEL STUDEBAKER, AND BEVERLY OBERLY

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Considerable information has been published regarding container media ingredients, their properties and their effects on root growth (1,2,3,4,6). Most modern day propagators use a soilless medium during propagation and/or for subsequent growing on in containers. Every medium has different physical and chemical properties that will affect rooting, and subsequent plant growth and development. In addition, a medium that may be best (poorest) for rooting may be the poorest (best) for growing on in larger containers (5). Consequently, finding a

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medium that would meet all of a growers specific requirements for both propagation and growing on may be difficult.

Optimum soilless medium properties alone will not eliminate all production problems, but understanding physical and chemical properties is a key component to improve rooting and subsequent plant growth. In addition, utilizing these factors will assist a grower in evaluating the cost benefits of a particular medium.

Some suggested medium standards used at Studebaker Nurseries are listed in Table 1. These chemical and physical standards should only be considered as general guidelines. Since the organic component(s) comprises 50 percent or more by volume of our various media, we generally are not as concerned with the chemical properties in a medium during its initial development. Once our medium has been formulated, we then will adjust cultural practices to attain proper chemical requirements, e.g., adjustments in medium pH. In the following brief discussion about some of the physical properties of a container medium, keep in mind that these properties are closely related. A change in any one medium ingredient can affect one or more other properties.

Table 1. Some suggested media standards used at Studebaker Nurseries.

Property	Comments
Chemical	
pH	4.5 to 6.5, preferred 5.5 to 6.5
Buffer capacity	As high as possible
Soluble salts	*400 to 1000 ppm (1 soil: 2 water by volume)*
Cation exchange capacity	25 to 100 meg/liter
Physical	
Bulk density	0.3 to 0.80 g/cc^3 (dry) or 0.60 to 1.15 g/cc (wet)
Air-filled porosity	15 to 40% by volume, ideally 20 to 25% range
Water holding capacity	20 to 60% volume after drainage
Particle stability	Materials should resist decomposing quickly. Decomposition can alter other media components.

Pore space is extremely important in a container medium and the amount required varies by species. Table 2 lists the approximate percent air space requirements of some selected ornamentals (7). The bottom line is that each kind of plant has its own minimum oxygen requirement below which a plant cannot root and absorb water and nutrients for proper growth. Also, respiring roots emits carbon dioxide and, in a poorly aerated medium, carbon dioxide can reach toxic levels if in-

sufficient air exchange is lacking between the medium and atmosphere.

Table 2. Approximate root aeration requirements of some selected ornamentals.[1]

Air space requirements[2]			
Above 20%	10 to 20%	5 to 10%	2 to 5%
Azalea	African violet	Camellia	Conifer
Fern	Begonia	Chrysanthemum	Carnation
Orchid	Foliage plants	Gladiolus	Geranium
	Gardenia	Hydrangea	Rose
	Gloxinia	Lily	Stocks
	Heather	Poinsettia	
	Rhododendron		
	Snapdragon		

[1]Adapted from: Criteria for Selection of Growing Media for Greenhouse Crops, *J.W. White, Penn. Ag. Expt. St. Journal Series No. 4574*
[2]Air space requirement after 24 hours of drainage.

During propagation, we try to keep our total medium porosity between 40 and 60%, and air space between 15 and 25 percent following 24 hours of drainage. We have found that as we approach the 60% porosity level, our medium tends to become too loose. Consequently, there is insufficient contact between the cutting and rooting medium, thus reducing rooting. We try to hold this porosity range through our liner stage of production which includes all pot sizes up to 938 ml (1 quart) volume.

A second medium property closely related to porosity is bulk density. Bulk density expresses soil weight per unit volume (g/cc) and takes into consideration solids and pore spaces between particles. A high bulk density generally indicates a "tight" medium and a low one indicates an open medium. Desirable bulk densities in field soils should be somewhere between 1.25 and 1.50 g/cc, which is considerably higher than what we prefer to have in our propagation or container medium (Table 1). We have found that *media with bulk densities of* between 0.8 and 1.0 g/cc (wet) are ideally suited for our propagation and liner production phases.

During our liner stage of production in 5 to 10 cm (2 to 4 in.) diameter pots, additional weight is often needed to prevent plants from tipping over in the wind. Maintaining bulk densities in the range of 0.8 to 1.0 g/cc, gives our containers additional ballast. The key to increasing ballast is to do so without drastically reducing porosity. At first, we often added sand to our media. Unfortunately, as we increased the amount of sand in our media to sufficient quantities for ballast, we did so at

the expense of reducing percent air space. This reduction was sufficient to affect rooting of a number of kinds of plants.

We had been quite satisfied with the use of coarse horticultural grades of perlite for improving media porosity and drainage. However, in fog propagation, using a small container (approximately 100 ml volume), our peat and perlite 1:1 medium was holding too much moisture. Furthermore, perlite in our operation is messy to use, expensive, and requires a special covered storage area.

To correct our production problems, we set out to find a medium component that could add ballast without substantially reducing pore space, was easier to use and store, and was less expensive. In our container operation, we were using a 9.5 mm (⅜ in.) diameter expanded shale product for increasing ballast. We asked the manufacturer to produce a smaller particle size product comparable to the particle sizes found in coarse horticultural grades of perlite. A comparison of particle sizes between a coarse horticultural grade of perlite we use and the expanded shale product is shown in Table 3. The expanded shale product compares favorably with the perlite. The biggest difference between the two products is the quantity of very fine particle sizes which are retained on the No. 50 and No. 100 screens and in the remaining pan material. These particle sizes generally fall into the category of dust. The perlite is comprised of 4% dust by weight while the expanded shale product has approximately 1% dust by weight. This reduction in dust substantially reduced a major handling problem we normally encounter with perlite.

Table 3. Comparison of particle sizes between a coarse horticultural grade of perlite and expanded shale manufactured to similar particle size.

		Expanded shale[1]			Perlite[1]		
		Retained (%)		Passed (%)	Retained (%)		Passed (%)
Sieve no.	Screen size (mm)	Wt.	Cumulated wt.		Wt.	Cumulated wt.	
4	4.75	0	0	100	1.3	1.3	98.7
8	2.36	64.7	64.7	35.3	40.9	42.2	57.8
16	1.18	33.8	98.5	1.5	51.5	93.7	6.3
30	0.6	0.8	99.3	0.7	1.4	95.1	4.9
50	0.3	0.1	99.4	0.6	0.4	95.5	4.5
100	0.15	0.1	99.5	0.5	0.2	95.7	4.3
Pan	-	0.5	100	0	4.3	100	-

[1]Mean of 3 replications.

To compare the performance of the products as media components, perlite and expanded shale were individually

mixed with sphagnum peat (1:1, v/v) and used to fill containers of two different sizes to approximate potting capacities of 94 and 770 ml. The resulting physical properties of each medium are listed in Table 4. In the 94 ml medium volume, total porosity, and water holding capacity between the peat-expanded shale and peat-perlite medium differed substantially. The peat-expanded shale medium's total porosity and water holding capacity were 11 and 22% less, respectively, than the same properties in the peat-perlite medium. This was desirable since we were trying to find a medium that was tighter and held less moisture during its use in fog propagation. In addition, these reductions in porosity and water holding capacity did not occur at the expense of reducing airspace. Both media had a similar percent air space after 24 hours of drainage. As volume increased from the 94 to 770 ml, the differences in water holding capacity of each became less. Because of the increased height of the larger container, additional water held in the peat-perlite medium was able to drain. There was very little difference in water holding capacity of the peat-expanded shale medium in either volume container.

The two media also differed substantially in their bulk densities. The peat-expanded shale medium was twice as heavy as the peat-perlite medium (Table 4). This provided the additional ballast we were seeking, while maintaining acceptable levels of percent airspace. The additional weight, of course, may be undesirable with respect to increasing shipping weight.

Table 4. Comparison of media physical properties using expanded shale or perlite — by itself or in combination with sphagnum peat in two different containers.[1]

		Media volume					
		94 cc			770 cc		
Media (V/V)	[2]Bulk density g/cc	Total porosity (%)	[3]Air space (%)	Water holding capacity (ml)	Total porosity (%)	Air space (%)	Water holding capacity (ml)
Peat (Pt)	1.06	72	20	52	63	17	46
Perlite (P)	0.34	71	50	21	67	49	18
Expanded shale (ES)	0.98	50	30	20	43	32	11
1 Pt: 1 P	0.54	66	22	44	60	23	37
1 Pt: 1 ES	0.94	55	21	34	54	18	40

[1]All data mean of 3 replications.
[2]Bulk density is wet bulk density; determined 24 hrs. after containers had initially been saturated and drained.
[3]Percent air space was determined after medium had been initially saturated and then drained for 24 hours.

To further test the performance of each medium we evaluated the rooting and subsequent growth of cuttings direct stuck at various times throughout the summer of 1985, into 5 × 5 × 6.3 cm (2×2×2.5 in.) containers (157 ml volume). For each kind of plant, equal numbers (ranging between 100 and 800 were stuck in both the peat and perlite, and peat and expanded shale media. All cuttings were placed in a fog propagation system until rooted. Following rooting, all plants were grown under 50% shade for the remainder of the summer season. On September 5, 1985, the percent rooting was determined and a visual analysis of the root system's quality was made. All cuttings had been rooted for at least 4 weeks or more. The rooting percentages are listed in Table 5. In most instances, the rooting percentages of each kind of plant in both media were comparable. The most substantial differences in rooting were amongst kinds that we have found to be sensitive to excessive moisture, e.g., *Rhamnus frangula* 'Asplenifolia' and *R. frangula* 'Columnaris'. For *R. frangula* 'Asplenifolia' and *R. frangula* 'Columnaris' an 89 and 83% rooting was obtained in the peat-expanded shale medium compared to 74 and 11% rooting, respectively, in the peat-perlite medium. The biggest difference between the two media was in root development after propagation. In all cases, the quality of the root systems in the peat-expanded shale medium was better than in the peat-perlite medium.

Table 5. Effects of propagation media on rooting of selected kinds of woody ornamentals.

Species	Percent rooting[1]	
	Peat: expanded shale (1:1, V/V)	Peat: perlite (1:1. V/V)
Cornus sericea f. bailey	100	89
C. sericea 'Flaviramea'	100	82
Cotoneaster apiculata	77	84
C. horizontalis	78	65
Forsythia × intermedia 'Arnold Dwarf'	86	91
Hypericum kalmianum	71	75
Rhamnus frangula 'Asplenifolia'	89	74
R. frangula columnaris	83	11
Ribes alpinum	78	73
Viburnum × burkwoodii 'Chenault'	78	73
V. × pragense	71	67
Weigela florida 'Java Red'	83	92

[1]Rooting percents are average of between 100 to 800 cuttings for each kind of plant in each medium.

We are pleased with the peat-expanded shale medium and are going to expand our tests next year to include additional kinds of plants. It appears that some plants still root better in

the peat-perlite medium but subsequent root growth is still superior on those plants rooted in the peat-expanded shale medium. Another benefit in using the expanded shale product is its cost and handling features. Based on 1985 prices, we are saving about $11.00 per cubic yard of raw material purchased. In addition, we do not have the dust problem in handling the product as we do with perlite and we do not need special storage facilities. The expanded shale product is brought in by tractor-trailer and stored outside in our media mixing area until needed.

In summary, development of a soilless medium necessitates the understanding of media properties and your crop needs. Each grower will have access to potential media ingredients that warrant consideration for use based on specific savings, availability, and specific characteristics they afford a growing medium. For our production system(s), the expanded shale product shows considerable promise.

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ROOTING MEDIA USED AT APPALACHIAN NURSERIES

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for cutting propagation. I will review these today, including costs and how much each medium is used in our propagation program.

PERLITE AND VERMICULITE

The first medium, and the one we use the most, is composed of perlite and vermiculite. This is used in the ratio of ⅔ perlite and ⅓ vermiculite in a layered configuration. We use this medium in our greenhouses with raised benches, which are 6 in. deep. Over a permanent gravel base, we place 2 in. of perlite, then 2 in. of vermiculite, and then another 2 in. of perlite on top. We use this medium for one year, starting in June with softwood cuttings and finishing in the winter with evergreen cuttings that are lifted in May. After one year's use, the medium is removed and the benches are disinfected and refilled. The theory behind using this medium is that the base of the cutting is stuck in the vermiculite, which retains more moisture and provides an ideal environment for new roots to form at the base of the cutting. The area above and below the roots stays moist but well drained, which under misting eliminates soggy or overly wet spots in the propagation bench. This is especially important, we feel, when doing softwood cuttings. This medium does become mixed over the course of its use, because of lifting rooted cuttings and releveling; however, the vermiculite level does retain some of its presence. This mixing is to our benefit when we come to sticking evergreen cuttings. The moist layer is then not as important, whereas a more homogenized mix works well for the hardwood evergreens.

Even after one year's use of this medium, we have experienced no disease problems. In the past, samples were sent to our state lab to culture for pathogens, all of which proved negative.

Cost for this medium was $0.002 per cutting. This is based on 1985 prices for perlite of $3.66 per 4-cubic foot bag and vermiculite at $5.47 per 4-cubic foot bag, divided by the total amount of cuttings stuck from May to November. Major genera we root in this medium, starting from first to last, are:

Viburnum
Picea
Euonymus
Acer
Berberis
Cotoneaster
Pyracantha
Forsythia
Ilex
Rhododendron
Juniper
Taxus
Thuja
Chamaecyparis

Although the initial cost per yard may be high for perlite and vermiculite, when the cost is spread over a year's use the cost per cutting becomes very reasonable. In addition to being easy to handle inside the greenhouses, perlite and vermiculite provide a dependable medium which is sterile and uniform.

PEAT, STYROFOAM, AND PERLITE

The second medium we use is a Canadian peat, styrofoam, and perlite mix at the ratio of 8 parts peat, 2 parts styrofoam and 1 part perlite. Captan and Aqua-Gro are added, the medium is mixed, and flats are filled for our evergreen azalea production. We stick approximately 60 cuttings per flat and place the flats on the greenhouse floor under mist. This works well for us, providing a good medium for rooting and growing on, since we do not lift these cuttings after rooting. The azaleas are sold the following spring in the same flat in which they were rooted. We root about 150,000 evergreen azaleas each year with this medium.

Based on our own tests, we switched to this mixture from a 50/50 peat and perlite mixture, since it proved to be far superior for rooting and is much less expensive. Cost for this medium per cutting was $0.004 for 1985, based on peat cost of $3.00 for a 3-cubic foot bale, styrofoam at $4.16 per 8-cubic foot bag, and $3.66 for 4-cubic feet of perlite.

PEAT AND PERLITE

Our third medium is another peat-based one and consists of the following ingredients: 50% Canadian peat and 50% perlite. Captan and Aqua-Gro are added, and flats are filled for use in our outside mist area. We stick an average of 175 cuttings per flat in this mix. Genera rooted in this medium include: *Berberis*, *Cornus*, *Euonymus*, *Ilex* (Japanese holly cultivars), *Prunus* and *Viburnum*. After rooting, these cuttings are lifted and potted, which makes this medium a short-term, once only mix. Cost per cutting for this medium was $0.002, based on 1985 prices for Canadian peat of $3.00 per 3-cubic foot bales and $3.66 for a 4-cubic foot bag of perlite.

SAND AND PERLITE

The fourth medium we use at Appalachian Nurseries is a sand and perlite mixture (1:1,v/v) which is used in our 6 in. deep greenhouse benches. Hardwood evergreen cuttings are rooted in this medium over the winter after being stuck in November and December, and are lifted in May for potting or as rooted cuttings. We mix perlite with sand, because the locally available sand alone is not coarse enough for good

drainage and root formation. We incorporate just enough additional perlite each year to level the benches before sticking.

A drench of Dexon and Terrachlor at recommended rates is applied each year before cuttings are stuck in this mix. Since we do not replace this medium each year, the one-time replacement cost could be spread over approximately 5 years of useage, which makes the cost per cutting insignificant. We stick about 200,000 evergreen cuttings in this mix each year. Genera rooted in this medium are: *Chamaecyparis, Juniperus, Thuja*, and *Taxus*.

To summarize the media discussed above provide us with the necessary variations to accommodate the specific needs of the many genera of plants we are rooting. It is obvious from these figures that the number of cuttings stuck in each medium and/or the number of times the medium can be used will directly affect the unit or cost per cutting for each mix.

IMPORTANCE OF PROPER AERATION IN SOFTWOOD CUTTING PROPAGATION MEDIA

MARK L. RICHEY

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I would like to share some observations I have made at Zelenka Nursery over the past several years as our propagation medium has evolved. Several years ago, the basic requirements of a medium were that it be inexpensive and reusable, as long as no major problems occurred. Our system originally consisted of ground beds under poly, using coarse sand as a medium. At that time, we were sticking about 750,000 softwood cuttings per year and space was not a problem. To reuse the beds the next year, we would mix in some perlite and fumigate. This system gave us acceptable results until we ran out of room to expand. Each year since 1979, our softwood rooting propagation has increased by an average of 750,000 cuttings per year. Therefore, a method had to be developed to increase our production in the same amount of space. We adopted a heavy plastic flat, figuring to get at least two crops of cuttings rooted under the existing mist lines. However, the weight of the flats with the sand medium was a major problem. Each flat weighed over 90 pounds, which made careful handling almost impossible. I also observed that the rooting medium in a flat held more water than in a bed, and this

drainage and root formation. We incorporate just enough additional perlite each year to level the benches before sticking.

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aggravated latent problems always associated with cuttings propagation. To correct these problems, we started using an organic mix of rice hulls, hardwood bark, and sand. This was a green mix that had been stockpiled for only one year. Since we grow the cuttings in the same medium they are rooted in, it has to have the capacity to hold nutrients available to the plants for growth. The green mix provided the drainage we needed but tied up the nutrients. This required us to start fertilizing at 600 ppm nitrogen using a 15-0-5 liquid fertilizer. The organic mix showed promise if the culture problems could be worked out. The following year we had to use a range of greenhouses that previously hadn't been used for cutting propagation. In the polyhouses the flats were set on the ground, but the compacted ground in the greenhouses did not give acceptable drainage. In addition, the porosity was about half that of the previous year when the medium was used the second year. No doubt, the fertilizer used the year before accelerated decomposition of the mix. For the next two years we tried to maintain a uniform medium; however, we were unable to start out with the same medium from one year to the next. In order to keep it uniform, we finally switched to a perlite-based medium. We mixed in ground reed/sedge peat for cation exchange capacity and to improve water retention.

To test porosity, we used a simple test taken from the book, *Nursery Management* by Davidson and Mecklenburg (1). We fill a 64 ounce coffee can with the mix to be tested and slowly added water until the moisture glistened on top. The amount of water used gives the pore volume of the mix. Hence, the porosity can be calculated as follows:

$$\text{porosity} = \frac{\text{pore volume of mix}}{\text{container volume}} \times 100\%$$

We simply punched holes in the plastic lid of the can and poured the free water into a measuring cup. This amount of water represents the aeration pore volume in the mix. Aeration porosity can be calculated as follows:

$$\text{aeration porosity} = \frac{\text{aeration pore volume}}{\text{container volume}} \times 100\%$$

Water-retention porosity is the difference between porosity and aeration porosity; therefore:

$$\text{water retention porosity} = \text{porosity} - \text{aeration porosity}$$

A few years ago, I made the incorrect assumption that aeration and water retention were relatively equal. If the medium was holding too much water under intermittent mist, I thought that decreasing the amount of water would increase the amount of aeration. However, cuttings without roots can die without enough air before the medium dries out sufficiently to give the aeration needed for rooting. The medium is at field capacity when all the gravitational water has drained out. The next critical step is the wilt point. That is when the *medium holds the water tighter than the roots can pull it* away. When unrooted cuttings are sitting in media at field capacity, and there is twice as much water as air, problems can develop. For example, our sand medium has an average of 30% total porosity, but 20% is water retention and 10% is aeration. I found that knowing the total porosity but without knowing the ratio of water-retention to aeration does not help. Our organic mix had a high total porosity but the variability was in the ratio of water retention to aeration from batch to batch. When deciding what perlite mix to use, I tested three combinations of perlite and reed/sedge peat and used our organic mix as the control. The porosity percentages are shown in Table 1. We ran the same amount of mist as needed by the cuttings. The rooting percentages were all about the same but the quality of the cuttings varied substantially.

Table 1. Water-retention porosity, aeration porosity, and total porosity of various media.

Media	Total porosity (percent)	*Water-* retention porosity (percent)	Aeration porosity (percent)
Sand	31	20	11
50% perlite and 50% peat	43	21	22
70% perlite and 30% peat	51	17	34
90% perlite and 10% peat	53	14	39
Organic mix[1]	65	10	55

[1] 40% rice hulls, 40% wood chips, 10% sand, 10% Michigan peat.

The organic mix gave us excellent heavy rooting but, because of the green matter, very little nitrogen was available to the plant and there was not any top growth. The 90/10 mix also produced excellent roots but required more fertilizer to produce the shoot growth that the 70/30 and 50/50 mixes had. In comparing the ratios of water retention to aeration porosities, I found for our operation a ratio of 1:1 to 1:3 of water-retention porosity to aeration porosity gave us the best compromise for rooting and subsequent growth of the cuttings. While more water retention is acceptable with fast rooting cuttings, slower rooting cuttings benefit from greater aeration.

In summary, from my observations, a well-aerated medium is much more forgiving than a poorly aerated one. We have found that with three times more air than water in a mix, we can stick as many as 25% more cuttings per flat than with a water to air ratio of 1:1. However, the cuttings become too crowded if allowed to grow at that density. Root initials form faster and develop with more secondary rooting in a medium with greater aeration. This is possible most of the time because you can use a higher concentration of hormone with less basal burn than in a low aerated medium.

Our requirements for a propagation medium have changed over the years. the proper ratio of water to air porosity, cation exchange capacity, pH, weight, and improved quality and quantity of cuttings rooted, will usually offset the higher initial cost of a medium.

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Thursday Afternoon, December 12, 1985

The Thursday afternoon session convened at 1:30 p.m. with Mark Bridgen serving as moderator.

HOW DOES TISSUE CULTURE BENEFIT THE PRACTICAL PLANT PROPAGATOR?

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How does tissue culture benefit the *practical* plant propagator? A practical plant propagator might ask, is tissue culture propagation (i.e., micropropagation, or *in vitro* propagation) appropriate for my operation? If so, to what extent? How does a propagator determine whether to use tissue culture methods or not? What are the options? Which methods should be employed and on what species? These and numerous related questions need to be asked by the propagator who is considering tissue culture as a possible propagation method. In answering these questions it is important to remember how the practical plant propagator determines whether to use any practice,

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material, or equipment. The answer is, as always, will it be profitable?

Propagators should not be over-awed by the science involved in tissue culture propagation. Instead, they should think of tissue culture simply as a relatively new propagation tool. Admittedly, it is a potentially powerful tool, but it still should be thought of as just another potentially useful method for asexual propagation (cloning). Cloning has traditionally been accomplished by cuttings, grafting, layering, division, apomictic seeds, and the use of special structures such as bulbs, corms, rhizomes, etc. It is now possible to add tissue culture to this list of techniques. To better put tissue culture into perspective, it may be helpful to think of the initial plant part used in tissue culture (the *explant*) as merely a tiny cutting. In fact, most tissue culture propagation can be thought of as a modification of cutting propagation. Because of this, it can be argued that many of the same principles that apply to propagation by cuttings should apply to tissue culture propagation.

WHAT ARE THE OPTIONS?

Let's first examine some of the options available to the propagator considering tissue culture, then some of the previously mentioned principles will be briefly presented. Some of the obvious possibilities are:

1) Construct a large tissue culture laboratory, hire a professional tissue culture manager and staff, and begin to propagate plants in large numbers. This is the most expensive option, at least in the short run, because of the large capital outlay required.

2) Ignore tissue culture propagation completely. This involves no initial investment, but the propagator may be passing up a potentially more efficient and profitable approach to propagating certain species. For example, micropropagation has rapidly become the propagation method of choice for *Spathiphyllum*, especially when it is to be used for landscape purposes.

3) Try an approach somewhat intermediate to options 1 and 2:

A) Test the water by trying a small-scale, low-budget approach such as that proposed to this Society several years ago by Stoltz (14).

B) Purchase your tissue culture propagules from established tissue culture producers.

i. Buy proliferating cultures, harvest the tiny shoots and root them as you would root softwood or herbaceous cuttings.

ii. Buy non-rooted microcuttings (shoots produced *in vitro*, but not yet rooted) and root them yourself.
iii. Buy rooted microcuttings. Typically these would be sold in a fashion similar to that used for bedding plants, i.e. in plugs, packs or flats.
iv. Buy liners produced by tissue culture and grow them on to a salable size.
v. Buy finished plants produced by tissue culture.

Note that buying proliferating cultures or non-rooted microcuttings would require special rooting facilities. Such facilities are more sophisticated than intermittent mist systems commonly employed for rooting cuttings. It has been shown that leaves produced in tissue culture do not have fully functional stomates and possess an anatomy that is substantially different from that of normal leaves (1,15). Therefore, conditions of high humidity (and often reduced light) are necessary to aid in the rooting of microcuttings produced by tissue culture (4,10).

It is obvious that no single option is best for all propagators. One should ask, what best meets the requirements of my particular production scheme? Can existing facilities and equipment be used or adapted to facilitate adoption of tissue culture? Ultimately, economic considerations must be the primary factor considered in making such decisions.

TISSUE CULTURE PRINCIPLES FOR THE PROPAGATOR

The principles of tissue culture methodology, hormonal manipulations, and potential applications to propagation have been well reviewed elsewhere (6,8), so the principles addressed here will concentrate on factors that a propagator typically considers when using conventional propagation methods.

1) *Check the literature.* It is always important to find out what is already known about propagating a particular plant, whether using tissue culture or conventional methods. If nothing has been published, perhaps information is available about a closely related species. Advice can also be sought from research and extension personnel working in horticulture departments at land grant universities and other research institutions. And, of course, don't forget to ask other knowledgeable propagators for their advice and unpublished experiences. Find the best information available and use it to your advantage. Check the Index of the IPPS Proceedings.

2) *Start with good stock plants.* Tissue culture requires disease-free stock plants that have received proper nutrition. Nitrogen and other nutrients provided to the stock plant have been demonstrated to influence the rooting of cuttings (5, 16). Likewise, nutrition of the plant from which the tissue culture explant is taken can have a profound effect on tissue culture success (11, 12). Furthermore, the stock plant light regime has also been shown to influence explant proliferation and subsequent rooting of microcuttings. Red light appears to increase the cytokinin levels in the tissue, which often stimulates shoot proliferation. Far-red light tends to elevate auxin levels which in turn stimulates root induction (2, 9, 12). Stock plant photoperiod and chemical treatments have also caused an increase in proliferation *in vitro* (11, 12). In addition, reduced light intensities applied to the stock plant or culture can cause higher auxin levels, thus facilitating rooting of microcuttings (2). In many cases, growth regulators such as IBA do *not* need to be applied to microcuttings, even for species where rooting stimulants would normally be required when rooting softwood cuttings (4, 9, 10).

3) *Use a good rooting medium.* Microcuttings, like other cuttings, respond favorably to a clean, well-drained medium free of pests, pathogens, and toxic substances. Microcuttings rooted in a soil-like medium usually experience less transplanting shock than those rooted *in vitro*. The pH of the medium also influences the rooting of microcuttings, especially those of species which are particularly pH-sensitive when grown in the field (3).

4) *Provide optimum environment when rooting microcuttings.* As mentioned earlier, high humidity, preferably near 100%, and light levels that are less than ambient may be desirable when rooting microcuttings. Fog systems seem to be near ideal for rooting most microcuttings. Use of a fog system or modification of an existing mist system often will enable the propagator to successfully root microcuttings. Bottom heat has also proven beneficial, while plastic tents over greenhouse benches and similar modifications may also aid the propagator in adapting existing facilities to help root cuttings produced *in vitro* (10).

WHAT NEXT?

Tissue culture is a propagation method of great potential. For some plants, it is already practical and will likely become the method of choice for many others. However, for many species, conventional methods will still be preferable to tissue

culture. For others tissue culture may be the best way to establish sufficient stock plant numbers for subsequent conventional propagation. It is likely that new chemicals and methods will be found that will enable successful tissue culture of previously difficult-to-propagate plants. For example, the use of forcing solutions similar to those used for extending cut flower longevity have been used to force softwood growth from cut woody stems. Such softwood shoots can then be used as a source of explant material for tissue culture during the winter period. The forcing solution has also proved to be a useful means of delivering growth regulating chemicals to the tissue prior to culture initiation. Forcing solutions thus may provide a simple new method of modifying tissue responses in vitro.

Somaclonal variation is another potential future application of tissue culture. It can be used as a new source of genetic variation. This phenomenon has been defined as any type of variation displayed by plants regenerated from any form of plant cell culture (7). An excellent review of this subject was published in Vol. 32 of the IPPS *Proceedings* (13). Identification of somaclonal variants in tissue cultures of horticultural crops may lead to the introduction of superior plants showing increased resistance to diseases, herbicides, drought or cold stress, or to plants possessing improved horticultural traits. These novel plant types could then conceivably be clonally propagated by conventional or tissue culture means for release to the consumer.

Practical propagators should monitor these and other developments in the world of plant tissue culture and take advantage of those that prove to be appropriate to their propagation requirements.

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ROLE OF CYTOKININ IN WOODY PLANT MICROPROPAGATION

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Abstract. Using what has now become a standard technology, woody plant micropropagation takes advantage of the effect of cytokinins in stimulating growth and causing shoot multiplication under controlled tissue culture conditions. Although the greatest impact of micropropagation involves species in Ericaceae and Rosaceae, a systematic survey of 130 species in 33 families and 16 orders indicated that the method could probably be extended to several woody taxa that are not currently being exploited (e.g. other species in order Ericales and species in families Bignoniaceae and Rubiacaea). The survey also identified taxa that are unresponsive to the cytokinins, N6-isopentenyladenine (i^6Ade), thidiazuron, and N6-benzyladenine. Apparently, woody species can be classified into three groups based on their tissue culture characteristics: 1) inherently responsive to cytokinins, 2) responsive to cytokinins after acclimation (e.g. *Magnolia* spp.), and 3)

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unresponsive. To obtain a better understanding of cytokinins in responsive plants, the uptake and metabolism of i^6Ade was studied in *Actinidia arguta* shoot cultures using HPLC methodology. When established cultures were subdivided and individual shoots were recultured on basal medium plus 30 μM i^6Ade, stem zeatin (io^6Ade) levels increased rapidly from 145 nmol/g to >900 nmol/g after 15 days then they declined. It is concluded that during tissue culture growth on i^6Ade, an important aspect of cytokinin metabolism in *Actinidia* involves the conversion of i^6Ade to io^6Ade which accumulates to levels in excess of the critical concentration (150 nmol/g) needed for optimal growth.

INTRODUCTION

In nearly every instance, methods for woody plant micropropagation exploit cytokinin-mediated regulation of shoot growth. By artificially increasing the cytokinin content of shoot explants under *in vitro* conditions, one theoretically supplies sufficient quantities of the phytohormone not only to nourish continued growth but also to overcome apical dominance. The result of this is *shoot multiplication*, a phenomenon that is the foundation of practically all micropropagation technology (10).

Undoubtedly, micropropagation will take on increasing importance as advances are made in biotechnology (2). Because of this, one of the goals of our research involves fundamental studies on processes crucial to micropropagation, especially the role of cytokinins. As more is learned about the scientific basis of micropropagation, the technology can be extended to previously unexploited plant species. In addition, improved understanding means that problems become amenable to logical (i.e. biorational) strategies of solution.

This paper deals with two questions related to cytokinins and micropropagation:

1) To what extent is the classical, cytokinin concept applicable to woody plants, generally? and

2) Do cytokinin levels in shoots increase, as expected, in response to cytokinin treatments and, if so, what are the magnitudes of the changes involved?

To answer the first question, shoot tips from 130 different woody species were surveyed for their cytokinin responses *in vitro*. The results, reported in terms of a framework relating micropropagation potential to systematics (1), suggest that the methodology is probably possible with several additional groups of plants that are not being exploited currently. They also suggest that shoot growth regulation in other groups may not be as easily manipulated by simple cytokinin treatments. With regard to the question of the cytokinin relations in micropropagated shoots, the results with *Actinidia* confirm, for

the first time, the basic assumption that cytokinin treatments elevate internal phytohormone levels. The results further demonstrate that micropropagated shoots are capable of accumulating cytokinin to concentrations far in excess of those present in the medium and of metabolizing supplied cytokinin extensively. The critical concentration of zeatin (io^{6}Ade) for growing *Actinidia* shoots is estimated to be approximately 150 nmol/g.

MATERIALS AND METHODS

Stock plants for tissue culture were greenhouse-grown seedlings (≤1 year old) from the Arnold Arboretum of Harvard University. To screen species for their responses *in vitro*, growing shoot tips (0.5-1 cm) were disinfected and transferred to each of 4 different media: 1) a basal agar medium containing inorganic (11) and organic (8) nutrients but no phytohormone, 2) basal medium plus 30μM N6-isopentenyladenine (i^{6}Ade), 3) basal medium plus 2.2μM thidiazuron (5,9), and 4) basal medium plus 33 μM N6-benzyladenine (bzl^{6}Ade) and 0.6 μM indole-3-acetic acid. Each species was tested on at least 3 different occasions, 4 replications per treatment in each experiment. Cultures (20 ml per tube) were incubated at 27°C usually with a 16 hr light (40-65 $\mu Em^{-2}s^{-1}$) and 8 hr dark photoperiod. A positive (+) response indicates continued growth of the majority of the shoots on at least 1 or more of the 3 different cytokinin media; a negative (−) response indicates no growth or only sporadic growth during the 6 week incubation period. In most cases of positive response, shoots were subcultured for at least 1 passage to demonstrate sustained growth *in vitro*.

To study the uptake and metabolism of cytokinins, shoots were extracted and analyzed by HPLC as described (3,4). Tissues were fixed overnight at 5° C in 95% ethanol (2.5 ml ethanol/g) and then the mixtures were homogenized and filtered. After concentrating filtrates by evaporation *in vacuo*, samples were suspended in 10% ethanol and fractionated by chromatography using a Varian 5000 liquid chromatograph equipped with a C_{18} micropak MCH-5 column and a 254 nm uv detector. Cytokinins, eluted with successive linear gradients of methanol from 15-70% followed by 70-15%, were quantitated by uv absorbance. The identities and purities of HPLC peaks have been confirmed for *Actinidia* based on characteristic uv and mass spectra (3,4).

RESULTS AND DISCUSSIONS

Micropropagation potential in relation to systematics. In spite of its demonstrated importance, micropropagation is still a fairly recent innovation. As a result, the technology has only

been applied to a limited diversity of plant taxa. Table 1 summarizes an extensive survey involving over 6000 cultures and nearly 3 years of investigation to determine the relationship between *in vitro* response of shoots and systematics. As indicated, explants from growing seedlings were tested on basal, phytohormoneless medium as well as on three cytokinin-containing media representing a natural cytokinin (i.e. i^6Ade) and two types of synthetic cytokinins (i.e. bzl^6Ade, an adenine analogue and thidiazuron, a phenylurea cytokinin).

Table 1. Taxa of woody plants tested for cytokinin response in tissue cultures.

Superorder	Order	Family	Number of species	Response
Magnoliidae	Magnoliales	Magnoliaceae	7	−
		Annonaceae	1	−
	Laurales	Calycanthaceae	3	−
		Lauraceae	3	±
	Ranunculales	Ranunculaceae	1	−
Hamamelidae	Fagales	Betuclaceae	7	+
Dilleniidae	Theales	Theaceae	4	±
		Guttiferae	2	+
	Malvales	Malvaceae	1	+
		Tiliaceae	8	−
		Sterculiaceae	3	−
	Urticales	Ulmaceae	7	−
		Moraceae	3	±
	Ericales	Actinidiaceae	5	±
		Ericaceae	3	+
		Clethraceae	1	+
Rosidae	Rosales	Rosaceae	5	+
		Saxifragaceae	1	+
	Fabales	Leguminosae	14	+
	Cornales	Cornaceae	7	±
		Nyssaceae	1	−
	Sapindales	Aceraceae	10	−
		Staphyleaceae	2	−
		Sapindaceae	1	−
		Rutaceae	7	+
		Anacardiaceae	5	±
Asteridae	Gentianales	Oleaceae	7	+
	Lamiales	Verbenaceae	2	+
	Scrophulariales	Scrophulariaceae	1	+
		Bignoniaceae	6	+
	Rubiales	Rubiaceae	2	+

Figure 1 shows clearly that cytokinin responsiveness varies according to the systematic placement of species. Only a single species out of 15 tested in superorder Magnoliidae (i.e. *Sassafras albidum*), for example, exhibited a positive response while all 18 species of superorder Asteridae that were examined could be grown as shoot cultures. In other superorders the response of species were more variable. Within superorder Rosidae, for instance, orders Fabales and Rosales were both consistently positive but order Sapindales contained negative as well as positive species. Likewise, superorder Dilleniidae

could be subdivided into positive and negative systematic groupings.

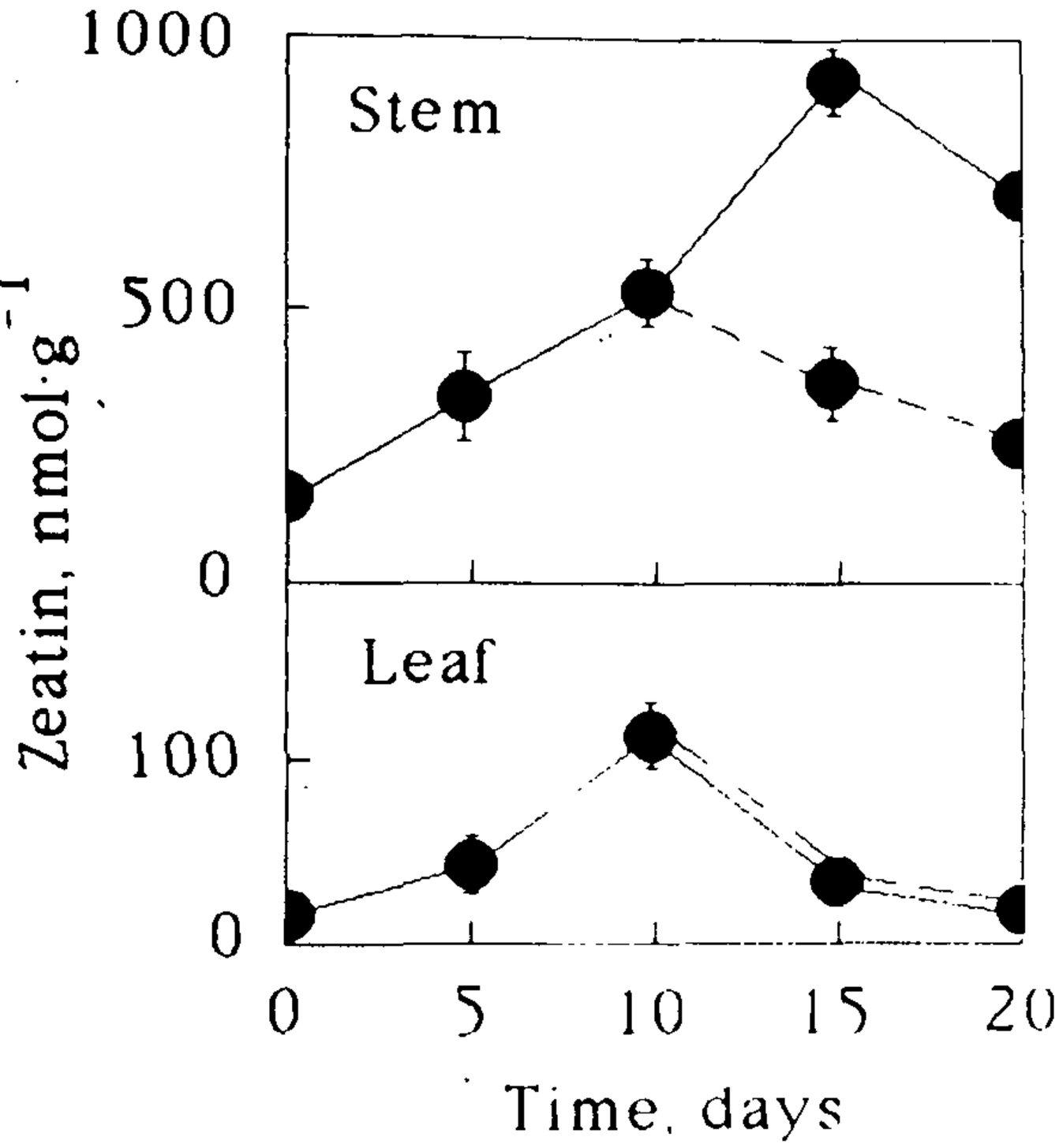

Figure 1. Framework relating the cytokinin response of shoots to systematics. Numbers indicate the different woody species within each order that were tested while stippling shows the percent of these species giving a postive growth response. Superorders: 2+, 3±; Orders: 7+, 7±, 2−, Families: 15+, 5±, 11−; Species: 72+, 58−.

Apparently, woody species fall into three different groups depending on the tissue culture characteristics of their shoots. The first group contains those species that exhibit an inherent response as explants; i.e. positive (+) species in our screen. Examples of plants in this group that are not being micropropagated currently include species in the important tropical tree families Bignoniaceae and Rubiaceae. The second group contains species that respond sporadically as explants or only after repeated subculturing, a phenomenon that has been referred to as *acclimation*, *phase transition*, or *habituation*. An example in this group is *Magnolia* × *soulangiana* which can be grown slowly from explants at a low frequency (approximately 5% of cultures responding) on the medium containing 30 μM i^6Ade. Finally, the third group consists of species that are unresponsive to cytokinin treatments.

Cytokinin dynamics of tissue-cultured shoots. Despite the fact that over 5 billion shoots have been produced by micro-

propagation in the last decade, very little is known about the fate of cytokinins during tissue culture growth. Because of this, and especially in view of the crucial role of cytokinins in micropropagation, studies of cytokinin uptake and metabolism *in vitro* are integral to improving the scientific understanding of micropropagation and, ultimately, to developing new technology.

Figure 2 shows the cytokinin content of *A. arguta* shoots subcultured on basal medium plus 30 μM i^{6}Ade. As indicated, at the time of transfer shoots already contained 145 nmol/g io^{6}Ade from the previous passage *in vitro*. Upon subculture to fresh medium, i^{6}Ade was taken up from the medium and converted to io^{6}Ade which increased in stems to 930 nmol/g during the initial 15 days of incubation and then declined. Interestingly, the io^{6}Ade contents of leaf tissues were significantly lower than those of stems even though leaves also exhibited an initial increase followed by a decrease in io^{6}Ade content.

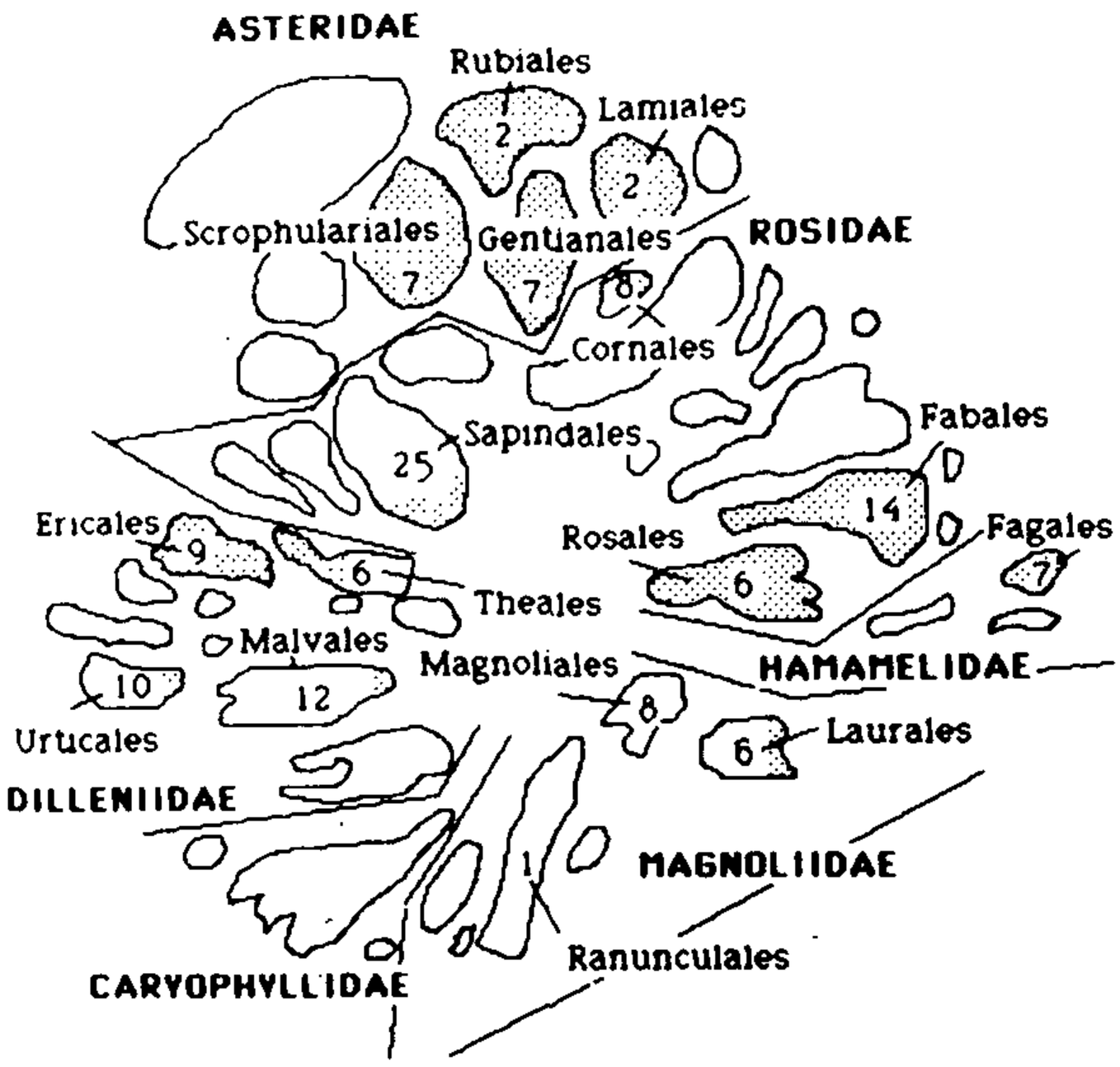

Figure 2. Zeatin contents of stem and leaf tissues in micropropagated *Actinidia arguta*. Shoots were transferred from established 4-week old cultures to medium containing 30 μM i^{6}Ade. The dotted lines show the effect of shoot transfer to basal medium on the subsequent zeatin contents of stems and leaves. All points are means calculated from 4 independent determinations ±SE.

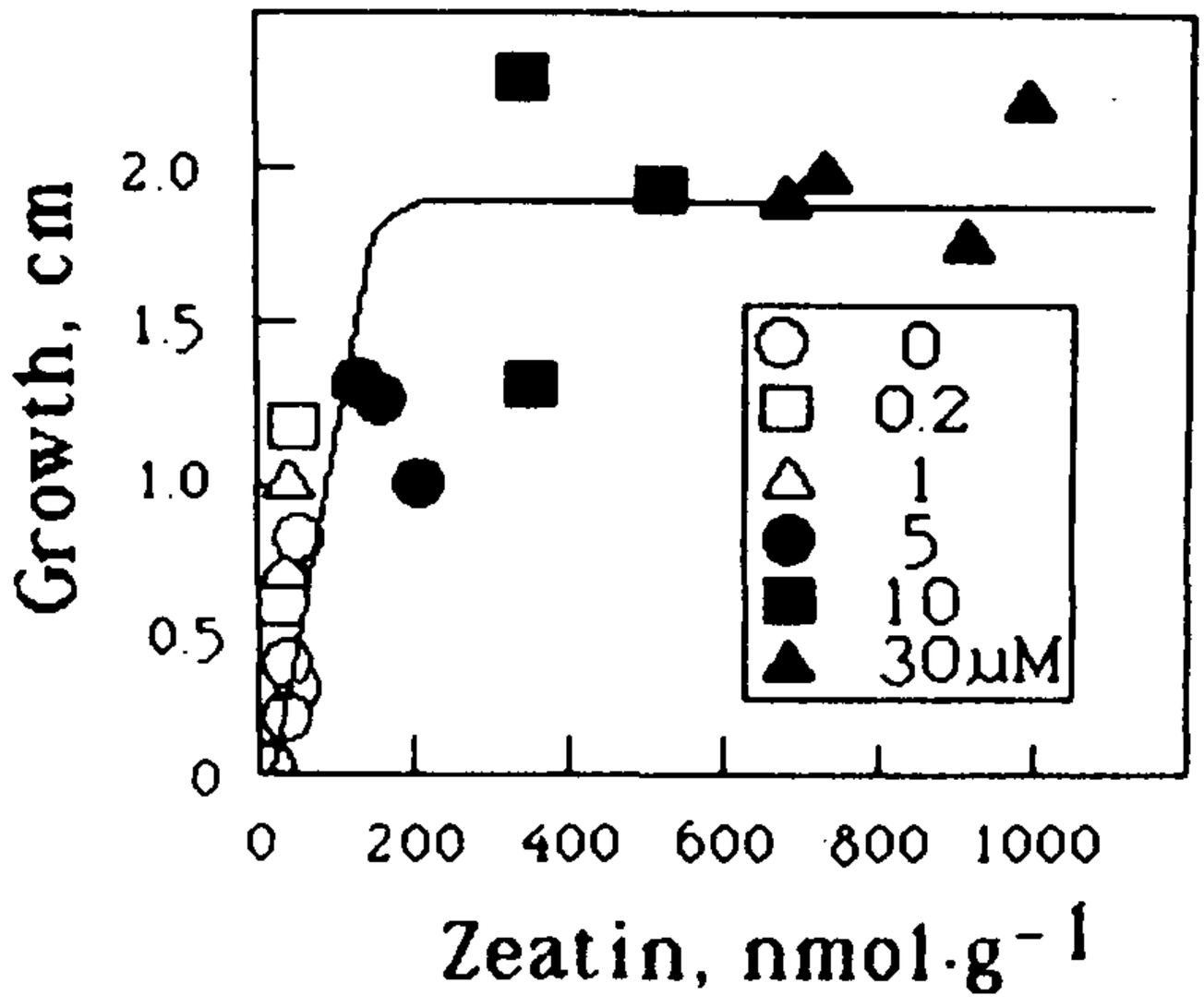

Figure 3. Growth of *Actinidia arguta* shoots in tissue cultures in relation to their internal cytokinin content. Shoots (1.0 cm) from established cultures were transferred to media containing the designated i^6 Ade concentrations (symbols) and incubated for 20 days. After measuring the growth increment, stems were extracted and analyzed for cytokinin contents by HPLC.

SUMMARY

The common objective of both areas considered in this paper is to provide fundamental information as the basis for a biorational approach to micropropagation. It is apparent, for example, that taxa vary with respect to their responsiveness to cytokinin-controlled manipulation of shoot growth. Designation of taxa into groups according to their tissue culture characteristics, therefore, is a way to predict whether or not a given species is a prime target for micropropagation. The process also identifies systematic groupings where further research is needed.

Likewise, an improved understanding of phytohormone assimilation during *in vitro* growth can serve as the foundation for studies to determine why shoots of other species do not grow. Are negative species, for example, able to generate a critical cytokinin concentration within their stems? If they are not, is it because of poor cytokinin uptake and/or transport, or are these plants especially active in destroying cytokinin? Answers to these simple but crucial questions about micropropagation will advance further our knowledge of the scientific basis underlying the technology.

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MICHAEL MARCOTRIGIANO: Question for John Einset. Do you think that some of the plant families that are not responsive are not responsive because you chose not to screen enough cytokinin sources? Possibily their ability to transform the synthetic cytokinin into zeatin is impared.

JOHN EINSET: It is possible. I tried to select media that were representative of media that are used in micropropagation. We had to set limits on the number of media and plants to screen.

RALPH SHUGERT: Question for John Einset. Have you had any experience with the genus *Taxus*? A concern of a propagator is the trueness-to-type when you have a cultivar of a species, such as *Taxus cuspidata* 'Capitata', and propagate it. We know what happens when you take lateral cuttings of that plant. What will we get if we do micropropagation of 'Capitata'?

JOHN EINSET: I have no experience with 'Capitata'. With regards to your second question, research with other plants has shown that if you start with organized structures and force laterals, it should be true-to-type. If you go through a callus you can generate variability, which is called somaclonal variation.

PAUL READ: This is a further response to Ralph's question. Cytokinins are a little tricky in that if you supply high cytokinin levels you may generate a bushier plant in the initial phases. That does not mean that you have modified the genetic make up of the plant. It does mean that you will have to find hormone levels that will give you a single stem plant if that is what you want.

RALPH SHUGERT: My question is, will you get a 'Capitata' type if you micropropagate from a lateral bud?

PAUL READ: I doubt that very much based on our current technology. If you look at something in the same category, *Araucaria*, you do not get good vertical growth from a lateral shoot. I have worked some on spruces and there is a similar concern.

JOHN EINSET: I think that we should remember that a micropropagated shoot is a small shoot and if you have problems with a cutting you will probably have trouble in a test tube.

EVALUATION OF A HOME TISSUE CULTURE MEDIUM

ANDREW BRAND AND MARK P. BRIDGEN[1]

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Abstract. A comparison between variations of a proposed Home Tissue Culture Medium to the Murashige and Skoog basal medium is described. African violets, Boston ferns and variegated wandering Jew were able to be micropropagated on each medium. Although growth occured on all media, the Home Tissue Culture Medium supplemented with a vitamin tablet produced the best growth. Results with this medium were comparable to those obtained with Murashige and skoog's medium. The Home Tissue Culture Medium supplemented with coconut milk had the worst growth. By using the medium described, plant micropropagation can be performed at home using household items and simplified procedures.

REVIEW OF LITERATURE

Plant tissue culture is used by over 267 commercial nurseries and greenhouse growers in the United States for plant propagation (4). Although technical procedures for micropropagation are diverse, the popularity of this microtechnique is spreading to plant hobbyists (1). Bridgen and Veilleux (2,3) proposed simplified procedures and a culture medium for

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amateur gardeners to use; however, data on the success of using this medium has not been reported. The following study is a comparison of variations of the proposed medium to the Murashige and Skoog (5) nutrient medium.

MATERIALS AND METHODS

Four media were tested in this experiment. Treatments 1, 2 and 3 each contained the Home Tissue Culture Medium constituents (Table 1) as the basal medium. Treatment 1 included 4 tablespoons of unfiltered coconut milk; treatment 2 included a crushed vitamin tablet (One-A-Day plus Iron); treatment 3 had both coconut milk and a crushed vitamin tablet added; and treatment 4 contained the Murashige and Skoog (MS) (5) vitamins and macro- and microelements, 3% sucrose, and 6% Difco Bacto-agar. The pH values of all media were monitored but no adjustments were made in the Home Tissue Culture Medium. The pH of treatment 4 was adjusted to a value equal to that of the other treatments (pH 6.2 ± 0.1). All media were autoclaved at 15 psi and 121°C for 13 minutes.

Table 1. Home Tissue Culture Medium[1].

Basic medium constituent	Amount
Table sugar	⅛ cup (23 g)
All purpose soluble fertilizer	1 cup (240 ml)[2]
Tap water	1 cup (240 ml)
Inositol tablet (250 mg)	½ tablet (125 mg)
Agar flakes	2 tbsp
Optional constituents	**Amount**
Coconut milk	4 tbsp (60 ml)
Vitamin tablet	¼ tablet
Dolomite lime tablet	½ to 1 tablet[3]

[1] Modified Bridgen and Veilleux (1983) medium for a total of 1 pint of medium.
[2] Use 1 cup from the stock solution prepared by adding ¼ tsp fertilizer per gallon water.
[3] To be used in areas where water pH values are very low.

Boston fern (*Nephrolepsis exaltata* 'Bostoniensis'), variegated wandering Jew (*Tradescantia fluminensis* 'Variegata'), and African violet (*Saintpaulia ionantha* 'Tomie Lou') were propagated on each medium. Explants consisted of 3 cm rhizome tips from the fern, leaf/petiole cuttings from the African violet, and 3 cm shoot tips from the wandering Jew. African violet and fern explants were removed from aseptic cultures; wandering Jew explants were disinfested in 0.5% sodium hypochlorite for 15 min followed by a rinse in sterile distilled water. Explants were cultured in Bellco glass tubes (150 × 25 mm) and clear polypropylene "eggs" (10 × 15 mm). Cultures

were incubated at 27 ± 3°C under a photoperiod of 16 hr using cool white fluorescent lights (60-70μE $s^{-1}m^{-2}$).

Although a paper support had been suggested previously for the Home Tissue Culture Medium (3), common household thickeners such as corn starch, tapioca, gelatin, and agar flakes were tried as support materials.

Each treatment was replicated at least 8 times. The experiments were repeated twice and set up in a randomized complete block design.

RESULTS

The agar flakes solidified the media as well as commercial agar and remained solid during the course of the experiments. The corn starch, tapioca, and gelatin proved to be inadequate; these materials lost the ability to support plant material within 2 weeks after media preparation. The following results are from experiments performed with agar flakes used as the support material.

The African violet, wandering Jew, and fern explants all formed leaves and roots on all media (Figures 1,2,3,4 and Table 2). Treatments 2 and 4 had superior rooting and leaf production on all species. The fern on treatment 2 produced more leaves in the first 4 weeks than the other treatments (Figure 1). However, after 8 weeks, treatments 2 and 4 had comparable leaf production. The same pattern existed in fern root production (Figure 2). The number of leaves produced per African violet explant was greater for treatments 2 and 4 during the entire 8 weeks (Figure 3). The least amount of African violet leaf production was observed on treatment 1. Root production on all African violet explants was satisfactory, but superior on treatment 2 (Figure 4). After 5 weeks in culture, the wandering Jew formed no new axillary shoots on any medium; however, either one or two roots formed per explant on treatments 2, 3 and 4. Root and leaf initiation on wandering Jew explants was faster on treatments 2 and 4; no new roots or shoots formed on treatment 1 (Table 2). The only difference noticed in leaf and root initiation with African violets was on treatment 1; leaf production was considerably slower than the other treatments.

DISCUSSION

When modified, the Home Tissue Culture Medium (HTCM) proposed by Bridgen and Veilleux will allow plant micropropagation as well as the (MS) medium. Although each modification of the HTCM was satisfactory for plant growth, the medium which worked the best for these species included a crushed vitamin tablet and no coconut milk.

Table 2. Number of days for initiation of leaves and roots on African violet and wandering Jew explants.

Treatment	African violet		Wandering Jew	
	Leaves	Roots	Leaves	Roots
1	50	16	NA[1]	NA
2	21	13	19	7
3	23	16	22	12
4	27	15	19	4

[1] Not applicable - after 5 weeks, no new roots or shoots formed.

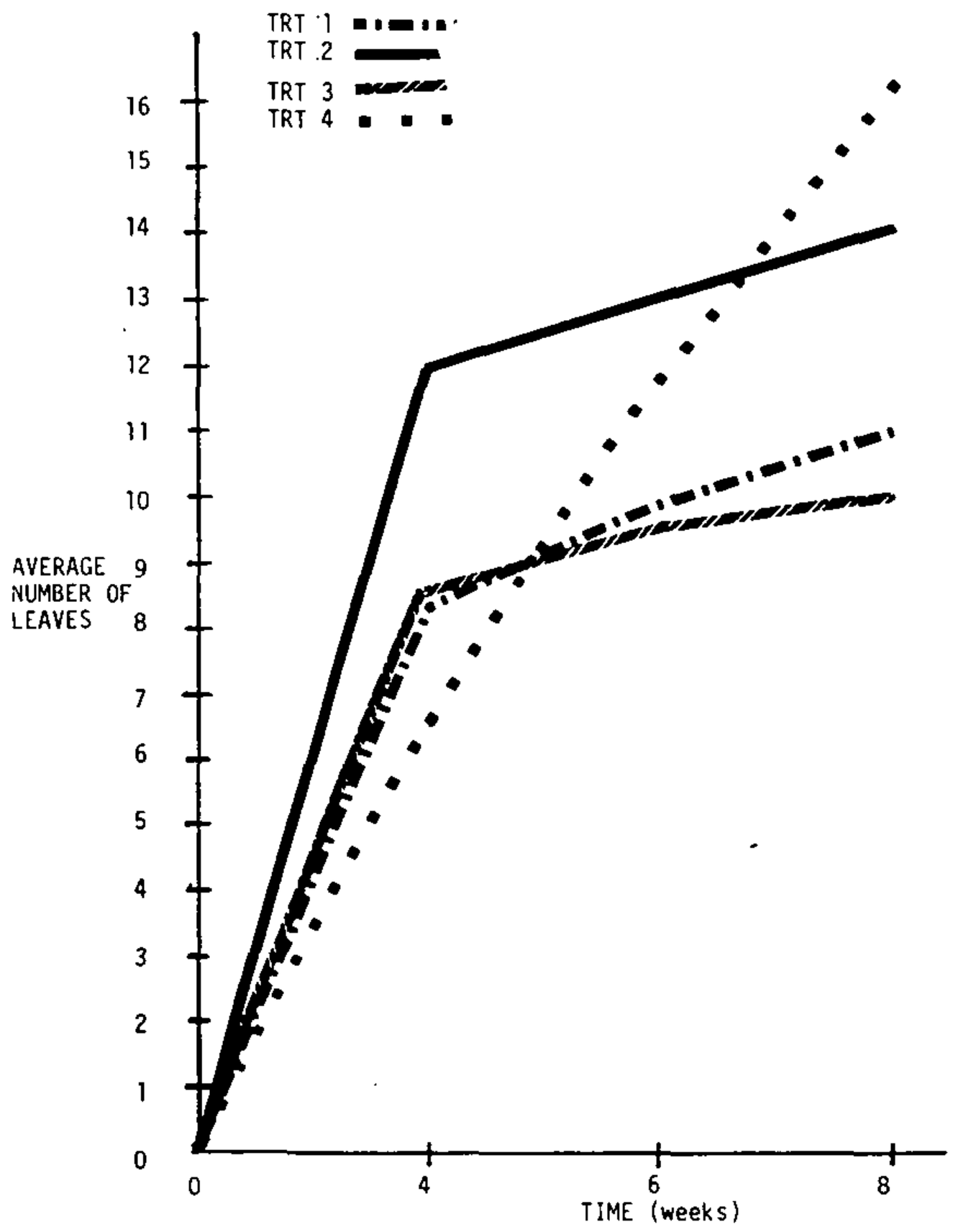

Figure 1. Average number of leaves produced per fern explant over an 8 week period.

Results of the HTCM may vary depending on the species propagated, the type of water-soluble fertilizer and vitamin, and the pH of water available. The pH of the tap water used for these experiments was not adjusted in order to simulate non-laboratory conditions. Distilled water could be used in areas with extreme pH values.

The kinds of water-soluble fertilizer and vitamin tablet used may also affect results. These experiments used Rapid-Gro fertilizer and One-A-Day Plus Iron vitamin tablets, but any other similar product could be used as long as the fertilizer is complete and the vitamins include thiamine. Coconut milk did not produce as favorable results as the medium without it. However, these results may vary for the species and propagule used.

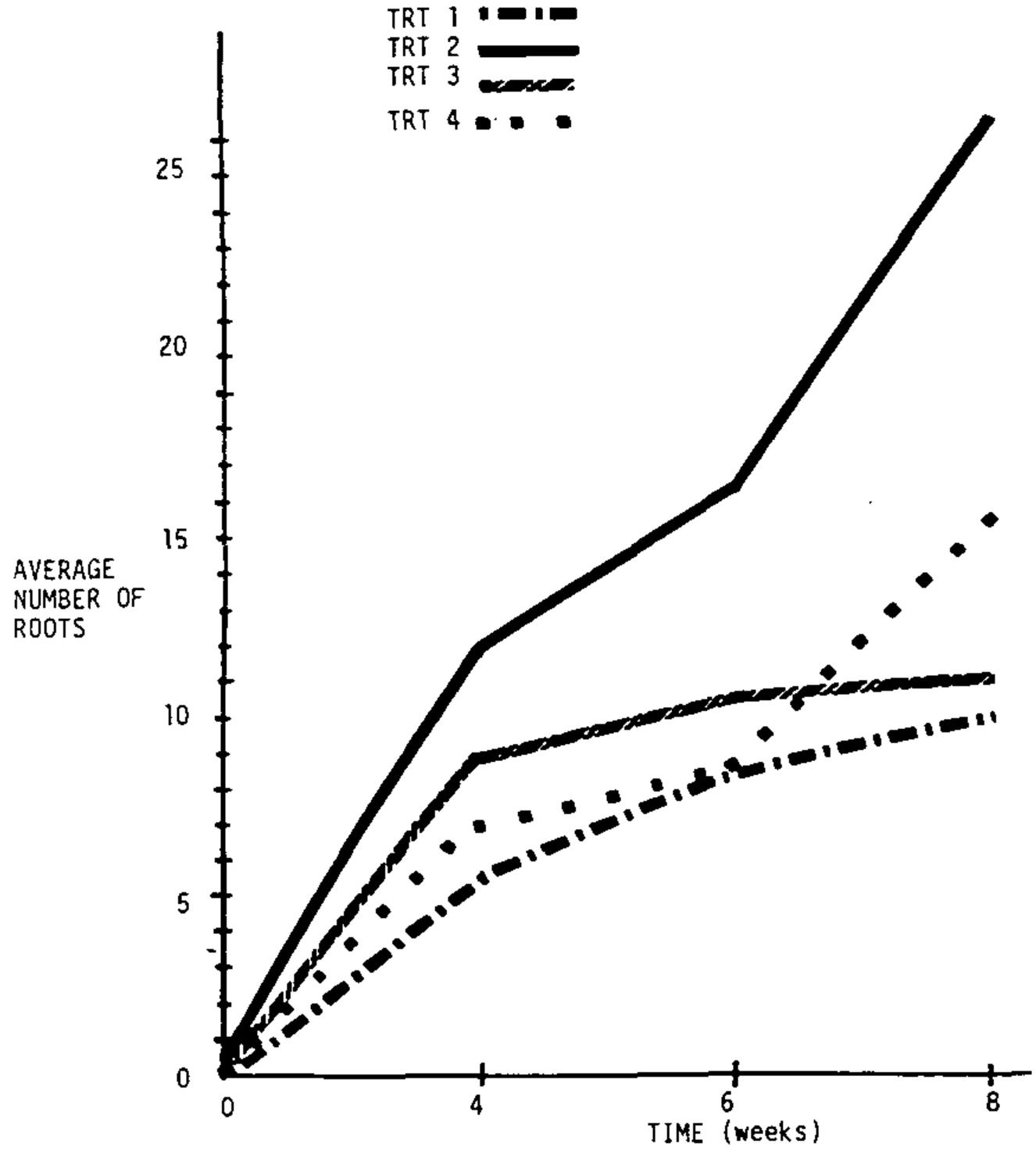

Figure 2. Average number of roots produced per fern explant over an 8 week period.

The data presented show that it is possible, using materials readily available to the amateur gardener, to micropropagate plants. The success of this medium will not only depend upon the preparation of the medium, but also the preciseness of the aseptic procedures. The hobbyist does not need laboratory conditions to perform microtechnique as long as procedures are followed quickly and aseptically (1,2). Although plant tissue culture will not become a major means of propagation for the hobbyist, it has the potential for becoming an intriguing project for plant enthusiasts.

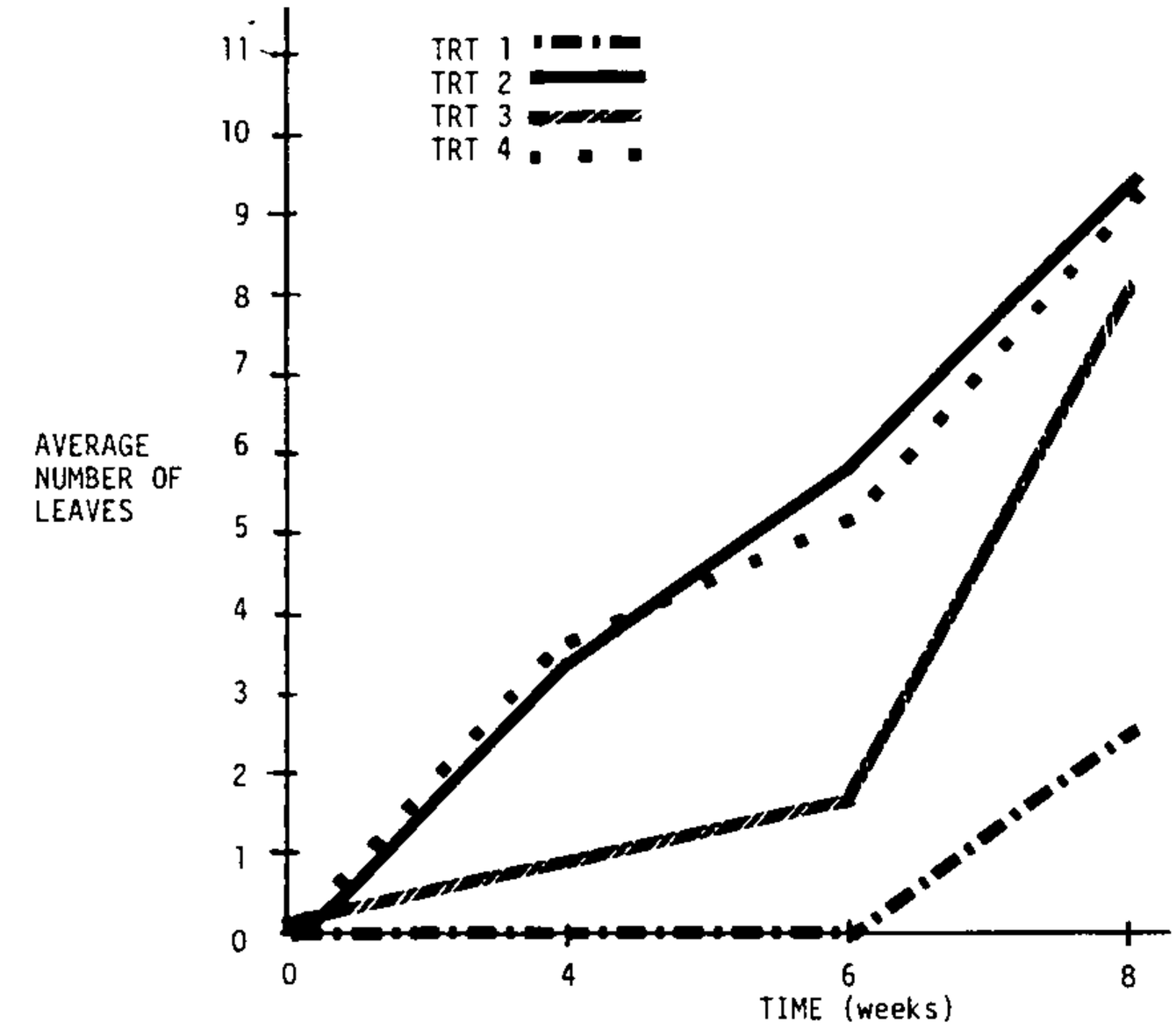

Figure 3. Average number of African violet leaves produced per explant over 8 week period.

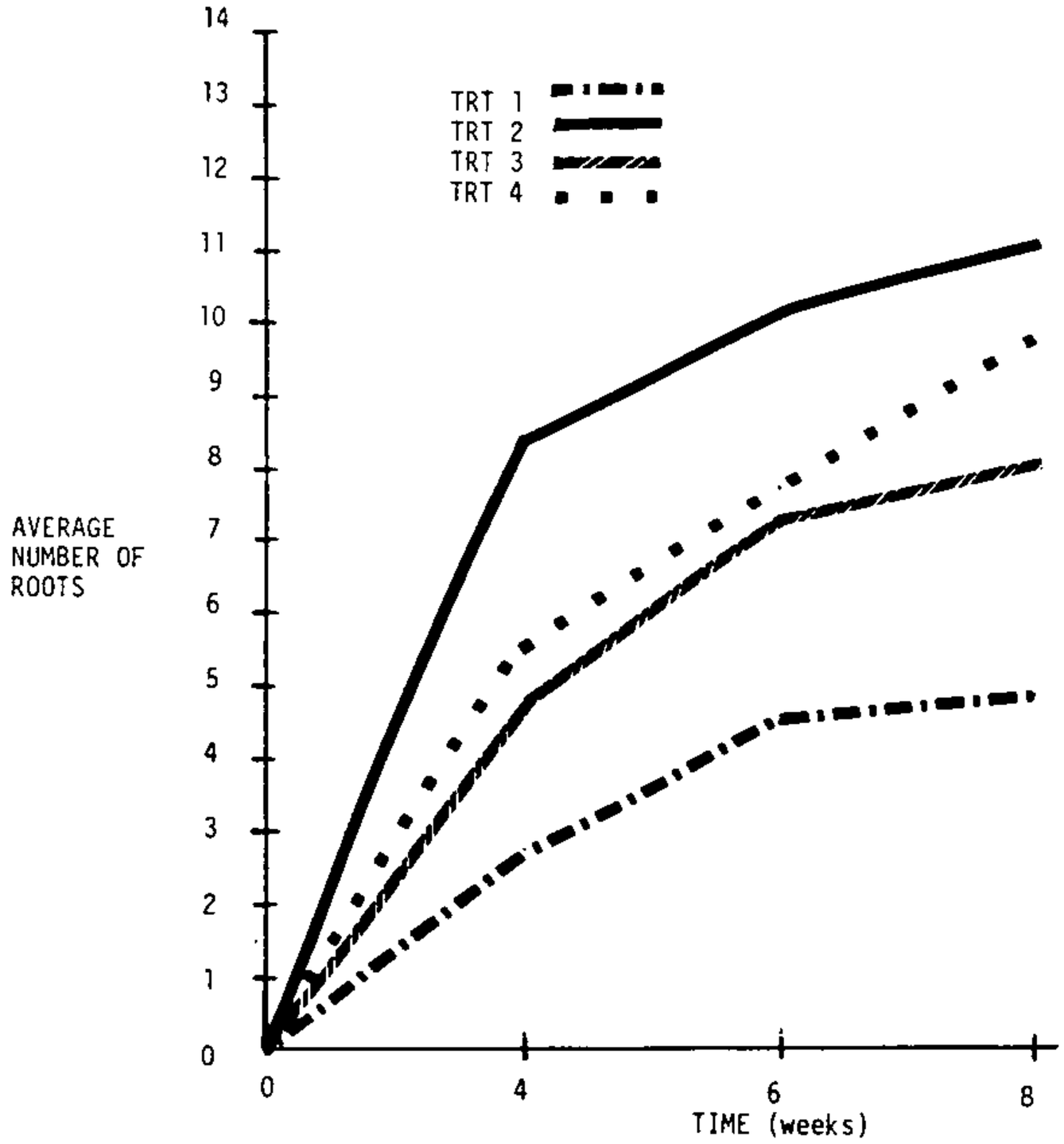

Figure 4. Average number of roots produced per African violet explant over an 8 week period.

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HYBRIDIZING, SELECTING, AND GROWING NEW FORMS OF *KALMIA LATIFOLIA*

R. WAYNE MEZITT

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HISTORY AND BACKGROUND

Although grown by relatively few nurseries until recently, the native mountain laurel, *Kalmia latifolia*, has had a number of devotees over the years. It was one of the first broadleaf evergreens we grew at Weston Nurseries; we first listed it for sale in our 1935 catalog. Those early plants were collected from the wild and grown in our fields to regenerate roots. It wasn't long before we noticed a significant amount of variation in flower color and began to see potential for interesting color in late spring landscapes.

In 1937 we bought some plants from Ernest Borowski, a nurseryman from Norwood, Massachusetts, who grew pink-flowered seedlings. These plants were originally grown and perhaps hybridized by Charles O. Dexter in his quest for more colorful flowers. Dexter was the first person we know who worked on improving mountain laurel. We soon found that our customers enjoyed having more colors from which to choose and by about 1945 we were beginning to raise seedlings of our own.

Things do not happen quickly in the nursery industry. Even though we had sold colored forms for some years it was not until 1959 that we grew enough to list in our catalog. At that time we charged a 50% premium for pinks selected from our growing fields. Since then we have refined our selection process and growing techniques. By the 1970's we were separating colored forms into three major groups: pink, red-bud-

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ded, and fuscata (banded). However, the majority of our sales were still the mixed seedlings (whites to light pinks) that we grew as regular *K. latifolia*. In the late 1950's we began noticing significant variation in plant growth habit and foliage. We started separating and observing some of the best, propagated some by grafting, and tried to root them from cuttings. Further development of named clones was seriously hindered by their difficulty of propagation. We continued to select seedlings and began to build up a rather large collection of unusual plants, but were unable to grow very many because of difficulties in propagating them efficiently.

Today, thanks in large part to tissue culture and clones that root more easily, we are growing and listing more forms of *Kalmia* than ever before. In 1985 we sold over 7500 *K. latifolia* in the 15 in. to eight ft size range. Almost 90% of them were the white to light-pink forms. *Kalmia* sales accounted for about 4% of our total income in 1985. We see a large potential for increased sales, especially with the newer selections now becoming available, and particularly to home gardeners who are largely unfamiliar with *Kalmia*.

BREEDING AND GROWING FROM SEED

There are four methods we use to produce mountain laurel seed. Collecting open-pollinated seed from field-grown or native plants is the easiest method and yields mostly white to light-pink flowered plants. Using open-pollinated seed from selected individuals is another approach which yields a large percentage similar to the parent, but we have experienced regression if isolated plants are used. The third method, caging, was used extensively by Dick Jaynes in his hybridizing programs. Seeds formed on plants that are enclosed in a cage with bumble bees have produced relatively predictable results. Lastly, hand pollinating between selected parents is the surest, though most tedious method. It also produces smaller numbers of plants but most are very predictable in flower color.

We harvest seed in October when capsules are mature, brown in color, and beginning to open. Cleaned seed is sown indoors in 6 in deep seed pans during December without stratifying. Our medium consists of about 1 in. of pure leaf-mold from the forest on top of 3 in. of perlite which is on a mesh screen over crushed stone. Germination occurs within 2 weeks and we transplant to flats during January and February. Seedlings grow in the greenhouse until danger of frost has passed and are then moved to outdoor frames where they remain until the spring of the next year. Minimal fertilizer is used during this period and top growth is sheared to encourage branching. Most often we transplant the 3 to 6 in. plants

into 5 ft beds about 7 in. apart until they are large enough to be grown in the open field 2 to 3 years later. Shade lath (50%) is used the first season in beds. In recent years we have transplanted some plants into containers both at the mature flat size and at the mature bed size. We are finding that containerized plants grow faster and more uniformly than comparable field-grown ones, but are more susceptible to root diseases.

When the 5-year-old seedlings are moved from beds to the open fields they are planted on an 18 × 18 in. format and mulched with wood chips or bark mulch. Over the next 5 years most of them are sold. The remainder are transplanted to 4- or 5-foot rows and grown until they are about 3 or 4 feet tall. We have had best results with bareroot *Kalmia* when it is transplanted in spring, although all seasons have proven successful. Plants moved bareroot in summer, fall, or winter tend to take about a year longer to recover from transplant shock. Balled and burlapped plants show no significant seasonal differences.

Growing tissue culture propagated plants requires a somewhat different approach until the time they are transplanted into flats. Much more detailed attention must be given the unrooted cuttings from the time they are harvested until they root and put on a flush of growth. Their dormancy requirement is also critical; we have experienced difficulties in restarting growth without a dormancy period. We now harvest plantlets so they can be kept in active growth until they can conform to the normal seasons and then be treated similarly to seedlings. Based upon our limited experience in growing tissue culture plantlets, the culture in beds, fields, and containers seems to be the same as that for seedlings.

EVALUATING AND SELECTING

We observe the plants growing in our fields and evaluate for characteristics of flowers, foliage, and growth. Flowers are judged by bud and corolla pigment, how the color changes as the flower matures, size and shape of individual flowers, distribution of flowers on the plant (truss or loose), date of flowering, bud set, alternate-year-flowering tendencies, and comparative earliness or lateness of bloom. Foliage is rated by size, color, shape, texture or leaf density, gloss, insect and disease susceptibility, color of stems and new shoots, and tendency to discolor in winter. Growth is characterized as upright, spreading, bushy (suckering readily), fast, slow, or compact; and winter hardiness is also evaluated.

Evaluation of flower color is a very subjective process. I have seen plants classified as "red-budded" whose buds are not as dark as some pink forms. Seasonal variation, maturity of the flowers, planting location, and other factors can apparently influence color fo flowers, especially pink and red-budded forms.

We begin evaluating red-budded and pink forms when the first flowers begin to open. There is a period of about a week and a half in Hopkinton during which the most reliable evaluations can be made each year. Before or after this period some of the red-budded forms may appear pink, or vice versa. Banded flowers require a fully open corolla because bud color can be the same in continuous or non-continuous bands. We choose only the continuous bands to be designated as fuscata. Red-budded forms are selected only from those flowers whose buds are truly red, not merely dark pink. Pink forms are best chosen when about half the flowers have opened and many pinks tend to intensify at this stage.

We tag plants individually as we select for color using commercially available vinyl tape. Pinks are tagged with orange (which fades far less than pink or red in the outdoors). Fuscata is tagged with blue tape. Red budded selections are tagged with individual red metal labels. These selections are either sold as tagged from their growing areas or individually transplanted to larger rows and grown on as "selected" forms. Blooming time is when we often begin evaluating because that's when we observe all the plants we grow. A better time to evaluate, though, is when they are not blooming because observations are not influenced by dramatic flower characteristics. We have found that soil fertility and consequent plant vigor can drastically alter the appearance of foliage. For this reason we try to observe foliage and growth characteristics of selected individuals over a period of years. Tissue culture now offers us the opportunity to propagate an appropriate number of plants to grow in different conditions and evaluate more reliably.

Growth characteristics tend to be most apparent in older plants. Our selection 'Twenty' was observed for at least a dozen years before it became apparent that it might be a truly compact growing form. Again, tissue culture would have been of great value because the original plant would not have had to be "chopped up" to get enough propagating stock. It could have been evaluated more readily along with the younger plants that were growing in different areas and many years might have been saved.

THE FUTURE

It is hard to envision the implications that tissue culture propagation creates for *K. latifolia*. Rarely has technology provided such a sudden impact on the availability of a previously hard-to-propagate major native plant. Tissue culture, in combination with dramatic improvements in color and form, creates the potential for vastly expanded availability of choice landscape plants unlike any the buyer has ever seen.

We are very excited about the prospects of *Kalmia* finally becoming a major landscape plant. The majority of the plants we grow and sell for the next few years will probably continue to be seedlings and selections. The testing and growing of clones will be expanding and we will offer many named cultivars within a few years. During this time we will be concentrating on properly developing a market to meet the anticipated supply of new forms.

I see three challenges to the nursery industry that are particularly evident with *Kalmia* but really apply to all nursery crops. These are:

(1) Establishing industry-wide standards for evaluation — rhododendrons and roses already have such criteria; a similar set of guidelines should be set up for *Kalmia*.

(2) Setting parameters for landscape performance. Because of the more exact cultural needs of *Kalmia*, our industry has an obligation to let the customer know how to succeed with it in the landscape.

(3) Develop effective marketing to maximize benefits to the consumer as well as the grower. We must have a system to assure that these superior new forms are grown and offered for sale to take best advantage of their virtues and create high customer satisfaction.

PROPAGATING AND PRODUCING *KALMIA LATIFOLIA* CONVENTIONALLY

JOHN (ED.) KINSEY
Kinsey Gardens, Inc.
4823 Skyline Drive
Knoxville, Tennessee 37914

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new selections and Richard Jaynes' book, *The Laurel Book*. We had had enough success to know it was possible to root some clones, but our local demand was very low. Up until recently, most mountain laurel was produced from collected plants that were cut back and transplanted to the nursery, or simply cutback or burned over and then dug in place a few years later. Quality and survivial have usually been undependable and variable. There were no named clones available. Prices for this material were relatively low and knowledge of how to grow and landscape with them was limited.

With the publication of Richard Jaynes' book (1) and his development of distinctively colored named clones, my interest in mountain laurel became much greater. Several years ago after an IPPS meeting at Rutgers University, Richard Jaynes sent me my first unrooted mountain laurel cuttings, 'Nipmuck' and 'Quinnipiac,' in a small sandwich bag. I stuck these in with my rhododendron crop and they rooted over 75%; that was very encouraging and I have been taking cuttings of these plants ever since. This year I plan to stick 10,000 cuttings of various mountain laurel clones.

With mountain laurel's increased availability through tissue culture, Kinsey Gardens is buying each of the new clones and evaluating them for rootability, habit, disease and insect resistance, and flower color under our conditions. If we cannot propagate our own by conventional cuttings, we are not interested in the clone.

We incorporate mountain laurel propagation right into our rhododendron production routine. The only difference is that we wait until January to take our cuttings. By this time dormancy requirements will be satisfied and we will have no trouble with the rooted cutting breaking bud uniformly in the spring. Cuttings are collected from the previous summer's last flush of new growth, washed in a Captan and Benlate solution and wounded as we do rhododendron. The cuttings are stuck in a 6 in. deep bench of peat and perlite (1:2,v/v) mix maintained at 72°F by hot air forced through a convection tube under the bench. Cuttings are misted for 10 sec every 10 min. Rooting occurs in 4 to 6 months. The rooted cuttings are then potted into 1-gal containers containing 100% pine bark, plus Staygreen Prostart and sulfur-coated fertilizers, and placed in a shaded house. After acclimation, the shade is removed and the plants are grown in full sun. The plants are sheared at least twice during the summer. Spraying is done every two weeks just as we do with our rhododendron. We generally do not sell 1-gal plants because we need to use them as stock plants for next year's cuttings, and it is difficult to produce a well-branched plant the first year. One-gallon plants are overwin-

tered under poly, and cut back in January for cuttings, and then shifted into 2-gal containers in spring. They are further sheared for uniformity and grown to salable sizes for fall and the following spring. Light shearing is done during that summer to further help branching.

Selections which we are producing conventionally include 'Nipmuck', 'Quinnipiac', 'Sarah', 'Pink Charm', and 'Silver Dollar'. We have had poor success rooting 'Ostbo Red' and 'Goodrich'. This year we will be evaluating 'Bullseye' and 'Elf'.

Another aspect of our mountain laurel production that is just now becoming reality is seed propagation. Seed is collected from native stands and from some red-budded crosses. I understand that red-budded plants come true from seed at a pretty good percentage, so we have planted several red-budded cultivars in close proximity for cross pollination.

Seed is sown in December in flats just as one would sow rhododendron, pieris, or azalea seed. The seeds are sprinkled on the surface of the medium in a flat with a salt shaker and misted in with a fog nozzle. The flat is slid into a white garbage bag which is held off the surface of the mix with bent wires arched into each side of the flat. The surface is sprayed with Captan plus Benlate and the bag is sealed and placed under fluorescent lights in a heated room for germination. Germination occurs in several weeks and the seedlings continue to grow in the bag for several weeks.

Then the bag is opened gradually to harden off the seedlings. The plants continue growing under 24 hr of light until being pricked out and transplanted into a flat of peat and perlite for growing on. While in the flats the plants are fertilized with dilute 20-20-20 liquid fertilizer.

Transplanting is generally done in the spring and by fall the plants are large enough to be potted or put in field beds to produce a heavy well-branched liner for further field transplanting or potting into 2-gal pots.

In closing, many clones of mountain laurel can be propagated successfully and economically by conventional means. I can foresee that as more and more named selections become available, easy to propagate cultivars will gain the greatest popularity.

LITERATURE CITED

1. Jaynes, R.A. 1975. The Laurel Book. Hafner Press, New York.

VOICE: What is the concentration of the growth regulator used for rooting?

ED KINSEY: It was 0.8% IBA.

JAMES BOODLEY: What type of lamps did you use, how close were they, and what was the photoperiod?

ED KINSEY: The lamps are ordinary cool-white type and they are placed 12 to 15 in. from the plants. We use a 24 hr light period.

DICK JAYNES: A lot of kalmia growers are having a problem with liners flopping over in the container or the roots not going down. What has been your experience?

ED KINSEY: I have had more of a problem with the tissue-cultured liners than rooted cuttings. As for the roots, we are using a pine bark mix with no problems.

Thursday Evening, December 12, 1985

The thirty-fifth annual banquet was held in the Ballroom of the Biltmore Plaza Hotel, Providence, Rhode Island.

On behalf of the Society, the first research award was presented to Dr. Nina Bassuk, Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, New York.

Lawrence Carville made the following Award of Merit presentation:

EASTERN REGION AWARD OF MERIT

Tonight we are privileged to honor one of our members with the highest recognition the Eastern Region can bestow, the Award of Merit. This award was first given in 1957 and has been awarded annually whenever a deserving recipient is nominated by the membership. The Award of Merit recognizes outstanding contributions to the art and science of plant propagation, either by a practitioner or an academician.

Our recipient this evening has been chosen from the practical field because he is a propagator in every sense of the word. To him, the motto of our Society, TO SEEK AND TO SHARE, is more than words. They are his daily creed.

Our honoree became a member of the Eastern Region in 1962 and presented his first of many papers in Cleveland in 1965. Some of you will recognize him from the title of this paper: "*Corylus* and *Cornus* from cutting." His papers appeared

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in subsequent Proceedings every year for six consecutive years.

I came to know this propagator because his knowledge was freely shared and was of tremendous help to me in my fledgling years as a propagator here in Rhode Island.

He served with me as a member on the Eastern Region Board and has continued to remain active as chairman of various committees, as a moderator, as participant in grafting workshops, and as a presenter of meaningful papers. He is the type of down-to-earth propagator who tells it like it is, who reports on not only the rooted cuttings but on the unrooted and dead ones as well.

Most of you in this room heard his presentation Tuesday on the subject of seed treatments to enhance germination. On Friday, you will enjoy his quick wit as co-moderator for the Question Box. Much like E.F. Hutton, when he talks, people listen!

I am honored and proud to present the 1985 Award of Merit to a good friend and good neighbor from the north, from Sheriden Nurseries in Oakville, Ontario. A warm and appreciative welcome for Joerg Leiss.

Friday Morning, December 13, 1985

The Friday morning session convened at 8:00 a.m. with Mark Widrlechner serving as moderator.

CONTAINERIZED SEEDLING AND ROOTED CUTTING TECHNOLOGY IN SWEDEN

HENRY F. HUGHES

International Forest Seed Company
Box 290
Odenville, Alabama 35120

As are their ornamental cousins of the domestic landscape, species of forest trees are subject to intensive selection and breeding. Genotypes superior in growth rate, disease resistance, wood characteristics, etc. are exchanged among members of forest tree improvement cooperatives. Grafted scions of these genotypes arranged in the field for adequate clonal dispersion and cross pollination grow to become production seed orchards. As more and more seed is collected from orchards,

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forest tree nurseries are being stocked increasingly with genetically improved seedlings.

To enhance the development of improved seedlings, nursery culture is intensified. Sites for new bareroot nurseries are carefully selected for soil and water quality. Intensively managed containerized forest nurseries are being established, some with rooted cuttings as well as with seedlings.

As has been the practice in Europe for many years, management of forest nurseries in the U.S. is increasingly being viewed as the prerogative of the horticulturist. Moreover, equipment and methods traditionally used for the propagation and production of ornamental plants are being adapted by forestry nurseries. Greenhouses, for example, are being used in many nurseries to extend the growing season and to reduce production time and to improve the growing environment of containerized seedlings.

In Scandinavia, highly sophisticated nurseries are a result of an overall increase in the mechanization of reforestation that began in the 1970's. To reduce very high labor costs, machine planting of containerized seedlings extends the planting season beyond the colder months. The cost effectiveness of machine planting is increased by using the machinery for more months of the year. In contrast, bareroot seedlings can only be planted in the winter while they are dormant.

The Hiko System is one method of producing and planting high quality containerized forest seedlings. Developed in Sweden in the 1980s, the system has been adapted in France, Austria, Ireland, Canada, and the United States for use with small-seeded species of spruce and pine. Modifications have made possible the manual sowing of large-seeded species and the sticking of cuttings. Use of the Hiko System in conjunction with greenhouses from Finland and computerized climate controls from Denmark has created a very efficient production system at Hilleshog Forestry AB in Falconberg, Sweden.

Though numerous types of fiber pots are used in Sweden, the Scandinavian country with the largest forest area, plastic container sets have been used the longest. The basic unit of the Hiko System is the container set, a polyethylene multipot measuring 21 × 35 cm. Sets have 40 tapered, ribbed, open-ended containers, each of 93 cm^3. Plants propagated in these containers develop a dense and fibrous root system.

Metal growing frames hold 60 container sets above ground allowing air pruning of roots. Frames may also serve as shipping units for plants and as storage racks for container sets. Storage of frames and sets for 5 million plants grown on one hectare is possible in a compact space 3 meters high by 30

meters square.

Stacks of container sets are fed automatically to the Hiko filling and sowing line and then filled, compacted, and sown in 5 electronically synchronized steps, which occur on 5 sets simultaneously. Growing medium is vibrated into the containers and compacted to 1 kg/cm^2.

Seed is moved from hoppers by vibration plates to two rotating cams, each with 20 indentations for single seeds. Seed is dropped into 40 tubes leading to the sets. Liquid gel may be added to maintain hydration between the seed and growing medium prior to seed germination.

With a three person crew, one set is completed every 5 sec — or over 20,000 containers are seeded per day. To insure that planting is done efficiently, seed must be very clean and of uniform size. This is accomplished with vacuum cleaning and sizing equipment. Very small seed can be encapsulated to a uniformly larger size and treated with pesticides, mycorrhizae, etc. Seeded container sets are moved by conveyor for automatic loading onto stacked growing frames.

Cuttings of Norway spruce, *Picea abies*, are easily rooted. Sets are filled with pure peat moss in place of the peat and perlite (3:1,v/v) medium used for seedlings. They are diverted to a room where refrigerated cuttings 8 to 10 cm are stuck. About 6,000 can be taken from field or potted hedges and stuck per person each day. Cuttings may be stored for several weeks if the dry weight is at least 30% of the fresh weight. Otherwise they may be stored only a few days. No hormones are used due to strict government safety regulations.

Frames are transported in stacks by forklift to the propagation houses measuring 25 × 114 meters. These are supplied by Kevythalli OY of Finland. Frames are unloaded by articulated hydraulic arms and arranged by seedlot or clone. Houses each take a week to fill with 1.2 million plants. To maximize space utilization, frames of container sets are pushed as closely together as possible. Thinning and transplanting are accomplished by "walking through" the container sets, whereby workers move sets behind themselves as they complete work on each set in front of them. A variety of Hiko traveling boom irrigators provide water. Relative humidity for the cuttings is maintained at 90% and dropped to 65% after rooting.

All fertilizer is applied through the irrigation line after 70% seed germination or after rooting has occurred. Herbicides are also applied in this manner after plants are about 2 months old. During winter propagation, light at 1,000 lux is applied by the boom every half hour to extend the photoperiod.

When the houses are filled, the temperature is gradually

raised to 23°C and then lowered to 20°C after 70% germination or rooting. The atmosphere is enriched to the economic optimum of 1500 ppm CO_2 during daylight hours by injection into the air circulation system.

All climate control is done with a computer from Dansk Gartneri Teknik of Denmark. Sensors monitor all climatic factors continously and record them every 15 minutes. An office terminal allows instant screen readout and printed records of accumulated daily and weekly data files. Should the programmed limits for any environmental factor be exceeded, sensors linked to alarm systems will detect the changes.

When winter crops of seedlings or rooted cuttings of Norway spruce are large enough, they are transferred to outdoor holding areas for overwintering. Though temperatures fluctuate below the freezing point during the long winter, only a minimal amount of protection is necessary. The growing frames are close to the ground and are pushed closely together. Salmon netting is stretched over the frames to support a spun fiber fabric which is sealed along the sides of the frames. This, along with snow fence protects the plants from wind and allows irrigation to continue throughout the winter.

Though plants may be transported on the growing frames, they are usually shipped in container sets in corrugated boxes with 120 plants per box. A variety of Hiko machine and hand-planting equipment is available that conforms exactly to the particular dimensions of the plug and top size of the plants. Though the equipment is designed for reforestation, it can be easily adapted to the outplanting of nursery liner stock.

Further information on the Hiko System and the greenhouses mentioned herein may be obtained from the author in the United States, or from the following address:' Hilleshog Forestry AB, 789 Don Mills Road, Suite 700, Toronto, Ontario, M3C 3L6, Canada.

QUESTION BOX

The Question Box Session was convened at 8:40 a.m. with Ralph Shugert and Joerg Leiss serving as moderators.

MODERATOR LEISS: Question for Dale Deppe. What is your misting nozzle?

DALE DEPPE: A Spraying System 1/4 E10. We operate it at 70 psi. It is available from Spraying Systems.

MODERATOR LEISS: Why do such outstanding nurseries, such as we saw Wednesday, hold to cow manure instead of chemical fertilizers; to hoeing and mule cultivation instead of

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machine and herbicides; and hand digging instead of machine?

RON ST. JAMES: The reason Rhode Island Nurseries uses mules is because they plant very close together and could not cultivate with a tractor. Van Hof Nurseries still uses hand weeding but also has a herbicide program.

MODERATOR SHUGERT: To any Newport, Rhode Island *Taxus* grower. Why do you pound (beat) the sand in your propagation benches?

RON ST. JAMES: Because it works and we see no reason to change.

MODERATOR SHUGERT: Question for Dale Maronek on his paper. Was that a 1:1 v/v haydite-peat moss mix? Did the haydite in the mix affect overwintering of the rooted cuttings?

DALE MARONEK: Yes, it was a 1:1 mix. I cannot answer the haydite question in full. We had problems with perlite in our peat-perlite mix during overwintering under microfoam. We wanted to cut the high porosity down and hopefully increase survival.

MODERATOR SHUGERT: Question for Dale Maronek. What is the size of the slate granules used in your planting medium? Can any other aggregates be used, such as granite?

DALE MARONEK: Around ⅜ in. particle size for one gallon and up. The smaller material lines up with perlite and is a blend of sizes that range from about 1-4 mm. With regard to the granite, I would recommend that you use whatever is readily available close by that is cheap and learn to grow in it. You will save yourself a lot of dollars. You can use almost anything. I was talking to one grower who grinds up used Ivory soap containers and puts it in his mix. Use what is economical in your area.

MODERATOR SHUGERT: When one sprays young rooted cuttings with fungicides such as Subdue, Zineb, Terrachlor, Captan, and other fungicides, what happens to the root mycorrhizal fungi?

DALE MARONEK: I cannot address Subdue. There is a wide variety of sensitivities of mycorrhizal fungi, but basically most are tolerant of the fungicides we use. You may knock the population down some but they will come back. In fact some, such as Benlate, appear to stimulate their growth. Therefore, some stimulate, some inhibit slightly, but there are only a few that have a devastating effect.

DICK BIR: In work with Subdue on Fraser fir to supress *Phytophthora*, we have found that it does not harm the mycorrhizal population. In fact, the mycorrhizal population increased.

MODERATOR SHUGERT: Would you see a problem in blending Subdue and Benlate together?

DALE MARONEK: I have not blended the two together and do not know if you would have phytotoxicity problems. Subdue does have problems with some products.

MODERATOR LEISS: Question for Dr. Marcotrigiano. Do you believe a graft chimera can be initiated in subjects such as *Acer, Cornus, Fagus* and *Magnolia* and, if so, what is the recommended technique?

MICHAEL MARCOTRIGIANO: In woody plants there are few cases in which graft chimeras have arisen because forming adventitious shoots from a graft union is not that common. The only ones that have occurred by accident that I know of are *Laburnum* and *Cytisus, Pyrus* and *Cydonia*, and *Crataegus* and *Mespilus*. This is an area with few studies.

MODERATOR LEISS: Question to Ed Kinsey. What is your fertilizer program for *Kalmia* seedlings?

ED KINSEY: For seedlings in flats it is a 20-20-20 every two weeks at about 400 ppm.

MODERATOR LEISS: What would it cost for a home tissue culture lab equipped and supplied for modest initial entry into micropropagation?

LEN STOLTZ: I have a paper in the *Proceedings* that addresses that very point. (Editor's note: See *IPPS Proceedings* 29:375.) Today I feel that you could get started for about $2000.

MODERATOR LEISS: How do you root *Euonymus alata* 'Compacta' during the winter months?

ED LOSLEY: The cuttings are taken in November-December; they are 6 to 8 in. long and from heavy current season's growth, single wounded, and dipped in 2% IBA powder. Incubate in a box with damp sphagnum moss and when you see callus, place in sand so only the top 2 to 3 buds show in a minimum heat house.

MODERATOR SHUGERT: Can *Myrica pensylvanica* cuttings be rooted?

CLAYTON FULLER: We root them from softwood cuttings about the third week of July. Use Hormodin #2 and take the cuttings from the soft growth of container-grown plants. We obtain about 70% rooting.

MODERATOR SHUGERT: What rule of thumb could you use in timing the kill of the companion grass in seed beds?

RALPH SHUGERT: I would think that Wayne Lovelace is looking to that last danger of frost.

MODERATOR LEISS: What are the pollination require-

ments of *Ilex verticillata*?

ELWIN ORTON: The plant is dioecious so you need a male plant for pollination.

ED LOSLEY: Some cultivars flower earlier than others and you would need a male that flowers at the same time as the female.

MODERATOR LEISS: Question for Peter Del Tredici. Will a cutting taken from a grafted specimen of a dwarf conifer clone exhibit the coarser growth of the grafted plant or the slower growth of the original clone?

PETER DEL TREDICI: I can only address this from my experience with the *Tsuga* cultivars 'Nana' and 'Cole'. Cuttings from the more vigorous grafts reverted back to the slower growth. So, you could use grafting to increase your stock material for dwarf plants.

MODERATOR SHUGERT: Question for Len Savella. What is rotten rock?

LEN SAVELLA: It is a local stone that has decayed over the years. People in our area use it for driveways. It is a very coarse but sharp material and we screen it before putting it in our propagation benches. It is an excellent material for rooting rhododendrons and the roots come off like hair on a dog's back. For those that are growing some of the fragile rooted rhododendrons I would recommend that you try it.

MODERATOR SHUGERT: Question for Mike Young. When you were evaluating the gelling strength of various agars, what pH did you use?

MIKE YOUNG: The pH was 5.7

MODERATOR LEISS: Is there a consistent way to root cuttings of sweet gum?

BILL FLEMER: We are not rooting them now but did some years ago. We made the cuttings about August 1st, placed them under mist, and used Hormodin #2. We had a problem overwintering them and had to place the rooted cuttings in a cold house that did not go below freezing. Freezing will cause stem cracking.

MODERATOR SHUGERT: Question for Dr. Waxman. How do you apply sucrose to cuttings and what concentrations are used?

SID WAXMAN: As a 10% solution to the base of the stem for 24 hr.

MODERATOR SHUGERT: Question for Dr. Waxman. What time of the year do you propagate your pine cuttings?

SID WAXMAN: January through April.

MODERATOR SHUGERT: Have you ever seen witches' brooms on deciduous trees, shrubs, and Virginia pine?

SID WAXMAN: I have seen them on Japanese maple and heard about black walnut. There are many others caused by diseases and I am not interested in those. With the Japanese maple I have grafted it and it reverted to an upright leggy plant; however, there are others who have grafted Japanese maple brooms that have remained as brooms. Richard Wolff might address this point.

MODERATOR SHUGERT: What is the dilution rate for Dip-N-Grow compared to powders, i.e. Hormodin? For example, is a 1:10 Dip-N-Grow equivalent to Hormodin #3?

ED KINSEY: A 1 to 10 dilution is equivalent to 0.8% IBA.

MODERATOR SHUGERT: Is there a dictionary of propagation terms and words? If so, what, where and how can I get one?

VOICE: The propagation book by Hartmann and Kester would be a good source.

MODERATOR SHUGERT: Can hardwood cuttings of *Forsythia ovata* be rooted?

JOERG LEISS: It is just about as hard to root as *Syringa*. You have to get it early as a softwood and it is still hard to root. We have a cultivar, 'Ottawa', that is also difficult. *Forsythia ovata* 'Robusta', which I think is a hybrid, is easy to root.

MODERATOR SHUGERT: What is the difference between *Tsuga canadensis*: 'Sargentii' and *T. canadensis* 'Pendula'?

PETER DEL TREDICI: I recognize that 'Pendula' is a clonal name that applies to a group of plants that has been grown from cuttings and seed, and there is a large number of plants that are readily recognized as 'Sargents' hemlock. I consider 'Pendula' to be the correct name.

MODERATOR LEISS: Has anyone used the probe type automatic soil pH testers? If so, how accurate are they compared to chemical testing methods?

FRANK GOUIN: Several years ago we ran a comparison and found that if the medium is on the dry side they will read too high, while a wet medium will read a lower pH. If you put them close to a granule of Osmocoat or sulfur-coated urea they will drop down to about pH 2. A soluble salt content of 700 to 1000 ppm is also required to give an accurate reading. In artificial media I would say definitely not, but in soil it would be more accurate except if placed in a fertilizer band. We prefer a regular pH meter.

MODERATOR LEISS: Question for Mike Young. What are

the current prices of the gels in your study?

MIKE YOUNG: I will include the prices in my paper.

MODERATOR LEISS: Are you or do you know of anyone propagating witchhazels using tissue culture?

STEVE McCULLOCH: We have overcome the contamination problem. They are very hairy which causes problems with contamination. They also are different in that they just want to elongate and we are working on that problem.

MODERATOR SHUGERT: Question for Dr. Jaynes. Has work been done on interspecific hybridizing of *Kalmia* to incorporate dwarf and hardy genes of *K. polifolia* or *K. angustifolia* into *K. latifolia*?

FRASER HANDCOCK: I asked Dr. Jaynes and he said he has not had any luck getting any fertile first generation plants.

MODERATOR LEISS: Question for Dixon Hoogendoorn. How do you root and flush *Hydrangea petiolaris*?

DIXON HOOGENDOORN: We have a stock block that we prune hard to force growth for cutting wood. Take the cuttings about the third week of June, treat with 5% Jiffy, and place in outside mist beds. They are rooted by September. We overwinter in our refrigeration unit at about 35°F because if they get any frost they will split. We also protect them from frost the second winter. The ones that you saw in the greenhouse were rooted last year and potted up.

JOERG LEISS: Once they set a flower bud you cannot root them.

BRUCE BRIGGS: Pick them off as soft as you can and as early as you can. If you see any browning on the stem you are too late. Another way is to collect your own seed, which is an excellent method.

MODERATOR LEISS: Question for Dixon Hoogendoorn. Please summarize your *Helleborus* production. Also discuss double dipping cuttings with respect to rooting hormones.

DIXON HOOGENDOORN: We collect our own seed about the third week of June before they drop to the ground. Dry the seed in the greenhouse for a short time, give it a warm stratification period in sand until around the end of September, and then plant it in outdoor seed beds. It is usually the first plant to come up — around the first of March.

For certain plants that are difficult-to-root for us, such as *Taxus baccata* 'Repandens', we dip in Jiffy (4:1) liquid and follow, after drying, with Hormodin #3.

MODERATOR SHUGERT: Question for Henry Hughes. Can the plug foot planter be adapted for planting other sized

rooted plugs or even bulbs?

HENRY HUGHES: Yes, it can be modified for other sizes.

MODERATOR LEISS: What is the address of Agritech?

EDITOR'S NOTE: Agritech, Inc., P.O. 33083, Raleigh, NC 27606.

MODERATOR LEISS: With the etiolated cuttings in Brian Maynard's paper, do you wound the stem before you put the band on the stem?

MICHAEL DODGE: No, the Velcro wounds the stem.

MODERATOR LEISS: What is the name of the material applied to the etiolated stem?

JOERG LEISS: Velcro — and it should be available from any sewing store.

MODERATOR SHUGERT: Question for Dr. Stimart. You stated that fertilizer is bad for overwintering cuttings which did not grow. What about those cuttings which did have new growth? Did fertilization also reduce their overwintering survival?

DENNIS STIMART: I am suggesting that you stay away from the nitrogen because some of the plants that grow, such as parrotia, have an overwintering problem that results in bark bursting. We are trying to figure this out.

MODERATOR SHUGERT: Question for Dr. Stimart. Which is killed first, stems or roots of overwintered cuttings? At what temperature does killing occur? What causes stem splitting?

DENNIS STIMART: My understanding is that roots are killed at a much higher temperature than shoots.

HAROLD PELLETT: I have not worked with newly-rooted cuttings but working with older roots of some of the hardier species one finds that the maximum hardiness potential is around 0°F and with less hardy plants it can be around 20 to 25°F. Stem tissues would be more hardy in all cases. With rooted cuttings which have younger tissues they are going to be less hardy.

FRANK GOUIN: With root hardiness you have to look at primary versus secondary roots. There can be as much as a 10°F difference in hardiness between the two.

With stem splitting you have to look at the maturation of the cells close to the ground that are the last ones to mature. We have seen this with some azalea work on the eastern shore. When you fertilize too late on a young plant they will burst. On an older plant you can hold some heat close to the ground and the stem will mature.

ART DEWITT: There was a report in the *Proceedings* a

number of years ago in which stem splitting was related to the weather. We had three weeks of warm weather in the spring and this was followed by a drop to 10°F one night. I can remember *Thuja* 'Pyramidalis' split a foot high.

PETER VERMEULEN: There is a direct correlation between stem water and splitting. One year we had a dry summer that was followed by a wet fall. That year we had some Gable azaleas that made most of their growth late in the season and were still lush when we had an early hard frost that resulted in 80 to 90% splitting. A technique of old time azalea growers in our area when such a condition existed was to break the feeder roots with a fork to check growth and harden off the plants.

MODERATOR SHUGERT: Question for Dr. Stimart. In your work, for cuttings which grew, did the amount of new growth per cutting seem to correspond with percent survival? That is, did cuttings that grew a lot survive better than those with only a small amount of growth?

DENNIS STIMART: We have not seen a correlation between the magnitude of growth and overwintering survival. It is not how much growth occurs but that they break bud and grow.

MODERATOR LEISS: Question to Richard Bir. Could you supply more information on olivine, such as composition, availability of magnesium, source, and cost?

RICHARD BIR: It is a mineral that is mined in our area and is used in the steel industry. Availability is from International Minerals Corporation which has an office in Spruce Pine, NC. They are bagging it in 100 lb bags of 100 mesh and it cost just slightly more than a bag of lime. You can arrange for bulk shipments.

MODERATOR SHUGERT: Can anyone tell us about *Pseudomonus* attacking Japanese maples and other plants? What fungicide can be used to control it?

CHARLES FINDLEY: There is no fungicide that would be effective against *Pseudomonus* because it is a bacteria. You need a bacteriacide.

KEEPING TRACK OF NEW CULTIVAR INTRODUCTIONS

RUTH KVAALEN

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Some time ago I read an article about Callery pear cultivars which mentioned the name of a cultivar with which I was not familiar — 'King Road.' No details about this cultivar were given. Let me tell you about my search for information. First, I consulted the "Checklist of Cultivars of Callery Pear," by Frank Santamour and Alice Jacot McArdle, from the *Journal of Arboriculture* in April, 1983, which contained a comprehensive list of cultivars. However, 'King Road' was not among the names listed.

I looked in McClintock and Leiser's *Annotated Checklist of Woody Ornamental Plants*, Dirr's *Manual of Woody Landscape Plants*, Gerd Krussmann's *Manual of Cultivated Broadleaved Trees and Shrubs*, the lists of patented plants, W.J. Bean's *Trees and Shrubs Hardy in the British Isles*, and the indexes of *HortScience*, all without success. Next I turned to nursery catalogs, but I didn't find the cultivar in question.

I wrote letters to two people, one to Frank Santamour at the U.S. Arboretum, who prepared the checklist that had appeared in the *Journal of Arboriculture*, and one to the editor of the newsletter in which I had seen the reference to 'King Road.' Dr. Santamour indicated that he had not run across this name previously. The editor of the newsletter did not answer my letter. Later, when I called him, he claimed to have no personal knowledge of the plant and no recollection of the name. The article, he said, probably had been picked up from some other source.

These experiences illustrate the difficulty in tracking down information about a cultivar. With large numbers of cultivars on the market and new ones being introduced each year, there is a need for some way to keep track of new cultivars as they originate.

A committee of the American Society for Horticultural Science (ASHS) has inaugurated a plan to assist in doing that. The purpose is to obtain information about a new cultivar while that information is still readily available. The committee has prepared a one-page form to be filled in with the appropriate data, such as kind of plant, cultivar name, trademark name (if any), originator, plant description, location of the original plant, and so forth. There is no cost to participate in this process, and it does not obligate the originator to anything. In

time, the committee plans to publish annual lists of new cultivars with brief descriptions and source information.

Collecting this information is designed to do the following: make the horticultural community aware of a new cultivar and its availability in the trade; establish who originated a particular cultivar, in case of dispute in the future; and provide a data base for historical information on cultivars introduced to the gardening public. Furthermore, it will afford an opportunity to make known regionally adapted cultivars, which otherwise get little attention beyond their region.

The goal of this committee of the ASHS is to have one person in each state who will receive the information about cultivars originating in his or her state. So far, more than half the states have a person acting in that capacity, whom we can call a State Coordinator.

After the one-page data forms are filled out by the person involved with the cultivar (most likely the originator or introducer), the forms should be returned to the State Coordinator who, in turn, will forward those collected each year to the Committee Chairman. Information about these new cultivars will then be published, probably in the *Journal of Environmental Horticulture* (a publication of the Horticulture Research Institute) or in *HortScience*.

However, supplying information to this organization does not substitute for registering the name of the cultivar with the International Registration Authority for that kind of plant. The person who originates or introduces a cultivar should take seriously the responsibility of having the name of the cultivar registered.

Registration is simply the acceptance of a cultivar named by a Registration Authority and the inclusion of the name in a register. The main objective of registration is to stabilize and standardize cultivar names.

Registration Authorities are national or international agencies entrusted with compiling and publishing lists of cultivar names within a particular genus, species, or group; establishing which names are valid and legitimate and which are clearly synonymous; advising on and accepting new names; and interpreting the *International Code of Nomenclature for Cultivated Plants* in certain instances.

Plant societies, such as the Holly Society of America, Inc., or the American Magnolia Society, often act as Registration Authorities. Within an institution or organization which has been appointed to act as a Registration Authority, usually one person is designated to act as Registrar. To learn the name and address of a Registration Authority, contact the American As-

sociation of Nurserymen at 1250 I Street N.W., Suite 500, Washington, D.C. 20005.

Before introducing a cultivar, one should consult the appropriate Registration Authority. The Registrar can supply a checklist of names already used in the genus, species, or cultivar group to which the cultivar belongs. This list will enable one to avoid picking a name too similar to names already in use.

As a cultivar, its name must follow certain rules and recommendations set forth in the "Cultivated Code" — the *International Code of Nomenclature for Cultivated Plants-1980.* The name must be applied to a cultivar not already legitimately named; it must be selected in accordance with the Code; and it must not duplicate a name already in use for another cultivar in the same cultivar class. A previously used cultivar name cannot be reused later for any other cultivar on the assumption that the original cultivar no longer exists.

The Registrar can advise whether the proposed name is acceptable, and he or she can proceed to register the new cultivar's name.

Once a satisfactory name is chosen, the name must be "published." This means that:

— The name must appear in printed reading matter which is distributed or available to the public. Non-technical newspapers and handwritten materials are excluded.
— The reading material must be clearly dated at least as to year.
— Publication of the cultivar name must be accompanied by a description of the cultivar, or by a reference to a previously published description. The description should contain particulars to distinguish the cultivar from related cultivars. (Note that a name published without a description is not a legitimate name and could be replaced by another name.)
— Whenever prossible, an illustration should be provided with the description.

If these criteria have been met, dated trade catalogs qualify as acceptable printed material, as do horticultural journals and magazines, or a registration list of a Registration Authority.

Registration prevents confusion that could arise from the use of the same, or similar, names for two or more distinct cultivars, or the application of two or more different cultivar names to a single entity. It ensures that the selected name is

the legitimate name for that cultivar only.

It must be emphasized that registration is a published and documented record of the name only and does not apply to the actual plant or clone being named. Acceptance of a cultivar name for registration does not imply judgment on the distinctiveness or merit of the cultivar.

To conclude, at any time when you are introducing a new cultivar, you should take these two steps:

1) Register the cultivar name with the pertinent Registration Authority;
2) Contact the Landscape and Turf Working Group of the ASHS, fill out their form and return it. If you do not know who your State Coordinator is, contact Dr. Gerald Klingman, Department of Horticulture and Forestry, University of Arkansas, Fayetteville, Arkansas 72701, for information and data forms.

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NEW PLANT FORUM

JACK ALEXANDER and GARY KOLLER, MODERATORS

JOERG LEISS: *Dianthus* 'Frosty Flame' starts to flower in May and continues to flower until frost. The color is an attractive deep red. The originator is Tony Huber of W. Perron and Cie, Montreal. It is easily propagated by softwood cuttings during the summer months under intermittent mist or under plastic.

Taxus cuspidata 'Aurescens' is a plant that has been in commerce for quite a while. It is sometimes falsely called *T. baccata* 'Aurea'. The foliage is banded in shade and bright yellow in full sun. There is a plant at the Arnold Arboretum. It propagates easily as does most *Taxus*, but grows best under light shade.

RICHARD LIGHTY: *Lindera angustifolia* has been in North America for at least 30 years, although it originally was circulated, probably by

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RICHARD LIGHTY: *Lindera angustifolia* has been in North America for at least 30 years, although it originally was circulated, probably by

Henry Kohankie, under the name *L. umbellata* var. *hypoglauca*. My plants were grown from seed given me by John Fogg, then director of the Barnes Foundation.

Lindera angustifolia is monoecious, unlike a number of other species in the genus and produces abundant, round, glossy black fruit in groups of 1-3 on a twiggy shrub to 8 meters. It is a useful plant in natural or informal landscapes at any season but can be one of the most spectacular plants in the landscape when it colors red in autumn. It does this with regularity in New England, and sporadically in the Delaware River Valley. The conditions under which this happens are not clear. In all areas the leaves turn uniformly tan as winter approaches, and persist into the new year.

This plant may be propagated by seeds by giving them a 2 to 3 month cold period followed by a warm period.

SUSAN BENTZ: The Japanese iris cultivars that I will present are from the breeding program of W.L. Ackerman at the U.S. National Arboretum. These cultivars resulted from a breeding program utilizing *Iris kaempferi* germplasm imported from Japan through the U.S. Department of Agriculture, Agricultural Research Service, Plant Introduction System. Goals of these genetic investigations included: the development of new floral forms and colors, extension of flowering season, increased floral longevity, and development of dwarf forms.

'Wine Ruffles' — Double, 30 in. tall, velvety purple falls with ruffled margins, bright yellow signal, vigorous.

'Grape Fizz' — Double, 33 in. tall, ruffled purple-violet falls with sharp white mosaic.

'Lavendar Krinkle' — Double, 30 in. tall, broad violet ruffled falls, white around signal.

'Sky and Mist' — Double plus, 24 in. tall, loose peony form, white falls with violet-blue veins, late blooming.

'Royal Fireworks' — Double, 40 in. tall, velvety ruffled violet, very early and vigorous. Repetitive flowering noted.

'Enduring Pink Frost' — Single, 22 in. tall, bicolor, white falls with lavendar-pink standards, long lasting flowers.

'Lasting Pleasure' — Double, 30 in. tall, purple-violet falls with white margins and light interveinal areas, long lasting flowers.

Japanese iris may be grown successfully in most parts of the U.S. Blooming after the tall bearded iris, they extend the season into the summer months. They do best in an acid soil (pH 5.5), rich in organic matter, and plentiful moisture during spring and through the flowering season.

Propagation is mostly by division.

GARY KOLLER: The following weigela cultivars were supplied by F. Svejda, ornamental plant breeder, Agriculture Canada, Research Branch, Ontario Region, Ottawa Research Station, Building 50, Ottawa, Ontario, Canada D1A 0C6.

Weigela 'Samba' was registered with the Canadian Ornamental Plant Foundation in 1985 by the Ottawa Research Station.

'Samba' is very hardy, freely flowering and is an attractive, medium high shrub with grey-purple foliage. Hardy flowering shrubs with purple foliage are rare. It resulted from a cross between *Weigela* 'Rumba' × *W. florida* 'Eva Rathke'. 'Samba' is a vigorous and well-branched shrub which reaches a height and spread of 0.8 to 1 m in Ottawa. The flowers are red (R.H.S. Color Chart (70A-B) with a yellow throat, 2.5 cm across, and a corolla tube 4 to 4.5 cm long. The leaves are abundant, healthy with purple tips and edges (187 A) and dark green bases and centers (147 A), 6 to 7 cm

long, 2.5 to 3.5 cm wide, leathery. 'Samba' has been tested in Ottawa since 1978. It is as hardy and freely flowering as 'Rumba' but does not flower repeatedly. It does not suffer from diseases and is easily propagated from softwood cuttings.

Weigela 'Rumba' is a very hardy new cultivar that is both free flowering and repeated flowering. The flowers are dark red (R.H.S. Color Chart 61A-71B with a yellow throat (11A), 2.5 to 3 dm in diameter. The corolla tube is 4-4.5 cm long. Leaves are abundant, healthy, yellow-green (147A) with purple tinted edges (187A), 7 to 7.8 cm long, 3.5 cm wide, obovate, acuminate, with serrated edges. It flowers as freely as 'Minuet' during the first few weeks, but subsequent flower production declines resulting in a lower average than 'Minuet'.

'Rumba' does not suffer from diseases. It is propagated easily from softwood cuttings.

Weigela 'Minuet' combines the features of both winter hardiness and low stature. This shrub is bushy and well balanced. It reaches a height and diameter of 0.5 to 0.7 m in Ottawa. The foliage is green, with a purple tint, 147A and 187A (R.H.S. Color Chart), and abundant. The leaves are 5 cm long, 2.5 cm wide, with serrated edges. Flowers are slightly fragrant, 3.5 cm in diameter, corolla tube 4 cm long. Color is two-tone: corolla tube and outer corolla are ruby red to magenta rose, 64A-64B; inner petal lobes vary from lilac purple to magenta rose, 70B-70C; throat is yellow, 11A. Bud color is ruby red, 64A.

'Minuet' is easily propagated from softwood cuttings.

JACK ALEXANDER: *Rhus chinensis* is a deciduous shrub or small tree that may vary in height from 3 to 24 ft. It is native to the Himalayas, China, Korea, and Japan. Its leaves are pinnately compound, 8 to 15 in. in length, and have 7 to 13 leaflets. The leaf rachis may be winged, but there is considerable variation of this character.

In the Boston area, large terminal panicles of white flowers are produced in mid to late August. It is these attractive inflorescenses and the brilliant display of fall foliage color, so typical of many *Rhus*, that makes this species horticulturally attractive. The small, reddish-orange fruit ripens in October. Seed may be germinated by soaking in hot water prior to a three month cold stratification period. Selected clones are easily propagated by root cuttings.

According to the literature, this species is hardy to −10°F., but this is based on few individuals and much more testing needs to be done to establish more accurate limits. Because of its wide native range, we should expect greater cold hardiness from collections made in colder regions.

Called Chinese sumac or nutgall tree, for the galls sometimes formed on its foliage when grown in China, and since sumacs and galls are not usually wanted in gardens, it would perhaps benefit from a different common name.

I interviewed a Chinese horticulturist about this species, hoping that another Chinese common name might be more appealing, but the name he knew it by translates to "salt skin tree." This because of the salty flavor borne on the skin of the fruit. He related that in years past, people in remote areas would soak the fruit in water to dissolve the salt, would then remove the fruits and evaporate the water to recover the salt. Still lacking an attractive sounding name, I discussed possibilities with our horticultural staff and we would like to propose Chinese plume tree as a more desirable common name for sales promotion.

PETER DEL TREDICI: *Akebia quinata*, the fiveleaf akebia, is not

new, having been introduced into cultivation in 1845 by Robert Fortune, but is not readily available from nurseries in the northeast. It has developed something of a bad reputation because of the extremely rapid and rampant growth. As is often the case, this reputation is undeserved. There are many situations that call for a very rampant plant to hide a very ugly structure. The fiveleaf akebia can smother other plants when planted near them; however, when planted off by itself, it can be a valuable addition to the landscape. *Akebia quinata* is hardy to U.S.D.A. Zone 4 and, in my opinion, is one of the best plants there is for rapidly covering and hiding chain link fences in an urban area. The fiveleaf akebia is a twining vine that is very useful for covering the stumps of big dead trees, such as the American elm, and it can be used for rambling over stone walls. In short, this is a plant for difficult conditions — both urban and rural.

Akebia quinata has a fine-textured foliage which stays until late fall or early winter, when temperatures dip into the low twenties. The inconspicuous maroon flowers are produced in early spring. The fruit, which matures in September and October, is a very dramatic purple color and comes in bunches not unlike bananas in size and shape.

Few people would argue with the statement that *A. quinata* produces the most bizarre fruit of any plant hardy in Boston. Unfortunately for the gardener, the plant does not produce these fruits every year. Fortunately, this was a good fruiting year for the fiveleaf akebia at the Arnold Arboretum, so I have cleaned, bagged, and stratified the seed for distribution today. The seed is mildly dormant and requires only 1 or 2 months of stratification in order to germinate. The seeds here today can either be sown immediately in a warm greenhouse or they can be put back into the refrigerator for sowing in the spring.

One note of caution. Growing right next to our plant of *A. quinata* is its close relative, *A. trifoliata*, which is not quite so attractive with its somewhat coarser foliage. It is quite possible that I may have collected a few fruits from *A. trifoliata* since the two vines are totally intertwined. It is also possible that there may be some hybrids between the two plants among the seeds, given that such a hybrid (*A.* × *pentaphylla*) is known to exist. *Akebia quinata* can also be rooted readily from softwood cutting. At the Arnold Arboretum, 25 out of 28 cuttings rooted when taken on 21 June and treated with a commercial rooting powder (Hormo-Root B) and placed under mist.

SIDNEY WAXMAN: *Larix decidua* 'Varied Directions' was a seedling found in Connecticut in 1968. Its growth habit is quite different from other weeping larches in that the major branches tend to grow outward with a slight upward curvature while the lateral branches, which are much thinner, cascade down. They are vigorous and can put on as much as 2½ ft of growth per year. Propagation by cutting remains a problem with rooting percentages between 40 and 60%. It can be grafted onto Japanese larch standards.

Sciadopitys verticillata 'Wintergreen' was selected from among a large group of seedlings after many years of observation and testing. It was given the cultivar name Wintergreen because it has consistently retained the dark green color of its foliage throughout the winter whereas the foliage on most other trees turn bronze. These color differences probably would not have been observed had the trees been growing in a sheltered location. Our nursery is located on a hilltop with full exposure to the sun and wind, and as a result, many of the umbrella pines exhibited color changes from green to bronze and, in some cases, to tan on their western exposures. A second attribute is that the tree is densely branched and has a slightly greater growth rate than others in the nursery. A third, and equally important attribute is that it can be readily rooted from cuttings. The tree after 29 years is over 16 ft tall with an annual growth of 14 in.

Pinus strobus 'Golden Candles' was a variegated seedling among many collected from a witches'-broom. Its outer needles are mainly yellow with green tips while the older foliage is entirely green. The plants after 9 years are about 6 ft. tall.

BILL FLEMER III: The Yoshino cherry (*Prunus* × *yedoensis*) is one of the most vigorous growers of all the Japanese cherries and is especially suited for street tree and park planting from Zone 5 south. The flowers are white or pale pink in color. The cultivar 'Afterglow' (P.P. No. 5730) is a seedling of the 'Akebono' cultivar of the Yoshino cherry. The flowers are a rich rose-pink color, much deeper than the parent tree.

It is a rapid growing tree, 40 feet or more tall, and as wide, that forms a flat-topped specimen at maturity. It has proved to be somewhat more cold hardy than the parent species and has come through unharmed when ordinary *P. yedoensis* trees have suffered winter cracks in the bark. It bears masses of large single pink flowers in late April and is a choice variety for street tree use or mass planting, either alone or in combination with the normal white Yoshino cherries.

The Green Vase zelkova (P.P. No. 5080) is a rapid growing tall tree with the vase-shaped branching habit of our native American elm, but not susceptible to the Dutch elm disease. It is taller and not so broad as Village Green zelkova when mature.

It is twice as rapid growing as the cultivar Village Green as a young tree and 2-year old trees are two or three times taller. It has large bright green foliage which turns an orange color in the fall. Like other zelkovas it is tolerant of atmospheric pollution and heat reflected from the pavement and grows well on city streets. It is a vigorous, and shapely addition to this increasingly popular species of shade trees.

The 'Summer Stars' dogwood (P.P. No 3090) is a cultivar of the Japanese dogwood (*Cornus kousa*) which is noted for its very unusual flowering period. The parent tree, which was discovered on Long Island, retains the flower bracts (petals) in an unblemished condition very late into the summer, many weeks after the flowers of normal Japanese dogwoods have faded and dropped. Although younger plants grown in other areas do not keep their flowers until the end of August as does the parent tree, they are still in a showy condition for at least three weeks after normal Japanese dogwoods have lost their flowers.

Because it is an abundant fruiter, 'Summer Stars' Dogwood has a second display period at the end of summer and early fall when it is covered with rosy-red, strawberry shaped fruits. These fruits are a preferred bird food and consequently 'Summer Stars' has great value for attracting birds into the garden. The fall color of the leaves is a vivid maroon red and the plant is more drought resistant and hardy than our native white dogwood. It is also highly resistant to the dogwood borer and club gall, both of which are serious pests of *C. florida*.

Being vegatively propagated, 'Summer Stars' dogwoods come into bloom at a very early age, normally 4 to 6 years before seedling dogwoods of the same age begin to flower.

GARY KOLLER: *Catalpa fargesii*, a tree native to western China, is represented at the Arnold Arbortum by a tree approximately 70 years old. As of December, 1985 it stands 55 feet tall and spreads 30 feet across forming a small, ovoid, open-crowned tree in the same size category as a large crabapple or hawthorn. The foliage is much finer in texture than most species of catalpa being only 3-4 in. long with a moderate green color throughout the summer. The leaves and young shoots are covered with fine stellate hairs. Farges catalpa appears to have the notable characteristic of

being free of powdery mildew which so severely affects several of our other catalpa species.

In Boston, Massachusetts, peak flowering occurs the third week of May. Flowers are produced in terminal corymbs with 7 to 15 blossoms per cluster. Flowers are 1½ in. long and nearly as wide, with 5 rounded, frilled lobes. Flowers have a white background color which is densely spotted with rose-purple spots giving the blossom a distinct appearance of being rose-purple. The floral throat bears two reddish brown blotchs. Flowers are slightly fragrant. Flowering is less prolific than the *C. bignonioides* but perhaps this could be improved by deliberate selection seeking superior flowering individuals. Seed pods are slender and 12 to 18 in. long.

According to published accounts this plant was first introduced to France towards the end of the last century and the first record of flowering, under cultivation, in the west, is at Aldenham House, Elstre, in Great Britain in 1914.

In addition to the typical species we are growing *C. fargessi* f. *duclouxii*, which is native to Central China, and was originally treated as a separate species. At the Arnold Arboretum it differs in having glabrous foliage and in being of a smaller stature and more open growth than typical *C. fargesii*.

Seeds being distributed today result from open pollination. Any variation in seedlings which result may be due to cross pollination with other neighboring species of catalpa growing at the Arnold Arboretum.

Seeds for *C. fargesii* were collected from A.A.17664 provided to the Arnold Arboretum by F. Meyer, U.S. Department of Agriculture, in 1914. Seeds for *C. fargesii* f. *duclouxii* were collected from A.A. 592-60-C originally provided as grafted plants by Hillier and Sons, Winchester, England in 1958.

Narrow form and healthy dark green foliage throughout the growing season provides Manchurian catalpa with two distinctive landscape attributes. *Catalpa bungei* forms a tall, narrow crown. The oldest tree at the Arnold Arboretum being 65 ft tall and 20 to 24 ft across making it a useful shape for narrow landscape spaces.

The leaves are narrowly ovate to somewhat triangular, 3 to 5 in. long, rich dark green throughout summer and appear to be free of powdery mildew.

In the Boston area peak flowering occurs the 3rd week of May. The inflorescence is a compact 3 to 12 flowered corymb. Individual flowers are 1½ in. long and wide, bear five lobes, and are white in color with maroon markings inside the throat. Seed capsules are long and slender ranging from 18 to 30 in. long.

This species is native to Northern China and is common around Peking. It was first introduced into North America in 1904 by the Arnold Arboretum in the form of plants provided by E.T. Williams from Peking. What is now grown and offered by the nursery industry in North America is incorrectly *C. bignonioides* 'Nana' and sometimes *C. ovata*.

Seeds being distributed today resulted from open pollination. Any variation in seedlings which result may be due to cross pollination with other neighboring species of Catalpa growing at the Arnold Arboretum.

Seeds for *C. bungei* were collected from AA 12977, the original introduction from China. Seeds require no special pretreatment to insure germination.

COMPARISON OF GELLING SUBSTANCES USED IN MICROPROPAGATION

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Abstract. Seven gelling substances were evaluated for the micropropagation of *Gerbera jamesonii* 'Pink Quill' and *Hemerocallis* 'Aztec Gold'. Although multiplication and rooting for both plants were similar on media gelled with several of the gelling substances, the commercial grade of Phytagar was generally superior and Nutrient Agar inferior to the others. Normal plantlets were produced on all gels except Gelrite, the use of which resulted in watersoaked and strap-shaped leaves in gerbera cultures.

INTRODUCTION

In most cases the nutrient media used for micropropagation are gelled. Gelling is brought about by the addition of agar to the nutrient solution during preparation. Until recently, the standard agar used in research and commercial laboratories, especially in the U.S., has been Difco-Bacto agar. In the last few years, in commercial labs in particular, Bacto-agar has often been replaced by other gelling substances. This switch has been a reflection of price and improved clarity of the prepared gel.

Comparative growth of various plant species on media gelled with different agars has been the subject of several studies (1,2,6,7). The influence of agar concentration on growth of cultures has also been evaluated (2,4,5,6,7). With the explosion in the commercial use of micropropagation, it was felt that a more thorough examination of several of the commonly available gelling substances was in order.

MATERIALS AND METHODS

Gel evaluation. Seven gelling substances were tested (Table 1). In order to obtain standard curves of firmness based on gel concentration, an Instron was selected for use.

Using Murashige and Skoog salts (3) and 3% sucrose, six concentrations of each gel were prepared. The pH was adjusted to 5.7. The solutions were heated to boiling on a hot plate and 140 ml aliquots were poured into triplicate 20 × 150 mm petri dishes. After the gels had set, the dishes were covered and placed in a refrigerator overnight at 5°C. Evaluations were done the following day.

Gels were allowed to warm to room temperature prior to testing. A probe with a cross sectional area of 1.3 cm^2 was used

Table 1. Gelling substances evaluated in study.

Gel	Source	G/liter
Bacto-agar	Difco	7.0
Gelrite	Kelco	1.6
Sigma Agar	Sigma	4.6
Phytagar-I	Gibco	4.9
Phytagar-CG	Gibco	4.3
TC Agar	Gibco	5.4
Nutrient Agar	Difco	11.5

with the Instron. Near the middle of each sample the probe was inserted into the gel at a speed of 20 mm/min to a depth of 10 mm by which time the gel invariably broke. The instrument reading at the point of breakage gave an objective measure of gel firmness or strength. Curves for each gel resulting from this evaluation are presented in Figure 1. Bacto-agar at 7 g/liter was used as the standard for comparison in this study. Bacto agar at 7 g/liter had a firmness or gel strength value of 233 g/liter. The horizontal line in Figure 1 intersects the curves of the other gels at gel strengths equivalent to 7 g/liter Bacto-agar at 7 g/liter had a firmness or gel strength value of 233 g/liter. The horizontal line in Figure 1 intersects the

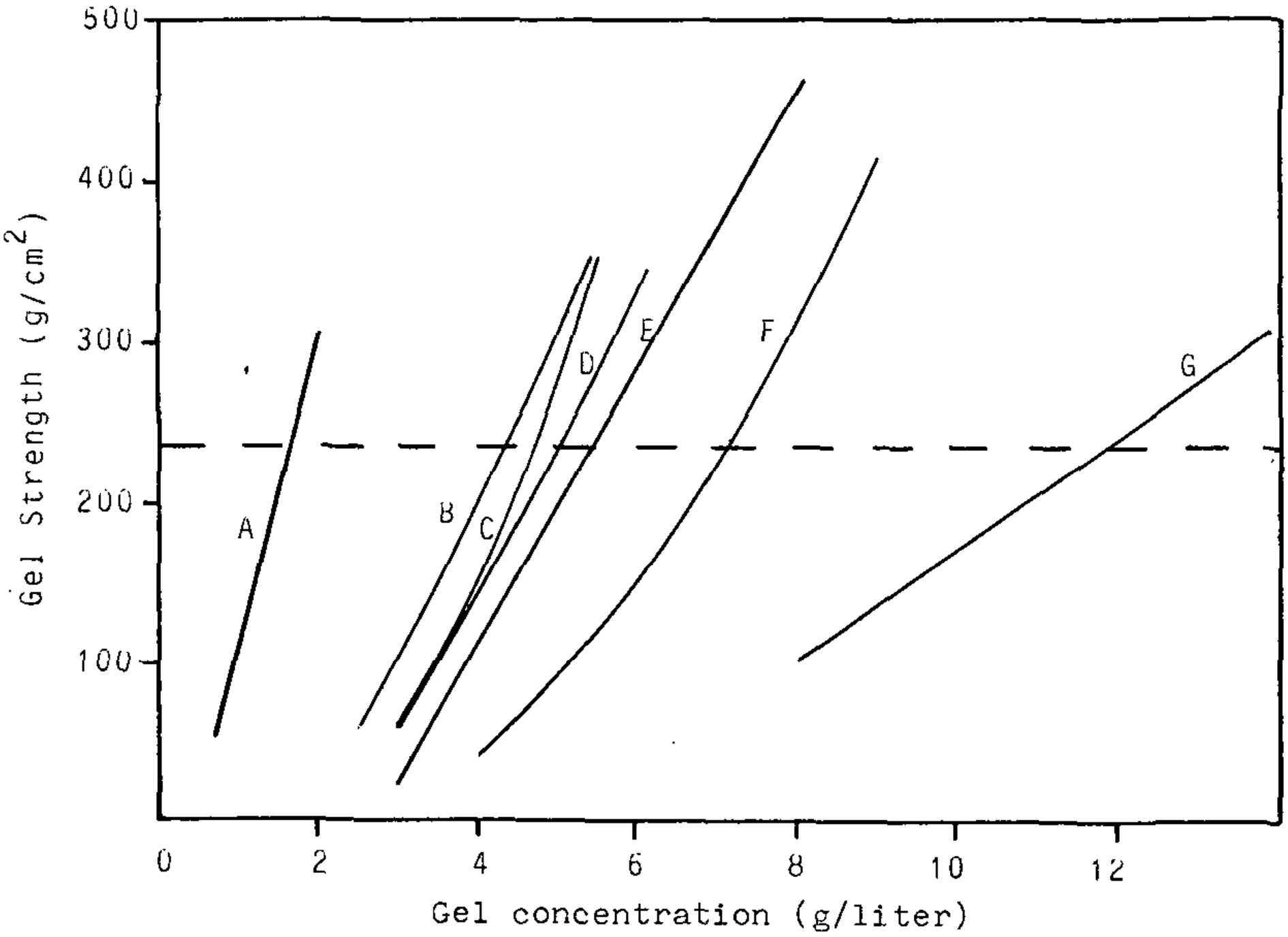

Figure 1. Standard gel strength curves for Gelrite (A), Phytagar-CG (B), Sigma Agar (C), Phytagar-I (D), TC Agar (E), Bacto-agar (F) and Nutrient Agar (G). Dashed line is at 233 g/cm^2.

Multiplication and rooting of *Gerbera*. Multiplying cultures of gerbera 'Pink Quill' were obtained from a commercial

micropropagation laboratory for the purposes of this study. A modified Murashige and Skoog medium with(in mg/l): kinetin(5) and IAA(0.5) was used for multiplication and IAA(10) for rooting. A sucrose concentration 4.5% and a pH of 5.7 was used. Three plantlets, each approximately 10 mm in height for multiplication and 20 mm in height for rooting studies were explanted into small baby food jars containing 25 ml of medium. There were 10 jars for a total of 30 explants per gel. Cultures were evaluated for multiplication after 6 weeks and for rooting after 3 weeks.

Multiplication and rooting of *Hemerocallis.* Multiplying 'Aztec Gold' cultures, obtained from the previously mentioned source were used. A modified Murashige and Skoog medium with(in mg/l): 2iP(16) was used for multiplication and IAA(10) and NAA(2) for rooting studies. A sucrose concentration of 3% and a pH of 5.7 was used.

Three plantlets, approximately 10 mm in height, were explanted into small baby food jars containing 25 ml of medium. There were 10 jars for a total of 30 explants per gel. Cultures were evaluated for multiplication after 6 weeks and for rooting after 4 weeks.

RESULTS AND DISCUSSION

Multiplication and rooting of *Gerbera.* Gerbera explants cultured in media gelled with the commercial grade of Phytagar (Phytagar-CG) formed more plantlets in general, especially when compared to those in Gelrite and Sigma Agar (Table 2). Along with the purified grade of Phytagar (Phytagar-1) and Nutrient Agar, plantlets growing in Phytagar-CG were taller. Increased height would facilitate easier handling of plantlets during subculture.

Table 2. Multiplication of *Gerbera* 'Pink Quill'[1].

Gel	Average	
	No. plantlets/culture	Plantlet ht.(mm)
Bacto-agar	7.7 ab[2]	25 c
Gelrite	6.2 b	27 bc
Sigma Agar	6.6 b	26 bc
Phytagar-I	7.9 ab	29 abc
Phytagar-CG	9.3 a	32 a
TC Agar	7.5 ab	25 c
Nutrient Agar	8.4 ab	31 ab

[1]30 explants per treatment
[2]Mean separation within columns by Duncan's multiple range test, 5% level.

The number of roots formed on the plantlets and root weight were similar with the exception of cultures grown on

Gelrite and Nutrient Agar gelled media (Table 3). In addition, root weight of plantlets on media gelled with Bacto agar was lower.

With the exception of media gelled with Gelrite, gerbera plantlets appeared normal. However, when Gelrite gel was used, the leaves were watersoaked and strap-shaped. This was true in both the multiplication and rooting stages. These plantlets were considered unsatisfactory for further use.

Table 3. Rooting of *Gerbera* 'Pink Quill'[1].

	Per plantlet	
Gel	No. roots	Root wt.(mg)
Bacto-agar	12.7 bc[2]	242 c
Gelrite	9.2 cd	286 bc
Sigma Agar	17.1 a	323 ab
Phytagar-I	17.0 ab	322 ab
Phytagar-CG	16.5 ab	360 a
TC Agar	16.5 ab	363 a
Nutrient Agar	8.9 cd	140 d

[1]30 explants per treatment
[2]Mean separation within columns by Duncan's multiple range test, 5% level.

Multiplication and rooting of *Hemerocallis*. Plantlet formation from 'Aztec Gold' cultures was similar for all gelling substances except Nutrient Agar which was inhibitory in this regard (Table 4).

Table 4. Multiplication of *Hemerocallis* 'Aztec Gold'[1].

Gel	Average no. plantlets (10 mm +)/culture
Bacto-agar	8.5 ab[2]
Gelrite	9.2 ab
Sigma Agar	9.4 ab
Phytagar-I	8.5 ab
Phytagar-CG	9.5 ab
TC Agar	7.8 b
Nutrient Agar	3.7 c

[1]30 explants per treatment
[2]Mean separation within columns by Duncan's multiple range test, 5% level.

Use of Nutrient Agar also resulted in the formation of fewer roots on subcultured plantlets and a lower root weight compared to the other gels (Table 5). In general, root weight of *Hemerocallis* plantlets on media gelled with Phytagar-CG was better.

In contrast to gerbera, *Hemerocallis* explants growing on the Gelrite gelled medium were normal in every respect.

Table 5. Rooting of *Hemerocallis* 'Aztec Gold'[1].

Gel	Per plantlet	
	No. roots	Root wt.(mg)
Bacto-Agar	10.9 a[2]	127 bcd
Gelrite	8.0 a	104 dc
Sigma Agar	9.4 a	139 bc
Phytagar-I	10.4 a	141 bc
Phytagar-CG	10.1 a	165 ab
TC Agar	8.6 a	107 cd
Nutrient Agar	4.4 b	83 d

[1]30 explants per treatment

[2]Mean separation within columns by Duncan's multiple range test, 5% level.

It is evident from the data presented that the micropropagator should examine several gelling substances before deciding on one to use as the standard for a particular plant species. In addition, cost of the gel should be considered in that the least expensive gel may be the logical choice, especially if multiplication and rooting are equivalent to the others. A comparison of prices of the various gels will show substantial differences in the cost to produce a multiplied or rooted plantlet.

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INTERSPECIFIC HYBRIDIZATION AMONG *CORNUS FLORIDA, C. KOUSA,* AND *C. NUTTALLII*[1]

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Abstract. A program of interspecific hybridization of plants of Cornus *florida*, *C. kousa*, and *C. nuttallii* has resulted in the selecton of five F_1 interspecific hybrids (*C. kousa* × *C. florida*) deemed worthy of patenting and introduction to commerce. These hybrids are noteworthy for their floral display, high vigor, and resistance to the dogwood borer. Material being evaluated in the field also includes hybrids of *C. florida* × *C. nuttallii*, *C. kousa* × *C. nuttallii* and hybrids combining genomes of all three species as in (*C. nuttallii* × *C. florida*) × *C. kousa*.

Starting in 1965, bare-root whips of many of the cultivars and/or numbered selections of Cornus *florida* L., *C. kousa* Hance, and *C. nuttallii* Audubon available in the nursery trade were assembled in performance trials at the New Jersey Agricultural Experiment Station, Cook College, Rutgers University. This was the first step in initiating a breeding program devoted to the development of new and superior cultivars of the large-bracted dogwoods through intra- and inter-specific hybridization. This paper describes the breeding value of the plant material, discusses the general approach, goals, and techniques involved in the work devoted to interspecific hybridization, and provides a progress report of those efforts.

PARENT MATERIAL

Plants of *C. florida* rank as one of the most popular of all small flowering trees throughout the eastern and south-central regions of the United States where this species is indigenous. Prized for the spectacular floral display of the white, pink, or red bracts, plants of this species are noted also for the brilliant autumn foliage coloration, bright red or yellow fruit, and for the winter silhouette of the horizontal branches. Truly, the plants add multiple season interest to the landscape. However, plants of this species are sensitive to several environmental stresses as a result of exposure to unfavorable environmental conditions. In recent years, in many areas of eastern United States, a sequence of drought in summer, followed by very low winter temperatures, and unusually wet spring conditions has weakened plants in the wild as well as in nursery plantings. All too frequently, these conditions have predisposed the plants to attack by the dogwood borer, *Synanthedon scitula* (Harris), and an assortment of pathogenic organisms causing such secondary disorders as cankers and spotting, or blighting, of the foliage. The combined effects of these debilitating factors have produced a severe "dogwood decline" during the

[1] New Jersey Agricultural Experiment Station, Publication No. D-12006-01-85, supported by State funds.

past 8 to 10 years. Thus, there is a real need for improved clones and/or hybrids of this large-bracted dogwood.

In the vicinity of New Brunswick, New Jersey, the floral display (bracts) of *C. florida* generally starts about May first and extends for a period of 14 to 16 days, with anthesis of the many small flowers occurring throughout the middle 10 days of this period.

Plants of *C. kousa* are native to Japan, China, and Korea. The floral display of the bracts begins after the plants are well foliated (about June 1 in the vicinity of New Brunswick, NJ). Thus, the plants have not been as popular as those of our native *C. florida*. The period of floral display of the bracts, as well as that of anthesis of the true flowers, usually approximates the duration noted for plants of *C. florida*. However, in some years, the white bracts persist through July and August with plants of certain clones, such as 'Summer Stars'. Plants of *C. kousa* are typically vase-shaped when young but exhibit a more rounded, spreading form after 20 years or more. Initially, my interest in utilizing germplasm of this species in interspecific hybridization traced to the observation that the plants are highly resistant to the ravages of the dogwood borer, as evidenced by a very low level of infestation under field conditions. To my knowledge, nothing has been reported regarding the nature of this resistance. It may be that the smooth, exfoliating bark of the trees does not provide good sites for deposition of the eggs of this clearwing moth. At any rate, the low incidence of damage by the dogwood borer among plants of *C. kousa* in conjunction with the severity of "dogwood decline" observed with our native *Cornus florida*, has contributed to a tremendous increase in demand in recent years for plants of *C. kousa* for use in landscaping.

Growers are urged to exercise caution in the selection of their seed source for growing seedlings of this species as the seedling material in commerce today exhibits tremendous variation in plant vigor and quality. It is my belief that seed sources utilized at present, in some cases, represent a relatively narrow genetic base as a result of brother-sister matings among seedlings that trace to a single introduction of seed collected abroad from a limited number of plants. On this point, I can state that I utilized various select plants of *C. kousa* growing at the Victor Morawitz Estate at Syosset, Long Island, NY in intraspecific hybridization. These plants were grown from seed that resulted from open-pollination among a group of seedlings grown from seed collected from western Hupeh province in China in 1907 by E.H. Wilson (3). Ten plants were utilized in 11 different parental combinations and a total of 742 resultant seedlings were grown-on in containers

and later in a seedling field for a total of 15 years. The plant material clearly showed evidence of inbreeding depression as the majority of the trees exhibited low vigor and a pronounced rounded, compact habit of growth with rather spindly branches and small leaves. The reduction in vigor was not as severe as that observed with the few plants of *C. florida*. that I obtained following self-pollination (1). However, after observing the field of *C. kousa* seedlings from a short distance, several New Jersey nurserymen assessed the material as being atypical in conformation for plants of that species.

A native of western North America, plants of *C. nuttallii* are found in coastal areas of California, Washington, Oregon, and British Columbia and are the giants of the large-bracted dogwoods, growing to heights of 60 feet or more in the wild. The flower heads are typically subtended by six large bracts, rather than four as in *C. florida* and *C. kousa*. The flower heads of *C. nuttallii* are much larger and the number of true flowers per flower head much higher than in either *C. florida* or *C. kousa*, but the bracts do not enclose the flower buds during winter as is the case in the latter two species. As a result, the true flowers are subject to "blasting" in eastern U.S. climates. Similarly, plants of *C. nuttallii* are not vegetatively hardy in central New Jersey (U.S.D.A. Plant Hardiness Zone 6a: −10° to 0°F) (2). Thus, the plants utilized in these hybridization studies were maintained in containers and overwintered in a heated structure. The large size of the bracts and the exceptionally high vigor of the plants were the main reasons for including plants of *C. nuttallii* in the program of interspecific hybridization.

One interspecific hybrid ('Eddie's White Wonder'), resulting from a cross of *C. nuttallii* × *C. florida* f. *rubra*, was available in the trade at the time these studies were initiated. Plants of this clone exhibit the upright habit and high vigor of the *C. nuttallii* parent as well as naked flower heads in which the bracts do not enclose the true flowers. As a result, the flower heads are subject to desiccation and/or winterkill in central New Jersey and the floral display of the bracts is typically very poor.

POLLINATION TECHNIQUES

The first barrier encountered in attempts to hybridize plants of the different species of the large-bracted dogwoods was the lack of coincident periods of bloom under normal field conditions. In the case of crosses involving *C. kousa* and *C. florida*, the latter was used as the staminate parent. The crosses were accomplished with stored pollen of *C. florida* that

had been collected from freshly opened flowers, then held in open glass vials in a desiccator over calcium chloride for 24 hours at 5°C (41°F), after which the glass vials were tightly stoppered and held at −17.7°C (0°F) in the freezer of a household refrigerator until used in pollinations. As the first two or three flowers in a flower head of *C. kousa* reached anthesis, the petals and stamens of all the flowers in the flower head were removed very gently with fine-pointed forceps. Then, the broad flattened end of a wooden toothpick was used to transfer the frozen pollen of *C. florida* from the glass vial to the stigmatic surface of each style on the flower head of *C. kousa*. At times, fresh pollen was available for use in making the desired crosses as coincident periods of flowering were achieved by forcing plants of *C. kousa* in a warm (24°C; 75°F) greenhouse.

When using fresh pollen, I prefer to use plants of *C. florida* as the staminate parent in crosses with *C. kousa* since the stamens of flowers of *C. florida* are easier to handle with forceps than are those of *C. kousa*. Similarly, when working with stored (frozen) pollen, the pollen of *C. florida* is easier to collect, store, and apply, than is the very fine pollen of *C. kousa*.

Plants of *C. nuttallii* presented more of a problem in obtaining coincident periods of flowering as the plants were overwintered in a plastic house held at a minimum of 2°C (36°F). Under those conditions, the plants flowered throughout the winter with the result that most of the flowers were senescent by early spring. Thus, it was necessary to force container-grown plants of *C. florida* and *C. kousa* into flower in a warm greenhouse in mid-winter or very early spring in order to have fresh pollen available from plants of *C. nuttallii*.

In my experience, plants of all three species of the large-bracted dogwoods have been highly self-sterile. Thus, it was not necessary to emasculate the flowers; however, with the crosses conducted in the greenhouse, the petals and stamens of the flowers of the pistillate parent were mechanically removed by forceps as the removal of this "debris" facilitated introduction of the appropriate pollen by either a toothpick or forceps-held stamens.

Seed resulting from the controlled crosses was harvested as soon as half or more of the surface of the enclosing fruit exhibited anthocyanin pigmentation. The fleshy portion of each fruit was removed by hand and the bony stones placed in moist, milled sphagnum moss in low density polyethylene bags. These bags were kept in the crisper (4°C, 40°F) of a household refrigerator until emergence of the radicle was ob-

served with one or more seed (60 to 150 days). At that time, all of the seed were planted in a sand:soil:peat (1:1:1 v/v/v) mixture in wooden flats in a warm (24°C, 75°F) greenhouse. Newly emerged seedlings were pricked-off to the same mixture in 4 in. clay pots as soon as the first true leaves were clearly evident. Subsequently, the plants were transplanted to larger, plastic plant-growing containers until field planted after two or three growing seasons.

SUCCESSFUL CROSSES

Hybrid progeny was obtained as a result of the interspecific matings listed below:

C. florida × *C. nuttallii*
C. kousa × *C. florida*
C. kousa × *C. nuttallii*
C. nuttallii × *C. florida*
C. nuttallii × *C. kousa*
C. kousa × (*C. nuttallii* × *C. florida*)
(*C. nuttallii* × *C. florida*) × *C. florida*
(*C. nuttallii* × *C. florida*) × *C. kousa*
(*C. nuttallii* × *C. florida*) × *C. nuttallii*
(*C. kousa* × *C. nuttallii*) × *C. florida*
(*C. kousa* × *C. nuttallii*) × *C. kousa*

All three F_1 interspecific hybrid combinations (*C. florida* × *C. nuttallii*, *C. kousa* × *C. florida*, and *C. kousa* × *C. nuttallii*) among the large-bracted dogwoods were readily achieved but considerable cross-incompatibilty was evidenced based on the low yield of viable seed. As would be expected, the matings listed above in which one parent was an interspecific hybrid exhibited a much higher level of sterility.

In some crosses, such as *C.* × 'Eddie's White Wonder' × *C. florida* f. *rubra*, little difficulty was encountered in obtaining as many as one or two viable seed per flower head. However, a high percentage of the seedlings exhibited low winter hardiness and/or a high incidence of morphological abnormalities. Based on the report (1) that the *rubra* characteristic in *C. florida* is conditioned by a single recessive gene in the homozygous state, one might expect that a backcross of 'Eddie's White Wonder' (*C. nuttallii* × *C. florida* f. *rubra*) to an unrelated pink- or red-bracted clone of *C. florida* would yield progeny exhibiting 1:1 segregation for white versus pink or red bracts. However, such crosses, in my experience, have not yielded any useful pink- or red-bracted hybrids, presumably as a result of chromosomal and/or genic disharmonies expressed in these advanced generation interspecific hybrids.

A limited number of the advanced generation interspecific hybrids listed above have been fully evaluated under field

conditions; however, seedlings of the primary F_1 interspecific hybrids have been field tested for 10 to 15 years.

HYBRID SELECTIONS

The F_1 interspecific hybrids resulting from crosses of *C. nuttallii* × *C. florida* or the reciprocal have yielded vigorous trees of erect habit that more nearly resemble the *C. nuttallii* parent than the *C. florida* parent. Vegetatively, the hybrids are only marginally winter-hardy at New Brunswick, NJ and the flower heads are subject to severe blasting as the floral bracts do not enclose the true flowers in the undeveloped flower heads. As the trees attain a size of 3 to 5 in. caliper at 4 in. above ground level, severe freezing injury (bark split) on the S and/or SW side of the tree trunk has been common. During years when the flower beds are not winter-killed, the period of floral display and anthesis overlaps, but is somewhat later than, that of plants of *C. florida*.

As might be expected, hybrids of *C. nuttallii* × *C. kousa* are typically upright in habit. The period of floral display and anthesis is intermediate, with very little overlap, to that of plants of *C. florida* and that of plants of *C. kousa*. The flower heads are very large, with 62 to 101 true flowers. As with the *C. nuttallii* parent, the floral bracts provide no winter protection for the true flowers and severe blasting of the flower heads during the winter is not uncommon. Vegetatively, the plants exhibit more winter hardiness than do the hybrids of *C. nuttallii* × *C. florida*. However, the trees are subject to freezing damage (bark split) on the S and/or SW side of the trunk during the cold, bright days of January.

The F_1 interspecific hybrids of *C. kousa* × *C. florida* offer high potential for direct use as new ornamentals for landscape use. Five clones have been selected for patenting and introduction to the nursery trade. Four of the hybrids are similar to *C. kousa* in growth habit and are intermediate to plants of the two parent species in period of floral display and anthesis. Three of these erect forms exhibit white bracts whereas the fourth produces bracts of a soft pink color. Plants of the fifth clone more closely resemble plants of *C. florida* in having a low, spreading habit of growth and a period of floral display and anthesis sufficiently early to overlap that of plants of *C. florida*.

The bracts of the *C. kousa* × *C. florida* hybrids are similar in size to those of plants of the parent species and, for the most part, are intermediate in shape to those of the parents. Surprisingly, the floral bracts do not enclose the true flowers as tightly as do those of either parent species. These hybrids are more highly sterile than are the hybrids of *C. nuttallii* × *C.*

florida or of *C. nuttallii* × *C. kousa*. Many of the plants have been found to be more vigorous than those of either *C. florida* or *C. kousa* and have been found to be highly resistant to attack by the dogwood borer. Vegetatively, these hybrids are fully winter-hardy at New Brunswick, NJ although the floral bracts may show injury following a severe winter, as is true with most cultivars of *C. florida*.

Advanced generation interspecific hybrids resulting from hybridization among plants of *C. florida*, *C. kousa*, and *C. nuttallii* are currently under test at Rutgers University and new hybrids are being generated each year. At present, the five F_1 interspecific hybrids of *C. kousa* × *C. florida* described above are being increased prior to introduction to commerce as Rutgers University's answer to dogwood decline.

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PROPAGATING RHODODENDRON CUTTINGS WITH FLEXWATT IN POLY TUNNELS

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Abstract. The effectiveness of rooting rhododendron cuttings in poly-tunnels heated with Flexwatt electric heating mats during late winter and early spring was examined. Mats maintained root-zone temperatures above 20.0°C (69.0°F) even when night temperatures dropped to −20.4°C (−4.7°F). Placing a Microfoam insulating blanket over the rooting medium and sticking cuttings through it reduced energy consumption by about 20%, but also reduced rooting and complicated removal of rooted cuttings. Time when cuttings were stuck, as well as length of the rooting period, influenced rooting percentage, root quality, and subsequent growth.

INTRODUCTION

Rhododendrons are usually propagated by cuttings stuck in September through December in bottom-heated greenhouse

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benches (4). While greenhouse propagation is effective, alternative methods using minimum structures may be equally effective and less costly (3) and especially useful where greenhouse space is unavailable. The objectives of this study were to determine: 1) if adequate rooting temperatures could be maintained in electrically heated poly-tunnels; 2) how well rhododendron rooted in electrically heated medium in poly-tunnels; and 3) how much energy use could be reduced by placing an insulating blanket over the rooting medium.

MATERIALS AND METHODS

Four outdoor poly-tunnels were assembled during the winter of 1983-84. The structures, oriented in a north-south direction, were 1.5 m (5 ft) wide, 4.5 m (15 ft) long, and 1.2 m (4 ft) tall. Bed sides were constructed of copper naphthenate treated lumber and were 25.4 cm (10 in.) high and anchored to the ground by 61 cm (2 ft) sections of 1.3 cm (½ in.) galvanized water pipe spaced at 91.4 cm (3 ft) intervals. Steel reinforcing rods; 1.3 cm (½ in.) in diameter and 3 m (10 ft) long were bent into a semi-circular hoops, inserted into the water pipe attached to the sides of the beds and covered with 6 mil white copolymer.

The bottom of each bed was lined with about 5.2 cm (2 in.) of fine gravel, providing a uniform base for the Flexwatt Agritape[1], a thin, flexible electric resistance heating mat in which copper strips are bonded into Mylar plastic. Four 28 cm (11 in.) wide mats rated at 17 watts per linear foot were placed across the bottom of each bed and covered with a single layer of aluminum screening. Bed sides were lined with 3.2 cm (1¼ in.) thick Thermax sheating[2]. Each bed was partitioned the width of the tunnel into four equal sections with Thermax sheating and filled to a depth of 20.3 cm (8 in.) with a sphagnum peatmoss:horticultural perlite 1:1 (v/v) propagating medium. Only the two center sections were used in the study. Shaded-pole blowers[3] ($^1/_{50}$) horsepower and set to activate when air temperatures exceeded 4.4°C (40°F) were installed at one end of each tunnel and the structure vented at the opposite end. Plastic irrigation pipe 2.5 cm (1 in.) in diameter, equipped with mist nozzles spaced 1.2 m (4 ft) apart, was suspended from the ridge for the length of each tunnel to provide overhead watering as necessary to maintain a moist medium. Bed thermostats were placed 7.6 cm (3 in.) deep and

[1] Ken-Bar Company, Division of Flexwatt Corp., Reading, MA.
[2] The Celotex Corp., Tampa, FL.
[3] Dayton Electric Manufacturing Co., Chicago, IL.

set to maintain a 21°C (70°F) medium temperature at 7.6 cm (3 in.), the depth of the base of the cutting. Air temperatures were monitored throughout the experiment by thermocouples inserted into silver-painted ping-pong balls (13). Medium tempertures were monitored with thermocouples.

In two of the four poly-tunnels, 6.3 mm (¼ in.) thickness Microfoam[4] was installed over the rooting medium, and cuttings inserted directly through the perforations. Beds in the other two tunnels were not covered with Microfoam. Energy usage for heating and ventilating in each tunnel was monitored continuously as kilowatt hour day^{-1} sq. ft.$^{-1}$ and the sum recorded daily.

Cuttings of *Rhododendron maximum* 'Pink' were collected the week of February 12 and again just before bud swell the week of April 7, 1984. Cuttings were stored in a refrigerator at 4.4°C (40°F) between the time of collecting and sticking. Cuttings were 10.2 to 15.2 cm (4 to 6 in.) long, with flower buds removed. The three to four leaves on each cutting were cut in half transversly.

All cuttings were wounded and treated with a solution containing Dip-N-Grow[5] root-promoting compound which contains 1.0% IBA and 0.5% NAA. Cuttings were wounded by removing two thin slices of tissue approximately 1.3 cm (½ in.) long from the basal side of each cutting using a sharp potato peeler. Cuttings were dipped to a depth of approximately ½ inch (1.25 cm) for 5 seconds in a Dip-N-Grow solution diluted with distilled water to contain 2000 ppm IBA and 1000 ppm NAA. One-half of the cuttings stuck in February were lifted six weeks later (in April) and evaluated. The remaining cuttings were left in place and evaluated in late May, 12 weeks after sticking. Another set of cuttings was stuck in April and evaluated in May.

A completely randomized experimental design with two replications was used with a split-split plot treatment arrangement. The main plot Microfoam treatment was randomized among the four poly-tunnels. Each main plot accommodated the sub-plots which were the different sticking and lifting dates. Each split contained 45 cuttings. Two border rows were stuck around the perimeter of each bed. In addition, data were taken in order to monitor uniformity of rooting across the bed. Differences among means were analyzed using Duncan's New Multiple Range Test.

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[4] Whitemarsh Paper and Specialties, Philadelphia, PA.
[5] Alpkem Corp., Clackama, OR.

When cuttings were lifted in April or May, the number of rooted cuttings was recorded. In addition, each cutting was rated qualitatively using a numerical scale of 1 (no roots) to 5 (excellent rooting) (5,8,16). Five randomly chosen representatives of each rating number from each treatment (total of 10 rooted cuttings) were potted in a sphagnum peatmoss-horticultural vermiculite 1:1 (v:v) potting mix and grown on for the remainder of the season. In early August 1984, potted plants were rated qualitatively using a numerical scale of 1 (dead) to 3 (actively growing).

RESULTS AND DISCUSSION

Throughout the experiment, Flexwatt Agritape heating mats maintained root-zone temperatures near 21° (70°F) in all poly-tunnels (Table 1). During the coldest 24-hour period, when the daytime outside high temperature was −5°C (23°F) and the low was −20.4°C (−4.7°F), root-zone temperatures in Microfoam covered beds ranged from 17.2 to 22.8°C (63 to 74°F), while the beds without Microfoam ranged from 15.6 to 22.8°C (60 to 73°F). Temperatures in the center of the beds were only 1 to 2°C (2 to 3°F) higher than at the edge. Average medium temperatures in all tunnels reflected changes in ambient outside air temperature, dipping below 21°C (70°F) on very cold nights and climbing above 21°C (70°F) on warm days.

Average air temperatures (Table 1) in all structures were warmer than ambient outside air temperatures at night and considerably warmer during the day, especially on sunny days. Air temperature fluctuated the most in poly-tunnels equipped with Microfoam (Table 1); temperatures were higher during the day due mostly to trapped solar radiation, and cooler at night as Microfoam restricted heat loss from the medium. Daytime air temperatures were lower in structures without Microfoam due to the absorptive capacity of the dark colored medium, but were warmer at night due to heat escaping from the medium. Although average air temperatures in poly-tunnels with and without Microfoam were practically the same (Table 1), the greater daily air temperature fluctuations in tunnels with Microfoam may have been responsible for the reduction in rooting.

On cold, cloudy days air temperature differences between tunnels varied only between 1 to 2°C (2 to 3°F). When temperatures warmed in the spring and fans were used to ventilate the structures, temperature differences were less than 1°C (2°F).

Poly-tunnels without Microfoam required about 25% more energy to maintain root-zone temperatures near 21°C (70°F)

Table 1. Low and high poly-tunnel air and root-zone temperatures (°C,°F) on selected days. Root-zone temperatures represent an average of 3 readings/bed over 2 poly-tunnels. Air temperatures represent 1 reading/bed averaged over 2 poly-tunnels.

	Coldest day[z] Low −20.4°C (−4.7°F) High −5.0°C (23.0°F) Ave. −11.8°C (10.9°F)		Cold/cloudy day[y] Low −7.3°C (18.8°F) High −2.3°C (27.8°F) Ave. −4.9°C (23.2°F)		Cold/sunny day[x] Low −5.6°C (22.0°F) High 1.1°C (34.1°F) Ave. −1.1°C (30.0°F)	
Treatment	Low	High	Low	High	Low	High
Air[w]	−14.2°C (6.5°F)	18.3° (65.0°F)	−0.3°C (44.0°F)	6.7°C (35.9°F)	−5.6°C (68.5°F)	20.3°C (38.0°F)
With microfoam						
Root-zone[v]	17.8°C (64.0°F)	22.8°C (73.0°F)	20.6°C (69.0°F)	23.0°C (73.5°F)	20.0°C (68.0°F)	22.8°C (73.0°F)
Air	−9.7°C (14.5°F)	15.3° (59.5°F)	−0.6°C (33.0°F)	5.3°C (41.5°F)	−3.0°C (26.5°F)	17.5°C (63.5°F)
Without microfoam						
Root-zone	16.9°C (62.5°F)	23.0°C (73.5°F)	20.3°C (68.5°F)	23.3°C (74.0°F)	19.4°C (67.0°F)	23.3°C (74.0°F)

[z] March 10, 1984
[y] March 13, 1984
[x] February 28, 1984
[w] 1 thermocouple reading/tunnel in the center of bed at cutting canopy height.
[v] 3 thermocouple readings/tunnel taken at cutting base depth (3 in) across the bed at equal intervals.

Table 2. Kilowatt hour usage (KWH) for poly-tunnel heating between February 27 and May 29, 1984

Poly-tunnel	Average 24 hour usage (KWH) March	April	May	Total usage[z] (KWH)
With microfoam				
Bed #1	12.30	11.50	9:30	1030
Bed #3	11.00	10.20	7.50	896
Mean	11.60	10.80	8.30	963
Without microfoam				
Bed #2	13.20	12.00	9:90	1096
Bed #4	11.90	15.10	14.90	1320
Mean	13.10	13.60	12.40	1208

z Poly-tunnel area = 75 sq. ft.

than tunnels with Microfoam (Table 3). This difference was partly due to equipment failure. A heating mat in poly-tunnel 4 malfunctioned during the experiment and caused higher energy use. If the energy use results from poly-tunnel 4 is ignored, differences in energy useage between tunnels with and without microfoam become considerably less. Lower ener-

gy use in tunnels with Microfoam was also due to its insulating properties and the higher medium moisture levels under the microfoam. This would improve heat retention, conduction and distribution throughout the medium (11) and reduce energy to heat the medium.

During this experiment poly-tunnels without Microfoam used 1208 KWH (16.1 kilowatt hours square foot^{-1}) while those with Microfoam used 963 (12.8 kilowatt hours square foot^{-1}) (Table 2). If energy use for this experiment is considered to be about 25% of the yearly total (7), then heating costs for these beds would be unacceptably high. However, the capital investment in these beds is much lower than for a larger structure, and combined with the ease of installation, could be considered an acceptable alternative. Dramatic reductions in energy use could probably be realized if these tunnels were installed inside a standard overwintering house.

Table 3. Effect of root rating and time of propagation on survival (%)[z] and vigor rating[y] of *Rhododendron* 'Pink Pink'.

	Survival (%)			Vigor rating[x]		
Root rating	Feb-Apr[w]	Apr-May[w]	Feb-May[v]	Feb-Apr[w]	Apr-May[v]	Feb-May[v]
1	0	0	0	1.0	1.0	1.0
2	100	62	0	2.1	1.6	1.0
3	85	83	100	2.2	1.5	2.0
4	100	100	100	2.7	2.5	2.3
5	100	–	100	3.0	–	3.0

[z] % survival at each rooting sequence based upon 10 observations; 5 from each root rating for each microfoam treatment.
[y] Vigor rating based on 10 observations; 5 from each root rating for each microfoam treatment.
[x] 1 = dead; 2 = 1 flush growth; 3 = 2 or more flushes of growth.
[w] 6 week propagation period.
[z] 12 week propagation period.

There was no significant interaction between time cuttings were stuck and the use of Microfoam. Therefore, rooting data with and without Microfoam were averaged for all sticking times for each of these two rooting replications. Rhododendron cuttings rooted significantly better without Microfoam as 74% of the cuttings rooted (Figure 1) with an average root rating of 2.7 (Figure 1). Only 31% of the cuttings rooted under Microfoam, and they had an average root rating of 1.8.

The thickness of the insulating blanket combined with areas where this blanket may not have been in direct contact with the medium may have prevented the shorter (10.2 cm. 4 in.) cuttings from being stuck deep enough into the medium. If the cuttings were not stuck as deep as in the uncovered beds, their bases may not have been maintained at a high enough temperature for rooting.

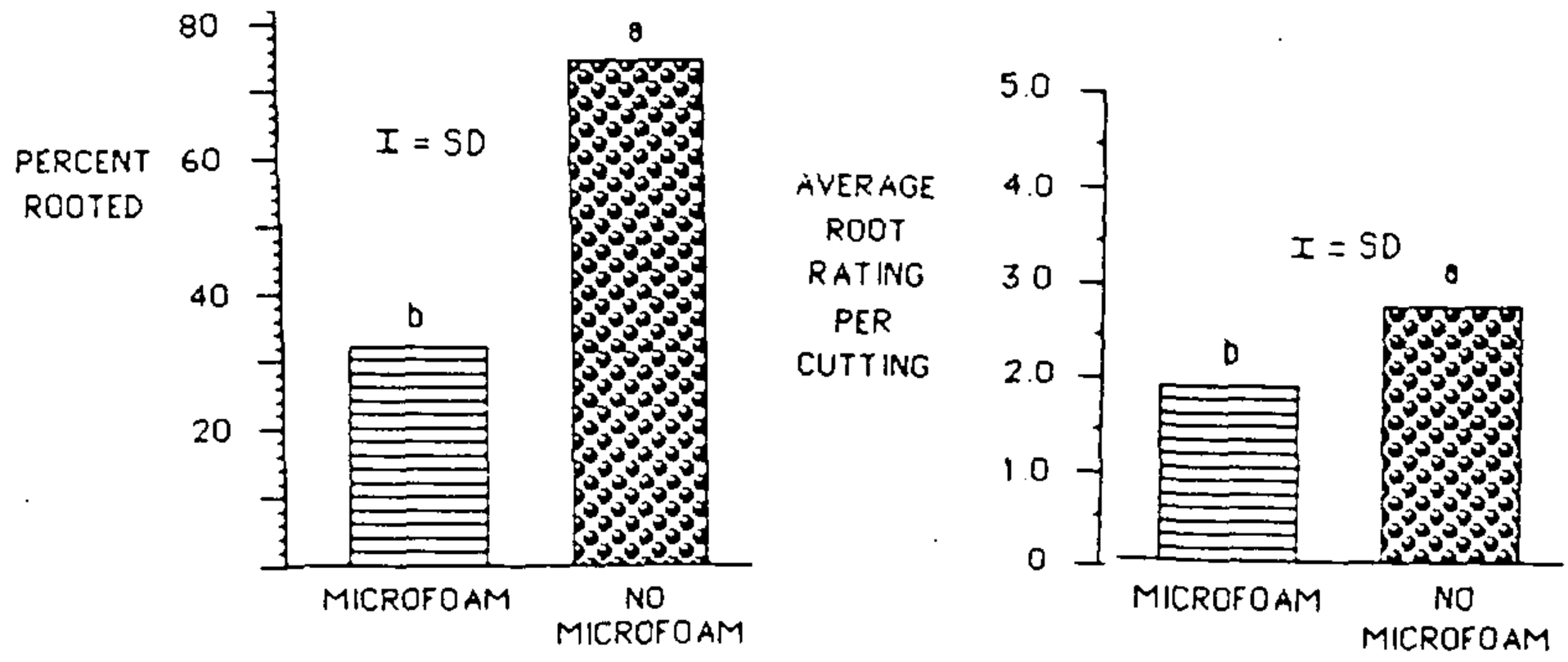

Figure 1. Effect of Microfoam on rooting percentage and average root rating per cutting of *Rhododendron maximum* 'Pink'.

Rhododendron rooting was significantly poorer in the April/May sequence than the February/April or February/May sequence (Fig. 2). Many plant species propagated by cuttings have optimal times where physiological condition of the cutting may be modified by environmental factors (1,14). Those stuck in April apparently missed the optimal rooting time.

Rhododendron cuttings are commonly rooted in June through early December (15). However, moderate success was achieved in this study when rooting cuttings in February. There was no statistical difference in number of cuttings rooted between the February/April sequence (61%) and the February/May sequence (68%) (Figure 2). However, cuttings left in the bed from February to May had a significantly higher average root rating than those left in from February to April (Figure 2). Most propagators believe that three months in the propagating bench is required to form a substantial root system on rhododendron cuttings (4,6). Cuttings stuck in April and lifted in May had significantly lower rooting percentages and root ratings than the other times (Figure 2). This was probably because the buds were swelling and cambial activity had already begun, and leaves were ready to develop.

The propagation structure, location of cuttings in the bed, and Microfoam had no effect upon survival and vigor of potted cuttings. Cutting survivability was between 80 to 100%. All of the cuttings rated 4 or above survived (Table 3). Of the cuttings with a root rating of 3, 80% of those that were in the propagation bed for 6 weeks survived, while 100% of those that were in the bed 12 weeks survived. Of the cuttings with a root rating of 2, 100% of those that were in the propagation bed from February to April survived, but survival of cuttings from the other sequences was poor. None of the cuttings with

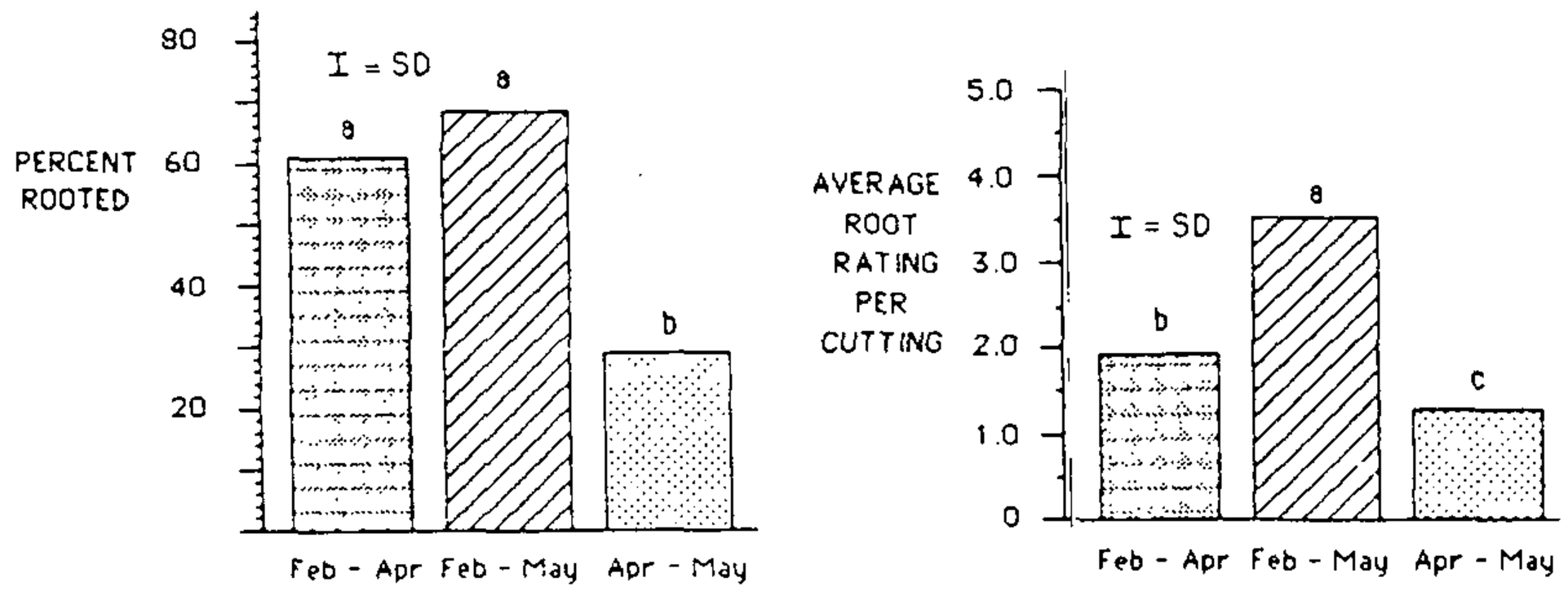

Figure 2. Effect of sticking and lifting dates on rooting percentage and average root rating per cutting of *Rhododendron maximum* 'Pink'.

a root rating or 1 survived.

During the first growing season, the plants rooted in the February-April sequence exhibited the most vigorous growth (Table 3). Cuttings that remained in the propagation beds from February to May did not grow as well, unless they had a root rating of 4 or 5 when planted. Cuttings from the April-May sequence grew poorly unless they had a root rating of 4 when they were planted.

Survivability and vigor were enhanced when cuttings were taken in February and potted 6 weeks later in April. Although larger root systems developed, there appeared to be no advantage to leaving cuttings in the bed for 12 weeks at that time of the year. The sooner plants were rooted, potted, and placed outdoors, the better the growth that season. Subjecting potted cuttings to cool early spring temperatures where transpiration was reduced, but conditions for root growth were favorable, enabled these plants to begin vigorous growth earlier. Many plants pass through alternative periods of active root growth followed by active shoot growth (12). This cycle is apparently controlled by the photoperiod, temperature, and the water and nutrient status of the plant. The plants potted in April probably developed the first flush of root growth in the containers, while those potted in May probably had their first flush of root growth in the propagation bed. This would account for the higher root ratings for the plants lifted in May. Disturbing the roots after the roots had their first main flush of growth would be expected to reduce the vigor of top growth. Cuttings potted in May, subjected to early heat stress, grew less. Based on these results, two crops could be produced if the sticking date in February was preceded by a rooting period initiated in late December or early January.

Although Microfoam does conserve energy, the additional

material expense, labor required to install and harvest cuttings stuck through this blanket, and the reduced rooting, makes its use questionable. A better way to reduce costs would be to shorten the time cuttings remain in the propagation bed. These experiments show that rhododendron cuttings can be successfully rooted if left in the medium for only 6 weeks and will grow vigorously when lifted and potted.

Propagators who want to root rhododendron cuttings in the winter no longer need expensive greenhouses but can use easy-to-assemble, low-cost poly-tunnel structures. Cuttings rooted during the winter allow a more even distribution of the work load, improving efficiency and increasing profits. Root-zone heating directs heat to the root zone for efficient rooting, has a relatively low initial cost, and is easy to install. A rooting period of 6 to 8 weeks is sufficient to develop adequate rooting. This short rooting period lowers production costs and allows time for two crops to be rooted during the winter. Finally, better disease control might be obtained in the propagation bed because of the low temperatures around the foliage and the short time cuttings remain in the bed.

In the future, cuttings may be stuck directly into containers (2,9) within the poly-tunnel. Direct sticking eliminates one transplanting step possibly lowering production costs. Without transplant shock, rooted cuttings develop into larger plants by season's end. In addition, because the cuttings would be more widely spaced, larger cuttings or multiple cuttings per pot could be stuck. This would result in the production of salable plants sooner (10).

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WATER QUALITY AND PLANT PRODUCTION IN CONTAINERS

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When considering factors that affect plant production in containers, water quality is generally considered but only passively. In the past, as long as the water had a salt level below 500 ppm, it was considered acceptable. The other factor often measured was pH. Unfortunately, pH is frequently used to judge the quality of irrigation water. But pH is only a measure of the relative proporations of acids and bases in the water. Neither soluble salts nor pH measurements give any clue to *what* salts are actually dissolved in the water. If pH is below 7.0, it means only that there are more acid-forming materials in the water than bases, or vice versa if it is above 7.0.

To demonstrate how little information pH of water actually provides, try this: take a sample of distilled water and measure the pH. If the distillation process was working properly, pH will be 7.0; and if a chemical analysis of the water is done, it will show no dissolved salts. Now add enough acid, any acid, to another sample of distilled water to make it read pH 4.0. To still another sample of distilled water add enough base (calcium hydroxide, slaked lime, sodium hydroxide, or other base) to make the pH of the water rise to 10.0. Now add the water from both these containers to the original container of distilled water, stir well, and measure the pH. If you have been accurate in your measurements and technique, the pH of the water is still 7.0. You can continue to add equal portions of acids and bases to the original water sample and as long as you add the same quantity of acid as you do bases, the pH of the solution will remain 7.0. Does pH of the irrigation provide any useful information? No. It does not give a single clue as to the total salt level in the water, only the relative proportion between acids and bases. Only a water quality analysis will show what is actually dissolved *in* the water.

Elements *dissolved* in irrigation water may or may not have a direct effect on plant growth. It depends on whether or not they are essential for plant growth, their concentration, and proportion or ratio to other elements. Two essential elements that are plentiful in most irrigation waters are calcium and magnesium. Calcium or magnesium dissolved in irrigation waters are available for plant growth, just as potassium or nitrogen are when injected into the water (1). For example, assume irrigation water contains 43 ppm calcium and 15.5 ppm

magnesium, and approximately 1 in. of irrigation water is discharged each application for 150 applications/year, then 0.0066 lbs. of calcium and 0.00238 lbs. of magnesium per 1 gal. container will be applied.

This is based on the following calculations:

A 6-in. container has a surface area of 28.3 in.^{2} (3.1416 × 3 × 3 or $\pi \times r^2$) 28 in.^{2} × 150 applications of one-inch each = 4.245 in.^{3} of water. Divide 4245 by 1728 (the number of in.^{3}/ft.^{3}) to get 2.46 ft.^{3} of water applied per container per year. If the water contains 43 ppm, there are 43 lbs. of calcium in 1,000,000 lbs. water. There are X lbs. of Ca in 153.6 lbs. of water (the weight of the 2.46 ft.^{3}/container/year. We find that X = 0.0066 lbs. of Ca per container per year from the water.

This seems like a very small amount of calcium; however, to grasp the relative amount, calculate the amount of Ca supplied per container if 9 lbs. of dolomite is added/cu. yd. of mix. If 9 lbs. of dolomite is added/yd.^{3}, it is necessary to know the volume of the container in cubic inches in order to calculate the amount of dolomite received by each container. Most "one gallon" containers hold about 160 in.^{3}. One yd.^{3} = 46,656 in.^{3}. so that we can say 9 lb./46,65614^3 = X/160 in.^{3}, we find that × = 0.03086 lbs. However dolomite is about 20% Ca. Therefore 0.03086 × 0.20 = 0.00617 lbs. Ca per container.

The same steps are followed to calculate the amount of magnesium supplied by the water as compared to the dolomite. However, dolomite is generally only 10% Mg. Therefore, 0.03086 lbs. × 0.10 = 0.003086 lbs of Mg/container from the dolomite.

In this case the quality of the irrigation water had a greater influence on the calcium level received by the plant than the 9 lbs. of dolomite added to the basic growth medium.

It would be easy to stop here in a general discussion of the influence of calcium and magnesium in irrigation water on plant nutrition, but a very important point would be missed.

A study of the solubilities of various calcium and magnesium sources shows a dramatic difference in solubility of sources of the two elements. The "Handbook of Chemistry and Physics" (CRC Press, Boca Raton, Fl.) lists the following solubilities for calcium and magnesium sources (Table 1).

The solubility of the calcium carbonate portion of the dolomite is only 0.0014 grams/100 ml. of water. By considering the number of irrigations required to dissolve all the calcium carbonate, we find it will require approximately 7.15 years to dissolve the calcium.

Now reconsider the 0.0066 lbs. (3.0 grams) of calcium supplied by the water that contained only 40 ppm calcium. The water supply is actually supplying over 7 times *more soluble* calcium to the container system during one growing season

than the dolomite at the 9 lbs. yd.^{3} rate.

Table 1. Solubility of sources of calcium and magnesium.

	Solubility in cold water, gm./100 milliliters of water
Calcium carbonate	0.0014
Calcium oxide	0.131
Calcium sulfate	0.209
Magnesium carbonate	0.176
Magnesium oxide	0.00062
Magnesium sulfate	26.0
Dolomite (calcium and magnesium carbonates)	0.032

Magnesium carbonate is much more soluble than calcium carbonate (0.176 in the pure state and 0.032 gm/100 ml. of cold water in dolomite). Doing similar calculations with magnesium in the water supply and in the dolomite reveals a similar effect. However, in this case, since the water contains only 15.5 ppm magnesium, and the magnesium fraction of the dolomite is much more soluble (0.032 instead of 0.0014 for calcium carbonate), most of the magnesium from the dolomite would be dissolved after about 30 waterings or about one-third through the growing season.

Actually, this is not an abrupt end to the availability of magnesium for plant growth. When magnesium and calcium are released from the dolomite, they are adsorbed onto the growth medium by the cation exchange capacity since both are strong cations with two positive charges. However, calcium is a stronger cation than magnesium since magnesium is always surrounded by water of hydration, which weakens its electrical charge. If most of the sites are already filled with calcium, the magnesium will be more readily lost to leaching since it cannot be adsorbed as strongly. Even if the magnesium has been released by the dolomite and absorbed by the growth medium, calcium released from the dolomite or added from another source will replace the magnesium.

If additional dolomite is top-dressed on plants in containers showing magnesium deficiency, the result can be confusing. Within a week or two the plants will respond to the additonal magnesium provided by the dolomite if they are otherwise healthy. However, the response will be short-lived and soon the plants will develop magnesium deficiency symptoms more severe than before. The reason is due to the rapid solubility of the magnesium contained in the dolomite. As soon as the bulk of the magnesium is released, the calcium that remains causes an even wider and less favorable ratio of calcium to magnesium than before.

If dolomite is used in the base mix and magnesium defi-

ciency is suspected, liquid applications of magnesium sulfate, ($MgSO_4$, Epsom salts) should be applied. A rate of approximately one lb. $MgSO_4$ per 100 gal. of water provides approximately 100 ppm actual magnesium. The magnesium should be applied every 10 to 14 days, or as needed. It can also be sprayed on the foliage at a rate of 5 to 8 lb./100 gal. water every 7 to 14 days. Dispensing magnesium sulfate through an irrigation system during cool weather may not be practical since it is difficult to keep in solution at temperatures below 60°F (15°C).

It can be seen from this discussion that excess calcium can strongly interfere with magnesium nutrition in several ways.

Now go back to the example dealing with the water quality. Since, in addition to the 40 ppm calcium, the water also contains 15.5 ppm magnesium, there is about 1.0 gram of magnesium added to the one-gal. container during the growing season. Therefore, the plants are liquid fertilized with magnesium as well as calcium throughout the growing season. This magnesium in the water supply prevents plants from suffering severe magnesium deficiencies in spite of the short effectiveness of dolomite in supplying magnesium.

If the rapid solubility of magnesium from dolomite, the accumulation of calcium in the growth medium at the expense of the retention of magnesium, and the importance of a ratio of calcium to magnesium of about 2-to-1 for excellent growth are true, plant growth should improve by using only this water source plus additional magnesium during the growing season. Dolomite would not be needed in the medium.

To test this hypothesis, magnesium-deficient liners of Wilton carpet juniper (*Juniperus horizontalis* 'Wiltonii') and healthy liners of shore juniper (*Juniperus conferta* 'Blue Pacific') and dwarf yaupon holly (*Ilex vomitoria* 'Nana') were grown with 1, 3, 6, or 9 lbs. of dolomite/yd.^{3} (0, 1.8, 3.6 or 7.2 kg./m.^{3}). A second group was grown with no dolomite added to the mix, but with magnesium sulfate added to provide magnesium equivalent to what the first plants received from the dolomite. Because the magnesium sulfate is very water soluble, one-half of each rate was added at planting time and one-half was added midway during the growing season. The plants in Figures 1 and 2 show the benefit of the improved calcium:magnesium ratio and the fact that a water supply with 40 ppm calcium can supply most, if not all, of the calcium needs of the plants. Plants of all three species were larger and had many more branches with the supplemental magnesium and no calcium other than that in the water.

The magnesium deficiency symptoms (yellowing of the older leaves) that were present on all liners at time of planting

Figure 1. Magnesium-deficient liners of Wiltoni juniper grown with (from left) no added calcium or magnesium other than that supplied by the water, or 3, 6 and 9 lbs. of dolomite/yd.^{3} or the equivalent magnesium that would have been applied had 6 or 9 lbs. of dolomite been used without the calcium proportion. The 6 and 9 lb. equivalent rates of magnesium was supplied by magnesium sulfate applied ½ at planting and ½ midway during the growing season. Note the decline in plant growth with the additional dolomite from 0 to 9 lbs./yd.^{3} and the excellent growth from both rates of magnesium sulfate.

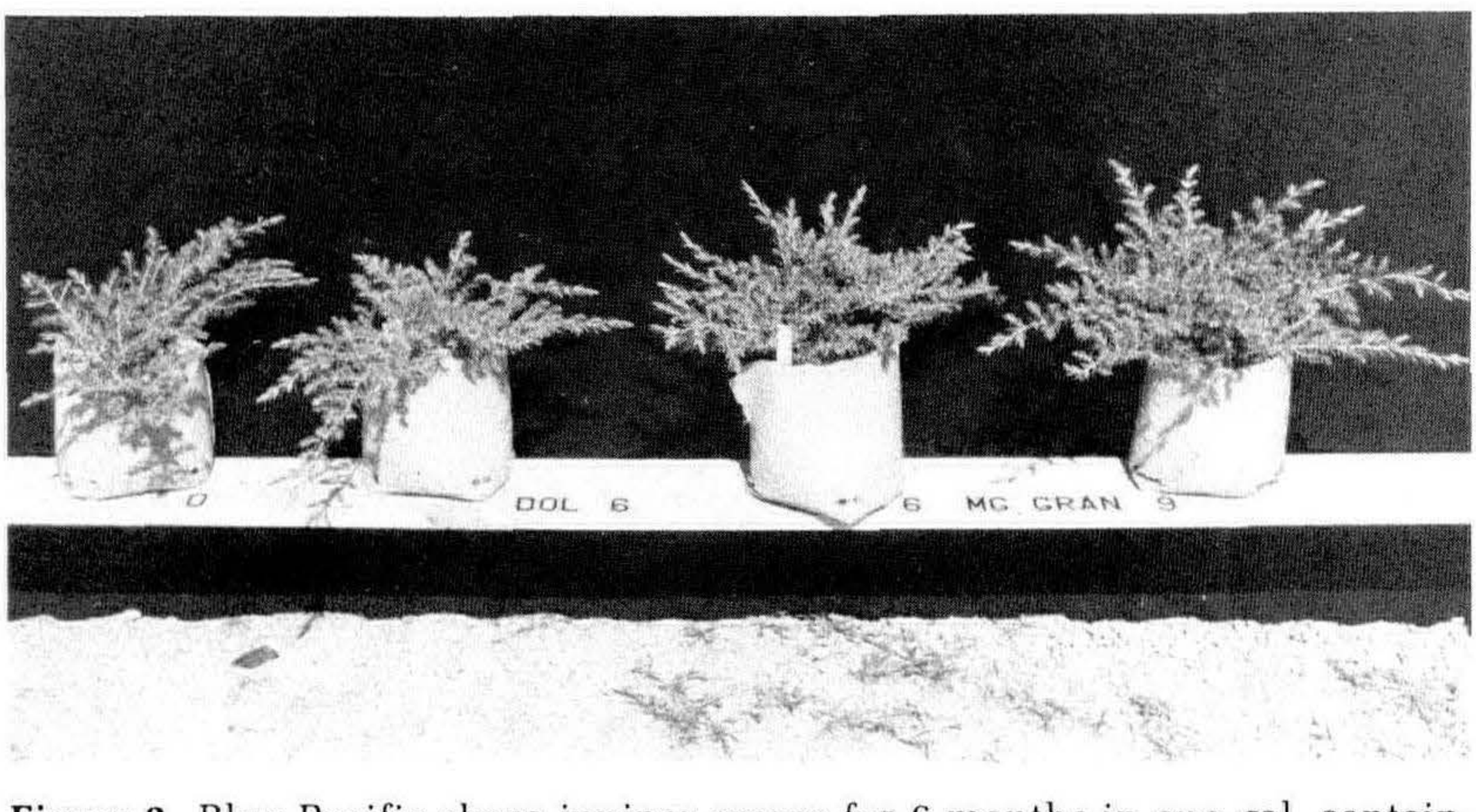

Figure 2. Blue Pacific shore juniper grown for 6 months in one-gal. containers with (from left) 0 to 6 lbs. of dolomite/yd.^{3} of mix or the equivalent magnesium that would have been applied had 6 or 9 lbs. of dolomite been used without the calcium proportion. The 6 and 9 lbs. equivalent rates of magnesium were supplied by magnesium sulfate applied ½ at planting and ½ midway during the growing season. The plant on the left (0) recieved only the calcium and magnesium supplied by the water, plus a small amount in the pine bark portion of the growth medium.

never re-developed.

The results of this experiment confirm the fact that dissolved salts in the irrigation water play a major role in nutrition of plants grown in containers. Water quality must be considered part of the overall nutritional program if maximum growth and quality are to be achieved.

LITERATURE CITED

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BUILDING A HIGH HUMIDITY PROPAGATION SYSTEM

BUTCH G'ADDY

Colesville Nursery, Inc.
P.O. Box 208
Ashland, Virginia 23005

We have been using high-humidity propagation at Colesville Nursery for five or six years. In 1982 I presented a paper to the IPPS - Southern Region (1), on our use of the Agritech high-humidity propagation system. While this system did work fairly well for us, the maintenance cost on the motors and other moving parts in the units became prohibitive. Also, the uniformity of the moisture was very irregular.

While visiting nurseries in Oregon in 1984, Al Gardner and I saw a small fog system at Mitch Nursery, which John Mitch was experimenting with in his operation. John, very graciously, shared all the information he had with us. Back in Virginia we began to construct a similar fog system in our 20 × 100 ft. propagation house.

A fog or high humidity system operates by atomizing water into microscopic droplets. These droplets are suspended in the air of the greenhouse creating an ideal atmosphere for plant propagation. The air is kept humid while not overly wetting the soil medium. In our case we are using high water presure to force the water through very small nozzles.

Our system starts with the water-feed line leading into a low pressure switch. The purpose of this switch is to safeguard the fog system pump in case the water pump in the well fails. From here the water goes through two water filters: the first has a wire screen filter and the second has a felt filter. The fog nozzles have an extremely small orifice; even with the two filters, a nozzle occasionally clogs up.

The water continues from the filters to a solenoid valve which, in our case, is controlled by a 5-min. time clock that, in

never re-developed.

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The water continues from the filters to a solenoid valve which, in our case, is controlled by a 5-min. time clock that, in

turn, is controlled by a 24-hr. time clock. From the solenoid the water then enters the high-pressure piston or plunger pump. The specifications for this pump list a maximum pressure at 900 psi but we are pumping at about 1000 psi. When we first began work on our system, we briefly had the pressure up to 2000 psi. The maximum flow capacity for this pump is 3 gal. per minute. We were able to adjust the pressure by changing the size of the sheave (pulley). The pulley size on the piston pump is 15¾-in. outside diameter. A smaller pulley would increase the pressure. This pump is run by a 1-horsepower Dayton electric motor with a 2½-in. outside diameter pulley.

The water, now at 1000 psi, enters the ½ in. stainless steel pipe. This pipe is currently suspended in the center of the house about 7 ft. off of the floor of the house and runs the length of the house. The fog nozzles are located every 3 ft. along the pipe.

The nozzles are Monarch Foggers[1], which are also used as oil burner nozzles. The model we are using is the F-80 NS series with a nozzle number of 0.85 and a spray angle of 80 degrees, which is for high-pressure situations. The flow rate for each nozzle at 800 psi is 1.56 gal./hr. Every other nozzle faces the opposite direction at approximately a 30-degree angle from the pipe. At the end of the house we have a nozzle facing each of the air-intake openings at the top of the greenhouse.

The greenhouse is vented using a 36-in. exhaust fan controlled by a thermostat set at 95°F. The air that is pulled through the house is usually dry which does cause us some problems. The nozzles that face the air intake vents do alleviate this somewhat.

There have been many talks and papers presented to the IPPS concerning the pros and cons of using high humidity or fog in plant propagation. We are convinced that it is a good system for us, but we have not yet constructed one that is completely satisfactory. There are several changes that we plan to make in our present system.

We still have an inconsistent moisture level across the width of the house because we use only the one line down the center. The first two ft. on either side of the greenhouse do not receive enough moisture and consequently our rooting percentage is still lower than we would like.

We plan to remove the center line and install a line on each side of the house about 4 ft. off of the floor. This pipe will be attached to the side of the house. The pipe we will use

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[1] Source for Monarch Foggers: W.A. Westgate Co., Inc., 412 G Street, P.O. Box 445, Davis, CA 95617

is ½-in. schedule 80 PVC pipe, which has an operating pressure of 850 psi. Because of this we will have to lower the pressure in our system but we should still have enough pressure to insure a small droplet size. The nozzles will then be 5 ft. apart facing toward the center of the house at a 30-degree angle. This should give us a much more uniform fog throughout the greenhouse.

We also plan to remove the 5-min. time clock and use a humidistat to control the system. The system now comes on four times for 14 sec. each time during the 5 minutes. This obviously does not take into account weather conditions, so it demands close monitoring. We will be able to set the humidistat at the exact relative humidity we desire. This will take into account the air intake for ventilation so we will not be replacing the humid air with outside dry air.

We began using this fog system in January, 1985. Our conifer cuttings were direct stuck in cell packs and set on a gravel floor. We were using EconoMix, which is a pine bark and styrofoam mix. We use Dip'N-Grow rooting hormone at 1½:20 ratio. The rooting percentages on our juniper, chamaecyparis, and spruce were much above what we obtained previously.

Estimated Costs of Installing a Fog System in a Propagation House at Colesville Nursery[2]

1 - General water filter, model # 2A17A wire screen	$ 33.00
1 - General water filter, model #2A17A felt filter	25.00
1 - Dayton ¾-in. solenoid valve, model # 1A578	53.83
1 - Teel piston pump, model # 2P046A	304.36
1 - Pressure gauge, 2000 psi, model #5×369	24.83
1 - 1 H.P. Dayton electric motor, model #6K699B	142.46
2 - Dayton fan belts, model # 5L600	10.00
1 - Sheave on pump, model # 3×386	13.77
1 - Sheave on pump, model *1W962	62.92
1 - Bushing for sheave model # 3×572	3.13
1 - Five-min. Dayton time clock, model # 2E356	49.00
1 - Twenty-four hr. Dayton time clock	24.06
1 - 120 ft. stainless steel pipe, 2500 psi, ½"	
30 - Stainless steel tees, 2500 psi, ½"	
1 - Stainless steel union, 2500 psi, ½"	498.63
3 - Stainless steel elbows, 2500 psi, ½"	
1 - Stainless steel plug, 2500 psi, ½"	
36 - Monarch nozzles, model # F-80, 80° NS (nozzle # .85)	257.95
36 - Brass bushings for nozzles	7.60
Approximate labor cost	350.00
TOTAL COST	$1860.54

We moved our nursery in the spring of 1985 and we were delayed beginning our summer propagation until July 22. For

[2] Source for all parts except the pipe and the nozzles: W.W. Grainger, 2050 Magnolia Avenue, Richmond, VA 23223

us this is about four weeks behind schedule. During that time we had wet and cool weather. We were running our fog system 40 sec. every 2½ min., which proved to be too long as our cuttings were much too wet. Our cuttings of *Ilex crenata compacta* and *I. helleri* decayed below the soil level, but they have now rooted at the soil line. We cut the fogging time back to 14 sec. every 1¼ min. This has proved to be better, but the edges of the medium still do dry out.

We are still experimenting with the fog system in propagation. We think the concept is a good one. With the changes we plan to make, we expect to alleviate the problems we have experienced.

LITERATURE CITED

1. Gaddy, B. 1982. My experience with high humidity propagation Proc. *Inter. Plant Prop. Soc.* 32:446-448.

A SIMPLE AND FLEXIBLE MIST CONTROLLER

BILL CRAVEN, III

Twisted Oaks Nursery
P.O. Box 818
Waynesboro, Georgia 30830

The propagation house is full of problems and pitfalls. One of the trickiest problems is controlling humidity around the cuttings. The usual methods of controlling mist cycles with standard time clocks and electronic leaves both have unacceptable trade-offs. Standard time clocks do not have enough flexibility, and electronic leaves and screen balances are too expensive to be used on a large scale. The mist controller outlined below is very flexible and is reasonably priced.

The Controller. The mist clock is a Richdel, Lawn Genie, 6-station lawn sprinkler controller (Figure 1). This controller is a common residential unit. The standard 24-hr. motor (M007) has been replaced with a motor (M001) that cycles every six min. The cycle is adjusted to mist once every two, three, or six min. This adjustment is easily accomplished by simply adding or removing tripper gears. Each station has an independently variable misting time that is adjusted by simply turning a dial. The mist can be set to come on for as little as one sec. to as long as 30 sec. per station.

The System. A single controller with a 24-hr. day-night clock to cut the controller on in the morning and off in the evening is very effective and economical. A much more flexi-

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The System. A single controller with a 24-hr. day-night clock to cut the controller on in the morning and off in the evening is very effective and economical. A much more flexi-

ble system is to use two controllers with each station connected by a three-way toggle switch. One controller could be set up with gears to provide mist every three min. and the other to mist every six min. Both clocks would be wired through the same stations through a three-way toggle switch for each station. Thus, by the flip of a switch, the mist cycles can be either on for three or for six-min intervals per station. If only one controller is used, then all six stations on that controller must have the same interval betwen on times. Another advantage in the use of two controllers is that as the day warms up and the cuttings need mist more frequently, the mist cycle can be changed from every six min. to every three min. by the flip of a switch.

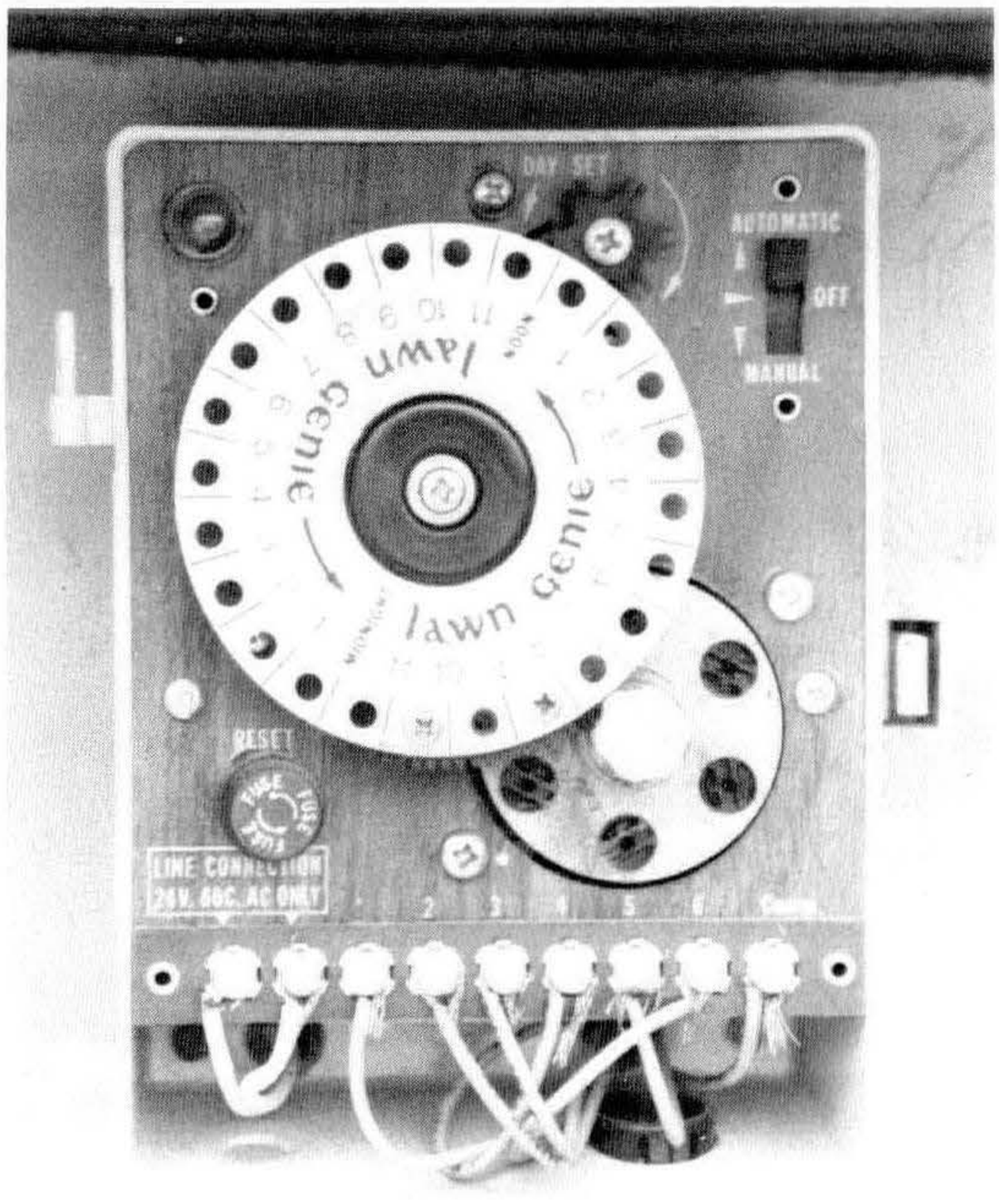

Figure 1. Richdel, Lawn Genie, 6-station lawn sprinkler controller converted into an inexpensive and flexible mist controller.

Another labor-saving device is the use of an on-off toggle switch for each station, with the addition of another 24-volt transformer. This switch is tied into the station wire as an alternate power supply for manual watering when the cuttings

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Note: A detailed electric schematic drawing can be obtained from the author.

have rooted. This additional switch allows the cuttings to be watered manually if for some reason a controller malfunctions. The complete setup has one advantage over most commercial clocks in that the person who wires it can replace most parts in place with little or no downtime.

This system offers much needed flexibility in the propagation house. The two biggest advantages this system has over commercial controllers are reasonable cost and simplicity of repair.

YOUR IRRIGATION WATER SAMPLE

PAUL C.H. CHU

A & L Eastern Agricultural Laboratories, Inc.
7621 Whitepine Road
Richmond, Virginia 23237

The purpose of water sampling is to collect a portion of the water source small enough in volume to be transported conveniently and handled easily in the laboratory while still representing the water source being sampled. A representative sample is the most important single element in the water analysis since the result of any test can be no better than the sample on which it is performed. A representative sample means that the concentrations of all components are the same in the sample as in the water source. The task of obtaining a representative sample often becomes more difficult as the size of the water source increases. A good grab sample can be representative if it is collected from a well-mixed water tank but will not be representative if it is collected from a pond. The sampling program should take into account the variations of time, area, depth, and the rate of the water flow. Quality can change overnight even with city water if a decision is made by city officials to soften the water.

It is impossible to give detailed sampling procedures under all conditions. In general, a representative sample can be attained by making a composite of individual samples collected at different locations or over a period of time. For example, if pond water is to be tested the samples should be taken from different depths and combined to form one composite. For well water a composite is obtained by taking samples over a period of 5 min. to 1 hr. or longer. Sometimes it is necessary to obtain more information about the variability of a water source by analyzing the individual samples separately. If flow rate in-

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The purpose of water sampling is to collect a portion of the water source small enough in volume to be transported conveniently and handled easily in the laboratory while still representing the water source being sampled. A representative sample is the most important single element in the water analysis since the result of any test can be no better than the sample on which it is performed. A representative sample means that the concentrations of all components are the same in the sample as in the water source. The task of obtaining a representative sample often becomes more difficult as the size of the water source increases. A good grab sample can be representative if it is collected from a well-mixed water tank but will not be representative if it is collected from a pond. The sampling program should take into account the variations of time, area, depth, and the rate of the water flow. Quality can change overnight even with city water if a decision is made by city officials to soften the water.

It is impossible to give detailed sampling procedures under all conditions. In general, a representative sample can be attained by making a composite of individual samples collected at different locations or over a period of time. For example, if pond water is to be tested the samples should be taken from different depths and combined to form one composite. For well water a composite is obtained by taking samples over a period of 5 min. to 1 hr. or longer. Sometimes it is necessary to obtain more information about the variability of a water source by analyzing the individual samples separately. If flow rate in-

creases, more settled material will be agitated back into the water. Flooding can decrease solute concentration.

Sampling Procedure. Prior to sampling make sure that your hands, sample bottle, and any other items that might come into contact with the water sample are clean. Use new bottles, preferably made of plastic, that have never been used for food or beverage. Sterilization is not necessary unless a bacteria test is requested. Rinse sample bottle a few times with the water being collected. If the sample is collected from a distribution system, flush the line to avoid the contamination.

A water sample collected at a certain time and place can only represent the composition of the water source at that particular time and place. Keep a record of time, place, flow rate, weather conditions and any other data you think might possibly affect the sample. Identify the sample bottles. To make a composite sample, collect at least five subsamples at a minimum of 100 ml. (about ½ cup) each and combine in a larger bottle. A final volume of 500 ml (about ½ qt.) is sufficient for most irrigation suitability tests. For herbicide or pesticide residue tests, one liter (about 1 qt.) is a minimum amount needed. Fill the sample bottle and secure the cap.

Sample Preservation (Table 1). In general, the shorter the time that elapses from the collection of water until its analysis, the more reliable the analytical results will be. A complete stabilization of the sample from the moment of collection to the time of analysis is impossible. When a water sample is taken out of its original environment where it is stable, the components of the water may change chemically or biologically. The most common example is white calcium carbonate precipitating out of the well water into the water line or collecting on the surface of a bathtub. Iron in reduced state (Fe^{++}) is soluble. When it is oxidized by the air to Fe^{+++}, it becomes insoluble and precipitates.

Storage at low temperatures is perhaps the best way to preserve most samples. Using acid to adjust the pH to less than 2.0 is another common preservation technique for metal tests. A second sample would be needed for pH and other tests. For most greenhouse usage the changes of the sample during the time of shipment (2 to 3 days) are normally non-critical and should not alter the conclusion as to whether or not it is suitable for irrigation.

Remember that it is also important to sample soil and plant tissue. Take enough small samples from several containers to give two good handfuls. Plant tissue gives an immediate indication of what the plant can utilize from the soil and water. The newest mature tissue should be used.

Table 1. Below are general guidelines for sample preservation for some common tests.

Tests	Preservation	Max. Storage Time
Acidity/alkalinity	Refrigeration	14 days
Boron	None	28 days
Chlorine residue	Analyze immediately	2 hours
Conductivity	Refrigeration	28 days
Metals	Filter, add nitric acid to below pH of 2.0	6 months
Nitrogen, ammonium nitrate, and total	Add sulfuric acid to below pH of 2.0, refrigeration	28 days
Pesticides, herbicides	Refrigeration	7 days
pH	Analyze immediately	2 hours*
Phosphorus	Add sulfuric acide to below pH of 2.0	3 days
Sulfate	Refrigeration	30 days

* pH may or may not change if storage time is longer. For irrigation purposes, the change during the shipment will not alter the medium or soil pH since it is weak-buffered.

A WOOD-BURNING FURNACE FOR HEATING PROPAGATION HOUSES

RONALD W. COPELAND

Apex Nurseries, Inc.

Route # 3, Box 276 B
Apex, North Carolina 27502

The escalating cost of fossil fuels in the winter of 1981 led our nursery to seek a more economical and reliable method of heating our propagating and liner-growing houses. After much research and evaluation it was decided that a wood-burning furnace was the answer to our needs. It was important that we answer the following questions:

1. Could the wood-burning furnace provide the heat needed?
2. What unit was needed and what would it cost?
3. Was hardwood available?
4. How much time would be required to operate and maintain the unit?
5. How much could we save by using wood instead of fossil fuel?

During the winter of 1981 our nursery spent about $10,000 heating approximately 13,000 ft.^{2} of space. The space heated included three houses used for propagation and four houses used for growing-on the rooted cuttings. Three of our units

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were heated by means of hot water using black pipe, fin radiation as bottom heat in raised beds. These three units were heated with an oil-fired boiler capable of providing 1,000,000 BTU's per hour. The remaining four units were heated with gas-fired space heaters with fan-jet systems and convection tubes. In the three bottom heat units a temperature of 70°F was maintained while in the gas-heated houses a minimum temperature of 38°F was maintained.

During the winter of 1982 the combined cost of gas and oil was approximately $8,500 to maintain these temperatures. It was our opinion that had a higher temperature been maintained in the houses used for growing the liners, we would have had much better root growth and, therefore, would have had much faster and better top growth the following spring.

These two high-cost winters and the possibility of even higher fossil fuel costs in the future encouraged us to consider seriously using wood for heat.

After much research it was determined that we needed a wood-burning furnace capable of providing 1.6 million BTU's per hr. This size furnace would give us the capability of meeting our present requirements with the possibility of either increasing the heat a good deal over the former system or increasing by 10% the amount of space heated.

The initial cost of a unit capable of providing 1.6 million BTU's per hour was $20,000. This cost represented approximately two years' costs of heating by the present method. In addition the wood-burning furnace did not pose the problem of oil and gas fumes in the greenhouse.

It was determined that we would need approximately 50 to 60 cords of hardwood to fire our furnace during one full heating season, which in our case is October 15 to March 15. At an average price of $40 per cord, fuel cost would be $2,000 to $2,400 per season. Without adding any cost for operation and maintenance, the fuel costs described above represented an annual savings of approximately $6,000 or 70%. This fact alone sold us on the wood-burning furnace.

After the initial investment in the unit, the only other costs involved are the costs of a very small amount of maintenance and the cost of one man filling the furnace each morning and each evening. This chore takes about 10 min. each filling.

Judicious purchasing of the wood can also bring tremendous savings. Our experience has been that all wood dealers are different in the quantity and quality of wood delivered. We have tried many methods of buying wood, either by the semitruck load or in small pulpwood-truck loads. They all

vary tremendously, and anyone is only as good as the man you are dealing with. The large semiloads come in 30 ft. lengths and require cutting into 5-ft. lengths, whereas the pulpwood comes in 5-ft. lengths and only requires restacking before use. The restacking facilitates the use of a front end loader or tractor to fill the furnace.

We are able to adapt our furnace in a manner that allows us to use our existing black pipe, fin radiation system in the one house. In the other houses we simply replaced the gas units with an exchanger that provides hot air to the fan-jet system. Each house is equipped with a thermostat, either soil or air, that activates a circulating pump that provides the needed heat for each unit being heated.

The furnace at our nursery is 28 × 8 × 8 ft. It is capable of using five-ft. log lengths, and the fire chamber is capable of holding 0.75 cords of wood per filling. The water volume is 6,000 gal. We try to maintain a water temperature of 180°F; it is possible for us to go from cold water to 180°F in three hours. During the normal winter night we fill the wood chamber at 5 p.m. and 7:30 a.m. During very cold weather (teens and lower twenties) we check the furnace at 11 p.m. and add wood if needed.

The unit used by our nursery is considered a medium-sized furnace. This manufacture makes units as small as 2,000 gal. of stored water with a 350,000 BTU output per hr. and a 0.25-cord wood chamber, utilizing 3-ft. long lengths. Their largest unit has a 25,000 gal. stored water capacity, 8 million BTU output per hour, three-cord wood chamber and a maximum log length of 9 ft. It is possible to use any combination of units in tandem to provide the needed BTU output.

All furnaces, like the make we use, have a high water-heat storage tank directly attached. None of the wood furnaces are pressurized. The units operate with an inducted draft, and the fire box is designed in such a manner as to provide high efficiency and low emission of excess gases. Our unit and all large wood-burning furnaces are tractor-fork loaded.

Maintenance of a wood furnace is very low. One must only remove the ashes on an average of once per wk. during the peak firing period. It takes one person approximately one hr. to remove the ashes and refire the furnace. The fact that the fire in the furnace must cool down some before the ashes can be removed is a disadvantage, especially in very cold weather when the water needs to be as hot as possible. It is also necessary to clean the tubes that run from the fire chamber to the stack. This allows the very hot air to pass through the water storage tank and thus heat the water on the average of twice per heating season. This task takes one person ap-

proximately 1½ hr. and must also be done when the fire is completely out in the fire chamber. This could also be considered a disadvantage as it may have to be done once during very cold weather at the peak of the heating season.

In summary, our wood-burning furnace has proven to be very economical, clean and safe. It is our belief that a wood-burning furnace can save one a minimum of 50% and a maximum of 80%. One statistic that bears this out is the fact that wood cost per 100,000 BTUs is $0.15 as compared to a fossil fuel cost of $0.73 per 100,000 BTUs[1].

The following trade publications give additional information on wood-burning furnaces:

Greenhouse Grower, April 1984: Energy:Dollars & Sense
Grower Talks, April, 1985: Fuel:Some New Answers
Florist Review, March, 1985

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[1] Florida Furnace Corp., Box 637, Apopka, Florida 32703.

AN INNOVATIVE APPROACH TO THE USE OF BOTTOM HEAT

JERRY BILLINGTON

Tawakoni Plant Farm
Route 3, Box 109B
Wills Point, Texas 75169

The idea of bottom heat in rooting cuttings is not new. The major drawbacks for most systems are the cost of installation, the purchase of equipment, and the maintenance. The system developed at Tawakoni Plant Farm has proven to be cost-effective and has returned the original investment more than twice in its first year of use. It was very easy to install and was built out of materials readily available through local supply firms. The goal was to install a system not so much for protecting liners, but more for rooting cuttings during the winter months. Both objectives have been achieved with this system. Admittedly, the winter of 1983-1984 was a deciding factor in building the system. That year almost ⅓ of all rooted liners were lost to freezing, causing serious planning, financing, and organizing problems. This system has the potential to alleviate losses of that nature and expand the propagation season to a year-round endeavor.

MATERIALS AND METHODS

The propagation department of Tawakoni Plant Farm consists of eight 30 × 96 ft. quonset-type greenhouses with 30% shade coverings. All greenhouses were covered with inflated

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MATERIALS AND METHODS

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double poly, four mil on the bottom and six mil on the top, to conserve heat during the winter. Five of the eight houses are for holding rooted liners. The other three are divided in half with separate controls for misting frequency and duration. After subtracting aisle space, six 1100-ft.^{2} mist beds are utilized. One of these six beds was used for construction of the bottom heat system.

After removing the irrigation system, construction was begun by cleaning, raking, and smoothing the gravel floor of the greenhouse. This was followed by placing four layers of Vis-Queen six mil poly on the gravel to serve as insulation.

Three header pipes were required in order to provide for circulation of the heated water. These were constructed from 2-in. PVC pipe with reduction tees on one-ft. centers for the supply and return pipes and tees on 6 in. centers for the opposite end. Two pipes were needed for the supply and return side of the system. The supply header was placed on the Vis-Queen with 13 inserts for tubing runs. The return header was placed immediately above the supply header. It consisted of 12 inserts for tubing, also on one-ft. centers, but was staggered in relation to the supply header, yielding an overall 6 in. spacing between tubes. All 25 tubing runs were 96 ft. long and were connected to the opposite header. Since all tubing was connected to one header at the opposite end of the bed, a consistent water temperature was achieved through mixing; ½ in. black polyethylene tubing was used because it is inexpensive and provides excellent heat exchange. The tubing was then anchored using 12-in. pieces of wire bent over the tubing and driven into the ground at six to 8-ft. intervals. Sand was then placed in at a depth of 3 in. to insure an even distribution of temperatures.

The water was heated with a propane-fired, Comfortzone swimming pool heater rated at 267,000 BTU's per hour. It is equipped with a pressure-sensitive switch to prevent heating when the water pressure is less than 2 psi or greater than 6 psi. The pump is a Sta-Rite ¾ hp. 230 volt swimming pool pump with 1½-in. inlet and outlet. It has a flow rate of 5 lb./in.^{2} pressure, which makes plumbing repairs almost non-existent. Both the heater and the pump are connected to a thermostatically-controlled relay. The thermostat is one of a special application, opening the circuit on temperature rise and closing on temperature drop. It is monitored by a remote probe placed in the sand. The pump and heater are activated when the temperature drops below 60°F and are shut off when the temperature reaches 63°F.

The system is supplied with a 50-gal. reservoir tank, which was filled once upon construction. Water is pumped out

through the bottom of this tank, into the heater, through the system, and is returned to the top of the reservoir tank. The tank is equipped with a ¾ in. opening in the top that remains open to prevent excessive pressure build-up. Since the water temperature is quite hot coming out of the heater, CPVC pipe is recommended between the heater and the supply header and between the heater and the pump. The heater, pump, and reservoir tank were placed on a 4 × 9 ft. concrete slab just outside the greenhouse and covered with a wooden shed for protection from wind and rain.

IMPLEMENTATION

On November 5, 1984, a test was conducted with 23 tree and shrub cultivars. All cuttings were direct-stuck into rose pots and placed under the intermittent mist. Rooting percentages ranged from 100% on some cultivars to 0% on others, which bears out the fact that winter propagation is not for all plants. However, the overwhelming success of several important cultivars has proven beyond doubt that the assets of the system outweight its costs. In addition, it must be pointed out that the east Texas area had a late winter in 1984, with unusually warm temperatures into December. This should be considered as a contributing factor in the success of such plant materials as photinia and Indian hawthorne.

Table 1 shows an item-by-item count of test plants.

After the initial test, larger numbers of the plants that had been successfully rooted were placed in the system. Many of these plants were stuck in 4 in. pots with 3 cuttings per pot. The idea was to produce a larger liner for direct potting into 2 and 5-gal. containers. Species tested included, *Photinia* × *fraseri*, *Ligustrum lucidum*, *Ilex cornuta* 'Burfordii, and *Ilex cornuta* 'Dwarf Burford'. Rooting success was impressive during December and January but declined during February and March. Table 2 shows the difference between cuttings taken early in the winter as compared with cuttings taken after the full impact of winter was in effect. Four of the five species showed definite decrease in rooting once the warm temperatures of December had subsided.

Upon rooting, these plants were hardened-off, grown out, and lined out in 2 and 5 gal. containers. All four species were successful in the 2 gal. container, growing out to salability in one season. The photinia and the *Ligustrum* were equally successful in the 5-gal. container, but the two *Ilex* cultivars proved to be too slow growing to be called successful in 5-gal. pots.

At present the program for these 4 in. liners has been expanded to include 14 cultivars for a total of 36,000 liners.

Table 1. Rooting of cuttings of 23 shrub cultivars over bottom heat during winter propagation.[1]

Species and cultivar	Percent rooted
Cleyera japonica	33
Cupressus sempervirens glauca	64
Euonymus 'Goldspot'	100
E. sp., Boxleaf form	100
Ilex cornuta 'Burfordii'	96
I. cornuta 'Dwarf Burford'	98
I. 'Nellie R. Stevens'	100
I. vomitora 'Nana'	78
Juniperus horizontalis 'Bar Harbor'	95
Mahonia bealei[2]	83
Nandina domestica compacta[3]	90
N. domestica 'Purpurea Nana'	100
N. domestica 'Woodsii'	92
Photinia × *fraseri*	100
Prunus cerasifera 'Krauter Vesuvius'[2]	0
Pyracantha 'Dwarf Red'	97
P. 'Navajo'	100
P. 'Teton'	100
Rahiolepis 'Jack Evans'	91
R. indica 'Pinkie'	96
R. indica 'Snow White'	98
Rosa banksia 'Lutea'[2]	85
Syringa × *persica*[2]	92

[1] 96 cuttings stuck except as noted
[2] 48 cuttings stuck
[3] 40 cuttings stuck

Table 2. Comparison of rooting response of five cultivars propagated at two different periods using bottom heat.

Species and cultivar	Date of Cutting 11/84 to 1/85		2/85 to 3/85	
	Number rooted	Percent	Number rooted	Percent
Hedera helix	576	100	1920	100
Ilex cornuta 'Burfordi Nana'	2020	98	3600	71
Ilex cornuta 'Burfordii'	1816	96	672	57
Ligustrum lucidum	2000	96	1000	92
Raphiolepis indica 'Jack Evans'	3216	96	5808	81

The fact that the time required to grow out many of the 2 and 5 gal. material has been reduced by a full year is very encouraging and will have a great impact on the production cost of these plants.

DISCUSSION

During November, December, and January, careful records were kept of the differences between outside temperature at

7:30 a.m., hotbed sand temperature, liner temperature on the hotbed, and liner temperature in the heated house, but not on the hotbed. As Figure 1 shows, sand temperature was fairly constant. Liners on the hotbed showed more variation but liners in the heated house — not directly on the hotbed — showed the greatest temperature fluctuation. These plants were from 5 to 15 degrees warmer than the outside temperature. The one temperature that dips for all four readings occurred on a cold, windy night when the pilot light was blown out. This situation was remedied by the addition of a wind shield on the north side of the wooden shed.

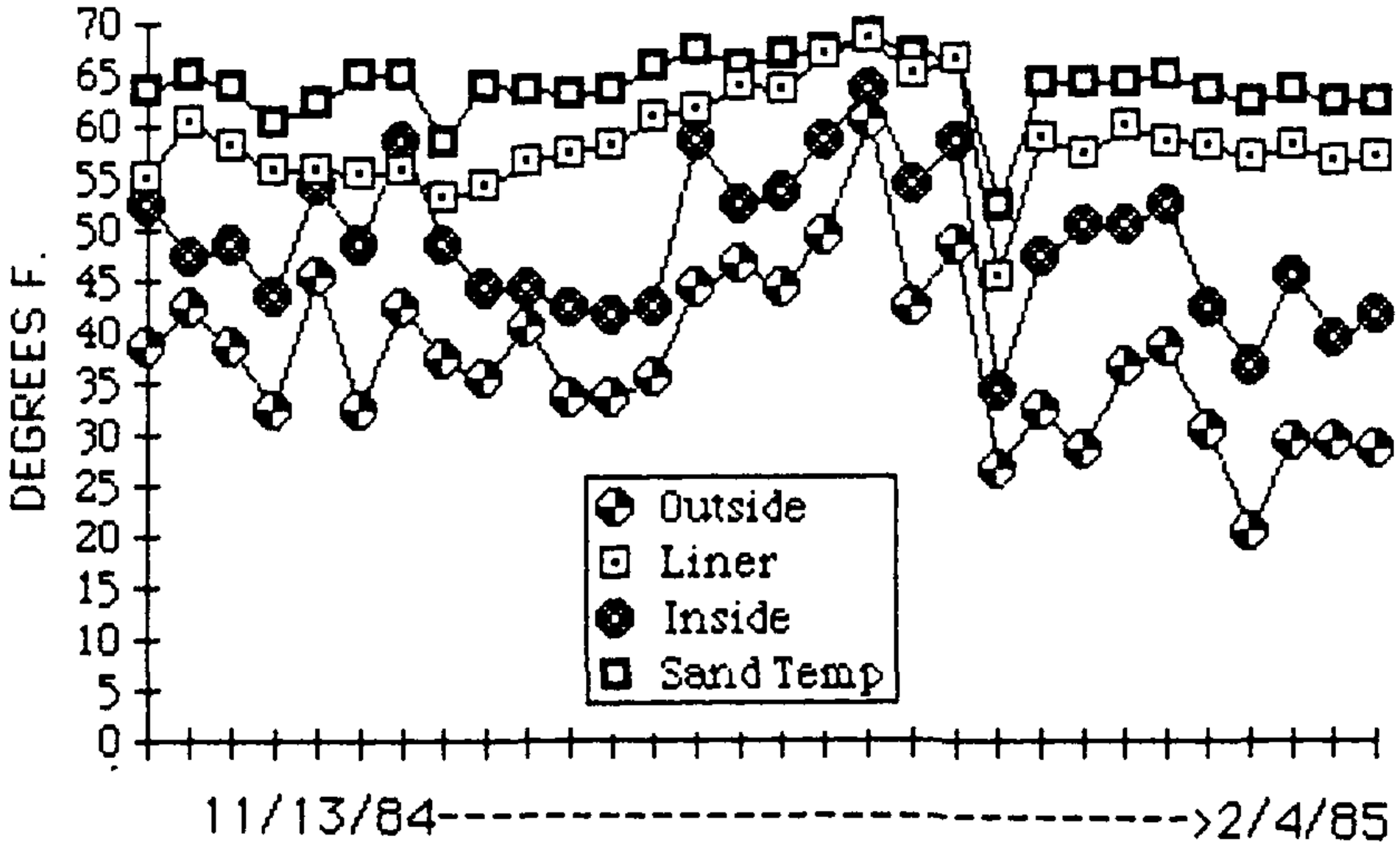

Figure 1. Temperatures measured outside and inside the propagation house and in liners with and without bottom heat.

After the original system was in use for 3 months, the results were so encouraging that a decision was made to double the size of the system. The heater did a very efficient job of keeping the liner temperature at a constant 60°F, consuming only $860 worth of propane during the entire 3-month period. The two hotbeds are used to root the cuttings, which are then moved over to the other side of the greenhouse to harden-off before planting out.

Our results formed the basis for the decision to put the new system in another house but use the same pump and heater to supply it. The idea worked well, but the thermostat was increased to 65°F in order to compensate for the additional heated area.

All in all this sytem is not the answer for everyone. It is

Note: A detailed schematic of the water flow system can be obtained from the author.

an alternative for those who want the protection and the increased flexibility of propagating in the winter months without the high cost of a commercially-designed system. Estimated cost for this system is shown in Table 3.

Table 3. Estimated installation costs for Tawakoni hotbed with respect to payback on investment.

Costs:	
Equipment cost:	
Heater, pump, reservoir tank, piping, etc.	$1769.66
Propane cost:	
Price at .88 per gal. over 4 months	868.60
Labor cost:	
Installation, cutting of plants to fill bed, mixing of soil, filling pots, etc.	780.00
Hardgoods cost:	
Pots, flats, soil, etc.	520.00
Total Costs	$3938.26
Assets:	
Cuttings stuck and placed on hotbed	19,764
Multiply by rooting percentage	× .85
Number of rooted plants produced	16,799
Multiply by lowest average market price	× 0.35
Total value of plants produced	$5879.65
Less costs	−$3938.26
Net profit in first year	$1941.39

GAS: A HEAT SOURCE FOR WINTER PROTECTION

PETER VAN DER GIESSEN

Cottage Hill Nursery
Rt. 2, Box 20
Irvington, Alabama 36544

The purpose of this project was to find an efficient and economical heat source for our liner houses.

Before Hurricane Frederic of 1979, the houses at Cottage Hill Nursery container division were equipped with Modine heaters. After the storm we had to rebuild, so this was a good time to consider changes in heating equipment. We decided to try different heaters to make our heating more efficient and economical. We considered three posibilities:

(a) Replace Modine heaters.

(b) Use an open-flame heater topped by a container of water.

(c) Turn on the misting system during extremely cold nights.

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These houses are used for overwintering liner stock, so we do not need a growing temperature. Choice (a) was out because of cost. Choice (c) required the presence of an employee at night, checking to see that timers were working properly. This also could present a problem of over-watering. Choice (b) seemed the simplest solution. We thought it would be economical. It produced warm moist air, required no ventilation, and kept the temperature above freezing.

The first heater we tried had several flaws. The burner with 100 holes was using too much gas. The placement of the valve made it difficult to turn on and off, and there was no easy way to light it.

Another heater we could have made locally with a one-hole orifice. This would cut down on fuel consumption. It had an easily-accessible valve for convenient lighting. This is the heater we chose.

Along with trying out new heaters we put double poly on each house and double front and back. We use a drop cloth in front of each door and window. Even in the cold 1°F temperature we experienced in January 1985, these heaters performed well. There was no ethylene damage.

Outside our icing-over produced phenomenal pictures, but not such good results. Our covered plants outside came through without any damage. Although the temperature in the house dropped to freezing we did not lose any significant number of plants.

We discovered we must take precautions against setting the flame too high. A high flame evaporates all the water in the barrel. A low flame, just enough to produce a fair amount of steam, is all that is required.

This system is practical, economical and has been a plant-saver at Cottage Hill Nursery.

INFLUENCE OF EXOGENOUS AUXIN APPLICATION ON THE MINERAL NUTRIENT STATUS OF 'CONVEXA' HOLLY CUTTINGS DURING INTERMITTENT MIST PROPAGATION

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Abstract. Hardwood stem cuttings of *Ilex crenata* 'Convexa' Thunb., treated with and without indolebutyric acid (IBA), were inserted into a perlite rooting medium and misted with deionized water during intermittent mist propagation in a controlled-environment chamber. Initially, and at weekly intervals for 6 weeks, leaves, upper stems (portion of stem above rooting medium) and lower stems (portion of stem in rooting medium) were analyzed for N, P, K, Ca, and Mg. At the conclusion of the study, both nontreated and IBA-treated cuttings showed a slight increase in dry weight with detectable but slight leaching of N and K and no detectable leaching of P, Ca, and Mg. Mineral nutrient mobilization to the lower stem was not detected during root initiation for nontreated and IBA-treated cuttings. Following root initiation and later budbreak on the upper stem, N, P, K, Ca, and Mg were all mobilized from the leaves of nontreated and IBA-treated cuttings to the upper stem, whereas only N, P, and K were mobilized to the lower stem of IBA-treated cuttings. For nontreated cuttings, all nutrients were mobilized from the lower stem to the upper stem, while for IBA-treated cuttings only Ca and Mg were mobilized from the lower stem to the upper stem. Root development, as influenced by IBA treatment and budbreak on the upper stem, had a strong influence on mineral nutrient mobilization.

During intermittent mist propagation of nonauxin-treated 'Convexa' holly cuttings, Blazich and Wright (2) reported no mobilization of N, P, K, Ca, and Mg from the upper portions (leaves and upper stems) of the cuttings into the stem base (portion of stem in rooting medium) during root initiation. Their data also suggested that up to the time of root initiation, there was little or no leaching of these mineral nutrients, in contrast to reports of leaching from cutting of other plants during mist propagation (5).

One provocative aspect of rooting with respect to nutrient mobilization is the role of exogenously applied auxin. Although workers have investigated the effects of applied auxin on mobilization of carbohydrates (1,4,10) and N (9,10) it appears that no research has addressed the question of whether or not applied auxin has any influence on mobilization of such mineral nutrients as P, K, Ca, and Mg. To consider this hypothesis and enhance knowledge of mist propagation, the following investigation was undertaken to explore the influence

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of exogenous auxin application on the mineral nutrient status of 'Convexa' holly cuttings during intermittent mist propagation.

MATERIALS AND METHODS

Uniform, hardwood, terminal stem cuttings, 12 cm long were taken on February 25, 1981 from containerized 'Convexa' holly stock plants growing out-of-doors at uniform fertility levels at Suffolk, Virginia. As cuttings were collected, they were wrapped in moist paper towels, placed in a cooler, and transported to Raleigh, North Carolina. The following day, the experiment was initiated at the Southeastern Plant Environment Laboratory (Phytotron) at Raleigh.

Cuttings were trimmed from the base to 10 cm in length and leaves removed from the basal 4 cm. Two rooting treatments were employed: nontreated and 5000 ppm IBA. When treating cuttings with IBA, the basal 2 cm were dipped into a 5000 ppm IBA solution for 1 sec. followed by 15 min. of drying before insertion into the rooting medium. The IBA solution was prepared by dissolving reagent grade chemical in 50% isopropyl alcohol.

Following treatment, cuttings were inserted to a 4-cm depth in plastic flats (53.0 × 37.5 × 6.5 cm) containing a moist medium of unscreened perlite, which had been thoroughly leached with deionized water. The flats were then placed in a Sherer CEL 38-15 growth chamber at day/night ambient air temperatures of 24/18 ± 0.5°C. An 11-hr. photoperiod was provided daily from 0700 to 1800 hours by a combination of cool white fluorescent and incandescent lamps providing a photon flux density (photosynthetic radiation between 400 and 700 nm) of 120 to 125 μmol/m^2/s (8.8 to 9.0 klx) plus a radiant power density (photomorphogenic radiation between 750 and 830 nm) of 2.1 to 2.2 W/m^2 measured at the top of the flats with Li-Cor LI 185A quantum/radiometer/photometer. Relative humidity was maintained at 97 ± 1%. The chamber was equipped with an intermittent mist system, utilizing deionized water which operated 20 sec. every 30 min. from 0630 to 1830 hours daily.

Initially, and at weekly intervals for 6 wk., the leaves, upper stems (portion of stem above rooting medium) and lower stems (portion of stem in the rooting medium) were analyzed for N, P, K, Ca, and Mg. For each rooting treatment, 4 replicates each consisting of the particular plant parts from 20 randomly selected, viable cuttings were oven-dried for 48 hours at 70°C, weighed, and ground in a Wiley mill to pass a 20-mesh screen. Total N was determined by a modified micro-Kjeldahl method (8), Ca, Mg, and K by atomic absorption spec-

trophotometry, and P colormetrically (11). Data were subjected to analysis of variance procedures and regression analysis.

RESULTS

Dry weight and total mineral nutrient status after 6 weeks. During propagation there was highly significant increase and a significant increase in the dry weight of the

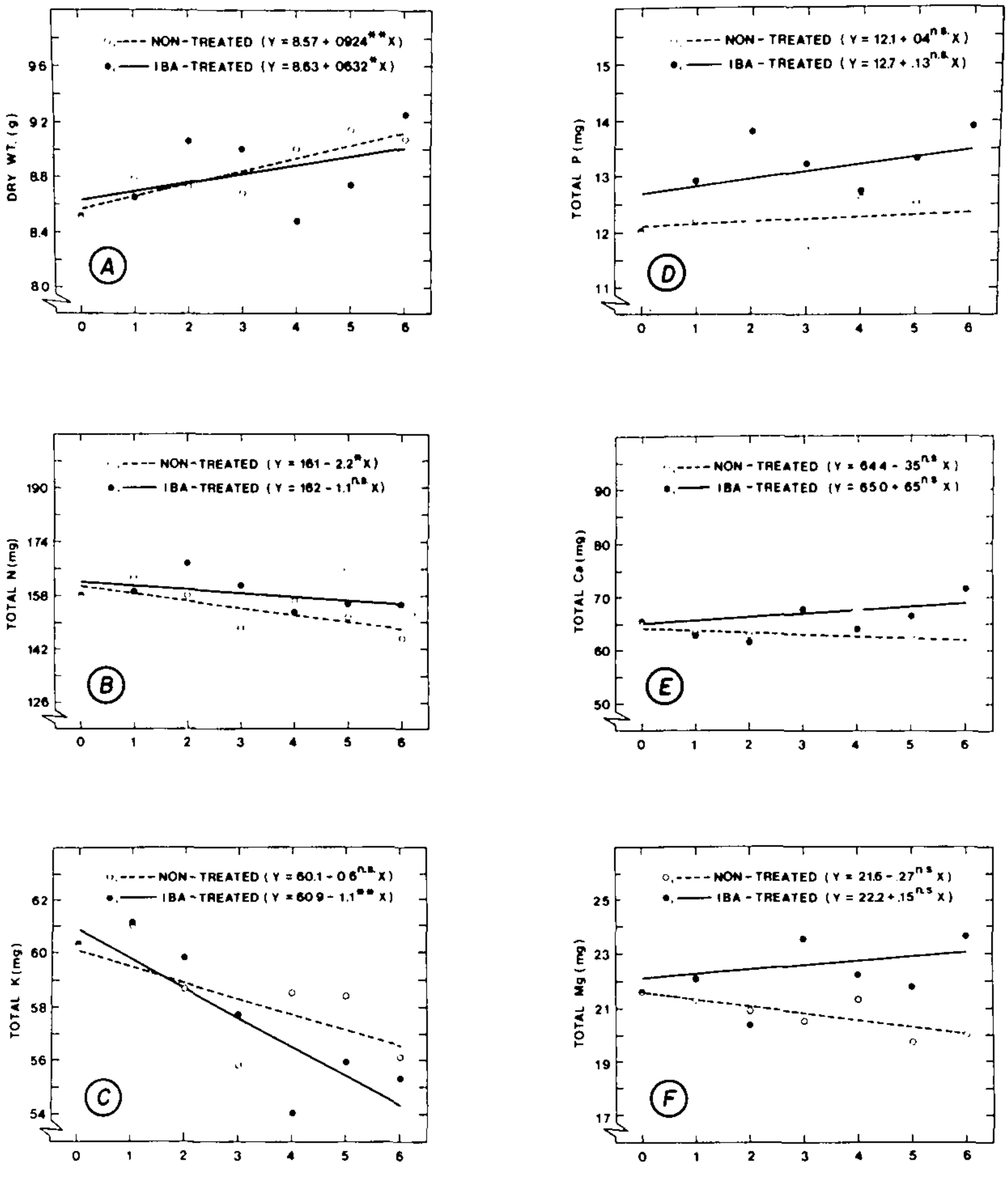

Figure 1. Dry weight and total N, K, P, Ca, and Mg content of nontreated and IBA-treated 'Convexa' holly cuttings during intermittent mist propagation for 6 weeks. Each data point represents the mean of 4 observations. The superscripts n.s., * or ** above each regression coefficient indicate the following: n.s. = nonsignificant, * = significant at 0.05 level, and ** = significant at 0.01 level.

nontreated and IBA-treated cuttings, respectively (Fig. 1A). A significant decrease of total N was found for nontreated cuttings while IBA-treated cuttings showed a decrease that was not significant for the same parameter (Fig. 1B). A similar but reversed relationship was noted for total K. The K content of nontreated cuttings decreased but not significantly while a highly significant decrease in total K was noted for the IBA-treated cuttings (Fig. 1C). However, no significant differences were found in a comparison of the regression coefficients for nontreated versus IBA-treated cuttings with respect to total N and K. For the other mineral nutrients considered in this study, there were no significant changes in the total P, Ca, and Mg content of the nontreated and IBA-treated cuttings (Figs. 1D, 1E, and 1F).

Changes in dry weight and mineral nutrient content of leaves, upper stem and lower stem after 6 weeks. At 6 weeks, major changes were noted in dry weight and in distribution of N, P, K, Ca, and Mg expressed as a percent change in fraction of total (Tables 1 and 2). The leaves of both nontreated and IBA-treated cuttings showed a highly significant decrease in all 6 parameters. The opposite, a highly significant increase for the same parameters was noted for the upper stem (Table 2). The magnitude of the dry weight increase in the upper stem was considerably greater in the nontreated cuttings in comparison to the IBA-treated cuttings (72% vs. 55%). The lower stem of nontreated cuttings, which included the newly formed roots (approximately 5 primary roots) exhibited a nonsignificant decrease in dry weight and a highly significant decrease in N, P, K, Ca, and Mg (Table 2). Conversely, for the lower stem of IBA-treated cuttings, which also included the newly formed roots, (approximately 70 primary roots), a highly significant increase was noted for dry weight, N, P, and K while a highly significant decrease was found for Ca and Mg (Table 2).

Table 1. Dry weight and distribution of N, P, K, Ca, and Mg in leaves, upper stem, and lower stem of 'Convexa' holly cuttings before treatment (time 0) expressed as a percent of total for each parameter.[z]

Portion of cutting	Percent of total					
	Dry wt.	N	P	K	Ca	Mg
Leaves	58.2	80.7	63.1	72.2	73.4	79.6
Upper stem	20.4	9.3	17.8	13.4	15.2	10.3
Lower stem	21.4	10.1	19.2	14.4	11.4	10.1

[z] Values represent intercept means of the regression lines for each portion of nontreated and IBA-treated cuttings.

Table 2. Percent change in fraction of total dry weight and distribution of total N, P, K. Ca, and Mg in leaves, upper stem, and lower stem of nontreated and IBA-treated 'Convexa' holly cuttings during intermittent mist propagation for 6 weeks.[z]

Portion of cutting	Dry wt.	N	P	K	Ca	Mg
	Nontreated					
Leaves	-22**[y]	− 25**	− 42**	− 41**	− 3**	− 6**
Upper stem	+72**	+245**	+169**	+247**	+29**	+97**
Lower stem	− 8 n.s.	− 18**	− 22**	− 31**	−19**	−53**
	IBA-treated					
Leaves	-27**	− 34**	− 49**	− 51**	−10**	− 12**
Upper stem	+55**	+180**	+137**	+203**	+61**	+134**
Lower stem	+23**	+102**	+ 40**	+ 73**	−13**	−34**

[z] Values are based on individual regression lines for each portion of cutting.
[y] (+) indicates an increase and (−) a decrease; n.s. indicates nonsignificant and ** significant at the 0.01 level.

DISCUSSION

Since no significant differences were found in a comparison of the regression coefficients for nontreated and IBA-treated cuttings with respect to total N and K (Figs. 1B and 1C) and, in addition, they agree in sign, we conclude that N and K were leached from both nontreated and IBA-treated cuttings during intermittent mist propagation. However, loss of total N and K in 6 weeks was small, amounting in nontreated and IBA-treated cuttings, respectively, to 8.1 and 4.1% N, and 5.8 and 10.8% K.

Leaching of N and K, as the data indicate, supports a previous report showing these mineral nutrients can be leached from stem cuttings of a wide variety of plants during intermittent mist propagation (5). This same report also showed that leaching of N, P, K, Ca, and Mg was more pronounced from hardwood than herbaceous and softwood stem cuttings. The previous statement is intriguing because hardwood 'Convexa' holly cuttings were used in the present study and only slight leaching of N and K was detected with no apparent loss of P, Ca, and Mg.

Although our data indicate that slight but detectable leaching of N and K occurred, a portion of these losses may have been due to flower bud development. By the fourth week of this study profuse flower bud development was noted on both nontreated and IBA-treated cuttings. However, due to the small size and fragile nature of the floral tissue, most of this material was lost in sample preparation, particularly during

drying and grinding. Loss of this tissue may have contributed to N and K loss. If indeed this occurred, then leaching of N and K might have been less than reported.

Slight increases, although nonsignificant, in total P content for nontreated and IBA-treated and total Ca and Mg content for IBA-treated cuttings were noted (Figs. 1D, 1E, and 1F). Since deionized water was used to mist the cuttings and analysis of the water and rooting medium showed trace amounts of these mineral nutrients, the increases can most easily be explained as sampling variation.

One week after the study was initiated, the basal portion of both nontreated and IBA-treated cuttings showed noticeable swelling, indicating root initiation had taken place. Swelling was more pronounced on the IBA-treated cuttings. In addition to the swelling, many of the auxin treated cuttings had vertical cracks in the epidermal tissue on the basal stem. This is usually observed as roots prepare to emerge. By 2 weeks, roots were observed emerging on both the nontreated and IBA-treated cuttings. Apparently root initiation took place within the first week whether or not cuttings were treated with auxin. The cracking of the epidermal tissue on some of the IBA-treated cuttings also suggests that for these cuttings, root initiation had occurred and root development and growth were progressing.

Comparison of lower stem dry weight and mineral nutrient data before treatment (time 0) and the first week showed some change in most parameters measured (data not presented). However the changes, particularly an increase, when noted were never of sufficient magnitude to suggest or conclude that mineral nutrient mobilization took place during root initiation regardless of the rooting treatment. Nonmobilization of mineral nutrients while 'Convexa' holly cuttings are undergoing root initiation is in agreement with previous work on this cultivar (2). In the weeks following root initiation, mineral nutrient mobilization particularly into the lower stem of IBA-treated cuttings could be observed as nutrients were mobilized in support of root development. Thus, it appears mineral nutrient mobilization does not occur until root initiation has taken place and root development and growth commences.

At the conclusion of the study, it was shown that redistribution of mineral nutrients took place in response to terminal budbreak (observed at 3-weeks for nontreated and IBA-treated cuttings) and root development on the lower stem. Redistribution of mineral nutrients during rooting and budbreak as observed in this study supports previous research (6).

Nutrients were mobilized to the lower stem in response to root development and (approximately 5 primary roots on non-

treated cuttings vs. 70 primary roots on treated cuttings) and to possible sinks created by budbreak on the upper stem (Table 2). The partitioning of mineral nutrients between the upper and lower stem of IBA-treated cuttings is reflected in less of an absolute increase in the dry weight of the upper stem of these cuttings in comparison to the non-treated cuttings. This probably occurred because in the nontreated cuttings, nutrient mobilization took place only in response to budbreak on the upper stem, whereas in the IBA-treated cuttings mobilization took place in response to both terminal budbreak and auxin stimulated root development. As suggested by Booth *et al.* (3) the effect of applied auxin on the transport of substances within the plant may be indirect as a result of auxin-induced growth stimulation and subsequent movement of various substances to these areas of growth.

As observed for the nontreated cuttings, IBA-treated cuttings showed highly significant increases in all 6 parameters for the upper stem (Table 2). For the lower stem of IBA-treated cuttings, highly significant increases in dry weight and N, P, and K content were observed which probably resulted from extensive root development. However, there was a highly significant decrease in the Ca and Mg content of the lower stem despite greater root development in comparison to the nontreated cuttings. It appears the sink created by budbreak on the upper stem had a stronger influence on Ca and Mg mobilization than the developing roots. As reported by Mengel and Kirby (7) the preferential movement of Ca to the upper stem of nontreated and IBA-treated cuttings may have resulted from the synthesis of indoleacetic acid (IAA) in the shoot apex which caused the growing point to become a sink for Ca accumulation (7). Why Mg was also mobilized out of the lower stem of both nontreated and IBA-treated cuttings is subject to speculation and might be related to the role of Mg as a constituent of chlorophyll. Perhaps a higher chlorophyll content in the newly developing tissue on the upper stem in comparison to a lower chlorophyll concentration in the lower stem had some bearing on this movement.

Initially, the leaves of the cuttings contained the greatest proportion of N, P, K, Ca, and Mg (Tables 1 and 2). The fact that leaves of both nontreated and IBA-treated cuttings showed a highly significant decrease in dry weight with a concomitant decrease in N, P, K, Ca, and Mg (Table 2), demonstrates that a large portion of the new growth produced by the cuttings was a result of mineral nutrients supplied by the leaves. These data demonstrate that when rooting cuttings, nutrients should be applied when roots are present to prevent depletion of nutrients from the leaves.

It is generally agreed that N, P, K, and Mg are mobile in

plants and Ca is immobile (7). The data in Table 2 support the mobility of these mineral nutrients and show that under conditions such as reported herein, Ca is also mobile.

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PHYSIOLOGICAL ACTION OF OXYFLUORFEN (GOAL)

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Goal® (oxyfluorfen) is a diphenyl ether herbicide with broad spectrum preemergence and postemergence activity. It was discovered and developed at the Rohm and Haas Research Laboratories, Spring House, Pennsylvania. Goal was first syn-

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Goal® (oxyfluorfen) is a diphenyl ether herbicide with broad spectrum preemergence and postemergence activity. It was discovered and developed at the Rohm and Haas Research Laboratories, Spring House, Pennsylvania. Goal was first syn-

thesized in 1971, and initial field testing was conducted in 1972, under the experimental code RH-2915. The first projects selected for field development was preemergence weed control in soybeans and post-directed applications for witchweed control in field corn.

The first commercial registration in the United States was approved by the Environmental Protection Agency (EPA) in May, 1979, for non-bearing fruit trees. In December, 1980, the registration was expanded to include bearing fruit trees. Conifers were added to the label in 1979; soybeans and corn in 1981; cotton, spearmint, and fallow bed in 1982; onions in 1984, and artichokes in 1985. Goal has rapidly filled many niches in modern agriculture, and new uses continue to be developed. An experimental use permit was granted in July, 1985 for use of Goal on cabbage, cauliflower, and broccoli. Work is currently underway to obtain registration for Goal in pine to be used in reforestation programs, horseradish, strawberries, tomato row middles, and garlic.

Outside of North America, Goal is reistered on numerous other crops. It is curently used in the production of sugar cane, rice, tea, coffee, eucalyptus, African palm, banana, plantain, rubber, avocado, mango, pineapple, kiwifruit, olive, and tung.

Herbicidal Activity. The mechanism of action of the diphenyl ether herbicides is not clearly understood at this time. Several theories ahve been proposed. We do know that Goal interferes with photosynthesis, and a toxic radical is generated in plant tissue. Light and chloroplasts must be present for this to occur. These radicals disrupt the structure and function of plant cell membranes. Membranes are no longer capable of compartmentalizing degrading enzymes. In a postemergence application this becomes apparent as water-soaked spots on leaves rapidly turn to necrotic lesions.

As a preemergence application, Goal works as a soil surface-barrier herbicide. As mentioned above, the presence of light is necessary for the activity Goal. This activity centers at the soil surface, where the presence of light and Goal cause the formation of the toxic radicals in the seedlings that cause rapid destruction of the weed seedlings. Since this process occurs at the soil surface, any practices that result in redistribution or disturbance of the soil surface after treatment will decrease the herbicidal effectiveness of Goal.

The selection action of Goal is also not fully understood. Tolerant species, such as conifers, probably are capable of neutralizing Goal by breaking it into non-active metabolities. Inability of Goal to penetrate leaves of resistant plants may also be a factor in selectivity. Goal, with its selective, broad

spectrum control is generally more active against broad-leaved weeds than grasses.

Important weeds controlled by Goal include groundcherry, teaweed, velvetleaf, nightshade, malva, filaree, redroot pigweed, witchweed, large crabgrass, barnyardgrass, goosegrass, and giant foxtail. Of particular interest to the nursery industry is the preemergence and postemergence control of common groundsel, dog fennel, prostrate knotweed, prickly lettuce, wild mustard, red sorel, bittercress, lambsquarters, morning glory, purslane, shepherdspurse, birdseye speedwell, and scarlet pimpernal.

Use on Conifers. Goal 1.6E can be used on conifer seed beds as a preemergence application at 1.25 to 5 pts./A. Goal should be applied after seeding but prior to conifer germination. Beds should be irrigated immediately after application with ½ to ¾ inch of sprinkler irrigation for maximum activity.

On conifer transplants and container stock, preemergence and postemergence control of weeds is obtained with applications of 5 to 10 pts. of Goal 1.6E/A. Optimum weed control is obtained when applications are made to weed-free containers or transplants. Postemergence applications should be made to weeds less than four inches high.

Goal 1.6E should be applied to dormant conifers. Applications to plants that have not fully hardened off or applications just prior to or after bud break can cause injury. This is due to the possibility that Goal, under certain conditions, violatilizes, or moves off the soil, and adversely affects crop foliage. This volatility is enhanced by wet soil, bright sun, and low relative humidity. These Goal volatility symptoms are dependent upon the rate of Goal used, the degree of volatility and, most importantly, the stage of crop growth (young, immature foliage is more sensitive than older, more mature foliage).

Application. Goal is quite surface-stable and can remain on the soil surface from 3 to 4 wks. without incorporation by rainfall or sprinklers. Irrigation, however, should be applied as soon as possible after application to maximize crop safety and weed control. In the southeast U.S. applications to dormant stock in December and February have been effective.

Goal has a low solubility in water (less than 0.1 ppm at 25°C) and is strongly adsorbed by organic matter and clay particles in the soil. These characteristics keep it from moving out of the treated soil.

Since activation occurs within chloroplasts and requires light, there is no root activity with Goal. Goal also is not translocated in the plant.

Herbigation has the potential for increasing crop tolerance

to applications of Goal 1.6E while reducing costs of application. The large volumes of water used in this type of application reduce the response of ornamentals to foliar applications of Goal 1.6E. The herbicide application can be immediately followed by a water rinse, which will wash the herbicide off nursery stock and provide additional safety. Application by herbigation should be made to relatively clean plantings; otherwise the postemergence activity of Goal will be reduced. Irrigation systems utilized for herbigation must provide a uniform application of water over the entire treated area in order to provide an accurate application of herbicide and consistent weed control.

On September 26, 1985 the EPA approved an expanded conifer label. Now included for use on conifer seed beds are: fraser, grand, and noble firs; eastern hemlock; jack, lodgepole, shortleaf, slash, mugho, Austrian, longleaf, ponderosa, Monterey, eastern white, Scots, loblolly, Virginia, and Himalayan pine; Douglas-fir; Norway, dwarf Alberta, blue and Sitka spruce.[1]

Conifer transplants and container plants that can be treated include yews, western hemlock, red cedar, five species of juniper, and two species of arborvitae, as well as those listed for seed-bed treatment.

Additional conifers as well as broad-leaved species will be added to the label as sufficient data are accumulated and sorted out.

[1]Firs:
Abies fraseri
A. grandis
A. procera

Hemlock:
Tsuga Canadersis

Pines:
Pinus banksiana
P. contorta
P. echinata
P. elliottii
P. mugho
P. nigra
P. palustris
P. ponderosa
Pines (cont.)
Pinus radiata
P. strobus
P. sylvestris
P. taeda
P. virginiana
P. wallichiana
[syn. *P. griffithii*]

Douglas fir:
Pseudotsuga menziesii
Spruce:
Picea abies
P. glauca
P. pungens
P. sitchensis

A GRANULAR FORMULATION OF OXYFLUORFEN (ROUT)

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The objective of Sierra Chemical's ornamental-herbicide research program encompassed the development of an herbicide product with an effectiveness/tolerance spectrum equal or superior to any product currently marketed. Strategy involved the combination of two unlike chemical structures with complementing activity. Specific combinations were evaluated to provide primary and backup candidates for product registration.

Target weed species for which control data was required included: common groundsel, prostrate spurge, and common chickweed. These weed species are noted for their prevalence and difficulty of control.

MATERIALS AND METHODS

The experimental layout involved a randomized complete block (RCB) design with three replications of each treatment. Six one-gal. containers comprised a subplot for each ornamental species and chemical treatment. A typical research trial involved six to eight ornamental species.

Chemical applications were made with a high clearance (21-inch) linear drop spreader shielded to prevent particle drift and assure accurate, uniform product distribution.

Chemical treatments shown in Table 1 were applied at

Table 1. Chemical treatments evaluated in Sierra's ornamental herbicide research trials (1983-1984).

Treatment number	Chemical treatment	Rate lbs a.i /A
1	Goal/Devrinol	2 + 1
2		4 + 2
3		6 + 3
4		8 + 4
5	Goal/Surflan	2 + 1
6		4 + 2
7		6 + 3
8		8 + 4
9	Goal/Lasso	2 + 2
10		4 + 4
11		6 + 6
12		8 + 8
13	OH-2 (Goal/Prowl)	2 + 1
14		8 + 4
15	Ronstar	4
16	Control	—

three-month intervals for a maximum of three successive treatment phases at each location. Each experimental treatment was applied at 1X, 2X, 3X, and 4X levels. Commercially-available standards for comparison included OH-2 (1X, 4X) and Ronstar (1X).

All experimental treatments were formulated on Floridin (−16+30) attapulgite clay (RVM). Formulations were based on a product rate of 100 lbs./A or 1 gm/ft.^{2}

Selection of ornamental species for evaluation was based on those species of major economic importance in each geographical area. Six to eight ornamental species were evaluated at each of the following 14 locations:

D & M Nursery, Canby, OR
Woodburn Nursery, Woodburn, OR
J-Mar Nursery, Auburndale, FL
Goochland Nursery, Pembroke, FL
Scarf's Nursery, New Carlisle, OH
Wolfe Nursery, Tyler, TX
Greenleaf Nursery, El Campo, TX
Turkey Creek Nursery, Houston TX
Zelenka Nursery, Grand Haven, MI
Western Tree Nursery, Gilroy, CA
Select Nursery, Fallbrook, CA
El Modeno Nursery, Santa Ana, CA
Powell Nursery, Thomasville, GA
Pleasant Cove Nursery, Rock Island, TN

Test locations were selected to provide geographical spread assuring:

1. varying climatic conditions.
2. a wide range of potting media or soil types.
3. Accesibility to a wide spectrum of broad-leaved and grassy weed species.
4. a broad range of ornamental species.
5. trials in major production regions of the U.S.

Sierra Osmocote 18-6-12 was applied in accordance with label specifications in all container trails to standardize fertility practices.

SUMMARIZATION OF RESULTS

Ornamental herbicide research trials were initiated during May, 1983. Weed control data were taken from May, 1983, through January, 1984 and includes two testing phases each of 3-mo. duration.

Goal/Devrinol and Goal/Lasso results are not discussed. Devrinol was not made available to Sierra by Stauffer Chemical; Goal/Lasso is currently on a registration hold.

Weed control effectiveness. Table 2 reflects the pooling of all weed data by weed species, ornamental species, location, and testing phase to provide a summary of weed control by chemical treatment.

a. Treatments producing greater than 80% control at recommended rates:

Rout (Goal/Surflan)
OH-2 (Goal/Prowl)

b. Treatment providing less than 80% control at the recommended rates:
Ronstar (4 lb. a.i./A)

c. Rout (Goal/Surflan 2 + 1) produced 3 and 17% greater respective weed control than either OH-2 or Ronstar.

Table 2. Summary of percent container weed control from Phase I and II treatments at 14 locations

Chemical Treatment	*(lbs. a.i./A)*	*Mean*
Rout (Goal/Surflan)	2 + 1	84%
	4 + 2	97
	6 + 3	96
	8 + 4	98
OH-2	2 + 1	81
	8 + 4	99
Ronstar	4	67

Note 1) Weed control computed from total weed counts taken from 1 + 2 replications of each treatment
2) Represents three-month residual data from each phase

Ornamental tolerance. A master summary of ornamental species involved in trials from Phases I, II and III are given in Table 3. It is important to note that the Rout label lists specific genus, species and cultivars for which *4X tolerance* levels exist. Tolerant species were established from a minimum of two to a maximum of three successive treatment phases.

Table 3. Summary of ornamental species evaluated in Phases I, II, III trials.

Description	Rout
Total species tested	94
Species failing tolerance criteria	8
Species requiring additional test data[1]	8
Total species recommended for labelling	78

[1] Species failing to survive environmental conditions irrespective of chemical treatment

DISCUSSION

Rout component characteristics: Oxyfluorfen (Goal) was developed by Rohm & Haas for selective preemergence weed control in agronomic, horticulture, fruit tree, and tropical plantation crops. Oxyfluorfen (Goal) is a diphenyl ether compound with the chemical name 2-chloro-1-(3-ethyoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene.

Oxyfluorfen is extremely active at low rates (0.25 to 2 lbs. a.i./A) on a wide range of annual broadleaf and grass weeds;

high levels of activity have been achieved from both preemergence and postemergence applications. The primary mode of action of oxyfluorfen is as a contact herbicide with light being required for herbicidal activity; very little translocation occurs from either root or foliar application. Oxyfluorfen is very resistant to removal by rain. Further, it is strongly adsorbed on soil and shows negligible leaching characteristics. Photodecomposition of oxyfluorfen on soil is slow. Volatilization occurs to a limited extent and is the basis for label precautions restricting use in enclosed structures and during periods of leaf bud break.

The water solubility of oxyfluorfen is < 0.1 ppm at 25°C. For comparison, the water solubility of Lasso, another ornamental herbicide, is 242 ppm. Lasso has an average soil residual of six to eight wks. in container-grown ornamentals while Goal (oxyfluorfen) has an average soil residual of eight to 12 wks. This low water solubility assures that the activity ingredient remains in the upper ⅛ to ¼ in. of soil surface, where many weed seeds germinate, providing long-term weed control residual.

LD_{50} is defined as the *lethal dosage* required to kill 50% of a test population and is expressed as mg/kg of body weight. The acute oral LD_{50} of the 2EC formulatin is $> 5{,}000$ mg/kg. For comparison the acute oral LD_{50} of 2,4-D ranges between 300-1,000 mg/kg.

Oryzalin (Surflan) was developed by Elanco for selective preemergence weed control in agronomic and horticultural crops, non-bearing trees and vineyards, and cropland areas. Oryzalin (Surflan) is a dinitroaniline compound with the chemical name 3,5,-dinitro-N^4, N^4-dipropylsulfanilamide. Oryzalin is very active at rates from ½ to 4 lbs. a.i./A on annual grass and broad-leaved weeds. The primary mode of action of oryzalin has not been fully established; however, it is known to affect physiological growth processes associated with seed germination. It does not, however, directly inhibit seed germination. There is no significant adsorption or translocation of oryzalin in tolerant species (soybean). Oryzalin leaches to a limited extent under natural rainfall conditions; oryzalin is adsorbed on soils high in organic matter and clay content.

Photodecomposition of oryzalin does occur in treated soil; volatilization from soil surfaces is minimal. The water solubility of oryzalin is 2.5 ppm. The acute oral LD_{50} is 10,000 mg/kg.

Characteristics of RVM Attapulgite Clay as a Carrier for Rout Herbicide: Generally agricultural and horticultural pesticides are applied as either liquid sprays, dusts, or granules. Several advantages are claimed for the use of granular formu-

lations over conventional liquid spray or dust formulations.

1. Absence of drift away from the target during application.
2. Good penetration of foliage, ensuring that the majority of granules reach the soil surface.
3. Reduction of handling hazards through using solid granules rather than liquid sprays or finely-divided powders.
4. Spills easier to deal with.

The solid granular formulations, as used for Rout Ornamental Herbicide, consist of biologically active chemicals mixed with a biologically inert carrier. The inert carrier for Rout is a naturally occuring, porous material mined in the southeastern U.S. and is termed attapulgite clay. Basically, two types or grades of attapulgite clays are used as pesticide carriers, LVM and RVM. LVM (low volatile matter) is calcined or heated during manufacture; RVM (regular volatile matter) is dried. The designations, therefore, refer to the amount of volatile matter remaining in the clay following manufacture.

RVM clays are somewhat soft and tend to disintegrate readily in water, while the LVM materials are sand-like and resist disintegration. RVM granules generally exhibit 85-90% breakdown in water while LVM granules disintegrate only 10-15%.

Each 50-lb. bag of Rout herbicide contains approximately 57,500,000 RVM attapulgite clay granules of the -16+30 mesh. This translates to aproximately 18 granules/inch^2 of treated surface area, which provides ample numbers of chemically-impregnated particles to stop weeds.

Rout herbicide is formulated at a 3% a.i./A composite concentration (2% oxyfluorfen, 1% oryzalin); 100 lbs. of product equals 2 lbs. of oxyfluorfen (Goal) + 1 lb. of oryzalin (Surflan) per treated acre.

Rout forms a dispersion in the presence of water; when applied granules receive rainfall, or are irrigated, the clay particles disperse, moving laterally on the soil surface to form a very thin film known as herbicide barrier.

CONCLUSIONS

Rout represents the first commercial product of its kind combining both oxyfluorfen (Goal) and oryzalin (Surflan) into one attapulgite clay formulation for long-residual, broad-spectrum weed control in ornamental nurseries.

PROPAGATION OF *ILEX VOMITORIA* 'NANA'

PATRICK H. DUCK
Rt. 1, Box 329
Loxley, Alabama 36551

There is very little room for error in the propagation phase of *Ilex vomitoria* 'Nana' (dwarf yaupon). Any mistake reduces percentage of take and profit goes down rapidly. To avoid this, a propagator must pay very close attention to detail from the time the cutings are taken until the time all the cuttings are rooted and the mist is turned off. It is very important that the cuttings are not allowed to go through any type of heat stress or water stress. This will probably have more effect on success than anything else.

Cuttings should be taken from clean stock, with care taken that there are no infestations of spider mites or leaf miners. These two pests can greatly reduce rooting percentage. I prefer cuttings taken from container stock over field stock because the container stock is normally more vigorous and healthy. We immediately put cuttings under wet burlap and take them back to the propagation house at regular intervals. Take large-caliper branch cuttings if possible, from current-year wood with the first branch ¼ in. from the basal end of the cutting. This will assure that the cuttings are not stuck too deep into the rooting medium. When this size cutting roots, it can almost be called a liner. The cuttings are prepared in the field and put into bundles of 25, which are held loosely with a number 64 rubber band. We can then dip in rooting hormone and be sure each one is treated. We direct-stick into 2¼-in. Lerio pots. This creates a more ideal micro-environment and at the same time allows us to get in more cuttings per ft.^{2} of rooting area.

I prefer to use covered houses because this gives more control over how much water the cuttings receive. Cuttings propagated in the spring and summer are covered with poly and a 55%-shade cloth; in the fall and winter they are covered with poly only.

Our propagation medium consists of 3 parts bark, 2 parts peat, and 2 parts perlite. To this we add 6 lbs. Osmocote (18-6-12), 8 lbs. dolomite lime, and 1½ lbs. MicroMax per yd.^{3}

The strength of the auxin dip varies with the time of year the cuttings are put in. Spring through summer we use K-IBA at 3000 ppm. Fall through winter we use K-IBA at 5000 ppm. We use a 3-sec. dip in both cases. I have used IBA at 1250 ppm and 1870 ppm but have had some problems with basal flaming. I have used NAA at 1500 ppm in combination with K-IBA with disastrous results. My advice at this time would be not to use

NAA on *Ilex vomitoria* 'Nana'. although the possibiilty exists that a low concentration of NAA could be beneficial. I would recommend that you experiment with this first on a small group of cuttings.

In summary, dwarf yaupon has been a difficult crop to propagate. There are so many interacting environmental, mechanical, and chemical factors that success is never assurd. Experience and luck are still the best tools a propagator can have in propagating dwarf yaupon.

PROPAGATION OF *BERBERIS THUNBERGII* 'ATROPURPUREA NANA'

BILL BARR

Hines Wholesale Nurseries
Box 42284
Houston, Texas 77242

There are three factors that I feel are extremely important in the rooting of all *Berberis* species. They are timing, application of mist, and the hardening-off process. I am convinced the most critical of the three is the mist control.

In Houston, we like to take cuttings as early in the spring as possible. The cuttings are taken from our container-grown plants in May and June. We start propagating as soon as the new growth is firm at the base of the cutting. The stem of the cuttings are a greenish yellow color; we do not use any brown wood. We use 5- to 6-in. cuttings.

These cuttings are then stored in a walk-in cooler until they are prepared. The propagators wear 0.02 gauge latex gloves while preparing this plant. The bottom leaves are stripped off the plant, which also removes most of the thorns. The cuttings are then put into bundles, and basal stems and tops trimmed to about 4 in. in length. The cuttings are then dipped in a fungicide bath of Benlate, captan and Agristrep at the recommended rates. The cuttings, still in bundles, are dipped into 1870 ppm IBA made with 50% alcohol. We have not seen any benefit from the use of K-IBA. Two cuttings are then stuck into a new 2¼-inch liner pot. The medium we are using is 50% pine bark, 25% peat, and 25% sand with an adjusted pH of 5.0-6.5; 2½ pounds of 18-6-12 (8-9 mo.) Osmocote is added to the mix.

The cuttings are rooted under mist, with a frequency two to three times what the mist is for most other crops. It is very important that the foliage not dry out during the normal mist-

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ing hours. This is extremely important; however, oversaturation of the medium can be a problem so we carefully monitor the duration of the "on" time. We usually cut down the "on" time to compensate for increased frequency. We will continue this until a small root system develps and will then start to harden the cuttings off. The nozzle that is being used is a ¼ E 5.8 parasol nozzle by Spraying Systems, Inc. It gives a fine spray without a lot of water volume. I am very pleased with this nozzle, but it does require 80 to 100 psi pressure. Ours are spaced 7½ ft. apart.

The cuttings are rooted in a 47%-shade mist area. This area is sprayed twice a week with the routine fungicide program. It is extremely important to monitor for root rot as the plants are very susceptible to this problem, especially under the high mist environment. The hardening-off process needs to be accomplished slowly. Rapid hardening-off will cause defoliation, and plants left under mist too long will get root rot. They should be ready for hardening in five to six weeks. These liners are ready for-fall canning of the same year.

PROPAGATION OF *CLETHRA ALNIFOLIA*

BLAINE A. BUNTING
Buntings' Nurseries, Inc.
Dukes Street
Selbyville, Delaware 19975

We propagate *Clethra alnifola* from two sources:

1.) Old stock plants, or 2.) liners, bedding plants

We usually take cuttings by the second week of June in our area, which is lower Delaware (Zone 7) along the Mason/Dixon Line of the DelMarVa Peninsula. These cuttings must be taken at this time as the percentage of rooting drops drastically as the growth on the stock plants harden off.

The second group used is the young plants (liners). Softwood cuttings of 3 to 6 in. can be taken any time as long as they are growing or have green stems. These softwood tip cuttings will root easily in about a month under mist. We take growing tip cuttings from liners up until October with reasonably good results.

We use Chloromone at a 1:3 dilution for our rooting compound. Wood's Rooting Compound has ben used with the same good results.

Clethra cuttings will root in almost any medium. However, I prefer half peat and half perlite in trays in outside mist beds

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under full sun. The mist is set 3 sec. every 3 min. After rooting, the trays are transferred to a plastic greenhouse to grow the following spring.

We have found that these young rooted cuttings in trays need to be kept in a heated plastic greenhouse the first winter with no lower night temperatures than 35°F. Daytime temperatures may go up to 70°F on sunny days. This environment keeps the cuttings in good condition. They seem to be much slower to break in spring than most plants.

The rooted cuttings are transplanted to fertile liner-growing beds in May each year. *Clethra* is a low-growing shrub compared to some others like forsythia. We like to see it at least one foot or taller to transplant to the field the following spring. These plants should grow in the field for two summers before they are sold.

PROPAGATION OF *VIBURNUM CARLESII* HYBRIDS

MILTON P. SCHAEFER, JR.
Schaefer Nursery
P.O. Box 62
Winchester, Tennessee 37398

Viburnum carlesii cultivars and hybrids are desirable for their fragrant flowers, excellent foliage, lack of serious pests, hardiness, and some fall color. The U.S. National Arboretum has introduced several interspecific hybrids that show promise.

We propagate several hybrids of *Viburnum carlesii* by cuttings. *Viburnum carlesii* 'Compactum', *Viburnum* × *juddii* (*V. bitchiuense* × *V. carlesii*), *Viburnum* × *carlcephalum* (*V. carlesii* × *V. macrocephalum* var. *keteleerii*), *Viburnum* 'Cayuga' (*V. carlesii* × *V. carcelephalum*), *Viburnum burkwoodii* (*V. carlesii* × *V. utile*), *Viburnum* × *burkwoodii* 'Mohawk' (*V.* × *V. carlesii*), *Viburnum* 'Chesapeake' (*V.* Cayuga; × *V. utile*), and *Viburnum* 'Eskimo' (*V.* 'Cayuga' × *V. utile*) are among those we produce.

Description of ground beds and equipment. We propagate in 4- × 48-ft. ground beds bordered by crossties or treated 6-in. wood poles. The rooting medium is Emory soil, a fine sandy loam, which has been amended over the years with sand and organic matter. I like this medium, as the clay colloidal material improves the cation exchange capacity and contains nutrients not available in artificial soils. We fumigate with methyl bromide at a rate of 1½ lb./100 ft.^{2}

We cover the beds and support the polyethylene with 6-

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gauge, 6-in. concrete reinforcing wire. We use either a 2-mil clear polyethylene, (which we cover with a 48% shade fabric), or a 3-mil white polyethylene, which has been manufactured to our specifications to transmit approximately 50% light. We have found the white poly to be satisfactory except in late summer when the sun scorches the plants through the ventilation holes.

We have constant water pressure to a solenoid valve connected to a wiring system controlled by time clocks. We have recently changed from ½-in. galvanized steel mist lines with nozzles every 46 in. to ¾-in., 100-PSI black poly pipe with spaghetti tubes leading to our nozzles. These new lines are easier to work and afford more flexibility as to nozzle placement than the galvanized steel pipes. We use a Spraying Systems nozzle with a D-1 orifice. We have modified the nozzle with a ⅛-in. stainless-steel welding rod to deflect the spray.

Taking cuttings. Cuttings of *Viburnum carlesii* hybrids are taken when the new growth hardens off enough so that it breaks crisply when bent. It is one of the first species we stick, usually in late May or early June. We stick a second crop as late as August or early September. We plan to hold these cuttings an additional year and sell as a two-year bed-grown plant.

We take our cuttings in the mornings when moisture stress is not a problem. We keep the cuttings turgid by keeping them moist and shaded at all times. In the field we keep the cuttings moist in 5-gal. buckets with wet burlap or cloth. We then put them in water in a cattle-watering trough or a 30-gal. garbage can in a pick-up truck and transport them back to the nursery. We do not like to keep the cuttings submerged in water for long. At the nursery we remove the cuttings to a structure that enables us to mist the cuttings constantly until they are stuck in the beds.

We leave 3 to 4 leaves on each cutting and do not cut the leaves. We bundle the cuttings in the field into groups of 25 to count production for our piece-rate system.

Sticking cuttings. We finish taking cuttings by noon and stick each morning's production in the afternoon of the same day. Cuttings are dipped in a solution of 2,500 ppm IBA and methyl alcohol. Production is counted at this step. We use a portable shade structure to keep the plants from wilting until we get the frames in place and the bed covered with polyethylene. At this stage the plants are misted as needed to provide as close as possible to 100% humidity on the leaf surface and still maintain a well-drained soil condition.

As rooting commences, the misting schedule is reduced

gradually and more cuts for ventilation are made in the polyethylene until the plants are hardened off or weaned. At this point all the polyethylene is removed. For a few days we shade and mist the plants every 30 min. After a few days we remove the intermittent mist, but leave the shade in place, and hand water 2 or 3 times a day. A few days later we remove the shade and hand water as needed. The entire process takes 6 to 8 weeks.

Fertilization. We test our soil with the Simplex system. We choose our fertilizer based on test results, paying particular attention to imbalances that may cause problems. During the growing season we monitor the soluble-salt level closely and fertilize so as to keep the soluble-salt level high yet below toxic levels. Previously we used liquid fertilizer with a venturi-type injector. We supplemented our liquid feed with various granular fertilizers as needed. This year we incorporated Osmocote 18-6-12 at a rate of 4 lb./100 ft.^{2} into the top 6 inches of soil.

Hardening off for winter. Normal leaf drop indicates that the plants have built up their carbohydrate reserve in the root system naturally and are becoming dormant for the winter. At that time we cover the beds with microfoam over the wire frames and cover the microfoam with polyethylene. We nail the polyethylene to the cross-ties with wooden strips and seal the edges with soil. Prior to covering we water the plants well and spray with a fungicide. The purpose of winter protection *is not to keep the plants warm but to protect from rapid* temperature fluctuations.

Harvesting. We dig the plants before they break dormancy but as late as we think is safe, so as to keep the plants as fresh as possible. We pack in polyethylene-lined and wax-lined boxes, with the roots wrapped in spaghnum moss and the tops separated with excelsior. We ship via United Parcel Service.

Handling bare-root deciduous viburnums. After deciduous viburnums are packed, they must be kept cold enough to prevent them from breaking dormancy. We do this by keeping them at 34 to 36°F. in a cold storage facility. Deciduous viburnums transplant well anytime during the late winter or early spring while they are still dormant. They should be placed under conditions where they can be kept cold but nor severely frozen until they warm up gradually and naturally as spring arrives. Putting deciduous viburnum liners suddenly into a warm greenhouse in late winter or early spring often gives poor results simply because the leaves appear almost immediately, before the roots have had time to develop.

Viburnums require a large number of hours of low tem-

perature, 40°F. or below, during their dormant season if they are to be healthy and grow well the next year. Deciduous viburnums respond well to fertilizer after they become established in the soil. They should be irrigated frequently, but they also require good drainage. It is advisable to dip the root system in a mud slurry or other wetting agent to keep the roots from drying while transplanting.

PROPAGATION OF *QUERCUS VIRGINIANA* CUTTINGS

DAVID L. MORGAN

The Texas A&M Research and Extension Center
17360 Coit Road
Dallas, Texas 75252

Traditionally live oak (*Quercus virginiana*) trees are propagated by seed. But oaks are wind-pollinated and are heterozygous by nature, so they often exhibit genetic variation in a great variety of characteristics, only some of which are visible.

Obvious differences can be found among individual live oaks in branching habit, height, leaf shape, even color. It is likely that other sources of variations may occur, such as in susceptibility to insects and diseases, response to fertility, vigor, and winter hardiness. Attaining the ability to select outstanding trees and successfully propagate them for their inheritable characteristics would represent a significant contribution to the landscape industry. Development of practical means of vegetative propagation is an important step toward that end.

Propagation by cuttings is generally regarded as the most important method of vegetatively increasing both deciduous and evergreen species. It is a means by which the parent plant is usually reproduced exactly with no genetic change (6). Yet propagating trees by cuttings often is more easily described than performed due to many factors one of which is juvenility.

Juvenility and rooting. It is not juvenility that causes concern to plant propagators. Instead it is the loss of juvenility that is coincident with the onset of the *adult* or *mature* phase in plant development. This physiological change typically occurs when flowers first begin to appear and the plant gradually shifts from a strictly vegetative to a reproductive condition. During this transformation, rooting of cuttings becomes more difficult in many woody plants. As a plant ages, it generally becomes more physiologically mature. Oak species vary widely in how old they must be before beginning flower produc-

perature, 40°F. or below, during their dormant season if they are to be healthy and grow well the next year. Deciduous viburnums respond well to fertilizer after they become established in the soil. They should be irrigated frequently, but they also require good drainage. It is advisable to dip the root system in a mud slurry or other wetting agent to keep the roots from drying while transplanting.

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Traditionally live oak (*Quercus virginiana*) trees are propagated by seed. But oaks are wind-pollinated and are heterozygous by nature, so they often exhibit genetic variation in a great variety of characteristics, only some of which are visible.

Obvious differences can be found among individual live oaks in branching habit, height, leaf shape, even color. It is likely that other sources of variations may occur, such as in susceptibility to insects and diseases, response to fertility, vigor, and winter hardiness. Attaining the ability to select outstanding trees and successfully propagate them for their inheritable characteristics would represent a significant contribution to the landscape industry. Development of practical means of vegetative propagation is an important step toward that end.

Propagation by cuttings is generally regarded as the most important method of vegetatively increasing both deciduous and evergreen species. It is a means by which the parent plant is usually reproduced exactly with no genetic change (6). Yet propagating trees by cuttings often is more easily described than performed due to many factors one of which is juvenility.

Juvenility and rooting. It is not juvenility that causes concern to plant propagators. Instead it is the loss of juvenility that is coincident with the onset of the *adult* or *mature* phase in plant development. This physiological change typically occurs when flowers first begin to appear and the plant gradually shifts from a strictly vegetative to a reproductive condition. During this transformation, rooting of cuttings becomes more difficult in many woody plants. As a plant ages, it generally becomes more physiologically mature. Oak species vary widely in how old they must be before beginning flower produc-

tion. A shumard oak (*Q. shumardii*) may not bear fruit until it is 20 years old, and a laurel oak (*Q. laurifolia*) typically does not mature before age 15 (11). A live oak (*Q. virginiana*), in contrast, may reach sexual maturity as a 2-year-old liner, or as late as its fifth growing season (personal observation). Regardless of the age of a woody plant, however, its basal portion, nearest the root crown, will remain juvenile, while the upper branches, though chronologically younger but producing flowers, may be mature physiologically and difficult to root. This phenomenon is known in the horticultural literature as *topophysis*; its consequences are that basal sprouts, or suckers, on an older tree can often be rooted easily while new growth higher in the trees cannot. The interactions of juvenility and plant propagation are examined in greater detail in the IPPS *Proceedings* by Davies (4) and by Kester (7), and elsewhere by Zimmerman (12), Borchert (1), and Hackett (5).

Tree age and rooting cuttings. The physiological, or *ontogenetical*, age of live oaks is of great importance in propagation, as recent research indicates.

Studies (10) have shown that even high concentrations (15,000 mg/liter) of indolebutyric acid (potassium salt), will not significantly influence rooting of cuttings taken from the upper portion of sexually-mature live oak trees. In one experiment uniform stem-tip cuttings were collected from field trees 5, 6, 7, and 8 years old at 1.5 m (5 ft.) heights. Ten cuttings were taken from each of 5 trees per age group and placed in a mist bench. Rooting was low among cuttings from all ages of the mature trees, but poorest among the oldest trees. An inverse linear relationship was found to exist between rooting success and increasing tree age ($r=-0.98$).

In a related study (10), I found that rooted live oak cuttings maintained under greenhouse conditions could also be used as stock plants for cuttings, perhaps indefinitely. Also, cuttings taken from the stock plants rooted better than cuttings taken from a field-grown tree originating from the stock plants. Other investigators (2,3) have had similar successes with several other woody plant species. Obtaining cuttings from such stock plants is known variously as "hedging", "repropagation" and "maintaining juvenility", depending on authority. Such results suggest that repropagation may be useful in the vegetative propagation of physiologically mature trees whose original cuttings root poorly. I have applied these practices to a few adult live oak trees and repropagated them in our greenhouses.

Among the live oak trees I have repropagated (Figure 1) are clones both susceptible and resistant to the gall-making activities of a small cynipid wasp (8), several trees evidence

drooping or weeping branches, and trees that exhibited vigor and cold tolerance. The sudden freeze of December, 1983 killed hundreds of southern-grown live oaks in North Texas, yet several of the experimental clones in our fields survived without serious injury.

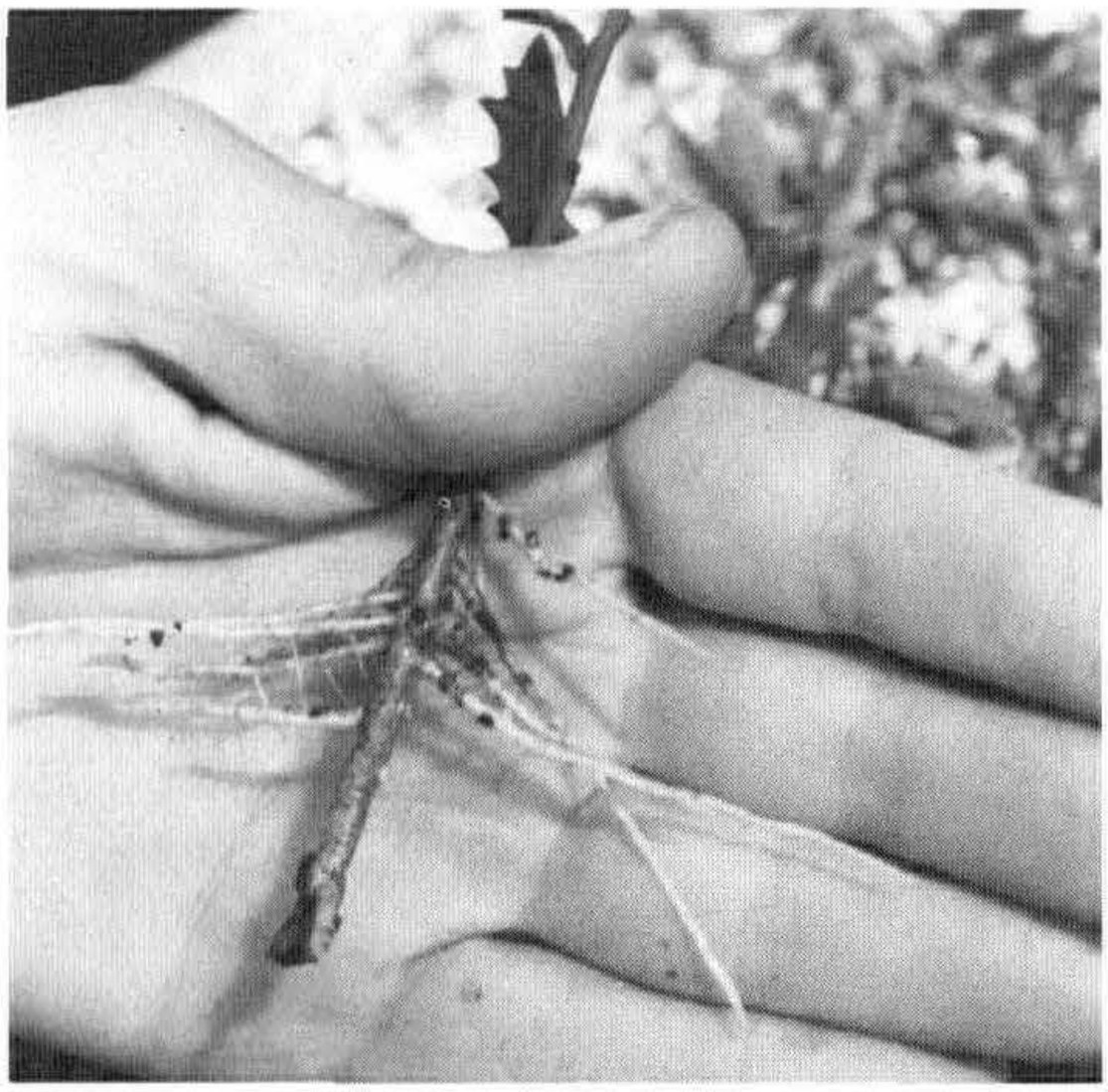

Figure 1. This live oak cutting produced roots in 5 weeks under mist. It is a clone of a field tree shown to be highly susceptible to the gall formation by an insect. It has been repropagated for further studies examining the differences between susceptible and resistant tree genotypes. Resistant clones also have been increased by cuttings.

I also found that the heterozygosity in a tree can influence rooting behavior of its cuttings (9). Live oak trees of the same age grown in a South Texas nursery (which collected them from a single location) can be separated into categories of low (0-6%), intermediate (7-24%), and high (25-71%) rooting.

What the grower can expect. Only through some means of vegatative propagation can the nursery consistently produce superior trees. To date, only increase by cuttings has been successful in live oaks. Little work has been done in other oak species. A tree's genetics may create an outstanding specimen tree that not only exhibits great vigor but also can be rooted well, even through the transition period between juvenility and maturity. With such a tree, the grower has additional time both to observe the tree critically as it ages and to establish a stool bed for repropagation, by maintaining juvenility in a clone of an otherwise maturing plant.

Propagating live oak trees by cuttings may never be as popular as growing from seed. However, for select growers the rewards of producing predictably better-adapted trees for metropolitan landscapes may outweigh the difficulties involved.

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PROPAGATION OF UPRIGHT JUNIPERS

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Some of the upright growing junipers have been a problem for propagators for as long as both have been around. Grafting has been the conventional method of propagating many of these, but it is a very costly and labor intensive method. Rooting of these junipers is gaining more and more momentum as more experiments with various rooting hormones continue. I will, therefore, focus this report on rooting some of the upright junipers — *Juniperus chinensis, J. scopulorum,* and *J. virginiana* cultivars.

Cuttings of all cultivars are prepared from about November through February. Although January and February are the best times, we cannot produce enough to meet our requirements in two months. Cuttings are collected from our own

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Cuttings of all cultivars are prepared from about November through February. Although January and February are the best times, we cannot produce enough to meet our requirements in two months. Cuttings are collected from our own

container stock. Approximately 3-in. cuttings are made with at least some hard wood at the base. Heel cuttings are preferred and used when possible. All of the foliage is stripped from the bottom inch of the cuttings. After the cuttings are prepared, they are disinfected by dipping them in a 15 ppm chlorinated water solution and a second dip of 200 ppm Physan solution. The base of each cutting is dipped into a rooting hormone designated for that particular cultivar. The cuttings are then stuck into a rooting medium of 90% perlite and 10% peat moss, which has been steam pasteurized at 150°F for 2½ hr. directly in the 18-in. square plastic flats. The flats hold about 250 cuttings each. After each flat is properly labeled, they are then taken to the outdoor rooting beds in the full sun. The mist beds are concrete, and within the concrete is ½-in. copper tubing spaced 9 in. apart. Hot water from our boiler facility circulates through the tubing. The concrete surface of the beds is disinfected prior to putting the flats down by rinsing them with Physan and applying Citcop 6E to the surface. The mist is cycle is adjusted to the weather conditions each day. Intervals range from 12 to 30 min.

Bottom heat is critical the first six weeks of propagation. It should be maintained between 60 and 65°F. This temperature will allow the basal wound of the cuttings to callus. Excessive heat too soon in propagation of all junipers can cause decay and disease problems. After the first six weeks are up, the heat will then need to be increased to 70 to 75°F. This temperature will now encourage roots to form. Most upright junipers root in 5 to 6 months. After rooting the juniper flats are hardened off by discontinuing the bottom heat and gradually reducing the mist. The rooted flats are then irrigated with impact sprinklers. The water used for irrigation at this time is injected with the same fertilizer that is used for our container production. Eventually the cuttings are potted into rose pots in a medium of 2:1:1 peat, redwood shavings, plaster sand. We recycle our spent propagation media into our potting mix, which is fumigated with methyl bromide before any potting is done.

We currently use as our hormones IBA (indole-3-butyric acid in 55% methanol), NAA (β-naphthaleneacetic acid in 55% methanol), and K-IBA (potassium salt of IBA), and combinations thereof in different concentrations, including 3000 and 6000 ppm. In this report I will refer to these concentrations as 3IBA, 6NAA or whatever the specific concentration is.

I will first cover the *J. chinensis* cultivars. We are currently growing 'Ames', 'Spartan', 'Fairview' [syn. 'Hetzii Columnaris'], 'Keteleeri', 'Robust Green', 'Kaizuka' [syn 'Torulosa'], and 'Wintergreen'.

The 'Ames' juniper is almost impossible to root, so we are making grafts only. The 'Spartan' and 'Keteleeri' root 80% with 3IBA. 'Fairview' and 'Robust Green' root at about 65% with 6IBA. The use of Benlate fungicide was with 'Robusta Green' and using fewer cuttings to a flat (about 200) helps control foliar diseases that this juniper can get in the propagation stages.

'Kaizuka' requires 6NAA, and will root at around 65%, whereas 'Wintergreen' only gives about 15% rooting with a combination of 3IBA + 3NAA. Almost all of our 'Wintergreen' production is currently from grafts, although we are continuing research, and rooted cuttings may someday replace grafts.

The upright *J. scopulorum* cultivars that we grow are 'Cologreen', 'Cupressifolia Erecta', 'Emerald Green', 'Gray Gleam', 'Medora', 'Moonglow', 'Pathfinder', 'Welchi', and 'Wichita Blue'. 'Cologreen' uses 12K-IBA with 55% rooting. 'Gray Gleam' is around 50% rooting with 6IBA. 'Medora', 'Wichita Blue', 'Pathfinder', and 'Welchii', use 8IBA with about 60% rooting. 'Moonglow' will root well to 60% with 6IBA. The 'Cupressifolia Erecta' is a difficult rooter with less than 5% at 16IBA. This cultivar is currently grafted. 'Emerald Green' seems to root well at 60% with 3IBA.

The upright *J. virginiana* cultivars that we grow are 'Cupressifolia', 'Idylwild', 'Manhattan Blue', and 'Skyrocket'. 'Cupressifolia' is an excellent rooter at 80% with 3IBA. 'Idylwild' roots at 70% with 3IBA also. 'Manhattan Blue' requires 3NAA and give 65% rooting. 'Skyrocket' is a weed as far as rooting upright junipers goes. We use 3IBA, but it will probably root without it. Bottom heat is not needed for 'Skyrocket' either. Rooting should be around 100%.

With some cultivars, such as 'Cologreen', 'Gray Gleam', and 'Wichita Blue', our propagation system involves grafting part of our production needs and doing a part from cuttings. The grafts make up for sales about a year faster. The cuttings can be potted at a more leisurely pace for future needs. Cuttings, however, are far cheaper to produce and less labor-intensive. Cuttings of most cultivars root in 8 months, are potted in July and August, and can be sold in October.

Why do we go through all of this work? It's because of the demand these plants have. They make beautiful landscape and accent plants with their wide array of shape and colors from bright green to the silvery blue and gray-foliaged ones. Also, many are hardy to zone 3, especially the *J. scopulorum* cultivars, another added benefit to gardens in northeastern U.S. and in Canada.

PRODUCTION OF × *CUPRESSOCYPARIS LEYLANDII*

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I feel that Leyland cypress can become a profitable plant for the commercial nursery, but like any plant it must be looked at carefully before beginning production.

PRODUCTION

Propagation. Leyland cypress cuttings are best rooted during the fall and winter months. I think December is best in our area but have had good results in January and February. We use intermittent mist in heated greenhouses. Our findings show older, thicker cuttings — tipped out — root best. Cuttings root in eight to 12 wks. Saleable liners in 2¼-in. pots are ready in six to eight months. We use 8000 ppm IBA quick dip. It is critical to avoid drying out.

Transplanting. Rooted cuttings placed in one-gal. containers in February grow off quicker than those left in 2¼-in. pots. The cuttings from the thicker wood make the best plants. Rooted cuttings in gallons grow to a height of 10 to 12 in. in six months. Transplants, either bare-rooted or from 2¼-in. pots, planted in gallons live and grow off satisfactorily but they must be kept moist.

Fertilization. Leyland cypress plants respond well to a good fertilizer program.

Problems. Difficulties I have noted are as follows:

a. Full grown 3-gal. container plants tend to turn over easily when grown in a bark mixture. They also tend to "burn out" when jammed together.

b. From the landscape viewpoint, I find that leyland cypress must be handled very carefully in shipping and transporting to the landscape site. We planted some 3-gal. (30- to 36-in. high) size plants at our nursery last fall for stock plants. These plants all lived and most of them grew to 6 ft. in height. On landscape sites where proper irrigation was a problem, there was 50% or more plant loss of 3-gal. material. These plant losses were also due to the root systems coming loose in the container. Staking seems to help some. There was little or no loss of other species of plants on these landscape sites.

MARKETING

1. Since it is such a fast-growing plant with few disease

and insect problems, leyland cypress does have a place in the landscape and should be produced by nursery growers.

2. Since it does not transplant well balled and burlapped, and the roots easily come loose in bark mixtures, a different potting mixture should be found that can produce a more stable root ball.

3. Garden centers and landscapers will need to be educated as to the proper handling of these plants.

4. There are several cultivars of leyland cypress available. 'Leighton Green' is the most popular. I like 'Naylor Blue' with its blue tint and 'Gold Cup' with its golden tips. The variegated type is not very colorful as a large plant.

5. Selling the plants is why we are in business. Leyland cypress is a saleable plant, but we must do a better job of marketing so it will be profitable to grow. There has been some discussion that leyland cypress will replace red-tip photinia as the fastest growing hedge. First we must instruct landscape designers and garden center managers about leyland cypress, then they will have to sell it to the public.

Note It occurred to me while listening to Dr Michael Dirr, Dr. John Creech, Dr J C. Raulston, and Don Shadow talk about possible new plant introductions that maybe we need an IPMS, International Plant Marketing Society arm of the IPPS to introduce new plants to the trade and, most importantly, to the public There are a lot of good plants available like Leyland cypress that are not being used because there is no demand. We must create a demand through better marketing

TEN OUTSTANDING FLOWERING TREES FOR POTENTIAL SOUTHEASTERN U.S. PRODUCTION

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Flowering trees are one of the most important visible parts of the landscape, adding color and drama against a green background. The southeastern U.S. is climatically suited for an enormous range of species and cultivars of flowering trees, yet relatively few taxa have become important in the nursery/landscape industries of this region. Probably 90% or more of the flowering trees now being used would be included in the following small list: *Cercis canadensis*; *Cornus florida* and cvs.; *Koelreuteria paniculata*; *Lagerstroemia indica* cvs.; *Magnolia stellata*, *M.* × *soulangiana*, and *M. grandiflora*; *Malus* cvs;

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Prunus subhirtella; and *Pyrus calleryana* cvs. Selecting just 10 recommended trees for this paper is a difficult task from the wide number of potential candidates available. Final selection of the ones presented was based on observation of plants in The NCSU Arboretum as being well adapted for use in this area of hot, humid summers and yet surviving without damage the recent years of record cold temperatures (to −7°F in 1985); a third consideration was their almost total absence of any current commercial production or use in this region. They are presented in alphabetical order.

1). *Aralia elata* 'Aureo-variegata' and *A. elata* 'Variegata'. Very coarse-textured large shrubs or small trees reaching 10-15 ft. in height and providing a spectacular tropical appearance in the landscape. The leaves can reach 2-3 ft. in width and length. These two variegated forms are showy throughout the summer. Though the yellow and white variegations are distinctly different in cooler climates, in the heat of the southeast both fade to the same pure white variegation during summer. Large panicles of white flowers appear in the terminals of the plant in July, and the plant will remain in flower nearly a month. It is considered a connoisseur plant in Europe due to the rarity of stock plants and the difficulty in propagating it. Only a few speciality nurseries in Germany, Holland, and England offer it — and at very high cost. It is patch- or chip-budded on to *Aralia elata* understock, which can be produced from seed or by division of the rhizomatous root system that suckers readily (4). Last year, we successfully cleft-grafted the white variegated form on a plant of *Aralia spinosa*, the native Hercules' club or devil's walking stick, which was growing in the arboretum. The major limitations to commercial production would be finding scion wood to use in budding, and learning to do the budding successfully.

2. *Cercis.* The eastern redbud, *Cercis canadensis*, is an extremely popular native small deciduous tree easily grown from seed and widespread in the nursery trade. Several other redbuds superior to the species eastern redbud are rare or totally unavailable in commercial production due to propagation difficulties. *C. canadensis* 'Forest Pansy' is presently being produced in the southeast in small quantities but market popularity warrants greatly increased production volume. 'Forest Pansy' is noted for its dark purple foliage which emerges almost purple-black under cool spring conditions. In climates with cool night temperatures this dark color can be retained through the summer until autumn; however, in the warm night conditions in the southeastern U.S. the color will fade to species green by midsummer with the speed of change dependent on the midsummer degree of heat encountered.

C. reniformis 'Oklahoma' introduced by Warren and Son Nursery in Oklahoma is vastly superior to the common eastern redbud, with dark green, waxy leaves and the darkest red-purple flowers of any redbud. As a plant it would be worth growing for foliage alone even if no flowers were produced. Another cultivar, *C. reniformis* 'Texas White', has the same handsome foliage and pure white flowers — stunning in spring.

A very rare species, *C. mexicana* (or *C. canadensis* var. *mexicana*) has the same glossy, dark green leaves but the margin of the leaf is undulate giving it perhaps the most beautiful foliage of any redbud. The Mexican redbud has proven hardy in zone 7 in Dallas and should be adaptable throughout the southeastern U.S. Redbuds are best propagated vegetatively by T- or chip-budding on *C. canadensis* seedlings in late summer (1). Work is in progress with tissue culture and supposedly 'Forest Pansy' is now in successful culture.

3). *Chionanthus retusus*. The Chinese fringetree is a small deciduous tree which may reach 25 ft. in height with glossy, dark-green leaves, which are handsome throughout the season. The pure white flowers appear in early summer and transform the tree into a solid mass of white. Hardy to zone 5. It is native to China, Japan, and Korea and has long been in cultivation in the west (1845) but has never achieved widespread popularity due to propagation difficulties. The seed exhibits double dormancy and is difficult to germinate (3). The plant can be rooted in low to medium percentages (our trials usually run 20 to 50%) with semi-hardwood cuttings under mist in summer. Juvenile cuttings from young seedlings will root easiest; once a ready rooting population is established, a stock block could be established to shear annually to the ground to maintain juvenility (5). Once rooted, cuttings have difficulty in becoming properly-shaped plants with a tendency toward shrub rather than tree form. Stubbing a 2 to 4 year old plant to the ground and pruning the basal sprouts to a single stem as they emerge may speed the development of a tree-form plant.

4). *Cornus controversa*. The giant or pagoda dogwood from China, Japan, and Korea is the largest of dogwood species, reaching 70 ft. in the wild and 30 to 40 ft. in cultivation. Introduced in 1880, and later proclaimed by Wilson as one of the finest of ornamental plants, it has fast, vigorous growth, masses of creamy-white flowers in panicles in early summer, attractive purple-blue fruit, and young branches with reddish-purple coloration in winter. Young plants have grown 3 to 5 ft. per year in the NCSU Arboretum and are far more tolerant of our poor clay soil than *C. florida*. Considering its ease in propagation, it is strange this outstanding plant has never

achieved wide-spread commercial success in the U.S. Seeds require 5 months of warm followed by 3 months of cold stratification for germination (2). We have had good success (60 to 90%) with both softwood cuttings in summer under mist and hardwood cuttings in winter.

5). *Cornus* 'Eddie's White Wonder'. A hybrid dogwood produced by a cross of *C. florida* with *C. nuttallii*, the Pacific dogwood. The Pacific dogwood is a large plant reaching 50 ft. in height with large flowers of 5 white bracts. It often reblooms in the fall. Though among the most spectacular of dogwoods, it cannot be grown successfully in the eastern U.S. The hybrid with the eastern dogwood has produced a plant with larger leaves and flowers with more vigorous growth than the eastern parent, but with 4 bracts rather than the 5 of the western species (a few 5 bract flowers do seem to appear). At the NCSU Arboretum it has not rebloomed in the fall. Though Dirr (2) states it is not suitable for eastern culture, its performance in Raleigh has been spectacular with vigorous growth and heavy flowering for the last 6 years. It should be budded on *C. florida* seedling understock (rather than *C. nuttallii*, which is less tolerant of eastern soils and may be responsible for reported failure in the east).

6). *Koelreuteria bipinnata*. A much showier species of goldenrain tree than the commonly grown *K. paniculata* with larger leaves that are bipinnately compound, yellow flowers that appear several weeks later in summer, and showy fruits pink to purple-pink in color in autumn. It is sometimes reputed not to be hardy, but such reports come from a common problem of mislabeled seed in commercial trade. Growers receive *K. elegans* [syn. *K. formosana*] (zone 9) instead of the true *K. bipinnata* which is hardy in Washington, D.C. and has withstood −7°F with no injury in the NCSU Arboretum. It is easily propagated by seed, which must be scarified and then moist stratified for 3 months.

7). *Lagerstroemia fauriei* and hybrids. The NCSU Arboretum has several plants of *L. fauriei* from the original U.S. National Arboretum distribution now probably 25 to 30 years of age and 15 ft. wide by 20 ft. tall. The red flaking bark on these magnificent multiple-trunked specimens will compare to any other ornamental plant in existence, and the plants should be widely promoted as small ornamental trees. The recent U.S. National Arboretum *L. indica* × *L. fauriei* hybrid introductions, and particularly 'Natchez', carry the beautiful bark and better flowers. Plants are easily propagated by softwood or hardwood cuttings. The two recent record cold winters have demonstrated the much greater hardiness of *L. fauriei* and its off-spring. These plants showed little or no injury at −7°F whereas all *L.*

indica cultivars (except 'Dallas Red') were killed to the ground. My observation of nursery comments of 'Natchez' injury and lack of hardiness seem to involve plants grown in containers and not properly overwintered to prevent root freezing, or of nursery plants being pushed into excess active growth in the fall by heavy nutrition and irrigation to get large-sized marketable plants quickly.

8). *Magnolia denudata* (or *M. heptpeta*). The Yulan magnolia from China has been in cultivation there for many centuries as one of the finest of classic garden plants and has been in western cultivation since 1789. It makes a small tree to 35 ft. with pure white fragrant flowers appearing very early in spring. It has been difficult to root from cuttings and is often grafted on *M.* × *soulangiana* (2). Recently west coast propagators have had better success with cuttings, and larger quantities of plants are becoming available. The NCSU Arboretum now has a block of 50 young seedlings grown from seed from the Beijing Botanical Garden. It is hoped that cuttings may be rooted more readily from these very juvenile plants and that by pruning they may be kept in a state of juvenility.

9). *Prunus mume*. The Japanese flowering apricot is considered one of the finest of small flowering trees in Japan where several hundred cultivars have been selected. It is a deciduous tree to 15 to 20 ft. with both single and double white, pink, and red, highly fragrant flowers appearing in January-February. It is the first tree to bloom in the landscape. There are also weeping, fastigate, and cork-screw branch forms. Concern has been expressed about potential hardiness with obvious growth activity in midwinter. In January, 1985, plants in the NCSU Arboretum were in full bloom the day temperatures dropped to −7°F and no limb dieback occurred. Plants grow rapidly with 3 to 5 ft. of growth per year under field conditions when young. We grew a block of about 200 seedlings last year in #1 containers, and some plants made 7 ft. of whip growth in one growing season. Propagation is by seed after 3 months' stratification, or cultivars are produced by semi-hardwood cuttings under mist in early summer (40 to 80% rooting) or by T- or chip-budding on to *P. cerasifera* understock (3).

10). *Rhus chinensis*. The Chinese sumac is a small tree reaching 15 to 20 ft. in height with masses of creamy white flowers in autumn, followed by yellow to red fall foliage color. The plant is quite variable from seed in plant qualities, flower panicle size, flower color, foliage coloration, plant form, and hardiness (dependent upon seed source as the species is native from subtropical Malaysia to subarctic Manchuria). 'September Glory' is a cultivar selected for excellent fall color. Plants may

be propagated by seed following stratification, or the cultivar propagated by pencil-sized root cuttings taken in January-February when the plant is dormant.

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TEN WOODY PLANTS THAT DESERVE A LONGER LOOK

MICHAEL A. DIRR

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Describing ten new outstanding plants is impossible. Describing ten outstanding plants is easy. The following plants have crossed my path many times. I have observed them north and south — east and west. Many grow in my garden and others have been used in propagation studies. These plants offer the southeastern nurserymen an opportunity to compete in the burgeoning market for "new" and better plants.

1). *Magnolia grandiflora*, southern magnolia, is embarrassingly variable when grown from seed. Most nurserymen realize this and have either made selections from seed populations or grow known cultivars. At least 25 cultivars are reported in the literature. Propagation is difficult. Grafting/budding, as well as cuttings are used. For the past three years we have worked with 'Bracken's Brown Beauty'. These are handsome trees with lovely blooms and beautiful fruit. Initial results were disastrous but through trial and error the following propagation procedures have evolved that produce 90% and greater success.

Water management has been a real problem. Intermittent mist, using an interval of 2½ sec./5 min. from 8 a.m. to dark has seemed to solve the problem. Sand or peat:perlite stayed too wet, so coarse perlite was substituted as the rooting medium. No concentrations of IBA in 50% alcohol gave good root-

be propagated by seed following stratification, or the cultivar propagated by pencil-sized root cuttings taken in January-February when the plant is dormant.

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ing results. In August, 1984, a rooting study with IBA, NAA, Wood's Rooting Compound and Dip'N Grow was conducted. Rooting was dismal, largely due to water management. Only NAA-treated cuttings or those treated with Dip'N Grow, which contains NAA, rooted. In comparative studies in 1985, 1% NAA produced 100% rooting compared to 27% rooting with 1% IBA. Cuttings were collected in South Carolina on July 3 and had rooted 10 weeks later. The NAA cuttings averaged 11 roots. IBA cuttings had one root. Thirteen of 15 NAA-rooted cuttings were successfully transplanted while only 2 of 4 IBA-rooted cuttings survived. There was no leaf drop with NAA.

Other factors that contributed to the success described above are:

1. Four- to 6-inch semihardwood cuttings from 8- to 10-ft. nursery-grown trees.
2. Terminal bud removed.
3. One-in. deep wound, one side.
4. Two terminal leaves left intact.
5. 1% a-naphthaleneacetic acid in 50% alcohol, 5-sec. dip, 5000 to 10,000 ppm NAA seems ideal.

In follow-up studies, we have found this formula to be foolproof for 'Bracken's Brown Beauty'.

Studies with terminal bud removed or present, and different concentrations of NAA are underway and should contribute more pieces of information to the jigsaw puzzle we like to call "*Magnolia grandiflora* cutting propagation."

Obviously, there is more than one way to root cuttings of *M. grandiflora*. The following points should be considered:

1. Use young stock plants (juvenile condition)
2. Practice good sanitation
3. A hormone is necessary, either concentrated dip or soak, Hormodin #3 or Rootone F.
4. IBA is preferred, based on most published research but NAA may be worth testing
5. Wounding is beneficial.
6. Cuttings should be in a semi-hardwood condition (terminal set) and not actively growing.
7. When rooting commences, reduce mist and start hardening process
8. Rooted cuttings transplant readily but care must be exercised not to damage the fleshy roots, which are often sparse
9. In southeastern U S July and August are probably the best months to take cuttings
10. Bottom heat is beneficial but is not used by all propagators
11. Medium should be well-drained and flats or beds should be deep (4 in. or more)

12 Intermittent mist on the order of ± 2 sec /5 to 6 min. appears essential in most cases

13 Four-to 6-in. long cuttings with 2-to 5-terminal leaves are ideal.

14 Cutting leaf surface to reduce area is not necessary.

15 Shading cuttings during rooting might be beneficial although two schools of thought exist.

The key to rooting *M. grandiflora* 'Bracken's Brown Beauty' is good water management and naphthaleneacetic acid. Whether this formula will work on other cultivars is unknown but should at least be examined.

2). *Disanthus cercidifolius* is a most unusual member of the Hamamelidaceae. It has redbud-like leaves, brilliant claret-red fall coloration and purplish insignificant flowers in October. It is a multiple-stemmed shrub that grows 10 to 12 ft. high and is free of insects and diseases. Best growth is achieved in moist, well-drained, acid soil and partial shade. Cuttings rooted in high percentages when collected in June, treated with 1% IBA-alcohol quick dip, placed in peat:perlite, under mist. Cuttings should be potted immediately after rooting (about 6 weeks) and fertilized with 18-6-12 Osmocote. Interestingly, fertilized plants continue to grow and may be 12 to 18 in. high by October.

3). *Malus* 'Callaway' is well-known to southern nurserymen. Introduced by Mr. Fred Galle, formerly of Callaway Gardens, it has become the standard of crabapple excellence for southern gardens. Pink buds open to 1½-in. diameter white flowers, followed in September-October by 1¼-in. diameter reddish fruits. The foliage is scab-free and suffers none of the miseries associated with the "rosy bloom" types such as 'Hopa', 'Eleyi' and 'Almey'. Traditionally, crabapples have been budded, but cutting propagation and tissue culture have entered the field.

In our work, cuttings taken in late May, treated with 2500 ppm IBA-alcohol quick-dip rooted 87% in 5 wks. Plants continued to grow after transplanting and many were 1½ ft. high by mid-October. Northern liner producers have gone to cutting production. Plants range in price from $1.31 to $1.58 each compared to rooted cuttings of common plants that average $0.35 to $0.85 each. The advantages of own-root crabapples include no incompatibility problems, reduced or no suckering, and lower production costs.

In another experiment, cuttings collected on June 25 and treated with different IBA levels rooted 92 and 96% when treated with 2500 and 5000 ppm IBA-alcohol quick-dip (Table 1). The cuttings were transplanted immediately after rooting and fertilized with 18-6-12 Osmocote. By October 15, 71% had

broken bud and were actively growing. All cuttings collected on May 29 broke bud after transplanting.

Table 1. Effect of indolebutyric acid concentration on the rooting percentage, root number, and total root length of *Malus* 'Callaway'

IBA concentration (ppm)	Total Rooting Percentage	Root Number	Root Length
0	40[z]	1	7 cm
2500	92	7	67
5000	96	13	99
10000	76	7	35

z Cuttings collected June 25, evaluated August 20, 1985 Number represents average of 20 cuttings per treatment

4). *Calycanthus floridus* 'Athens' ('Katherine') is a yellow-flowered, exceedingly fragrant form of the native sweetshrub. This robust form has large lustrous dark green leaves and forms a 6 to 10 ft. high, mounded, somewhat stoloniferous shrub. Flowers appear before the leaves in April and continue sporadically into June. Cutting propagation has proven difficult with rooting averaging around 50%. Alcohol quick-dips burn the cuttings and have not proven highly successful. In 1985 the potassium salt of IBA, which is soluble in water, was used along with a host of other treatments. Cuttings were taken on August 13 and evaluated October 1. K-IBA proved excellent and resulted in 93% rooting (Table 2).

Table 2. Effect of selected hormone treatments on rooting percentage of *Calycanthus floridus* 'Athens'

Treatment	Rooting Percentage	Root quality
Control	37	Poor
50% ethanol quick-dip	41	Poor
1% IBA-50% ethanol-quick-dip	82	Good
1% K-IBA in H_2O-quick-dip	93	Excellent
1% K-IBA in H_2O-24 hour soak	0	All cuttings dead
1% NAA 50% ethanol-quick-dip	7	Poor

5). *Amelanchier arborea*, downy serviceberry, needs selection work in the southeastern U.S. This superb small tree offers white flowers before the leaves in late March-April, palatable purplish fruits, fine yellow to red fall coloration and smooth gray bark. Unfortunately, seedling material is variable in all traits mentioned above as well as leaf retention. Many

trees drop their leaves before coloring in the fall. A tree on the University of Georgia campus has consistently beautiful apricot fall color while a grouping of six trees at the Botanical Garden offers no color. All came from the same nursery source. *Amelanchier arborea* and other species have been rooted successfully from softwood cuttings taken when the new growth was several inches long. *Amelanchier laevis* has been successfully tissue-cultured.

6). *Illicium parviflorum*, anisetree, is a worldbeater in the opinion of this author. It might prove to be a suitable replacement for the evergreen privets that have been devastated by the low temperatures of recent winters. *Illicium parviflorum* has survived −9°F without significant injury. The plant forms an upright, broadly pyramidal evergreen shrub and may also develop a suckering habit. I have seen both types. the 2- to 4-in. long, olive-green leaves are consistently beautiful through the seasons. The small yellowish-green flowers and brownish, star-shaped fruits offer little interest. It thrives in moist soils but, on the University of Georgia campus, has been used in dry situations under heavy shade with good success. Cuttings collected in late August and treated with 0.3% IBA-50% ethanol quick-dip rooted 100% in 4 to 6 wks. Several Georgia propagators are producing the plant and have had no trouble rooting it. Landscape designers and contractors have become interested in this species and are now specifying it. It is native to moist soil areas in Georgia and Florida.

7). *Stewartia monadelpha*, tall stewartia, was purchased in dormant condition by the author as *S. pseudocamellia*. When it flowered, I found out the true identity. Any stewartia is a wonderful garden plant, and this has proved no exception. The rich reddish brown, exfoliating bark is the outstanding attribute, although fall color in one particular year was an excellent bronze-red. The white flowers are only about 1-in. diameter and do not hold a candle to those of *S. pseudocamellia*, *S. koreana*, *S. ovata*, or *S. malacodendron*.

Over the years I have lost every rooted cutting of *S. monodelpha* during overwintering. Cuttings taken on June 16, treated with 0.5% IBA-alcohol, rooted 100% in 8 wks. Cuttings were stuck in individual cells and undisturbed, yet bark split occurred. Attempts with extended photoperiod to induce growth after rooting have been unsuccessful. Seeds of *S. monodelpha* germinated successfully by providing 5 months of warm/3 months cold stratification.

8). *Hamamelis* × *intermedia* 'Arnold Promise' and other wonderful cultivars of witchhazel are superb garden plants for much of the U.S. southeast. Dr. J. C. Raulston, North Carolina State University, has assembled one of the best collections in

the United States and believes, like myself, that propagators are missing the boat. All flower in February-March, offer flower colors from soft yellow to red, fine fragrance and fall color. Grafting has been the principal means of propagation but many nurseries are reluctant to fool with grafting. I have seen many grafted forms of *H.* × *intermedia* with incompatability and pronounced suckering. Also, the understocks, usually *H. virginiana*, often overgrow the scions. I have rooted cuttings of 'Arnold Promise' every June-July using 1% IBA solution, peat:perlite, mist, and individual containers, but I have been successful in overwintering only two plants.

9). *Lespedeza thunbergii*, Japanese bushclover, is a superb plant for massing and large area use. In northern gardens it is a herbaceous perennial, but in Zone 8 (Athens, Georgia) it exists as a semi-woody shrub. I cut the plant back in late winter, apply a handful of 10-6-4 fertilizer and stand back and marvel. Growth of the season ranges from 4 to 8 ft. The stems start upright and gradually arch to form a fountain-like habit. The rich blue green foliage is maintained into November. The rosy-purple flowers appear in June and again in September with equal flair. The flowers are borne in a 2- to 2½ ft. long racemose-panicle that is almost unbelievable. I have grown the plant for three years and have been impressed by its heat- and drought-tolerance. It is easily rooted from softwood cuttings in May through August. A 1000 ppm IBA-50% ethanol quick-dip proves beneficial.

10). *Chimonanthus praecox*, fragrant wintersweet, has always been cherished for its fragrant winter flowers that appear in late December, peak in January, and perish in early February. It is a large (15 ft.), rather coarse shrub that is not suited for every landscape. The flower buds appear as golden-yellow inflated balloons and open to translucent yellow petals on the outside with a purple blotch in the center. A brilliant golden yellow-flowered form, 'Luteus' or 'Mangetsu', is available and is far superior to the usual form.

Seeds have proven easy to germinate when fruits are collected in late May-June, seeds extracted, and sown immediately. Germination is complete in four weeks and averages 90%. If fruits are allowed to dry, seeds must be provided a 2- to 3-month cold stratification period. Cuttings are not easy to root; however, 70% of the cuttings rooted when collected in late July in Athens, Georgia, treated with 3000 ppm IBA-alcohol quick-dip, and stuck in peat:perlite under mist. About half survived the winter. This may be a species where alcohol dips prove harmful.

The previous ten plants represent but a precious few of the magnificent garden gems that can be grown in southern

gardens. All do not propagate as readily as aucuba, abelia, and spirea but are certainly worth the extra effort.

NEW FOLIAGE PLANTS WITH POTENTIAL

DON SMEDBERG

Shemin International
16350 S.W. 200th Street
Miami, Florida 33187

Shemin International is a world-wide plant resource for growers throughout the U.S. and Canada. We concentrate mostly on sales of foliage and flowering plants, with some ornamentals and perennials. Plants are provided in various stages, such as rooted and unrooted cuttings, seedlings, liners, or tissue culture in stages 2, 3, and 4. Our buyers travel extensively in search of new plants as well as high quality established cultivars. Plants come from Holland, Denmark, Belgium, Israel, Ivory Coast, Puerto Rico, Costa Rica, Honduras, Guatemala, Australia, and the U.S. I will briefly describe the plants we feel have or will have potential impact on the U.S. and Canadian markets.

1). *Dieffenbachia* 'Nelly'. This plant is a mutation found in France. It has a U.S. patent and is sold as an unrooted cutting. It has a strong branching habit, does not develop a leggy cane like other "camro" cultivars. The leaves are durable, with blended tones of yellow, cream and green. One 4- to 6-in. unrooted cutting produces an extremely compact 10-in. container plant in approximately 8 months.

2). *Dieffenbachia* 'Tropic Sun'. 'Tropic Sun' is a branched sport of dieffenbachia 'Tropic Snow' found in Belgium. One 18- to 20-in. unrooted cutting makes a heavily-branched 10-in. container in approximately 9 months. U.S. patent is pending.

3). *Ficus benjamina* 'Golden Princess'. This ficus, found in Holland, has lime green and cream colors on the leaf margin. It develops very distinct variegation up to 70% shade and grows as fast as *F. benjamina*.

4). *Schefflera* 'Diane': This plant, found in Japan, has yellow and green variegated leaves and stem.

5). *Schefflera* 'Gold Capello': Found in Holland, Gold Capello is a large grower with yellow-gold and green leaves. It is the strongest grower we have found of all the variegated schefleras.

6). *Schefflera* 'Renate': 'Renate' is solid green, very compact and has a curly-edged leaf.

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7). *Stereospermum* 'Danielle' or 'China Doll': 'Danielle' was found in Holland. This is a member of the Bignoniaceae family and is also referred to as *Radermachera sinicia*. It can be produced from seed or cuttings. The plant has a lacy, delicate look with green maple-like leaves, but it is very durable for the interior landscape and grows quickly to produce large standard trees or bushes. Use of B-Nine will regulate growth and produce a compact table plant.

8). *Brachychiton populneus*. Bottle tree. The bottle tree is indigenous to desert regions of Australia and Africa and comes to us by way of Israel. This is a new application or treatment of an established ornamental tree used in the landscapes of southern California. These are among the most impressive trees of the world because their trunks resemble bottles. The plants, tested under low- and high-light conditions, are very durable and need little water. Extreme twisted and gnarled trunks are enhanced by applications of Cycocel. Plants are shipped as dormant, woody 8-to 10-in. trees. In a low-profile container, bottle tree will develop into an exotic bonsai-type plant in 3 to 4 months.

These 8 plants I have described have been successfully introduced into the U.S. and Canada. The next group of 10 plants are ones that are currently being tested for marketability.

1). *Ardisia japonica* 'Ito-Fukurin'. Common name marlberry: The plant comes from Japan and China. It is an herbaceous perennial, broad-leaved, compact ground cover. It has a moderate growth rate and becomes 6 in. high with a 4-to 8-ft. spread. Foliage is green with white and cream edges. The showy fruit is scarlet red. In the landscape it has value as a ground cover, a border, or tub plant. It can be used to obtain a naturalizing effect or on a slope. It does best in acid soil that is well-drained but moist. Marlberry grows in half to full shade. It propagates by division of the rhizomes. It is hardy to zone 8.

2). *Ardisia japonica* 'Hakukan': 'Hakukan' is similar in many respects to 'Ito Fukurin' with the following exceptions. It has green foliage with white edges with pink new growth and pink variegation. It has been mentioned as possibly being hardy to zone 5 or 6. It could make a good hanging-basket plant. It spreads rapidly by rhizomes.

3). *Homalomena novoguineensis*, family Araceae. Commonly referred to as silver-drop tongue. The plant comes from New Guinea and is hardy to zone 10. It is herbaceous, perennial, and broad-leaved with moderate growth and compact habit. It reaches a height of 1 to 2 ft. with a spread of 2 to 4 ft. Silver-drop tongue has variegated green with silver-green fo-

liage. It has landscape value as a border, tub, or specimen plant or in a mass planting. It needs well-drained soil and tolerates half to full shade. It propagates by division.

4). *Aspidistra elatior*, family Araceae. Cast-iron plant: Aspidistra comes from Japan and is hardy to zone 7 in well-protected sites. It is an herbaceous broad-leaved perennial. It has a slow growth rate and remains compact. It reaches a height of 1 to 2 ft. and a spread of up to 2 ft. One cultivar has foliage variegated with yellow spots. Flowers are brown and appear in spring. It has value as a ground cover, border, or tub plant and is an excellent, durable interior landscape plant. It needs a well-drained-soil and will tolerate half to full shade, dust, humidity and drought. It propagates by division, and perhaps will do well in tissue culture.

5). *Boehmeria biloba*, family Araceae. False nettle, an herbaceous, perennial, evergreen shrub. It is compact and has a moderate growth habit. It is 6 to 12 inches tall with a spread of 2 ft. Foliage is green; flowers are light green and appear in the fall. It has value as a specimen, tub and indoor plant. It requires a well-drained soil and will tolerate half to full shade, heat and humidity. It propagates from herbaceous cuttings. Related to the *Pilea*, it has an interesting, feathery, leaf texture.

The following five plants are a group of different sansevierias, family Agavaceae. All are hardy to zone 9 and are excellent, durable house plants. They are propagated by herbaceous cuttings, rhizome division, offsets, or possibly tissue culture.

6). *Sansevieria senegambica:* This perennial, an evergreen succulent, comes from Senegal and Gambia. It has a moderate growth rate and moderate density. A mature plant is 1 to 2 ft. high with a spread up to 2 ft. Its foliage is green.

7). *Sansevieria trifasciata* 'Silver Queen': This, too, is perennial and succulent with a moderate growth rate and density. It has a height of 2 to 4 ft. It has silver foliage and greenish-white flowers. 'Silver Queen' comes from South Africa.

8). *Sansevieria longiflora:* This species has been grown in Hawaii. It is herbaceous, perennial, and evergreen. Growth rate and density are moderate. This sansevieria reaches a spread of 1 to 2 ft. Foliage is green with silver specks. It will tolerate half to full shade, dust, and drought.

9). *Sansevieria desertii*. Common name is rhino-grass: Origin is Southern Rhodesia and South Africa. Another sucullent perennial, rhino-grass has a slow growth rate and an open density. At maturity it is 2 to 4 ft. high. The flower is white.

10). *Sansevieria suffruticosa:* This sansevieria comes from Kenya. It has a moderate growth rate and remains open.

We believe that among these plants you will find some valuable additions to the list of those you already grow.

TEN OUTSTANDING PERENNIALS

DAAN KNEPPERS

10319 Pierce Drive

Silver Springs, Maryland 20901

1). *Paeonia*, family Paeoniaceae, peony:

Peonies are rated among the most beautiful of all perennials, both in plant and flower. They are easy to grow and long-lived. The peony is hardy in every state of the U.S. and in Canada. Disease and insects rarely bother them if the following suggestions are followed. They make excellent cut flowers and give beautiful landscape effects.

They do best in a sunny well-drained location. Plant a peony with the top of the eyes pointing up, eyes not over 2 in. below soil level. Plant in 1 gal. or 2 gal. container. The planting time is in the fall or early spring.

Fertilize peonies with a slow-release fertilizer (low in nitrogen), after the first roots are established, in the spring or early fall.

The stembuds, or "eyes" as they are called, are formed soon after blooming season at the base of the stems. They are the beginning of next year's growth.

The blooming season begins in early spring, about the time the tulips open, and it ends 6 to 8 weeks later. As soon as the foliage turns brown in late summer, leaves may be cut off to soil level.

Spraying plants against Botrytis. Spray the plants against *Botrytis* as soon as new shoots appear. Spray the second time when the plant is half grown, and spray again just before they bloom. Use Captan or Benlate.

Why do peonies not bloom? Plants may be too young and immature or planted too deep. Buds may have been killed by late frost or by *Botrytis*. In this case they turn black and die. Too much shade makes plants leafy and tall with little bloom.

Peonies are sold in the trade by the number of eyes: 2 to 3 eyes/division, 3 to 5 eyes/division. Following is a short list of outstanding cultivars.

10). *Sansevieria suffruticosa:* This sansevieria comes from Kenya. It has a moderate growth rate and remains open.

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10319 Pierce Drive

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1). *Paeonia*, family Paeoniaceae, peony:

Peonies are rated among the most beautiful of all perennials, both in plant and flower. They are easy to grow and long-lived. The peony is hardy in every state of the U.S. and in Canada. Disease and insects rarely bother them if the following suggestions are followed. They make excellent cut flowers and give beautiful landscape effects.

They do best in a sunny well-drained location. Plant a peony with the top of the eyes pointing up, eyes not over 2 in. below soil level. Plant in 1 gal. or 2 gal. container. The planting time is in the fall or early spring.

Fertilize peonies with a slow-release fertilizer (low in nitrogen), after the first roots are established, in the spring or early fall.

The stembuds, or "eyes" as they are called, are formed soon after blooming season at the base of the stems. They are the beginning of next year's growth.

The blooming season begins in early spring, about the time the tulips open, and it ends 6 to 8 weeks later. As soon as the foliage turns brown in late summer, leaves may be cut off to soil level.

Spraying plants against Botrytis. Spray the plants against *Botrytis* as soon as new shoots appear. Spray the second time when the plant is half grown, and spray again just before they bloom. Use Captan or Benlate.

Why do peonies not bloom? Plants may be too young and immature or planted too deep. Buds may have been killed by late frost or by *Botrytis*. In this case they turn black and die. Too much shade makes plants leafy and tall with little bloom.

Peonies are sold in the trade by the number of eyes: 2 to 3 eyes/division, 3 to 5 eyes/division. Following is a short list of outstanding cultivars.

Paeonia officinalis 'Rubra Plena': Blooms approximately 2 weeks earlier than the regular hybrids. It comes in double red, white, and pink, grows 24 in. high with approximately 4-in. flowers.

Paeonia 'Krinkled White': Blooms late to midseason. It is a large single flower with great, broad pure white petals and strong stems.

Paeonia 'Monsieur Jules Elie': Double, early pink, large blooms, very free-flowering, light green foliage. One of the most popular peonies.

Paeonia 'Festiva Maxima': Double, white, early flowering, fairly fragrant; flower has some crimson flakes on a few central petals. Large dark-green foliage, very old but still a good cultivar.

Other good peonies are: 'Karl Rosenfield', red; 'Shirley Temple', white; 'Red Charm', red; 'Mother's Choice', white.

Information is from the American Peony Society.

2). *Phlox paniculata* [syn. *Phlox decussata*], family Polemoniaceae. Border or garden phlox.

The spectacular show produced by garden phlox is equalled by no other summer-blooming perennial. The 5-in. diameter flower heads are very fragrant and are long lasting.

Phlox are very adaptable and respond to good cultivation. They do best in rich porous soil and respond to a moderate to heavy fertilizing schedule. They also need protection from wind, a period of winter dormancy, and most important of all, plenty of water during the summer months while they are blooming. They grow in full sun or light shade.

Phlox is not at all a maintenance-free perennial. They are particularly susceptible to powdery mildew, especially toward the end of the season. A spray program including Benlate, Acti-dione P.M., sulfur, and Bayleton can help. Spray plants every 2 to 3 weeks. Avoid watering foliage, which encourages the fungus mildew. To encourage flowering, remove the main flower head when it fades. If you do not do this, eventually the seedlings will take over the main plant. The seedlings will not come true to type.

Colors of the hybrid phlox range from pure white through every shade of pink to red and from pale blue to deep purple. Many cultivars have bright central eyes of contrasting colors.

Border phlox is propagated by root cuttings taken in the fall or stem cuttings taken in the summer. Divide clumps every 3 to 4 years. Phlox are available in the trade as 4- to 6-eye divisions.

Some good cultivars include: Bright Eyes, white with pink eye; Mount Fujiyama, large white heads; Spitfire, salmon red; Starfire, red; Orange Perfection, orange; Blue Moon, dark purple.

3). *Astilbe*, family Saxifragaceae. Sometimes called false spiraea:

Astilbe do best under light shade and with ample moisture. They are very hardy, long-lived, low in maintenance, with beautiful spikes of flowers and very attractive foliage. They form woody crowns and can produce massive growth in good moist soil. In hot and dry regions the foliage will easily burn and turn brown. The ferny foliage of the dark and red-flowering astilbe is dark or red-tinted, others are green. Astilbe is a heavy feeder. It needs a very rich, moist soil and exhausts the soil very quickly. Fertilize with a quick-release fertilizer, 5-10-5. When dormant, the roots do not tolerate dry or soggy or alkaline soil. Astilbe is propagated by root division, mostly in 2-to-5-eye divisions.

They are also very good for cut flowers or dried flowers. You can force the plants in the greenhouse, cut the flowers, then plant outside and treat as a perennial.

An easy-to-grow cultivar is *Astilbe chinensis* 'Pumila'. This plant takes more sun and less moisture than any other astilbe. The foliage is creeping. It makes an excellent edging plant. Another nice plant is *Astilbe thunbergi* 'Straussenfeder'. This has pendulous flowers — a very different astilbe. Other good cultivars are:

Astilbe × *arendsii* 'Fanal', red; *A.* × *arendsii* 'Peach Blossom', salmon pink; *A.* × *arendsii* 'Red Sentinel', deep red; *Astilbe japonica* 'Europa', clear pink; *A. japonica* 'Deutschland', white; *Astilbe taquettii* 'Superba', purple rose, and fairly heat- and drought-resistant.

4). *Liatris*, family Compositae; gay-feather or blazing star:

This is the only spike-flowering perennial to my knowledge that flowers from the top to the bottom. It has to be grown in full sun and does best in a sandy soil. The brightly-colored purple to pink or white small flowers gather around the slender stem.

The fleshly corm-like roots should be divided every 3 years, otherwise they get too crowded. *Liatris spicata* can easily be grown from seed and is one of the most adaptable species and fairly drought-resistant. There is also a white form, *L. spicata* 'Alba'.

Liatris is very good as a fresh cut flower, dried flower, or grown in a container as a pot plant. For better show, plant

more corms per pot. The flowering time of *L. spicata* is mid-summer.

L. spicata 'Kobalt' is compact and blooms 2 to 3 weeks earlier. This dark purple, 2 foot-high plant is only grown by division. It does not come true from seed.

5). *Iris pumila*, family Iridaceae. Dwarf bearded iris:

This compact dwarf flowers at daffodil time and is the first bearded iris to bloom. The dwarf bearded iris is 8 to 16 in. high (flowering height). These plants have unbranched flower stalks.

Iris pumila is very useful as an edging plant or in front of taller and later flowering irises. It is also small enough to use in rockgardens. *I. pumila* is very vigorous and extremely hardy, quickly growing to large clumps, covered with lots of blooms.

Iris pumila grows best in full sun, in well drained soil, which is not too acid. Application of lime is suggested to make a sweeter soil. It is propagated by rhizome division done in July or August. The rhizomes of the dwarf bearded iris should only be half covered with soil when planted. The sun should shine on the top of the rhizomes.

Some good cultivars are: Flaming Gold, yellow; Banburry Ruffles, dark blue; Lenna M., apricot; Cherry Garden, purple; Ritz, yellow with brown edge.

6). *Hosta*, family Liliaceae. Plantain lily:

Hosta is a very hardy and easy-to-grow perennial. Plants are mound-shaped and feature large attractive leaves from deep blue to light green. A wide range of variegated leaf forms have come on the market in recent years.

Hostas do best in moist rich soil and light shade. A hosta can stand wet soil when in growth, but not when dormant.

Hostas are rated among the most beautiful perennials for shade growing. Leaves can be lance-shaped, rounded or somewhere in between and range from less than an inch to more than a foot across. The texture of the leaf can be smooth, ribbed, waved, flat or twisted. Leaf colors include light green, dark green, yellow and grayish or blueish green. Some plants have leaves that are edged or have various patterns in white, cream or yellow.

The height of hosta ranges from 3 in. to over 3 ft., not including flowers. The flowering height can vary from 10 in. to as tall as 6 ft. The flowering season is between early June and October. Few cultivars are fragrant. Flowers are of secondary importance. Hostas are grown in partial to almost full shade.

They can withstand more sun if they have enough moisture, but otherwise they burn. Hostas are mostly grown in one-qt. or one-gal. containers or are field grown. They are usually pest-free. The worst enemies are slugs and snails; the larger the leaf the more apparent the damage. A good remedy is to spray a liquid slug and snail killer on the leaves, which is more effective than pellets or powders scattered on the ground. Treatment must start early.

Propagating is done by root division and tissue culture. Tissue culture can be a way to provide a quick and good supply of the rare and new cultivars.

The following cultivars are some we feel are outstanding: *Hosta sieboldiana* 'Francis Williams': the number one rated hosta for three years by a popularity poll of the American Hosta Society. The interior leaf of this beautiful plant is blue-green with a gold edge. Flowers are white.

Hosta sieboldiana 'Elegance': This is a gigantic, excellent blue hosta. The clump is 2 to 4 ft. tall and as much as 4 to 5 ft. across at maturity. Attractive white flowers rise just above the foliage.

Hosta 'Krossa Regal': The leaves are blue-grey. The clump is vase-shaped. Flowers are soft orchid on stalks up to 6 ft. high. It is an excellent plant and good grower.

Other good hostas include: 'Royal Standard', shiny green leaf with white fragrant flowers; *Hosta lancifolia* 'Kabitan', small variegated border plant; *Hosta* 'Tokudama', true blue, good medium-size plant; *Hosta undulata* 'Albo Marginata', an old but still good variegated cultivar.

7). *Dicentra spectabilis*, family Fumariaceae. Old-fashioned bleeding heart:

An old-fashioned plant that no garden should be without. It has pendulous arches of clear pink, tiny hearts. The bleeding heart is taller and wider than the other species of *Dicentra*. Foliage is very pretty but less finely divided.

Dicentras have deep, fleshy roots and need a loose, moist soil. Grow in partial shade. Foliage usually dies back in the early summer. After the dicentra flowers for the first time, it can be cut back to 2 to 4 in. above soil level and will flower again.

Dicentra spectabilis can be propagated by division, by root cuttings taken in early spring, or by stem cutting in spring or ealry summer. White-flowering *Dicentra spectabilis Alba* is slightly less robust than the pink variety.

8). *Hemerocallis*, family Liliaceae. Daylily:

Daylilies are among the most adaptable and satisfactory perennials. They withstand heat and dry weather better than most garden flowers and can be grown in almost all parts of North America. These plants grow with minimum care in full sun or light shade in almost any soil. Daylilies produce long, narrow leaves and showy large flowers in a very wide range of colors. Depending on the cultivar, the blooming time ranges from early spring until frost. Each plant bears many flowers on branching stems. The individual flower lasts only one day; however, they follow each other quickly, and some cultivars have long blooming times. The flowers are carried on strong 1-to-4 ft. stems. Flower sizes vary from 2 to over 6 in. Some cultivars have a very heavy substance, so they can withstand the hot, dry, sunny days. Some cultivars can have as many as 30 flowers per stem and as many as 20 stems or more on a mature plant. Spent flowers should be picked regularly to encourage future flowering. Every year there are more than 1000 new hybrids registered in every color and height.

There are dormant and evergreen cultivars. The dormant ones are best for the north as the evergreens have a very limited hardiness. They are excellent for the deep South and southern California.

Daylilies can be divided in fall or spring and are sold mostly in one-eye divisions. They are also successfully propagated through tissue culture. In the nursery a daylily is best grown in one-gal. containers. When roots are established, add a slow-release fertilizer and grow in full sun to partial shade.

There are hybrids that flower in spring, in early or late summer or in the fall. There are now cultivars that will rebloom and flower almost from late spring until frost. Most daylilies are 2½ to 3 ft. tall when in flower, but there is an increasing range of dwarf plants and miniature flowers in all kinds of colors.

Good cultivars include: 'Mary Todd', early ruffled yellow; 'Lusly Leland', red; 'Stella D' Oro', 11 inches, fragrant, golden yellow; this excellent daylily blooms from June until almost frost. 'New England Night', very dark red; 'Just Watch', yellow; 'Asstelot' almost white; 'Anna Warner', pink; 'Butter Cup Parade', soft yellow.

9). *Iris kaempferi*, family Iridaceae. Japanese iris:

Japanese iris grows 3 to 4 ft tall in full sun or partial shade. Japanese iris have huge flat-topped blooms in colors of pure white, yellow, clear pink, every shade of lavender, purple, blue and bicolor. Some hybrids bear flowers as big as 1 foot across, but most plants have 6 to 9 in. blooms. They flower approximately 2 weeks later than standard tall-bearded

iris.

When Japanese iris is in growth, the soil should be kept constantly moist. In the winter they should have a much drier soil. They will do best in humus-rich soil. free of lime, with a pH of 5.5 to 6. Add sulfur, if necessary, to make the soil more acid.

They are propagated by root division in early fall or spring and are divided into two- to three-eye plants. Some good named cultivars are: Beni Botan, maroon purple; Mura-Komo, purple/white; Aichi-No-Kagayaki, yellow; Pink Lady, pink; Agogakujyo, deep purple; Haku Botan, pure white.

10). *Lilium*, family Liliaceae:

In my opinion this plant is very underrated for garden use and for a pot plant in the greenhouse, to bring in bloom different times of the year.

Lilies grow from bulbs, which are built up by scales. These scales are connected at the bottom. Lily bulbs are never dormant. They should be stored in a very humid, cool place to insure a good bud count and should never dry out.

The lily makes one stem, on which all the foliage grows. On top of the stem are the flowers. Each flower will last three to four days. They flower only once per year. Lilies should be grown in a moist, rich well-drained soil, in full sun.

The most common types of lilies listed according to blooming time are hybrid lilies, tiger lilies, trumpet lilies, oriental lilies and rubrum lilies. By planting these different types at one time, you will have flowers from June till September.

The hybrids are the largest group. This plant comes in almost all colors. Rosita, pink; Sterling Star; white; Aristocrat, orange; Corina, red; other colors are yellow, salmon, apricot and some newer cultivars in bicolor.

A lily grows on stem roots. It is important to plant a lily about 4 in. deep because the plant gets most of its food through absorption by the stem roots. This way the plant is healthier, has a better appearance, and will have a better bud count. The warmer the bulb temperature, the lower the bud count. A lily is an excellent perennial for garden use. It is hardy, easy to maintain, and gets more beautiful every year. Lilies also make good cut flowers.

Another group of lilies that deserves some extra attention, is the oriental lily. This is the most beautiful flower you will ever see. Some cultivars are very fragrant and come in rich pink lavender, and now also pure white colors. This is the Cadillac of all lilies!

Lilies are propagated by the stem bulbs which grow above the original bulb. Another way is by scaling the bulb. Give the scales a heat and cooling treatment, plant them, and grow for two years in the field. By then the bulb will be full size. This way stock can be built up rapidly. The newest cultivars are propagated by tissue culture. Commerical growers in the U.S. generally plant lilies in 1 gal. or in 6 in. containers. Plant 3 bulbs per pot, because this will give more show, and they will have a much longer shelf life.

ACCLIMATION AND WINTER PROTECTION OF CONTAINER-GROWN NURSERY CROPS

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Acclimation and freeze tolerance of woody plants was addressed at the meeting of the Southern Region, IPPS in 1977 by this author and published in the Proceedings (9). In that paper the mechanisms whereby plants acclimate to cold temperatures and survive freezing temperature and desiccation injury were discussed. In the present paper an attempt will be made to build upon that information by explaining a new model for plant cold acclimation as it relates to winter storage, with emphasis on container production.

A physiological model called "Degree Growth Stage Model" (°GS) has been proposed by Fuchigami *et al.* to describe the annual growth and hardiness of woody plants (3). Plants go from 0°GS to 360°GS in one calendar year (Figures 1 and 2). The °GS is not related to days in the year but to the physiological condition of the plant. For example, 180°GS may coincide with leaf fall may be October 1 in northern Ohio but October 15 in northern Alabama, depending upon the species in question. Another important point about plant development and responses to the environment is that plants are active physiologically even in the winter. Thus a proper understanding of these physiological events will assist the grower in protecting plants from winter injury.

Spring bud break starts at 0°GS and proceeds with rapid growth. During this time plants do not have the capacity to acclimate to freezing temperatures. The rapid growth phase is followed by a period where shoot growth slows and ultimately stops in response to decreasing photoperiod and warm tem-

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Spring bud break starts at 0°GS and proceeds with rapid growth. During this time plants do not have the capacity to acclimate to freezing temperatures. The rapid growth phase is followed by a period where shoot growth slows and ultimately stops in response to decreasing photoperiod and warm tem-

perature. This period starts at 90°GS (about August 15 in southern U.S.) and is complete at 180 G.S. when vegetative maturity is complete; plant tops have stopped growing, and stage 1 of cold acclimation has occurred. Plants can at 180°GS survive light freezing. A point of reference is the fact that vegetative maturity and the completion of stage, acclimation can occur for deciduous plants at the time of leaf fall although not always.

The development of vegetative maturity or the first stage of acclimation can be delayed by cultural practices such as applying high levels of N in late summer or early fall. Gilliam *et al.* (4) have shown leaf drop of *Acer rubrum* to be delayed with high levels of N. Late flushes of growth on plants such as *Ilex* and *Rhododendron*, and prolonged growth of plants such as *Forsythia* due to late applications of fertilizer are many times killed by the first freeze in the fall (personal observations). This injury can be related to the overriding effect of nutrition, which delays vegetative maturity and the completion of the stage 1 of acclimation.

The second stage of acclimation begins at 180°GS with the rate of acclimation being much more rapid than during the stage 1. Plants will acclimate at temperatures as high as 20°C but the rate of acclimation is increased at temperatures around 0°C Deacclimation does not appear to be a problem during this growth stage. Freeze injury may be a problem in years when temperatures remain abnormally high in the fall, which slows acclimation, In the same vein, nurserymen should delay the application of winter protection that may expose plants to high temperatures during this stage of acclimation. The decrease in acclimation rate could result in plant damage by early freezes. The main objective is to protect plants before temperatures occur that will kill roots of the species in question. On the other hand, if nutritional practices have prolonged vegetative growth late in the season, early protection may be necessary to prevent freeze damage of unacclimated plants. The role that roots play with winter injury of containerized plants will be discussed later.

Plant hardiness is at a maximum between 270 (about December 21 in the South) and 315°GS. Plant growth does not occur as long as temperatures remain low. Rest is ended when a sufficient number of chilling hours have accumulated and certain physiological requirements within the plant have been met. This time corresponds to 315°GS, after which increasing temperatures will cause the plant to deacclimate and resume growth. Thus, the growth cycle will be complete with bud break commencing at 360°GS. At 315°GS, the higher the temperature, the more rapid will be deacclimation in contrast to a

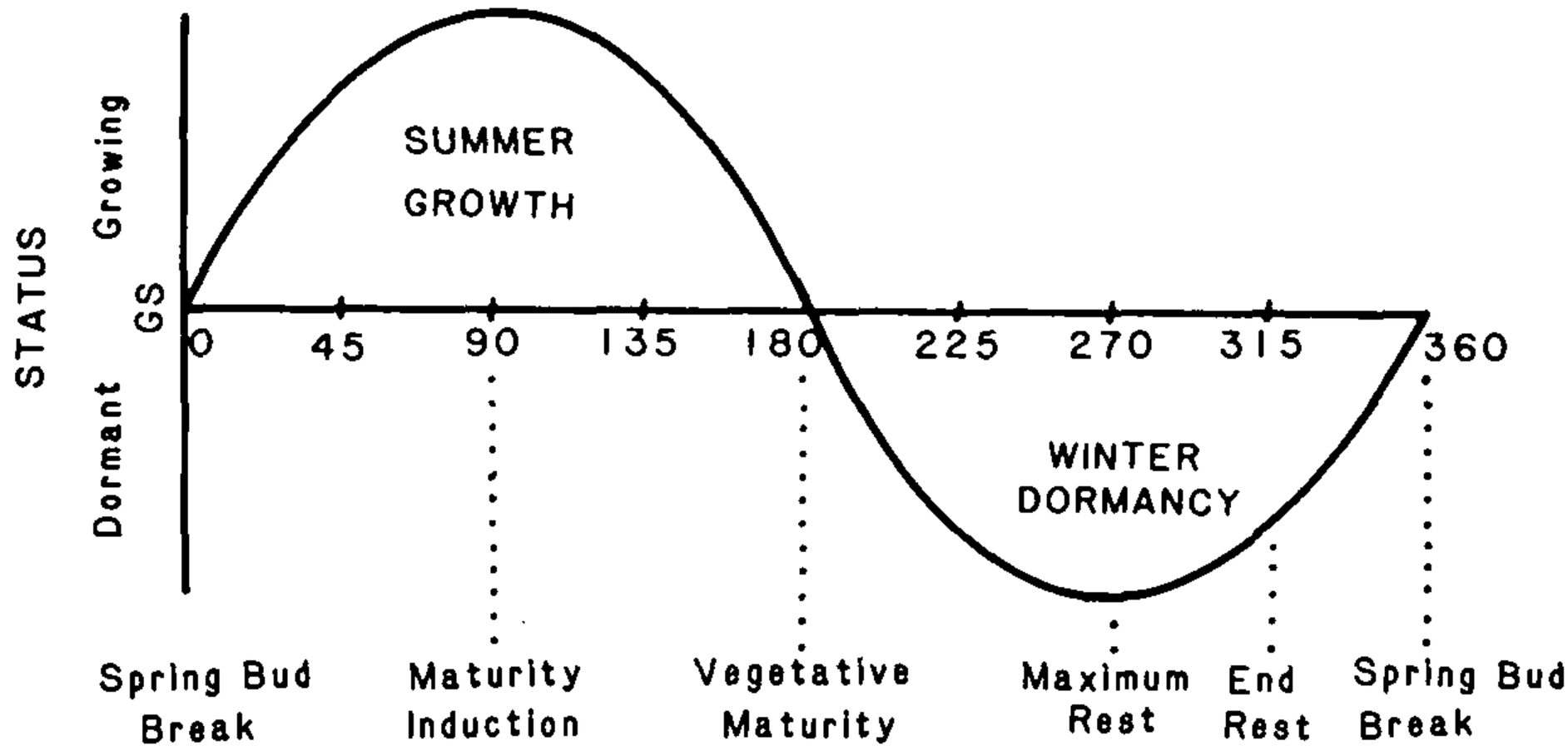

Figure 1. Degree growth stage and growth of plants.

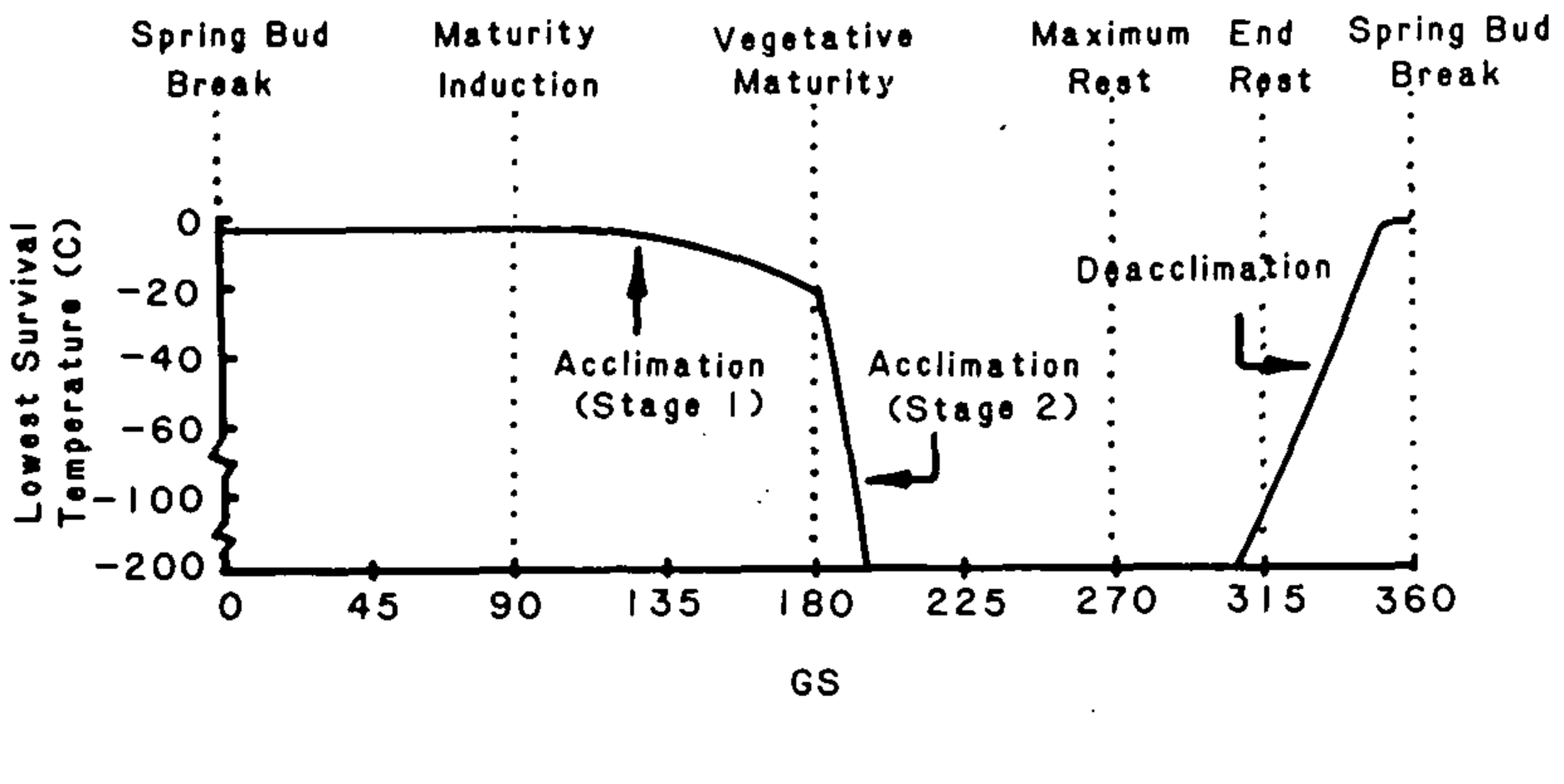

Figure 2. Degree growth stage and hardiness of plants.

more rapid acclimation rate in response to lower temperatures in the fall.

During the time when plants are capable of deacclimation, temperatures as low as 5°C have been shown to cause some deacclimation. It is, therefore, important to remove winter protection or properly ventilate in order to maintain a low temperature environment and prevent premature deacclimation and growth. A good rule of thumb is to remove protection as soon as minimum temperatures are above that which will cause root injury. This precaution is especially critical if plants are to be marketed to the north of the growing area since they may have deacclimated to temperature above which they will be exposed at a new location. This same reasoning is why plants are normally marketed no more than two hardiness zones north of the production location.

The main concern with winter protection of container grown nursery crops is to provide adequate protection to the root system and to prevent desiccation of plant tops during winter. Freeze injury to plant shoots is normally minimal since only hardy species and cultivars should be grown. Roots do not have the capacity to acclimate to the same extent as shoots. The example of *Pyracantha coccinea* 'Lalandei' has been given often in which stems survive −15°F while older woody roots are killed at 2°F and young roots are killed at 22°F (8). Higher root-killing temperatures compared to shoots for both deciduous and evergreen azaleas have also been demonstrated (1). Alexander and Havis (2) found that roots of 'Springtime' azaleas grown at 18°C temperatures were not as hardy as roots grown at 2°C. Roots do not go dormant as do the buds on shoots and the rate of root growth is a function of temperature, provided other environmental and internal physiological factors are not limiting. The higher the temperature, regardless of the photoperiod or time of year, the more active the roots and the less hardy they are. Green and Fuchigami (5) have indicated that this physiological difference between roots and shoots is one major reason for the difference in hardiness between shoots and roots.

The root system of container-grown plants is poorly buffered against changes in temperature in contrast to field-grown plants. Container-grown plants are exposed to ambient air temperature and have a small quantity of medium surrounding the roots. Consequently the root temperature of container-grown plants fluctuates greatly in response to changes in ambient air temperature. Thus, every effort should be made to maintain temperature above that which will kill roots and, just as important, to prevent significant elevations in temperature which may cause roots to deacclimate and be injured by the

next freeze. An ideal root temperature for over-wintering containerized plants would be just above freezing. This would be above root killing temperature (20 to 25°F for many species) (5) but cold enough to inhibit root growth and deacclimation. It is, therefore, important to apply winter protective procedures as late in the fall as possible to allow for maximum acclimation of the tops and roots. It is equally as important, and maybe more, to remove protection as early in the spring as possible to prevent deacclimation and freeze injury of shoots and roots.

As already mentioned, another key reason for providing winter protection for container-grown woody plants is to prevent winter injury of shoots due to desiccation. The factors that influence desiccation have been addressed in an earlier paper by this author (9) and by Green and Fuchigami (5). As temperature approaches freezing, the root system is not as effective in supplying water lost by transpiration from the shoots. This is due in part to an inactive root system and increase in the viscosity of water at lower temperatures. This condition is even more critical when the water, and the roots in the container medium, freeze resulting in no movement of water to the shoots. This frozen condition may exist for an extended time even though air temperature may be above freezing and loss of water from the tops via transpiration is possible.

Any factor that may increase the air temperature around the plant will result in a decrease in relative humidity and a greater difference between the relative humidity of the air and that of the internal part of the leaf. The result will be the loss of water from the leaf and desiccation if water is not resupplied by the root. The use of white co-polymers or microfoam is effective in winter protection since they maintain a more uniform temperature within or under the structure (6,7).

Desiccation can also be minimized if winter protection methods are employed to eliminate wind exposure or air movement around plants. The greater the wind velocity, the greater the loss of water vapor from the leaves. Care should be exercised to make structures or coverings as air-tight as possible. Elimination of air movement will also cause plant temperature to remain much higher since an increase in air movement results in the removal of large quantities of heat energy from the plant and container medium. The observation that plants along the northern edge of container beds are more prone to injury is partially due to the wind factor.

This paper attempts to present winter protection in a context that considers the physiological growth and development of a plant throughout the year. As one's knowledge of these

relationships increases, greater success in overwintering containerized woody plants will be realized. It has been said that the person that knows how will always have a job. But the person that knows why will be the other person's boss. In respect to growing plants in containers, the person that learns all he can about plant acclimation and how plants respond to freezing temperature will most likely remain in business, have people to manage, and plants to sell.

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TISSUE CULTURE PROPAGATION OF *SOPHORA SECUNDIFLORA*

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Abstract. *Sophora secundiflora* can be established *in vitro* by sterilizing explant material in 1% Liquinox for 3 min., 70% ETOH for 3 min., 10% Clorox for 30 min., with 3 rinses in sterile water. Explants can be multiplied on WPM with 5, 7.5, or 10 mg/l BA. There is currently not an adequate treatment for shoot elongation. Plantlets can be rooted using a quick-dip for 5 min. in 1000 ppm IBA.

Sophora secundiflora, Texas mountain laurel, is a woody-ornamental shrub native to west Texas that has considerable value in the landscape. Some of the desirable characteristics include dark evergreen foliage, fragrant blue flowers, as well as drought and pest resistance. Currently, *Sophora secundiflora* is commercially propagated by seed, since cuttings have very low rooting ability. Because of the genetic variability in seedlings, clonal propagation is desirable which will permit selection for specific characteristics such as flower color, growth habit, and drought tolerance. Within the past several years tissue culture propagation has been used to propagate many woody plants (2). Woody ornamentals such as sweetgum (8), red maple (9), oak (3), and birch (6) have been successfully micropropagated. In order to clonally propagate Texas mountain laurel, it is necessary to use tissue culture techniques since other asexual methods have not been commercially feasible. The objectives of this study were:

1. To determine the best sterlization procedure to establish explants *in vitro*.
2. To determine the best medium and growth regulator(s) concentration to induce multiplicatio'
3. To determine the best growth regula.or and concentration to induce rooting.
4. To acclimatize the plantlets successfully.

MATERIALS AND METHODS

Plant material for *in vitro* propagation was obtained from one-year-old greenhouse-grown seedlings. All seeds were collected from a single tree located on the Texas A&M campus. Plants were grown under 18-hr. daylength in order to prevent dormancy. Single-node stem sections 1 to 2 in. (2.5 to 5.0 cm.) in length as well as shoot tips were used as explants.

Three different sterilization procedures were tested. They were:

1). 3 min. 1% Liquinox, 3 min. 70 ethanol, 15 min. 10% Clorox, rinsed 3 times with sterile distilled water plus 2% Clorox.

2). 3 min. 1% Liquinox, 3 min. 70% ethanol, 30 min. 10% Clorox, rinsed 3 times with sterile distilled water plus 2% Clorox.

3). 3 min. 1% Liquinox, 3 min. 70 ethanol, 30 min. 0.01% $KMnO_4$ (1), rinsed 3 times with sterile distilled water plus 2% Clorox.

All leaves were removed prior to sterilization and stems were cut into 3 to 4-inch (7.6 to 10.2 cm.) sections.

Explants were cultured on Woody Plant Medium (WPM) (5) with 0.8% Bacto-Difco agar (8 g/l). Multiplication medium contained either no growth regulators, or benzyladenine (BA) at 1, 3, 5, 7.5, and 10 mg/l, or 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine (PBA) (4) at concentrations of 1, 3, and 10 mg/l. Elongation medium contained either no growth regulators or gibberellic acid (GA_3) (10) at concentrations of 0.1, 0.3, 1, 3, and 10 mg/l.

All media were adjusted to pH 5.7 before adding agar; 10 ml was placed in each 150 × 25 mm test tube. The test tubes were capped with Magenta caps and autoclaved at 121° C (247° F) for 15 min. Tubes were cooled upright. Cultures were placed on a growth shelf under cool white fluorescent lights on a 16-hr. photoperiod. The temperature was kept at 25° ± 1°C (77° ± 1°F). Cultures were transferred every three to four weeks. For rooting, shoots were excised and quick-dipped in indolebutryic acid potassium salt (K-IBA) for 5 min. at concentrations of 500 and 1000 mg/l. They were then stuck in moist peat pellets that were soaked in half strength WPM (5) with the pH adjusted to 5.7 Pellets with explants were kept under clear plastic cups on the growth shelf. Holes were punched in the cups to reduce humidity and acclimatize the plantlets.

RESULTS

Sterilization. Of the three sterilization procedures tested, the 30 min. treatment with 10% Clorox had the highest percent of clean cultures (Table 1). Most of the contamination was from bacteria — very little was fungi, but the percentage of clean cultures was lower than desired. To improve this, stock plants were drenched every 3 to 4 wks. with Subdue at 1 oz./100 gal. of water or Banrot at 8 oz./100 gal. of water. Handling techniques during sterilization were also adjusted. These changes led to an increase in clean cultures from 28% to 40%.

Table 1. Sterilization results of *in vitro*-propagated *Sophora secundiflora*. All sterilization treatments included an initial 3 min. 1% Liquinox and 3 min. 70% ethanol application[1].

Treatment	Percent clean cultures
15 min. 10% Clorox	11
30 min. 10% Clorox	28
30 min. 0.01% $KMnO_4$	12

[1] 36 explants per treatment.

Multiplication. Multiple shoots were formed on media containing cytokinins. BA at 5, 7.5 and 10 mg/l was more effective than PBA in promoting bud break and shoot development (Table 2). BA at 7.5 mg/l produced 5.3 shoots per explant.

Table 2. Effect of BA and PBA on shoot multiplication of micropropagated *Sophora secundiflora*[1].

Treatment	Avg. number of shoots/explant
Control	1.0
BA 1 mg/l	1.5
BA 3	2.2
BA 5	4.4
BA 7.5	5.3
BA 10	5.0
PBA 1	1.4
PBA 3	2.0
PBA 10	2.5

[1] 15 explants per treatment

Elongation. Since a very small percentage of shoots sufficiently elongated for easy handling, explants were transferred to media containing either no growth regulator or GA_3 (9). The percentage of shoots greater than 5 mm was not significantly different among any of the treatments including the control (Table 3). The percentage of long shoots was not, however, as high as desired.

Table 3. Effect of GA_3 on alongation of *Sophora secundiflora* shoots propagated *in vitro*[1].

Treatment	Avg. number of shoots>5mm
GA 0 mg/l	0.3
GA 0.1	0.4
GA 0.3	0.2
GA 1.0	0.6
GA 3.0	0.6
GA 10.0	0.6

[1] 15 explants per treatment

Rooting. A rooting experiment was conducted to determine if simultaneous rooting and acclimatization is feasible for micropropagated shoots. Quick-dipping shoots for 5 min. in 500 mg/l K-IBA resulted in 10% rooting; the 1000 mg/l treatment resulted in 20% rooting.

DISCUSSION

Sterilization. Sterilization procedures must include a pre-sterilization treatment. This should include the use of systemic fungicides, such as Banrot and Subdue, as well as growing stock plants under greenhouse conditions. We observed that the use of a pre-sterilization treatment greatly increased the percentage of clean cultures.

Multiplication. Shoot multiplication was greatest with 7.5 mg/l BA, though there was not a significant difference between the 7.5 mg/l treatment and the 5 and 10 mg/l treatment. PBA (4) promoted bud break, but shoots were not as well developed or as numerous as those produced by the BA treatments. As the concentration of cytokinin increased, the number of shoots formed also increased. Toxicity symptoms such as thick, stunted shoots with curled leaves were observed at higher concentrations of BA. Only a very low number of shoots sufficiently elongated for easy handling during sectioning or rooting.

Elongation. There was very little difference among treatments in percentage of shoots greater than 5 mm. or average length of shoots greater than 5 mm. Before a commercial tissue culture propagation system can be implemented, greater elongation of the shoots must be achieved. This lack of elongation may be due to the absence of endogenous GA. Since there are no roots to produce GA (7), the mechanism to stimulate shoot development and elongation is reduced. By incorporating GA and BA into the basal medium, this problem may be overcome. Experiments are currently underway to determine if this is the case.

Rooting. From the rooting experiment, it appears that micropropagated *Sophora secundiflora* has the potential to root. Roots were observed in approximately 4 wks. No callus was observed in this treatment so higher concentrations of auxin may be used to increase rooting. It was also observed that the larger shoots rooted quite readily, while the shorter shoots did not root. This is probably due to the better contact of the longer shoots to the peat pellet. More rooting experiments are being conducted to determine the optimum treatment for rooting.

CONCLUSION

Using the *in vitro* micropropagation techniques as explained in this paper, we have a potential basis for clonal propagation of Texas mountain laurel. The ability to propagate *Sophora secundiflora* clonally will enable propagators to select for specific characteristics and mass produce certain genotypes. By having specific cultivars available, Texas mountain laurel will be more marketable as an ornamental landscape plant for the south.

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PLANT PATENTS, TRADEMARKS, AND OTHER VARIETY PROTECTION DEVICES

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What is a patent? Why do we have patents? What can be patented? What do you mean by a plant patent? All of these are questions of interest to plant breeders and plant propagators. Today I will give you a few answers I hope may clarify these questions and stimulate your interest in plant patents and other forms of breeders' rights.

PLANT PATENTS

The Constitution of the United States gave Congress the power to enact laws relating to patents in Article I, which reads, "Congress shall have the power to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." The first patent law was enacted in 1790. It has been updated and modified several times; the last general revision was in 1952.

In the language of the law any person who "invents or discovers any new and useful process, machine, manufacture or composition of matter, or any new and useful improvments thereof may obtain a patent." This statute specifies that the subject matter must be "useful".

Who may apply for a patent? Only the inventor. If two or more persons make an invention jointly, they apply for a patent as joint inventors. A company or organization may *not* apply for a patent. A financial backer of an inventor may *not* apply for a patent or be a joint inventor.

Originally, it was felt that plants were not covered by existing patent laws and regulations. To correct this the Townsend-Purnell Plant Patent Act was enacted by Congress and signed into law by President Hoover, May 23, 1930. In 1931 plant patent number one was granted to the discoverer of a climbing rose, which was named 'New Dawn'. The plant patent for 'New Dawn' has long since expired. Since then over 5300 plant patents have been granted. The law specifically provides the granting of a patent to anyone who has invented or discovered and *asexually* reproduced a distinct and new variety of plant, including cultivated sports, mutants, hybrids and newly-found seedlings other than tuber-propagated plants or plants found in an uncultivated state. All patents, including

plant patents, are for a term of 17 years and may *not* be renewed or extended. The purpose of plant patents is to afford agriculture, so far as is practical, the same opportunity as industry to participate in the patent system. Plant patents provide incentive for achievement in plant breeding, gardening, and agriculture. A plant patent is no guarantee. It is not an endorsement by the government of quality or merit. All the plant patent says is that the invention is distinct, new, and useful.

The rights granted for a United States patent extend throughout the territory of the United States. It has no effect in a foreign country. An inventor who wishes patent protection in other countries must apply for a patent in each country where he wishes protection. Almost every country has its own patent laws, although many do not have *plant* patent laws as such. They may have breeders' rights, or they may accept plants under their regular patent law. In the United States an inventor, regardless of his citizenship, may apply for a patent on the same basis as an American citizen. One of the most critical and important points in filing a plant patent application is that no United States patent can be obtained if the invention is already patented abroad, or if a foreign application has been *filed more than one year before filing the U.S. application.* That is, if any plant patent or breeders' rights application is filed in any other country, a U.S. plant patent application must be filed within one year of the earliest filing in any other country.

The patent laws are found in title 35 of the United States Code with Plant Patents found in Chapter 15. Section 163 reads, "In the case of plant patents the grant shall be of *the right to exclude others from asexually reproducing the plant or selling or using the plants so reproduced for 17 years.*" This gives the patent owner the right to license others to reproduce asexually or sell or use the plants covered by the plant patent, and this exclusive right lasts 17 years from the date the plant patent is issued. When granting any of the these rights the patent owner, as the licensor, may charge a fee (royalty) to the licensee. Although it is legal to charge a royalty on each one of these rights, it is customary to charge only one royalty.

Among the prerequisites for filing an application for a plant patent are:

1. The new plant *must have been asexually reproduced* by the applicant and must retain the same characteristics through successive generations of asexual reproduction.

2. The new plant must not have been described in a printed publication, nor introduced to the public nor placed on

sale *more than one year before the filing of the application* and, as mentioned earlier, a foreign application for a plant patent or breeders rights must not have taken place more than one year prior to filing the application in the United States.

3. The new plant variety must have originated: (a) as the result of some act of cultivation by the applicant such as cross pollination, treatment, selection and/or breeding efforts; (b) as a seedling found by the applicant in a cultivated area or; (c) as a sport found by the applicant.

PLANT VARIETY PROTECTION ACT

In the 1960's a move was begun by the seed breeders of the U.S. to obtain legislation giving seed breeders the same basic rights and opportunities as other plant breeders. On December 24, 1970 the "Plant Variety Protection Act" was approved by Congress and was signed into law.

It was cited as an act: "To encourage the development of novel varieties of sexually-reproduced plants and to make them available to the public, providing protection available to those who breed, develop or discover them, and thereby promoting progress in agriculture and in the public interest."

The PVPA, as it is commonly called, is administered within the Department of Agriculture, unlike the Patent Law administered in the Department of Commerce. The PVPA now covers all types of seed-propagated plants although there were originally six exceptions.

COPYRIGHTS

Some persons are confused by patents, trademarks and copyrights. There may be some resemblance in the rights of these types of intangible property, but they are very different and serve different purposes.

Copyrights protect writings of an author aganist copying. Literary, dramatic, musical and artistic works are included within the protection of the copyright law. And in some cases copyright law confers performing and recording rights. A nurseryman's use of copyrights would be for a catalog and perhaps photographs and sales aids. Obtaining a copyright is simple and economical. Copyrights are registered in the Copyright Office of the Library of Congress.

TRADEMARKS

A trademark, as defined by Section 45 of the Tradmark Act of 1946, popularly known as the Lanham Act, "includes any work, name, symbol or device, or any combination thereof adopted and used by a manufacturer or merchant to identify

his goods and distinguish them from those manufactured or sold by others."

The primary function of a trademark is to indicate origin. However, trademarks also serve to guarantee quality.

In order to qualify for registration a mark must be used in interstate commerce. That is, rights in a trademark are acquired only by use and use must continue if the rights are to be preserved. Registration of a trademark in the Patent and Trademark Office does not in itself create or establish any exclusive rights. It is, however, recognition by the government of the right of the owner to use the mark in commerce to distinguish his goods from the goods of others.

A few generalities about a trademark: It may not be a descriptive term, such as blue, large, superior, or best; it may not consist of geographically descriptive terms such as Rocky Mountain, Carolina, or Arctic, except as indication of regional origin; it may not consist of or comprise the name, likeness or signature of a living person except by written consent; it may not resemble a mark already in existence and still in use if it could cause confusion and be deceptive.

A trademark must be registered within one or more classes of good established by the Patent and Trademark Office. Class 31 covers "agricultural, horticultural, and forest products and grains not included in other classes; living animals; fresh fruits and vegetables; seeds; live plants and flowers; foodstuffs for animals, malt."

Once a trademark is issued it will be cancelled at the end of six years unless the owner shows that it is still in use. Once that requirement is satisfied the term of the trademark is 20 years from date of registration and may be renewed for periods of 20 years unless it is cancelled or surrendered.

ENFORCING YOUR RIGHTS

When you own a plant patent, breeders' right, trademark or copyright, you have lawful rights *and* duties. First of all, when you own a plant patent, trademark, copyright, or breeders' right, it is your obligation to put everyone on notice. In the case of patents, the plant patent number should appear with the variety name in all printed matter originating from the patent owner and all licensees. Each plant should have a tag or label giving the name, plant patent number, and a statement to the effect that asexual propagation is prohibited.

If a person is found making or selling a patented plant without a license or that was made without a license, it is an infringement of the patent. The patent owner may immediate-

ly bring suit against the infringer stopping such action and seeking triple damages in feederal court.

Canada does not offer any sort of plant protection or breeders' rights. Accordingly, any plant protected in the U.S. can be freely grown in Canada. However, a plant grown in Canada may not be brought into the U.S. when it is patented in the U.S.

Once a sale of a patented and properly licensed plant is completed, there is no further control of its use or further sales. But making the patented plant is still forbidden. Likewise, a plant that is propagated under license while the patent is still in force and not sold until one or two years after the patent expires is still subject to royalty payment.

With respect to registered trademarks, it is mandatory to put public on notice that the trademark is registered. This is done by use of the letter "R" in circle, ®, which must appear with the trademark.

A trademark may be licensed by the owner in much the same way a plant is licensed. This is common practice in the world of fashion and is gaining a foothold in horticulture.

When a registered trademark is used with a plant there is only a restriction on the use of the trademark. Any infringement of the trademark by an unauthorized person can be stopped immediately with relative ease. However, the trademark itself carries no restriction on the making, using or selling of the plant.

Incidentally, all of these rights can be bought, sold and transferred just as the title to any piece of real property can be bought, sold and transferred. When a transfer takes place an assignment is registered in the proper government office.

BENEFITS OF PATENTS, TRADEMARKS, AND BREEDERS' RIGHTS

The public will benefit from new and improved forms of plants for their use and enjoyment. Increased research can be financed by the royalties collected on plant patents. The public has a better chance to see improvements in the form of plants; vigor in plant growth, hardiness and disease resistance; new flower colors, form, fragrance and lasting quality. Many new plants have come into existence in recent years that have completely replaced those grown 40, 30 or only 20 years ago.

The Plant Patent Act has given the consumer protection from unscrupulous promoters in two ways. The patent owners within certain limits can keep a patented plant from being produced and sold by growers not qualified to produce the quality to which the public is entitled. Before the days of plant

protection, an unscrupulous grower could easily take a superior new variety, rename it as his own and freely enjoy the benefits of someone else's work.

In addition to the stimulus given the professional plant breeder, plant patents and breeders rights have offered encouragement to amateurs and those of less experience who had curiosity and the powers of observation. Plant Patent 2463, now expired, was granted to the rose variety named 'Sea Foam.' This was the development of an automobile mechanic whose plant breeding was a hobby. In 1971 the rose 'Portrait', covered by plant patent number 3097, won the coveted All-America Rose Selection Award. It was created by a pipefitter in a Cincinnati meatpacking plant. He, too, enjoyed roses as a hobby. Each had the ability to recognize something that was distinctive, new and different and useful. For this they were granted plant patent on their inventions, and they were well rewarded financially for their efforts.

A housewife became curious as to why the native holly didn't have nice glossy leaves and why the hollies that did have a nice glossy leaves did not survive the winters. Her curiosity led to research and breeding hollies in her kitchen.. Kathleen Meserve went on to develop hybrid hollies such as 'Blue Girl', 'Blue Boy', 'Blue Maid®', Blue Stallion®, 'Dragon Lady®', 'China Girl®,', and 'China Boy®'. All were or are patented and some of the names are trademarked. She has been well rewarded for her work, and American gardens and yards are much prettier as a result.

Without plant patents these superior new cultivars might have become known only to very narrow local circles. Some of the royalty is invariably spent for advertising and publicity. This gets new cultivars into use much more quickly.

At the same time a plant patent is no seal of approval. The marketplace is still the proof of whether a new plant has merit.

Do the plant patent, trademark and breeders' rights systems work? You bet they do. Of the well over 5,000 plant patents issued there has been very little litigation. And no litigation has, to the best of my knowledge, invalidated any plant patent. These laws work. They have upgraded the nursery industry in many respects. First of all, before the days of NMC and Fall Is For Planting, it was primarily patented plants that were advertised directly to the consumer. This enhanced and benefitted the entire industry, not just the patent owners or licensees. As the result of plant patents, grades and standards have been significantly improved so consumers have benefitted from better-quality nursery stock and have had

more satisfactory experience with gardening and landscaping. And, as mentioned earlier, it has stimulated the search for new plants within our industry and by consumers.

It's not just a matter of what's new in the way of propagating techniques but what new plants are there. We all talk about new plants, new techniques, what's new! Our landscape would be much less colorful if it were not for plant patents, plant breeders' rights, and trademarks.

FORECASTING FAST TURNOVER CROPS

CYNTHIA J. STAHA

Tatterson Greenhouses
Box 7
Port Haywood, Virginia 23138

Tatterson Greenhouses is a wholesale operation growing in 28 quonset greenhouses. Our greenhouse area equals 100,000 ft^2, and we have 60,000 ft^2 in outside growing areas equipped with sprinkler irrigation. We are located in Mathews County, Virginia, located about 60 miles east of Williamsburg, Virginia.

Our product line consists of, in order of volume, bedding plant flats, 10-inch hanging baskets, 4-in. annuals, hardy garden mums, poinsettias, 4-in. perennials, and zonal geraniums.

The spring season is our busiest, and accounts for 75% of our annual sales. In five months we turn over 800 different crops, and sell 300,000 units—all on 160,000 $ft.^2$. So, from our perspective, we think our crops can be classified as fast-turnover crops.

Now, I would like to share with you how an operation like Tatterson Greenhouses plans, grows, and prevents total chaos in the bedding plant season, or in other words, "how do we forecast fast-turnover crops?"

We have two types of forecasting: long-term and short-term.

LONG-TERM FORECASTING

Long-term forecasting is done in advance. Our analyzing, planning, and ordering for a future season occurs when the present season is finished. For example: the 1986 bedding-plant season was forecast in June, 1985, and our 1986 poinsettia season was forecast in January, 1986. The following is the process we go through, and the factors we consider when forcasting our bedding-plant season.

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When the Mother's Day rush is over, the owners, sales manager, crew supervisor, and grower gather written and mental notes, and discuss the season. We discuss each bedding plant cultivar in terms of quantity, quality, color, performance, durability, availability, timing of the crops, and what we would like to see next season. Then the rounds of decisions between the owner and grower begin.

The owner goes to his corner and uses money as the basis for his decision making. He decides on (1) what is affordable, (2) which product mix is the most profitable, and (3) what needs to be grown to obtain the desired sales. In the meantime, I am in the grower's corner using plant performance as the basis for my decisions. I decide on (1) what and how many plants to grow, (2) when to grow them, and (3) what grows best in our situation. Now we have to make joint decisions and plan for the next spring season.

We use these factors to help us make the plan:

Production and sales records. This data provides us with the knowledge to answer, "How much do we grow?" From our sales records we know cold-weather vegetables have declined since 1982, therefore, we cut them back in our plan. Also, these records tell us how much we realistically produce — do we stick with 60,000 hanging baskets a year, or go for 90,000; how about if we gamble on a late crop of tomatoes?

Customer wants and needs. We listen to them. They help us answer, "What do we grow?". If they want a certain cultivar, we will consider adding it, as we did when a customer requested gazanias in 1983. And most of all they tell us "color, color, color," especially for Easter and Mother's Day.

Time of the year. This factor answers, "When do we grow it?". As I mentioned, our customers want color throughout the season. Breaking the season into smaller seasons tells us when it is the most profitable to grow certain plants. It also helps simplify planning. For instance, pansies in February, hanging baskets in March, vegetables and bedding plants in April, and anything that blooms in May.

Market trends and sales representatives. These sources keep us informed. The October, 1985, issue of *Greenhouse Manager* (1) stated that impatiens are still number one, vegetables are on the decline, and petunias and vinca are on the rise. The sales representatives, of course, tell us about new seed and plant cultivars. We also consider results of AAS trials.

After considering the records, customers, profitability, and everything else that ever mattered, we complete our plan by July.

SHORT-TERM FORECASTING

By January we are ready to put the plan into action, and this is where our short-term forecasting steps in. In other words, this is our day-to-day decision making. In our industry we must be aware of the following to manipulate our crops.

Sticking to the plan. We have found that it's okay to change the plan, but don't add to it. It is tempting to increase production numbers if the season is going well.

Space. It is limited, and availability changes from day to day. We utilize every inch by growing under, on, and above the greenhouse tables. If we increase one cultivar by 2,000 flats in the middle of the season, 2,000 flats of another cultivar need to be decreased. That's why it's important to stick to the plan.

Timing of the crops. Timing walks hand-in-hand with space. We allot space for germination, growing, holding, and shipping. Then we strive to keep the plant material moving from one area to the next, and stagger our propagation times to prevent clogging the system.

Shelf life. The shelf life of our product is relatively short. It takes a bedding-plant flat about 12 weeks to get from seed to sale. Once salable, decisions must be timely to prolong the shelf life if necessary, and to avoid plants being taken to the dump.

Being aware of the plan, space, timing, and shelf life helps us make decisions to manipulate our crops, but how do we manipulate? We can, for example: utilize sodium vapor lights to encourage growth; apply bottom heat to encourage growth; reduce temperatures to hold a crop; increase temperatures to hasten a crop; automate seeding, transplanting, and moving plants; apply growth regulators such as B-Nine[1] or Cyocel[2] to prevent stretching; withhold water and fertilizer also to prevent stretching (I've been accused of stepping on the plants to keep them short); place the plants outside after March 1 to hold them until sold; step up a flat into a four-inch pot, 10-inch hanging basket, or 7- × 15-inch window box.

So, that is how we try to forecast our fast-turnover crops at Tatterson Greenhouses. We plan in advance, try to stick to the plan, keep the plants moving, take advantage of our crop manipulation tools, and hope for good weather. We try to sell our product within the season, because we cannot profitably hold a fast-turnover crop.

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[1] B-Nine is a registered trademark of Uniroyal Chemical Co.
[2] Cyocel is a registered trademark of American Cyanamid Co.

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CROP FORECASTING FOR TWO TO THREE-YEAR CROPS

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What do we grow? Broadleaved evergreens primarily in raised field beds. How many do we grow? Currently over 300,000 plants of about 100 cultivars annually. What is the length of production cycle from propagation to sale?

Almost ½ of production is sold in 2 to 2½ years.

Almost ½ of production is sold in 3 to 3½ years.

(Exceptions — A few items are sold within 15 months. A few items are held for almost 4 years.)

HOW DO WE FORECAST FOR 2 TO 3 YEAR CROPS?

Our overall business philosophy actually sets the basic foundation for deciding what plants to grow and in what quantity. Over the years we have aimed to:

1. Build our nursery by growing the best broad-leaved evergreens available in the industry.

2. Limit production to what we can produce while maintaining the very top quality available.

3. Make a fair profit consistently.

4. Avoid the boom and bust cycles common to our industry.

5. Efficiently execute a planned production cycle.

6. Sell out every year at our preset catalog price.

7. Build business volume by supplying quality and service that holds regular customers who purchase in increasing quantities every year.

Of course, each grower has to choose the plan or philosophy that suits him and his nursery operation. There are certainly advantages and disadvantages to the plan we have chosen.

One of the advantages is that it makes deciding what and how many to grow fairly simple and effective. Our forecast now for two to three years ahead is primarily based on what we have been growing and selling in the past. These numbers

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CROP FORECASTING FOR TWO TO THREE-YEAR CROPS

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Chesapeake Nurseries, Inc.
Pemberton Drive
Salisbury, Maryland 21801

What do we grow? Broadleaved evergreens primarily in raised field beds. How many do we grow? Currently over 300,000 plants of about 100 cultivars annually. What is the length of production cycle from propagation to sale?

Almost ½ of production is sold in 2 to 2½ years.

Almost ½ of production is sold in 3 to 3½ years.

(Exceptions — A few items are sold within 15 months. A few items are held for almost 4 years.)

HOW DO WE FORECAST FOR 2 TO 3 YEAR CROPS?

Our overall business philosophy actually sets the basic foundation for deciding what plants to grow and in what quantity. Over the years we have aimed to:

1. Build our nursery by growing the best broad-leaved evergreens available in the industry.

2. Limit production to what we can produce while maintaining the very top quality available.

3. Make a fair profit consistently.

4. Avoid the boom and bust cycles common to our industry.

5. Efficiently execute a planned production cycle.

6. Sell out every year at our preset catalog price.

7. Build business volume by supplying quality and service that holds regular customers who purchase in increasing quantities every year.

Of course, each grower has to choose the plan or philosophy that suits him and his nursery operation. There are certainly advantages and disadvantages to the plan we have chosen.

One of the advantages is that it makes deciding what and how many to grow fairly simple and effective. Our forecast now for two to three years ahead is primarily based on what we have been growing and selling in the past. These numbers

come from over 20 years of adjusting. Much adjusting during the early years was done by trial and error.

To sell out every year, we must have the proper mix. Our forecasting is enhanced by fine tuning our propagation list each year at the last opportunity in mid- to late June. By this date about ⅔ of our next year's inventory of salable plants has been booked. It is fairly easy to run down the inventory printout of orders booked for the 100 or so items we grow. We can see what is moving or not moving and spot trends that are very current. Adjustments, usually small but important in estimating the proper mix, are made to the propagation list.

While setting the propagation figures each year is, in essence, casting in stone our two- to three-year forecasts, there are several items other than current ordering trends that influence our forecasting.

Being aware of what the customer wants is important. Telephone communication and visits with customers help. Several years ago we sent out a very comprehensive four-page questionnaire to our customers and got back a lot of good information about what they wanted, including not only cultivars but also service. Two years ago we sent a small form with each trailer shipped from the nursery. Practically every customer completed and returned the form, which gave us important feedback.

Visits with other growers help in our forecasting by making us aware of what others are growing.

Attending trade shows and meetings informs us of what is happening in our industry. This information helps in better forecasting.

Searching out new plants or plants new to us, testing them and growing the good ones helps in getting the proper mix our customers want. Selecting new additions is one of the hardest things to forecast successfully. Over the years there have been many items that we liked and tried but for various reasons, often hardiness related, they have not been right for us.

Also factored into our forecasting would be our long-range plans looking out five to 10 years or more and considering anticipated expansion or major changes in production.

I am thankful that I do not have to attempt to factor into our forecasting the fluctuations of interest rates and housing starts and the ups and downs of the economy. The more I see the experts unable to predict the economy with any degree of accuracy, the more I realize our goal of growing good plants in moderate numbers suits me just fine.

In summary, I would say the accuracy of our forecasting is

determined more by successful execution of our business plan or philosophy than by being astute in predicting the future.

FORECASTING FOR CROPS: 3 TO 5 YEARS

EARLE ROBERT MARVIN

Wildwood Nurseries
Route 4, Box 616
Walterboro, South Carolina 29488

Wildwood Nurseries is a three generation nursery, which will be 50 years old in 1986. My grandparents, W.R. and Alta Marvin, started our nursery, planting plants they loved, azaleas and camellias. Today, we are not so fortunate, we have to choose plant material that will meet wide geographical conditions and also meet the need of a changing population and environment.

Our nursery is located on 480 acres, of which we use about 150. We have a very intensive field operation, extending from field to container operation. This field to container operation gives us flexibility, and we have been working on improving this system for 11 years.

My father, Robert E. Marvin, and I own Wildwood Nurseries. Dad is a landscape architect. We base our sales goals and plant material cutlivars on the needs of the landscape architect. Their certain needs are our specialty, whether it be small or large evergreens, flowering trees, large trees for sun control, large or small screening material, plant material for a certain location, leaf size or color for the purpose of depth perception or esthetic effect in the landscape. We have a mailing that goes to landscape architects throughout the country, advising what we have and asking what they want.

We then consider our choice of plant material based on its ability to sell well, its geographic range, and its freedom from maintenance problems. Due to our particular methods of growing and rotation, we like our plant material to be fast-growing and what we call reasonably transplantable. If we agree that a plant meets a number of these requirements, it goes on trial. We have approximately 25 plants on trial at this time. The plant is then observed for liveability after planting, its ability to be moved or harvested with minimum lost. For trial purposes, we usually plant 25 to 50 plants. If we receive good customer response to this new plant, then we proceed with planting based on sales demand.

We do not believe in planting a plant because it is different or because it is selling well at the moment. We do consider

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FORECASTING FOR CROPS: 3 TO 5 YEARS

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customer needs and our service to them. We do listen to our customer needs and are influenced by the market, trade shows, trips, and consultants that we use frequently. Our sales area ranges from Washington, D.C. to Florida, to Texas, and in between. Each has its own special needs, climates, and requirements that we fit our program of plant selections around.

We do the best possible job to assure we have the most transplantable material that can be bought. We believe reliability and uniformity help sell our product. In the end, we do not sell plant material, we sell satisfaction.

Now, I would like to end by asking you a question. I am looking for a tree: 30 to 40 ft., small leaves, early shed, beautiful bloom, fall color, fast growing for sun control, shade in the summer and sun in the winter? Does anyone have such a tree?

FORECASTING FOR PURCHASING

AL FRITZ

Shemin Nurseries, Inc.
P.O. Box 355
Burtonsville, Maryland 20866

Shemin Nurseries, Inc. is a joint venture with Weyerhaeuser Co., Inc., Tacoma, Washington. In 1979 Emanual Shemin joined with the Weyerhaeuser Company in a venture designed to expand Manny's original unique concept of a "one-stop horticultural distribution center". From 1963 to 1979 Shemin's was a wholesale-retail center in Bronx, New York and later was changed to strictly wholesale in Greenwich, Connecticut.

With the financial backing of a committed international company, expansion of this concept began in the fall of 1980 with the purchase of property in the Washington, D.C.-Baltimore, Maryland area. Centers were soon added in Atlanta, Georgia, in spring of 1981; Chicago, Illinois in 1983; Detroit, Michigan, Miami, Florida and Aalsmeer the Netherlands in 1984. Philadelphia, Pennsylvania in 1983; Toronto, Canada and Boston, Massachusetts will follow in 1986. Future plans include many other major cities. Each site is from 22 to 40 acres of fully-automated irrigated beds.

Forecasting purchasing on this scale is a tremendous undertaking. At present one full-time and one part-time person purchase more than 2000 trailer loads of live nursery stock, including bareroot, container, and balled-and-burlapped stock. Purchases are distributed as follows: 600 trailer loads to Con-

customer needs and our service to them. We do listen to our customer needs and are influenced by the market, trade shows, trips, and consultants that we use frequently. Our sales area ranges from Washington, D.C. to Florida, to Texas, and in between. Each has its own special needs, climates, and requirements that we fit our program of plant selections around.

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necticut, 500 to Maryland, 375 to Atlanta, 250 to Chicago, 100 to Detroit, 75 to Philadelphia, and 150 to Toronto. Sites in Florida and Holland are foliage sites.

A 10-year-old facility, which we consider a mature operation, will sell in excess of 600; 5 to 6 year old sites, 500; 3 to 5 year olds sites, 250 to 375; and 1st year centers, 75 to 100 trailer loads per year.

So you see, in order to forecast our need for this amount of material we must ask ourselves a number of very important questions.

The first is: What is our business plan? What do we propose to do in sales in each of the sites that are functioning, and what are our plans for future sites? If we assume that the seven functioning sites will grow at a conservative rate of 75 to 100 trailer loads per year and that the new Boston site will use about 75, we will need 525 to 675 additional trailer loads next year. Any unforeseen new acquisitions or quick start-ups that are not necessarily in the plan will, of course, increase requirements even more.

The second question is: What is our market? We must consider the characteristics of the area as well as the primary activity of our customers themselves. Is the area heavy in can production, such as Atlanta; or are we in a heavy B & B producing area, such as Maryland? Will our customers be accustomed to going directly to these local growers?

And what about our customers? Are they landscape contractors, property managers, builders, or government agencies, who traditionally use larger B & B material? Are they garden centers or mass merchandisers who use smaller B & B and cans?

We must also ask, "What is in fashion? What are the hot items in greatest demand? Leyland cypress, perennials, gumpo azaleas, hemlock, upright or blue hollies? What has fallen out of fashion?" For example, many landscape architects used Kwanzan cherry one year and Yoshino cherry the next.

Another factor in fashion is related to hardiness. *Raphiolepis* is popular in the South, *Nandina* in the mid-Atlantic, and certain *Ilex* cultivars in the Northeast. Consumer acceptance, or acceptance based on semi-hardiness, are strong influences on forecasting.

It is also essential that we consider our supply sources. What is the supply locally, regionally, and nationally? Who do we depend on? Can our usual suppliers keep up? Do we need more supplies?

Let us begin with the case where material is in short

supply. We first look to our regular suppliers, knowing that they have a reduced length and breadth of supply. The first question we ask is: Can we at least get our fair share? Then, what are our tools to ensure this supply?

1. We pay our bills on time.
2. We can pre-pay deposits.
3. We commit early.
4. We honor our commitments (even when fashion changes saleability).
5. We try never to take unwarranted credits.
6. We can take large amounts of materials that a grower may be long on to help balance his inventory.
7. We try to take a broad-based product mix.

We must be cautious in our approach and commitments to new suppliers. Because of the tight supply, the growers are in the so-called driver's seat, leery of one-time business, leery of our insatiable appetite for goods. "Shemin can use your whole production!" We must impress on them a number of key points:

1. We know that we are "johnny-come-lately" and that they have a loyalty to and long-lasting relationships with previous customers.
2. We do not want to be every grower's largest customer.
3. We want to start on a trial basis working toward a mutually beneficial arrangement.
4. We want the grower to plan with us and grow with us as we expand.

Let us also look at our procedure when plant material is in overproduction. With our regular suppliers we must continue our relationships:

1. We should not be concerned only with price, although the price must be in line with the market.
2. We should continue to purchase, especially from those who were fair to us when shortages were prevalent.
3. We must be aware that, although the shoe is now on the other foot, unfortunately for both the grower and us, the cycle will swing back again.

We must gauge this carefully and be very conservative with new suppliers so as not to fail to take our fair share from those who helped us.

How do we assess our market? Frequent trips into the marketplace give us our best view. Each grower that we use is

visited at least once each year. Larger growers in terms of volume may be seen 3 or 4 times. We make many trips into the local areas surrounding each site for local growers. These trips will give us a good overview of what is in production and improve our sensitivity to the market.

How do we assure ourselves of adequate purchases? We do it by knowing the business trends. Are single family or townhouses the trend? Is the area commercial or residential? Will there be new plantings in growth areas like Atlanta and Maryland, or replantings as in Connecticut? We make sure to keep our relationships with our vendors on an even keel. We pay constant attention to the supply side. What is ready now? Should we arrange contract purchasing and, if so, how far ahead? What items should be contracted — specialty items, bread-and-butter, or novelty items? We assure adequate purchases by making our commitments early and taking what we commit to. We do it by making sure that although it's of primary importance to us that we make money, it is also important that our suppliers flourish and make profit.

How can we help the grower? Specifically, I feel we are obligated to pass on market trends, fashion, and changes in customer types. We should work together toward making the market drive production, bringing a sense of order, rather than allowing production to drive the market. When production drives the market, price cutting is the result, which is disastrous for both the grower and the wholesaler.

In summary, in order to forecast purchasing you must know the following:

1. Your business plan.
2. Your market and customers.
3. The current fashion.
4. The available supply.
5. The tools needed to assure adequate purchases.

PLANT MODELING: DEVELOPING AN APPROACH[1]

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WHAT IS PLANT MODELING?

Webster defines a model as information, data or principles which are arranged or grouped mathematically. The algebraic formula $y = mx + b$, which is used to fit a straight line, is a

[1] Texas Agricultural Experiment Station Journal Series No. TA. 21194.

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simplified form of a model. Basically a model is a means of classifying or categorizing. In order to simplify daily activities, we use models frequently. When meeting a stranger, we may categorize or classify that person based on our previous experience or "models" in our minds. We may classify or categorize how we produce an azalea crop versus a *Pittosporum* or *Ligustrum* from the standpoint of media requirements, pH, and light intensity. The difference with plant modeling is that we are using hard data. We take quantitative values and plug these numbers into a statistical program (equation) to derive a statistical model.

In September, 1985, the American Association of Nurseryman published a list of research priorities that included the need to determine growth dynamics for various nursery crops; that is, to develop mathematical models that could describe environmental treatments and effects on plant responses. The ultimate goal is to increase plant productivity through better understanding of how environmental treatments influence plant growth, characteristics and potential.

Modeling is a *predictive* response. Modeling is accomplished by using equations to help quantify and give us an estimate on the growth response of a plant based on the environmental conditions under which that plant is being manipulated.

Goals of plant modeling. Modeling is designed to have direct application to: 1) predictable plant quality, 2) predictable plant inventory turnover, i.e., minimizing plant residency in the nursery, 3) maximizing people, plant, materials, energy, and scheduling efficiency, 4) customizing growing conditions, and 5) minimizing costs.

In modeling it is necessary to quantify and keep records. It is important that environmental data be collected and quantified so that management decisions can be made based on facts, and not just intuition or guess work. Modeling attempts to take some of the *art* out of propagation and production and make it more of a *science*.

Current usage of plant modeling. There are many examples of plant modeling in use. Growth chambers from small cabinets to large specialized warehouses are manipulated to determine and control environmental conditions for optimum plant growth. In the greenhouse industry modeling is being utilized, particularly in environmental climate-control systems. In Holland there are some 8,000 climate-control computers employed in commercial greenhouse operations (3). In agronomy, degree-heat days are used to predict when corn should be planted and when maturation will occur for harvest-

ing and processing. In fruit crops, chilling-degree hours are monitored to determine dormancy requirements of apples, peaches, and other crops. Once the designated number of hours at 43°F (5°C) is reached, the dormancy requirement, or the ability of that plant's buds to force out has been met. Chilling-hour requirement is a model to help give a rough estimate of when this occurs for a particular plant.

The important area of water relations is also being used for model development. In production of nursery pine seedlings, Weyerhaeuser Corporation utilizes pressure bombs to determine water management programs. The pressure bomb helps to assess leaf water status, which can then be used to determine necessary irrigation frequency to maximizing seedling girth, height and other characteristics. Manipulating the irrigation frequency can also bring seedlings into dormancy in the fall to improve the plant's survivability after the seedlings have been lifted for transplanting. Jackson and Perkins are using pressure bombs to determine water status before digging dormant field rose bushes. Objectives are to correlate water status of rose bushes with optimum survivability of processed rose bushes.

Model user vs. modeler. It is important to differentiate between being a model user versus a modeler. Most of us will use statistical programs (models) that have been designed by researchers and statisticians (modelers) to be used on personal computers. Once suitable models are developed for nursery propagation and production systems, we will see much greater usage on a commercial scale.

Computer usage — monitoring, controlling, modelling. Computer usage in nursery crops currently consists of monitoring, using data loggers or automated weather collection systems. For example, in determining fungicide application programs for apple scab control, data loggers gather information on relative humidity and temperature. The producer can then make more accurate management decisions on most efficient fungicide usage. Controlling climate is another aspect of computer use. And last, statistical equations, or models to determine optimal environmental conditions for plant productivity are slowly being developed and adapted.

In order for modeling to be successful we must first select test model nursery crop species to use. Environmental conditions must be standardized where possible. This is difficult in container production and under open field conditions. However, there are opportunities for environmental control under propagation and greenhouse systems.

Methodology of crop modeling. Methodology of crop mod-

eling in the nursery begins with data collection. Gathering data from a data logger (automated weather collection systems) and compiling it into a computer data base would be one way to collect data. Data analysis consists of utilizing the data collected, quantifying it by using spread sheets such as Lotus 1-2-3®, and then adapting a statistical program such as Plotit® which can be utilized with an IBM PC and other systems (5).

Plant propagation, production, and modeling. Crop modeling can be applied to propagation systems using a statistical technique known as regression. In the mathematical model presented, for seasonal rooting of hardwood rose cuttings, a slope known as the regression line is fitted to the various points that represent the month cuttings were propagated and the subsequent rooting percentage (Figure 1) (2). From this model, or statistical package, one can better understand environmental parameters under which the cuttings were taken and the ultimate predicted success rate in future years.

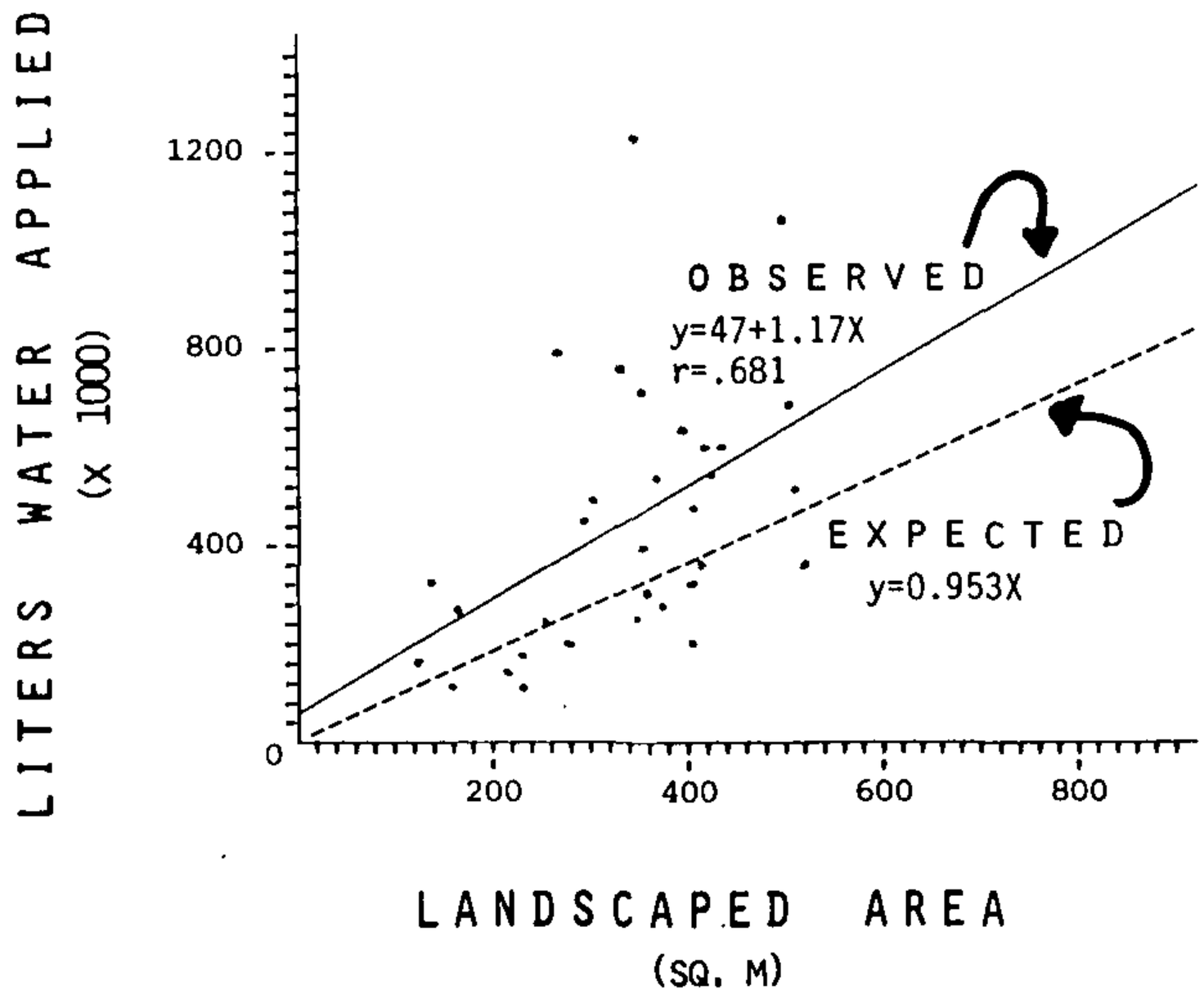

Figure 1. Regression model of propagation date on percent rooting of *Rosa multiflora* hardwood cuttings. $y = 21.196+33.866x-5.143x^2$ $R^2 = 0.22$. [From C.E. Hambrick, 1985, (2)]

Models can also be used as management tools. For example, pan evapotranspiration estimates as a model can be used to predict expected water usage needed to water a consumer's yard and then compared with actual observed water usage that occurs later (Figure 2). From the predicted model (dotted line) versus that of the actual water usage (solid line), one can determine if water is being wasted by the consumer (1). Based on the prediction model, 40% more water is used to irrigate

than is needed. This same type of model could be used in wholesale nursery production where frequently more irrigation water is applied than is needed.

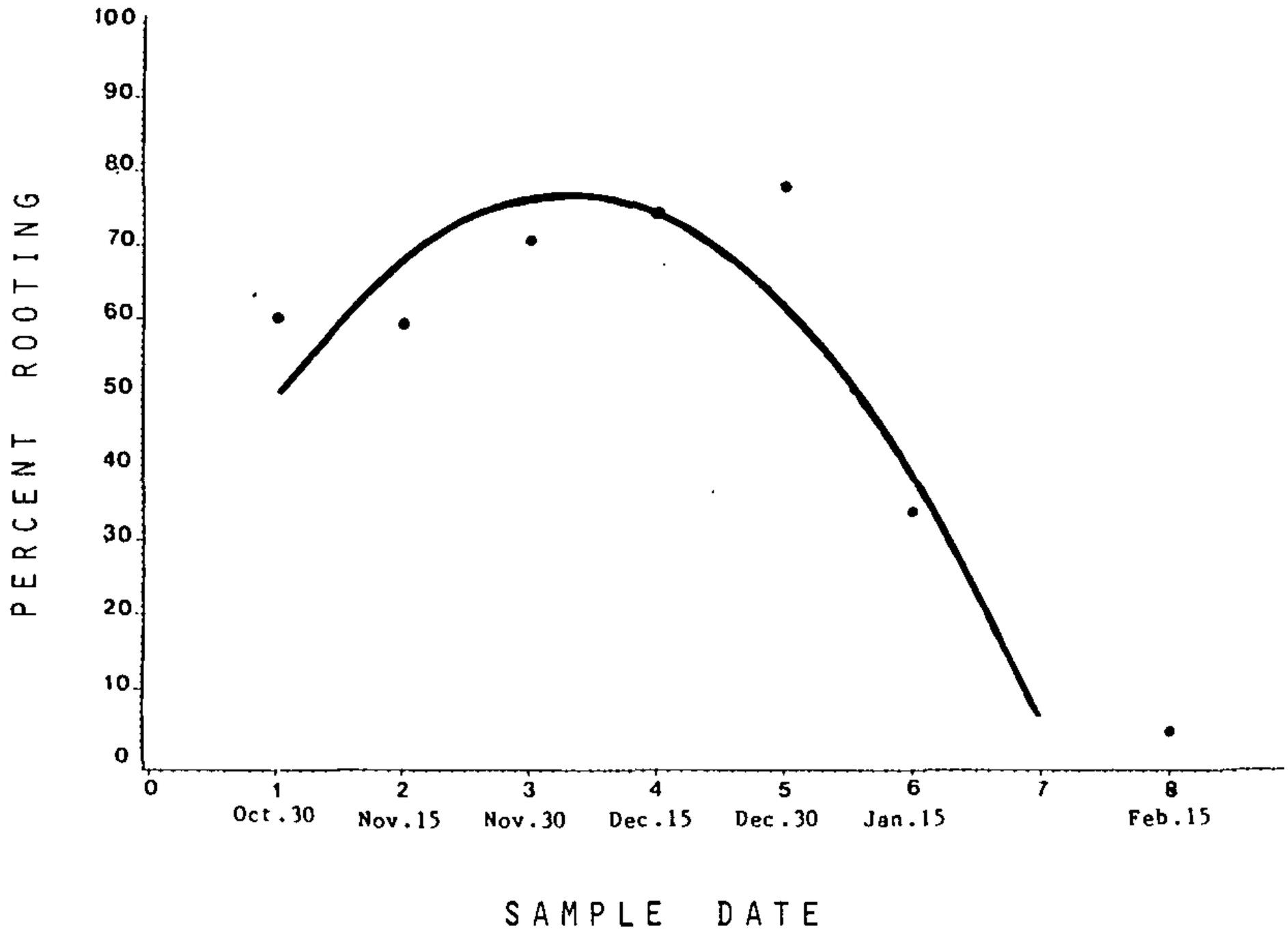

Figure 2. Water application rates on urban landscapes. The effect of landscape size on actual and expected water use. From Cotter and Chavez, 1979, (1).

In England environmental computer control systems are being utilized in commercial plant propagation systems. One method of propagating cuttings in England is to stick conifers during the fall and early winter in trays covered with plastic without intermittent mist. When temperature and light intensity are properly controlled, cuttings root without the detrimental effects of leaching and pathogens often found with intermittent mist systems. A computerized propagation system is used to monitor light intensity, photoperiod, CO_2 levels, temperature, and relative humidity. Acceptable light intensity levels are normally 1.5 to 3 megajeuls/m^2/day, or 100 watts per m^2, for ideal propagation. When light intensity becomes too high, the system triggers automatic shading from the top and sides of the propagation house.

Models could also be used to manipulate temperature of

media in rooting cuttings. Some commercial nurseries on the U.S. West Coast are testing temperature responses of propagation beds by recording temperature on data loggers (Campbell Scientific, P.O. Box 551, Logan, Utah 84321), then funneling data onto an IBM personal computer, quantifying the data, and using a statistical program to develop a model. From the model developed, optimal temperature conditions can be determined for future propagation. The advantage of developing a model is that the grower in the future can program his bottom heat to obtain optimum rooting response. In containerized production in quonset houses where growth continues during the spring, winter, and fall months, light intensity and temperature can be manipulated and modeled to determine optimal crop growth responses.

In an open container nursery or field production system, the ability to manipulate environment is considerably more difficult than that found in propagation or greenhouse systems. However, plants can be grouped by growth characteristics. The light intensity, fertilization media, and pesticide programs can be changed accordingly. Examples of outdoor systems available are ARAX (Transwave Corp., P.O. Box 489, Vanderbilt, PA 15486). This is basically a data-logger system used to establish and collect climatology data as well as soil parameters. By quantifying the data from the ARAX system, the grower and producer can determine more accurately irrigation systems, fertility programs, pesticide and fungicide applications.

Plant stress and modeling. Another important goal of modeling is the potential to reduce plant stress. Under commercial production systems in the southern U.S., high container-media temperatures cause plants to undergo summer dormancy and greatly distort root growth and development. Work has been done by Newman and others (4) to study leaf-water status by utilizing pressure bombs based on various high-temperature regimes. By following fluctuations in the water status of leaves and roots, one can establish plant models based on actual growth and development of plants at various temperatures.

Models could also be developed to predict the fate of plants in shipping. It is not uncommon in the south for nonrefrigerated truck cargo temperatures to reach 140° to 150°F (60° to 66°C). This very much influences the longevity and quality of nursery products.

What are the limitations of plant modeling? The noted plant modeler, Dr. Ben Zur of Israel, has pointed out that to date management model programs have only shown us good management techniques already known to good producers. These management model programs may be useful to new and

to less successful growers. However, lack of precise knowledge of plant inputs, poor data collection and methodology limit the establishment of accurate predictive models.

The long range benefits of plant modeling. We need to think in terms of propagating and producing plants not just with today's technology but with new systems coming in the next 20 years. It may well be in the next 25 to 30 years that a sizeable portion of retail nursery items will be produced under specialized warehouse conditions where environmental controls are manipulated. Tissue culture and accelerated growth techniques (AGT) of light, fertility, CO_2, and water manipulation are examples of such controlled conditions.

Growers must become more receptive to computer usage in the quantification of data to make better managerial and production decisions. As our ability to take more accurate environmental and plant data improves, the use of more precise models to make management decisions will enable us to be more productive and efficient nursery producers.

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PLANT MODELING — PRACTICAL APPLICATIONS

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A "model" is another term for a set of equations that describe the system in question. Their purpose is to help make decisions. These models can be very simple or complicated and are simply an organized expression of knowedge about the interacting factors in a given system. Models may cover very broad areas or deal with only very specific situations. Vrecenak and Harrington (1) attempted to model the transpiration of trees in urban areas. They concluded that modeling held promise of aiding in urban plant management but noted that

to less successful growers. However, lack of precise knowledge of plant inputs, poor data collection and methodology limit the establishment of accurate predictive models.

The long range benefits of plant modeling. We need to think in terms of propagating and producing plants not just with today's technology but with new systems coming in the next 20 years. It may well be in the next 25 to 30 years that a sizeable portion of retail nursery items will be produced under specialized warehouse conditions where environmental controls are manipulated. Tissue culture and accelerated growth techniques (AGT) of light, fertility, CO_2, and water manipulation are examples of such controlled conditions.

Growers must become more receptive to computer usage in the quantification of data to make better managerial and production decisions. As our ability to take more accurate environmental and plant data improves, the use of more precise models to make management decisions will enable us to be more productive and efficient nursery producers.

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PLANT MODELING — PRACTICAL APPLICATIONS

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A "model" is another term for a set of equations that describe the system in question. Their purpose is to help make decisions. These models can be very simple or complicated and are simply an organized expression of knowedge about the interacting factors in a given system. Models may cover very broad areas or deal with only very specific situations. Vrecenak and Harrington (1) attempted to model the transpiration of trees in urban areas. They concluded that modeling held promise of aiding in urban plant management but noted that

more accurate input information for the model was required.

An example of a very broad model would be one describing the demand for large container-grown trees in succeeding years. The model might consist of the following equation:

$$D = C + L + S + / - A + / - P + / - W - O$$

D = demand for container-grown trees in general

C = construction starts in your geographic sales area

L = local attitudes for tree planting

S = sales effort/promotion

A = alternative tree-production practices

P = price

W = weather conditions

O = other nurseries' reactions to anticipated demand

Construction starts are easy to obtain from city or county records. Local attitudes towards tree planting are more difficult to obtain. However, a good example of an influencing factor is the "Oklahoma City Beautiful" program, which is having a positive influence on the number of trees being planted.

Sales effort and promotion of container-grown trees is dependent on personnel and, to some degree, the quality of the product. Adding a good salesperson in an active geographic area may have a great influence on sales. Or splitting a sales region if the current sales person is unable to make contact with all the possible customers could have the same effect.

Alternative tree-production practices such as conventional field production and B & B or tree spade digging practices will remain. However, if winter and spring rains frequently limit harvest and sale of trees, field-grown and geographic conditions limit summer digging/handling of trees grown/dug with these methods, then container production would be a plus. For example, late spring and summer planting of B & B or spade-dug trees in the mid-Atlantic states is not as risky as it is in the prairie corridor of Texas, Oklahoma and Kansas.

Price is always a factor to consider, especially relative to demand the various alternative production/handling methods. In general, the cost of producing sizable trees in large containers is more expensive than field production. Because of the greater production cost and the large up-front capital investment required, estimates of future demand must be as accurate as possible.

Weather conditions could be separated into many segments or grouped as I have done here. In general, I am treating weather conditions as a broad area including summer-heat

stress and overwintering stress relative to the wholesale producer, the landscape contractor or retail garden center. Wind and the problem of keeping container-grown trees upright is another weather variable. Weather conditions in northern states could be a substantial negative factor due to the cost of overwintering an above-ground container. On the other hand, in areas of Florida and the southeastern states weather conditions might be a minor negative factor.

The reaction of other nurseries to the anticipated demand must also be considered. If many wholesale nurseries in your geographic sales area are also expanding their production of container-grown trees, a larger negative factor should be included.

To take the example further, place some hypothetical numbers in the equation. Construction starts are projected to be up 10% in two years when the crop of container-grown trees you are considering will be ready for sale. The sales effort/promotion is to be increased 25%. There are no current or anticipated changes in attitudes relative to the geographic sales area. Alternative tree production is up — but only about 5%. The price of the final product will be up about 15%, but alternative production will be up a similar amount so, proportionally, consider no change. Weather conditions have been consistently hurting alternative (conventional field) production of trees. Add a 10% advantage to container-grown trees. Other nurseries are generally increasing their production of large container-grown trees as well, so adjust your estimate down by 15%.

You end up with the following equation:

Demand for container grown trees = + 10% + 0 + 25% − 5% − 0 + 10% − 15%. Thus, anticipated demand will be up by 25%. If your nursery sold 11,253 trees in containers 10 gal. or larger last year, you should consider producing 25% more for sale in two years, or 11,253 + 2813 = about 14,066.

One could argue that by simply taking sales figures for several years past, then projecting into the future, a similar value would be reached. Projecting from current and past sales does provide useful information. However, it does not take into consideration the assortment of present and future factors that can be incorporated into a model.

.Consider a second example that deals with a much more specific situation. The calcium and magnesium requirements of plants grown in soilless mixes in containers appears to be quite specific. However, there are several factors involved: 1) the amount of calcium and magnesium in the components of the mix; 2) amount of calcium and magnesium in the water

supply; and 3) the length of time the crop requires to reach salable size. Since dolomite is used almost universally as the supplemental source of calcium and magnesium, set up a model as follows:

$$\text{Approx. 60 ppm calcium is needed for plant growth} - \frac{\text{ppm Ca in mix}}{\text{number months of crop}} - \frac{\text{ppm Ca in water}}{\text{supply}} = \frac{X}{7.5}$$

One lb. of dolomite will supply approximately 7.5 ppm calcium in a container growth medium. Therefore, if the equation for a specific nursery mix and water is

$$60 - \frac{150}{7} - 40 = 1 \text{ ppm needed, or essentially no dolomite.}$$

On the other hand, if another nursery has only 8 ppm Ca in the water supply and is using the same growth medium the equation would be:

$$60 - \frac{150}{7} - 8 = \frac{31 \text{ ppm needed}}{7.5} = \text{Approximate 4.1 lbs. of dolomite}$$

The same procedure could be done for the magnesium, which appears to be approximately ½ of the calcium requirement.

These figures are rough approximations at this time. However, with additional experimentation and data the equation can be adjusted and refined for greater accuracy. Remember, the equation is simply an organized expression of knowledge about the interacting factors in a given system. The equation should also be an effective tool in preventing oversights of factors when considering adjustments in cultural practices.

Use of models in various aspects of the nursery industry is new but holds promise of becoming another useful tool, especially when incorporated into computer systems.

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QUESTION BOX

The 1985 Southern Region Question Box was moderated by Bryson James, McMinnville, Tennessee, and Carl Whitcomb, Stillwater, Oklahoma.

TED RICHARDSON for Robert Wright: What would be an unacceptable temperature for a hardened plant root of a young plant?

ROBERT WRIGHT: It would depend on how high temperatures had been previously. It is difficult to be precise because of the many variables involved.

DON COVAN: What if only the xylem is affected? Is water movement inhibited?

ROBERT WRIGHT: The damage will show up later when water stress occurs. Research indicates that bark split is caused by ice crystals between the xylem and the phloem. The southern exposure of a plant can quickly reach 60° to 70°F in the sun. There is a relationship between the rapidity of change and the amount of damage. However, it is hard to tell just how fast actual damage does occur.

FRED MAY: What effect does nutrient level have?

ROBERT WRIGHT: Adequate nutrition makes for a healthy plant that is better able to withstand cold temperature. The danger comes when growth is prolonged too late and new shoots have no chance to acclimate. In that case the new shoots would be killed.

I was asked about the use of Kocide to prevent ice formation. I do not think application of the material is a viable alternative to proper acclimation.

Question to DAVID MORGAN: Have you done any selection for edible acorns?

DAVID MORGAN: No, I have worked primarily with landscaping characteristics.

Questions to JERRY BILLINGTON: How much of your bed is supplied with hot water?

The entire bed is supplied

How do you clean the sand?

We do very little preparation. We do use some fungicide but have had no disease problems.

Is there anything covering the sand?

No, the flats are placed directly on the sand.

Question to DAAN KNEPPERS: Are there any liquid formulations for slug control?

Yes, there are several.

BRYSON JAMES: Guthion and Zectran are both effective.

Questions to PETER VEN DER GEISSEN: How much area can you heat with one burner?

We used one burner in the middle of a 30 × 100-ft. house at our location near Mobile, Alabama.

Is the heat even?

The heat is being carried by the steam; and when either door is opened, the steam is there.

TOM MCCLOUD: There was a question asked about the use of Dip'N-Grow. We use this product but sometimes get burning. We are not sure of the material's consistency, but usually have good results. Dip'N-Grow is a 2:1 combination of IBA and NAA.

CARL WHITCOMB: Jim Berry's report in the 1984 IPPS Proceedings gave excellent information on rooting materials and how to mix them.

DICK BIR: There was a question about a fungus that develops on sourwood during the growing season. We have seen this but find that if the trees are in full sun and receive adequate moisture, there is no problem. They must be cared for.

DAVID MORGAN: I was asked about the performance of shade tree cuttings when they are grown out to full size. We have seen no problems as compared to those propagated from seed or grafting.

FLETCHER FLEMER: They probably do not grow off quite as well for us as the budded trees, but the cuttings do make a very acceptable plant.

CARL WHITCOMB: We have had very good luck with cuttings of lacebark elm and London plane tree. There is really nothing to keep us from using cuttings for shade trees as we learn the techniques of rooting the various cultivars.

Question to BILL BARR: How do you get a cutting of 'Crimson Pygmy' barberry as long as 6 inches?

We have no trouble finding cuttings this long, although about 4-in. cuttings are probably best.

BRYSON JAMES: How often do you fertilize the plants that you use as a source of cuttings?

BILL BARR: We fertilize with every watering.

I was asked about using dormant cuttings with bottom heat. I have not tried that but have tried taking dormant cuttings late. I have not been successful. Temperatures would naturally be warmer then than during the usual time for tak-

ing dormant cuttings. I understand that other propagators have been able to root cuttings at that time.

TED GOREAU: Some years we have been able to root 'Crimson Pygmy' clear into October — then the next year, no luck.

ALAN BUSH: I was asked about a safe granular herbicide for use on *Hemerocallis.* We have had no trouble with Treflan, Devrinol or Surflan in tests. We use very little in actual practice.

CARL WHITCOMB: Ronstar and Goal may cause injury if trapped by the leaves.

KIM WHEELER: We use Eptam, then irrigate, and have no damage.

LARRY EDWARDS: Is there a herbicide recommended for liriope?

CARL WHITCOMB: Treflan seems safe.

CHARLIE PARKERSON: I was asked to give the cost of chlorine that we use for water treatment. The way we buy it, our total annual cost for the chlorine gas in cylinders is $800.

TED RICHARDSON: There has been a good bit of interest in the container-grown hemlock the group saw yesterday on the tour. My tip on these is to buy the trees almost ready for market — 13-yr-old seedlings, perhaps — then containerize and sell. I found these at a good price and am doing just that.

Question to MICHAEL DIRR: What treatments are needed for germinating seed of *Stewartia*?

These seeds have double dormancy and require 5 months of warm stratification followed by 3 months of cold. Cuttings root fairly well, but transplanting can be a problem. They should not be moved until they go through one season of dormancy.

TED RICHARDSON: I have found that the leaves must not dry out at any time. Mine go to Florida following the rooting, so transplanting is no problem. The roots are fine and seem not to harden.

BILL CRAVEN: I have found it hard to overwinter *Stewartia* cuttings even in a heated greenhouse.

THOMAS MCCLOUD: One question that seems to come up repeatedly is whether or not the base of cuttings should be stripped. Both Don Covan and Milton Schaefer tell us they have found no difference. Milton says he strips deciduous cuttings only enough to get into the medium easily. The Eastern Region had a panel discussion on the very question. The panel members had found this same thing. The only advantage

to stripping bottom leaves was the ease of sticking the cuttings.

WILL WITTE: There has been a question about an unexplainable dying of Japanese black pine that has been reportedly due to a stem nematode. Actually, the pinewood nematode is a fairly common problem with most pines. If there is a question about whether or not nematodes are present, take core borings, put them in water and the nematodes will come out and can be seen using a microscope.

CHARLES ELSTRODT: Apparently also there is a disease present that is carried by a beetle. The insect is attracted by a pheromone given off by a dying tree. Thus, it is only attracted to trees that are already in trouble.

CHARLIE PARKERSON: There had been some discussion of the problem of apparently healthy azaleas breaking off right at the soil line. I have been told this is a genetic, mechanical, or disease problem; but we have had no luck in finding any of these causes present. The malady seems to move through a bed.

CARL WHITCOMB: Kenneth Baker, IPPS Western Region, thinks this characteristic is in the tissue but that the plant does not always express it.

LARRY EDWARDS: Was there any relationship between this and using Benlate?

CHARLIE PARKERSON: We did not find any.

RICHARD YOUNG: I have had it diagnosed as cylindrocladium. I do not think it is freeze damage.

RICHARD MARSHALL: We don't use herbicides in our azaleas and use very little Benlate but still have the problem. I believe it is stem-related, perhaps cylindrocladium, as the roots have looked good.

ROBERT WRIGHT: I have been asked about the bicarbonate problem in water. Perhaps this explanation will help. The hydrogen in the bicarbonate can change the solubility of many of the micronutrients in the soil so that they remain unavailable to the plant. As limestone dissolves, the carbonate changes to bicarbonate so that it, too, affects the solubility of other compounds in the soil and soil solution. The biological activity of the plants themselves enters in. The benefit of foliar feeding microelements is very marginal. Only extremely small quantities are needed so there is danger involved in applying in this way to compensate for their unavailability. Don't guess about what is being put out or about what your plants need.