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IMPORTANCE OF EARLY NUTRITION IN PLANTS

BRIAN C. HANGER

Department of Agriculture, Horticultural Research Institute, Knoxfield, P.O. Box 174, Ferntree Gully, 3156, Victoria

Abstract. Three studies were conducted to demonstrate the importance of nutrition on the growth and development of young seedlings and rooted plants from cuttings. Seedlings of four Curcurbiataceae species were grown in rockwool without nutrient for 14 days from sowing and then given one application of nutrient. Strong growth responses occurred within 3 days of nutrient application, an indication that the internal nutrient reserves had become exhausted even before the appearance of visual deficiency symptoms. *Gerbera jamesonii* seedlings were fed weekly for 10 weeks from sowing with nutrient solutions of different strength. Optimum growth was achieved when solutions had electrical conductance values between 2 and 3.9 mS cm^{-1}. *Daphne odora* cuttings were taken from mother stock of different vigour and struck in rockwool blocks, with and without nutrients. They were grown-on in rockwool then transplanted into scoria and grown hydroponically for one growth cycle. Absence of nutrients in the rockwool caused the production of very long roots which were prone to damage on transplant. After one growth cycle, best plants were from cuttings taken from strong healthy mother stock and supplied nutrients throughout.

INTRODUCTION

Plant propagators hold many opinions on the need to supply nutrients to newly germinated seedlings and cuttings prior to or at time of rooting. Some hold the view that the early application of nutrients is unnecessary because the internal reserves in the seed and cutting are adequate to fully sustain early stages of growth. Also, without nutrient application, algal growth is suppressed and possible damage from excess salts is avoided. Propagators who do apply nutrients to the medium are often uncertain about what nutrients to apply, how much, and in what form.

Many studies on the nutrition of seedlings and cuttings have demonstrated immediate and long term (9,12) responses to early application of nutrients. However, it has also been found that such responses may be influenced and modified by many factors such as the age and status of the mother stock used for cuttings (9,16,19), the method (3) and rate of nutrient application (12,15,18), effects of individual or certain combinations of nutrients (4,8,16), seasonal and environmental factors, and response differences among plant genera and species (2). This variability in response to nutrition probably contributes to much uncertainty as to any benefit to be gained in feeding very young seedlings and pre-rooted cuttings.

The movement and distribution of nutrients in plants. A knowledge of the basic principles of the movement and distribution of nutrients in plants can help in the evaluation of the nutritional requirements of very young seedlings and cuttings. Sixteen elements are required for normal plant growth and development. Carbon, oxygen, and hydrogen are normally derived from water and the atmosphere, and the remainder from the root medium. Six (nitrogen, potassium, phosphorus, calcium, magnesium, and sulphur) are required in relative large amounts, while the others (iron, manganese, boron, zinc, copper, molybdenum and chlorine) in micro quantities. Each of these elements has distinct and specific functions if the plant is to grow normally. A shortage or an excess of one or more will cause disturbances in the metabolism and function of the plant which results in the development of distinct and recognisable visual symptoms.

The long distance transport of nutrients and water in the plant takes place via two major pathways. One, the xylem, is a system of rigid interconnected dead cells which carries water and nutrient from the roots to the tops. Flow is mainly directed to areas where water loss is high (e.g., transpiration from the leaf surface), but there is considerable leakage along the way into surrounding tissue. The xylem is non-selective in what nutrients are carried. The other system, the phloem, is composed of living cells and is very selective in what nutrients are carried. It is the major pathway for the movement of sugars produced by photosynthesis, and some inorganic nutrients from mainly leaf tissue to other plant parts such as the roots, fruit, and storage organs. Lateral movement also occurs across the cell walls into surrounding tissue and the xylem.

The different selectivity properties of the xylem and the phloem influences the distribution pattern and mobility of each inorganic nutrient in the plant. Nitrogen, phosphorus, potassium, sulphur and, to a much lesser degree, magnesium, move in the phloem, and are therefore freely mobile throughout the plant. If root uptake of any one of these nutrients is reduced, they can be withdrawn from old and storage tissues and redistributed to the young tissue under stress. Therefore, with these nutrients, deficiency symptoms develop in old tissue — not the young. Also, with the onset of senescence, the mobile nutrients are moved out of senescent tissue to other parts of the plant for use or storage. In contrast, calicum, iron, and a number of the micronutrients have a limited mobility in the phloem, and tend to accumulate in older tissue with time. In time of nutrient stress, they are not withdrawn from the older tissue and, as a consequence, deficiency symptoms develop in young tissue (e.g., the growing points).

The nutrient content of a plant organ is influenced by the pathway through which the nutrients are imported. For example, the major pathway into fruit is via the phloem. At maturity, seeds have relatively high reserves of essential nutrients per unit mass compared with other plant organs except for calcium and iron, which are relatively low. Chemical analysis of seed from five Proteaceae species (14) showed nitrogen, phosphorus, zinc, and copper to be highly concentrated compared with mature leaf tissue. Potassium, sulphur, magnesium, and manganese accumulated to a lesser degree, but calcium and iron were low.

When seeds germinate, the internal reserves must be mobilised to sustain early seedling growth. For example in peas in the first 4 weeks, 82% of the potassium was withdrawn from the cotyledonary leaves into the seedling, but only 26% of the calcium (7). There is very little information available on the length of time seed reserves can fully sustain seedling growth without an external supply. What is available suggests calcium to be the most critical nutrient. Krigel (13) found that subterranean clover seedlings required an external calcium source within 7 days of germination, phosphorus in 10 days, nitrogen and magnesium in 14 days, and potassium 21 days. With pecan seedlings (17), 82% died within one month of germination with no external calcium supply, and 23% died when there was no boron.

A cutting must draw on internal nutrient reserves stored in the stem tissue until roots have been initiated and become functional. Those nutrients which are readily mobile in the plant can be redistributed within the cutting to the zone of root initiation, but those of limited mobility, e.g., calcium can not. Therefore, it is important that nutrients should be present in the rooting medium for immediate uptake by the roots.

The nutrient reserves in the cutting material is directly related to the nutrient status of the mother stock. The fertiliser regime used on the mother stock can, therefore, have important effects on the growth of cuttings. For example, cuttings taken from nitrogen-deficient carnations were found to produce few breaks and were slow to start growth (9). Over-fertilisation, or a nutrient imbalance of the mother stock, may also have adverse effects on rooting and growth of cuttings.

Mist applications, used for the maintenance of high humidity around the cutting during root initiation, can leach nutrients from the cutting and result in the appearance of deficiency symptoms (5). The periodic application of nutrients through the mist can compensate for nutrient leaching and improve production of roots and growth break (20). However, some plants have been shown to be sensitive to nutrient mists, e.g., azalea (11), with the occurrence of leaf burn. Also nutrients encourage algal growth.

Experimental objectives. Three studies were conducted to demonstrate various effects of early nutrition on the growth and development of seedlings and cuttings. In two studies with seedlings, one objective was to show that young seedlings respond rapidly to an early application of nutrients grown under conditions in which an external nutrient supply was limited. For this study, four Cucurbitaceae species were used of variable seed size. The second objective was to demonstrate that seedlings require an optimum nutrient supply, outside of which growth is restricted. Seedlings of *Gerbera jamesonii* were used for this study. The third study was conducted with cuttings of *Daphne odora*; the objective was to show that the mother stock vigour and early nutrition influence the rooting behaviour of the cuttings and subsequent growth of the plants.

MATERIALS AND METHODS

Study A: Cucurbitaceae seedlings. Seeds of 4 Cucurbitaceae species (Table 1) were sown in plastic-wrapped rockwool cubes (75 × 75 and 65 mm high) presoaked in water. Two types of cubes were used: one had a circular well (33 mm diameter, 40 mm deep) cut into the top surface. This well was filled with a 50:50 mix by volume of perlite:vermiculite, and two seeds were sown to a depth of 25 mm. The other type had no well, but the seeds were pushed down between the vertical fibres of the rockwool to the same depth. Each treatment (4 species and 2 types of cubes) were replicated ten times. Fourteen days later, when the majority of seedlings had emerged to the first true leaf stage, each treatment was divided into two; half the number of cubes were continued on water, while the others were thoroughly soaked with a complete hydroponic nutrient solution. The solution was made up from premixed salts which, when used at the rate of 1.75 g 1^{-1}, gave a solution with the following composition: 10.4 mM NO_3-N, 1.1 mM NH_4-N, 7.3 mM K, 1.1 mM P, 1.0 mM Mg, 4.1 mM Ca, 3.5 mM S, 0.03 mM Fe, 0.02 mM B, 6.7 μM Mn, 0.5 μM Cu, 0.9 μM Zn, and 0.1 μM Mo. This solution was also used for the other studies. Seedlings were thinned down to one per cube. All seedlings were harvested five days later. Growth parameters measured for each plant were hypocotyl length, area of cotyledonary leaves, and total area of plant tops.

Study B: *Gerbera jamesonii* seedlings. Gerbera seed (Pan American Company) were sown singly into rockwool propagation blocks (approx. 40 mm cubed). Each seed was inserted vertically to a depth just below the top of the block. The nutrient solution was applied weekly in sufficient volume to thoroughly saturate the blocks and induce leaching. Light applications of water were also applied between nutrient feeds if required. The premixed nutrient salts were used at six strengths; nil, 0.5, 1, 2, 4, and 8 g l^{-1} (Table 2). Each treatment contained 30 plants. Seedlings were harvested 35, 52, and 69 days from sowing. At the first harvest, 14 plants were sampled; at the other two harvests, 8 plants each. Growth parameters measured for each plant were: total leaf area, number of emerged true leaves, and dry weight of tops.

Study C: *Daphne odora* cuttings. Shoot tip cuttings, 3 cm long, were taken from relatively weak mother plants grown in the open in soil, and from strong plants grown in hydroponics in a greenhouse. Each cutting was trimmed to 3 to 4 newly-expanded leaves and inserted in rockwool blocks (40 mm cubed) to a depth of approximately 15 mm. Two treatments were applied: the blocks were either soaked in water, or in the complete hydroponic nutrient solution of normal strength (1.75 g l^{-1}). The cuttings were held under a plastic tent in an environmentally controlled greenhouse, and on day 74 were assessed for percentage rooting, total number of roots visible in the walls of the rockwood block, the length of the longest root which protruded from the block, and whether the terminal bud had commenced active growth. Rooted cuttings, undisturbed in the rockwool blocks, were transplanted into larger rockwool cubes (75 × 75 mm, 65 mm high with a well in upper surface) presoaked with either water or nutrient solution. The earlier two treatments were split to give four treatments (Table 4). Water or nutrients were added to the cubes as required and, after 64 days, the number of roots which protruded from the walls of the cube was recorded. All rooted plants were transferred undisturbed in the rockwool cube to scoria in 17 litre black-wall bags and grown hydroponically for 10 months (late winter to late autumn) in a greenhouse. At the end of the period, total shoot growth was measured.

RESULTS AND DISCUSSION

Study A: Cucurbitaceae seedlings. All seedlings emerged within nine days and made rapid growth. At the time of nutrient application, there was no visual evidence to suggest that the absence of nutrients in the rockwool had had any detrimental effect on growth and development. However, within three days of the nutrient application, the treated plants showed a strong visual growth response which was confirmed by the growth measurements taken on the fifth day (Figure 1). In five days, total surface area of the seedlings fed nutrients increased by between 68% for zucchini to 142% for cantelope over the water-fed controls (Table 1). This growth response by all species to nutrients indicated that the seedlings by the 14th day, and irrespective of their initial seed size, had exhausted their internal nutrient reserves sufficient to restrict further organ growth but not to induce visual foliar symptoms. Growth retardation also occurred in the cotyledons which indicated that these relatively mature organs are also subject to nutritional stress if an external supply is limited in the early stages of seedling development.

Seeds sown directly into the rockwool fibre instead of the open-structured perlite:vermiculite mix produced seedlings with shorter hypocotyls. The two largest seed species experienced the greatest impedence to hypocotyl growth (Figure 1). There was no evidence to suggest that this impedence had any effect on subsequent seedling growth. Because of the relatively firm fibrous structure of the rockwool cube, any hole made to hold a seed must be of adequate dimensions to allow the seedling to emerge without hinderance.

Table 1. Average seed weight and percentage increase in total surface area of Cucurbitaceae seedlings five days after application of nutrients to the growing medium.

Species	Cultivar	Common name	Average fresh wt per seed (mg)	Nutrient response Percent increase in total surface area over water controls
Cucurbita moschata	Triamble	pumpkin	294	93 2
Cucurbita pepo	Blackjack	zucchini	179	68 2
Cucumis sativus	Crystal Apple	cucumber	31	104 3
Cucumis melo	Sweet and Early	cantelope	21	141 9

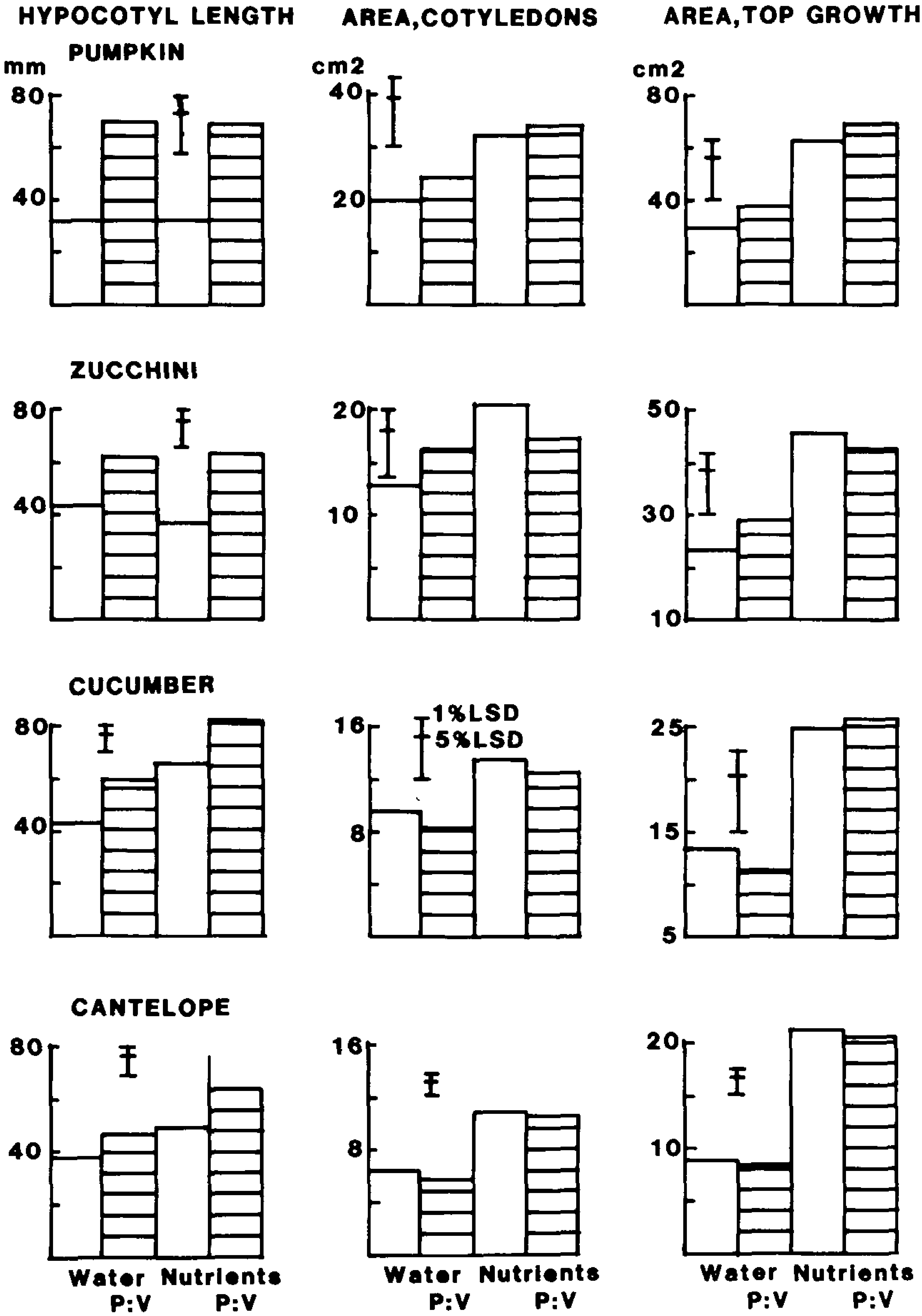

Figure 1. Effect of early nutrition (water vs nutrient) and planting method into rockwool blocks on growth of seedlings of four Cucurbitaceae seedlings P V = 50 50 perlite-vermiculite mix

Study B: *Gerbera jamesonii* seedlings. Seedling emergence began on Day 4. By Day 35, those receiving no external nutrient supply had developed symptoms typical of nitrogen deficiency. Plants fed at 4 g l^{-1} or above were very dark green, and at 8 g l^{-1} leaves were slightly puckered. At the final harvest on Day 69, the nil plants were stunted, pale green and with a pinkish colouration. The strength of 8 g l^{-1} proved toxic. It suppressed growth, induced leathery-type leaves, tip necrosis of new foliage, and death of a number of plants. Seedlings of best appearance were those at strength 2 g l^{-1}. Dry weight of tops and total leaf area (Table 2) showed that optimum seedling growth occurred at nutrient strengths 2 and 4 g l^{-1}. This effect was evident by Day 35, and became more pronounced at later harvests as the depressive effects of the nil, and strength 8 g l^{-1} became more restrictive on growth. Strengths of 1 g l^{-1} or less were insufficient to sustain maximum plant growth. Plant development (i.e., leaf number, Table 2) was delayed at nutrient strength of 0.5 g l^{-1} or less.

This study demonstrated the need for the grower to determine the optimum fertiliser programme for the particular culture method used. Otherwise seedlings may be grown under nutritional conditions which superficially appear adequate but do not permit maximum growth to occur. If the regular application of a balanced nutrient supply is suboptimal (e.g., 1 g l^{-1} or less in the above study) seedling growth will be progressive but never at its maximum potential.

A deficient nutrient supply is relatively easy to define compared with an excess, because seedlings of different species, and cultivars within a species vary in their response and tolerance to high total salt levels in the medium (18). *Gerbera* appears to be more sensitive to high salts in the medium than chrysanthemum (1). Thus the problem for the propagator is to know the upper and lower nutritional parameters for the plants under cultivation.

Table 2. Effect of nutrient solution strength on the growth (dry weight, leaf area and leaf number per plant) of *Gerbera* seedlings harvest 35 (H_1), 52 (H_2), and 69 (H_3) days after sowing.

Nutrient solution			Top dry weight (mg) per plant			Total leaf area (cm_2) per plant			Leaf number per plant		
g l^{-1}	mS cm^{-1}	pH	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
Nil	0	5 6	12	13	16	5 3	7 0	6 4	1 5	1 6	1 9
0 5	0 6	6 2	21	38	80	10 0	18 6	31 8	2 1	2 9	4 1
1 0	1 1	6 2	25	56	163	14 0	26 0	60 6	2 5	2 9	5 9
2 0	2 0	6 0	35	89	274	18 1	40 5	89 4	2 7	4 3	5 7
4 0	3 9	5 5	29	71	240	14 2	36 5	84 8	2 8	4 6	5 4
8 0	6 9	5 2	20	21	40*	9 3	9 3	15 2*	2 3	4 1	4 0*
	LSD	0 05	14	31	70	3 4	11 7	23 4	0 5	1 1	1 5
		0 01	19	41	94	4 5	15 6	31 5	0.7	1 5	2 1

* Many plants dead Omitted from statistical analysis

Study C: *Daphne odora* cuttings. The vigour of the mother stock, and the nutrient status of the rockwool propagation block had strong effects on strike rate, root growth, and subsequent growth of the grown-on plant.

All cuttings from the greenhouse-grown stock produced roots, whereas the strike rate for cuttings from the weaker outside stock was less than 80% (Table 3). In addition, greenhouse cuttings produced more roots, and some bud burst occurred. The nutritional status of the rockwool affected the root system in that the strike rate of outside cuttings were lower, but this may have been from damage caused by insects attracted by algal growth. With nutrients in the rockwool, fewer roots protruded from the walls, and these were relatively short (Table 3). Such cuttings were less prone to root damage when transplanted. A change in the nutrient treatment of the rooted cutting on transfer to the larger rockwool cube altered root growth behaviour in the same way as already described (Table 4).

The growth of plants 10 months after transfer to scoria and on completion of one growth cycle, reflected both the vigour of the mother stock and the influence of early nutrition on the rooted cutting (Table 4). Overall, plants from outside stock made poorest growth and had the highest mortality rate. Cuttings taken from greenhouse stock and provided with an early nutrient supply yielded the largest plants with the highest survival rate. Many of the plant deaths were from *Botrytis* following infection of senescent flowers.

Table 3. Effect of mother stock and nutrient treatment of rockwool on strike rate, root growth, and bud burst of *Daphne odora* cuttings

Source of mother stock	Rockwool treatment (rooting)	Strike rate percent	Number of roots protruding from rockwool	Length longest protruding root (mm)	Bud burst percent
Outside plants	Water	78 6	7 0±1 8*	5 3±0 6*	0
	Nutrients	51 7	2 9±0 6	1 4±0 3	0
Greenhouse plants	Water	100	19 3±1 1	15 6±1 0	21 4
	Nutrients	100	11 3±1 3	4 1±2 1	57 1

* Standard error of the mean

Table 4. Effect of mother stock and nutrient treatment of rockwool on the growth of rooted *Daphne odora* cuttings before and after 10 months in hydroponics

Source of mother stock	Rockwool treatment (for rooting)	(for growing on)	Number of roots protruding from rockwool	After 10 months in hydroponics: percent plant survival	Mean shoot length/plant (mm)
Outside plants	Water	Water	11 0±2 4*	20	195
		Nutrients	1 7±0 4	66 7	206
	Nutrients	Water	15 8±3 7	25	150
		Nutrients	2 3±0 9	50	188
Greenhouse plants	Water	Water	15 4±2 4	71 4	351±59*
		Nutrients	3 4±1 3	57 1	443±87
	Nutrients	Water	46 4±4 7	85 7	518±78
		Nutrients	23 9±5 8	85 7	637±102

* Standard error of the mean

CONCLUSIONS

No evidence supported the view that nutrient supply in the medium is not required at the early stage of seedling growth and rootstrike of cuttings. All studies showed the importance of early nutrition, and that a restricted external nutrient supply in the first few weeks after seed germination hindered growth of seedlings of all four Cucurbitaceae species, irrespective of initial seed weight. The heavier seeds with larger reserves were equally incapable of sustaining seedling growth when the external nutrient supply is limited, probably because the seed reservoir had to support structurally larger seedlings.

The study of *Daphne odora* cuttings showed that a shortage of nutrients in the medium modifies the root system which develops, and that plants never recover from the effect of poor nutrition at the cutting stage. Careful selection of the mother stock is very important. Cuttings taken from weak mother plants had lower strike rates, and good nutrition was unable to fully compensate the rooted plant for the initial lack of vigour.

There is need for the propagator to determine the optimum nutritional requirements of the plants being propagated. If nutrient supply is inadequate optimum growth and development is not achieved. An over-supply of nutrients can be equally counter productive.

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