JUVENILITY AND PLANT PROPAGATION

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The phenomenon of juvenility is well-known to plant propagators, in that it plays a critical role in the propagation of a number of woody plant species. And while this phenomenon presents a major developmental process in plants, little is known about its precise nature, or about the level of control that plant propagators may exert over the maturation state of a given plant.

In order to examine juvenility and its relationship to propagation, some definitions must be made:

Juvenile — that stage in the life cycle of a woody plant during which flowers cannot be induced to form

Adult/mature — that stage in the development of a woody plant during which flowering may occur

Transition — that period between the adult and juvenile phases during which flowering may be initiated by the normal flower inductive treatments

Phase change/maturation — the process that controls the development of the juvenile form into the adult

In all of these definitions, the sole basis of differentiation is flowering. In the juvenile form, flowers cannot form; in the adult, they can; and in the transition, they may occur under specific conditions.

Importance. Juvenility is important to plant propagators in three major areas: the rooting of cuttings, the field performance of those cuttings, and the breeding of woody plants.

Cuttings of many species form adventitious roots more readily when taken from juvenile rather than adult tissue. In a number of woody plant genera, juvenile tissue is the only tissue which will force any roots. No single reason has been suggested for this difference in rooting ability. Research has uncovered four areas that may link maturation state and rooting. These areas are: stem anatomy, levels of rooting co-factors, levels of endogenous rooting inhibitors, and presence of preformed root initials.

In English ivy, as well as other species, mature stems contain a ring of sclerenchyma fibers that has been suggested as being a barrier to root development. However, some evidence suggests that the presence of this ring does not prevent rooting.

Also in English ivy, juvenile tissues appear to contain higher levels of rooting co-factors than adult tissues (3,4). In some plant material, the level of endogenous inhibitors increases with plant age (9). In *Eucalyptus*, a direct relationship exists between the presence of such an inhibitor and decreased rooting.

Finally, some plants, such as English ivy, possess preformed root initials in the juvenile phase which are absent in the adult phase.

Juvenility also can be important to plant propagators in the performance of cuttings after they are removed from the propagation bench. Libby and Hood (6) compared field performance (4 years after planting) of plants obtained from juvenile and adult tissues of *Pinus radiata*. Juvenile wood was collected from plants that had been 'hedged' to prevent maturation; adult wood was collected from normal 'tree-form' trees. Hedge-originated propagules were more vigorous in a number of measures of overall tree vigor, including dry weight (hedge-originated weighing 60% more than tree originated), current year's growth rate, trunk diameter and stem form. Tree-originated propagules were 10% taller than hedge-originated. Although this type of field performance data is rare, it does point to an often overlooked aspect of the effects of maturation upon growth.

Finally, juvenility is important to propagators because it places severe constraints upon the development of new selections and cultivars. With the length of the juvenile phase lasting for up to 30 years, progress in the area of the breeding and genetics of woody plants is very slow (Table 1). (For data on the length of the juvenile phase of specific plants, see USDA Handbook 450 — *Seeds of Woody Plant in the United States*. Under most genera is a giving the "minimum seed bearing age".)

Table 1. Length of Juvenile Period in Some Woody Plants

Rosa (Hybrid tea)	— 20-30 days	*Pinus* spp	— 5-40 years
Vitis spp	— 1 year	*Malus* spp	— 2-8 years
Prunus spp	— 2-8 years	*Hedera helix*	— 10 years
Pyrus spp	— 4-8 years	*Quercus robur*	— 25-30 years
Citrus spp	— 5-8 years	*Fagus sylvatica*	— 30-40 years

Morphological Changes Associated with Maturation. Although the common measure of juvenility is flowering, this is not the only morphological character that changes over time. The development of a number of characters is influenced by the phase of the plant. Perhaps the best example of the morphological changes is found in English ivy, (*Hedera helix*), where the juvenile and adult phases are very distinct. The juvenile form possesses lobed leaves, anthocyanin pigmentation in the leaf petiole, alternate leaf arrangement, prostrate growth habit, preformed root initials, and no flowers. The mature form lacks lobed leaves, the anthocyanin pigmentation and the preformed root initials; and possesses a spiral leaf arrangement, upright growth habit, and flowers.

While English ivy is well known as an example of the differences between juvenile and adult phases, in reality, the number of plants which, possess morphologically distinct forms is rather small More commonly it is very difficult to distinguish adult from juvenile on the basis of morphology. Flowering appears to be the only trait upon which the phase of many plants may be determined

Rooting and Maturation. One aspect of the development of maturation which is becoming clearer is the concept that phase change is not a single on/off event, but is an accumulation of events. A plant becomes mature over time, not overnight. There are numerous experimental observations demonstrating that characters which change with the phase of a plant do so over time, and at their own rate. In a practical sense, the ability to form adventitious roots may be lost long before flowers appear This type of change has been demonstrated in Douglas fir, in which flowering does not occur in the first 20 years Yet, the ability to form roots changes much earlier. In one experiment, cuttings taken from 9 year-old Douglas fir trees rooted 100%. But the rooting ability declined rapidly after then, and may be only 5% by 15 years (2). In some species of *Eucalyptus*, rooting ability is lost as early as the fourth node (7). Perhaps many of the plants we consider to be 'difficult-to-root', lose the ability to do so very early in their life cycle.

Such experimental results help us to understand the observation that a 'gradient of juvenility' from base to periphery exists in many plants, with more juvenile tissues retained at the base One apparent example of this gradient exists in the Fagaceae, where a 'cone of juvenility' is found in many species. Here, a morphological marker of the plant's phase lies in it's ability to retain leaves in the fall (actually, an inability to form the necessary abscission zone). Juvenile shoots retain the leaves throughout the winter and into the spring. Adult shoots lose the leaves as normally expected. This is a clear indication of juvenile and adult phases existing within a single plant.

Further evidence is derived from observations on the rooting of Douglas fir cuttings (12). Cuttings taken from the bottom one-third of 16 year-old trees rooted at 71%, whereas cuttings taken from the central or upper third rooted at 53 and 51%, respectively Many nurserymen and propagators have long observed that shoots from the basal area of trees root more easily than those higher up in the tree.

Rejuvenation. If we assume that most trees possess at least some juvenile tissue at their base, it might be possible to induce juvenile shoots to develop, shoots which would have a high(er) rooting potential. Such rejuvenation has been induced experimentally by severely pruning or hedging plant material. Using this practice on hard-to-root Monterey pine trees, Libby *et al* (5) have been able to double the percentage of rooting (as compared to cuttings taken from normal, unhedged trees). Rooted cuttings from hedged trees had more roots per cutting and the overall root system was more symetrical and fibrous. Mazalewski (7) used a combination of pruning and cytokinin application to induce the formation of shoots of *Eucalyptus ficifolia*, which rooted at a higher percentage than normal plants. Another example of this practice is the use of stool beds for rootstock production.

There may be a question as to whether such pruning treatments are indeed causing rejuvenation of mature tissue or are inducing the production of shoots which have a high capacity for root formation. It has been generally thought that shoots arising from adventitious buds are juvenile. Whatever the physiological basis, the result is production of shoots with a greater ability to root.

Experimentally, such rejuvenation (or reversion) has also been induced by treatment with gibberellic acid, and by a combination of high temperature and low light.

Evidence is also accumulating that *in vitro* propagation of woody plants may be a rejuvenating process. Two recent findings with *Hedera* (1) and *Vitis* (8) demonstrated that *in vitro* rejuvenation occurs, in both callus and shoot tip cultures. Many propagators who use tissue culture as a propagation tool are finding reversion occurring after a number of sub-cultures. Hackett (personal communication) has suggested that a major use of tissue culture in the future will be in the propagation of 'difficult-to-root' plants, using the rejuvenation process.

SUMMARY

In summary, propagators must be aware that the phenomenon of juvenility involves a number of physiological processes, including flowering and the ability to form adventitious roots. As a general developmental process, phase change does not occur all at once, but over a long period of time. The loss of rooting ability with age may or may not coincide with the onset of flowering or even the ability to form flowers. These two characters are distinct in their physiological basis.

It is also important to remember that while these two phases are quite stable, reversion of the adult form to the juvenile can occur. With careful manipulation of the mature phase, propagators may be able to produce juvenile cuttings with a high capacity for rooting.

LITERATURE CITED

1 Banks, M 1979 *Plant regeneration from callus from two growth phases* of English ivy, *Hedera helix* L Z *Pflanzenphysiol* 92:349-353.

2 Black, K 1972 The influence of shoot origin on the rooting of Douglas-fir stem cuttings *Proc Int Plant Prop Soc* 19 77-82

3 Girouard, R 1969 Physiological and biochemical studies of adventitious root formation Extractible rooting co-factors from *Hedera helix* *Canad J Bot* 47 687-699

4 Hess, C 1962 Characterization of the rooting co-factors extracted from *Hedera helix* and *Hibiscus rosa-sinensis* *Proc 16th Int Hort Cong* 382-388.

5 Libby, W , A Brown, and D Fielding 1972 The effects of hedging radiata pine on production, rooting and early growth of cuttings *N Z J For Sci* 2 263-283.

6 Libby, W J and J V Hood 1976 Juvenility in hedged radiata pine. *Acta Hort* 56 91-98.

7 Mazalewski, R 1978 The influences of plant growth regulators, hedging, and other rejuvenation methods upon the rooting of *Eucalyptus ficifolia* stem cuttings M S Thesis, Univ of California

8 Mullins, M , Y Nair, and P Sampet 1979 Rejuvenation *in vitro* Induction of juvenile characters in an adult clone of *Vitis vinifera* L Ann. Bot 44 632-627

9 Paton, D , R Willing, W Nicholas, and L. Pryor 1970 *Rooting of stem* cuttings of *Eucalyptus* A rooting inhibitor in adult tissue *Austral. J Bot* 18 175-183

10 Robbins, W 1957 Gibberellic acid and reversal of adult *Hedera* to a juvenile state *Amer J Bot* 44 743-746

11. Robbins, W 1964 Topophysis, a problem in somatic inheritance *Proc. Amer Philos Soc.* 108 395-403

12 Roberts, A and F Moeller 1978 Phasic development and physiological conditioning in the rooting of Douglas-fir shoots. *Proc Int Plant Prop Soc* 28 32-39

13 Sachs, R , F Loreti, and J. De Bie 1964 Plant rooting studies indicate sclerenchyma tissue is not a restricting factor *Calif. Agr* 18.4-5

INFLUENCE OF HIGH IBA CONCENTRATIONS ON ROOTING

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Abstract. Cuttings of *Acer saccharum*, *Cotoneaster acutifolius*, *Malus pumila* 'Mor Spur McIntosh', *Malus* 'Hopa', and *Taxus cuspidata* were treat-