PROPAGATION OF DOGWOOD BY HARDWOOD CUTTINGS

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One of my first attempts at rooting *Cornus florida* cuttings came when a large supply of potential cuttings were available from moving a 12-year-old plant of *C.f.* 'Waltham'. The cuttings were divided into three lots: large, 8-10" long; medium, 6-8" long; and small, 3-4" long, on February 26, 1971. Two hormone treatments, 0.8% IBA in talc and 0.8% IBA + 5% benomyl, plus an untreated check, were used. None of the check cuttings rooted while 50, 60, and 90% of large, medium, and small cuttings treated with 0.8% IBA rooted. With 0.8% IBA + 5% Benomyl results were 50, 10 and 20% for large, medium, and small cuttings. Small cuttings treated with 0.8% IBA gave the highest percentage rooting, but larger cuttings produced a heavier root system. There was no apparent advantage of using Benomyl with the IBA.

With the encouragement of being able to root up to 90%, the next attempt to root hardwood cuttings of *C.f.* 'Waltham' was on March 6, 1974 when cuttings from the plants produced in 1971 were available. In this trial we compared rooting in a flat *vs* rooting in individual tubes. The average rooting percentage in the flats was 17% while rooting in the tubes was 20%. It proved difficult to extract the cuttings from the tubes to evaluate rooting without damaging the roots. Check cuttings rooted 15%, while 0.8% IBA in talc and 10% Dip N'Grow (DAG)-treated cuttings rooted 19% on the average. Dip N'Grow contains 1% 3-indolebutyric acid, 0.5% a-naphthaleneacetic acid, 0.1% dichlone, 0.0175% boron, 20% dimethylsulfoxide, and 78% alcohol and deionized water. The best treatment was soaking the base of the cuttings in 200 ppm Ethrel (2-chloroethylphosphonic acid) for 72 hours before treating with 0.8% IBA in talc or 10% DAG, as 40% of the cuttings rooted. The Ethrel solution was changed every 24 hours.

The 1975 trial was primarily a cultivar screening trial. IBA in talc at 0.8% was used immediately or after soaking the base of the cuttings in water or 200 ppm Ethrel for 48 hours. The water and Ethrel solutions were changed after 24 hours. The results of this trial are shown in Table 1.

Table 1. Rooting percentage of *Cornus* cultivars treated with 0.8% IBA and rooted in perlite. Cuttings inserted 2/13/75. Results recorded 5/21/75.

Cultivar	Pre-Hormone Treatment		
	None	Water 48 Hr. Soak	Ethrel 48 Hr. Soak
Cornus florida			
'Cherokee Chief'	50%	10%	0%
'Cherokee Princess'	0	0	20
'Cloud 9'	0	0	0
'Fastigiata'	0	0	0
'Hillenmeyer White'	20	0	20
'Pygmy'	20	0	0
'Plena'	10	0	0
'Rainbow'	0	0	10
'Rubra'	10	0	0
'Salicifolia'	0	0	0
'Springtime'	0	0	0
'Waltham'	0	20	30
'Welchii'	0	0	0
C. alba 'Westonbirt'	40	80	90
C. kousa A	20	0	0
C. kousa B	0	0	0
C. mas	40	0	0
C. nuttalli 'Corigo Giant'	0	0	0
C. n. 'Goldspot'	0	0	0
C. 'Eddy's White Wonder'	0	0	0

Results are so variable at this time that we can't recommend hardwood cuttings for propagation of *Cornus*; however, they have been used to a limited extent at Iufer Nursery and Beaver Creek Nursery in Oregon. Since all propagation attempts to date have been in perlite other media, such as peat-perlite should be tried before dropping this method.

Hardwood cuttings take little space in the propagation bench, are done at a relatively quiet propagation period, and are ready to plant into a growing container the first year.

FIELD BUDDING PRACTICES

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We have found at our nursery that T (shield) budding is the fastest and by far the most successful budding method. However, to achieve a 90-95% take the following basic conditions must exist:

1. Soil should be of good tilth with a good balanced feeding program and weeds kept well under control, both before and after planting.

2. Understock must be disease-free and of good quality.

3. Budwood should come from an indexed source, if possible. If not, it should be selected from trees and shrubs with good colour and vigour.

4. Budding knives must be kept sharp always.

5. A high level of sanitation, probably the most important single factor in a successful bud take, must be maintained.

6. Bud-eye maturity must coincide with the ripening of the understock.

We acquire our understock seedlings from the United States, Holland, Belgium and Canada; I like to bring them in as early as possible, at which time we dip them in Benlate and place them temporarily in cold storage. Early in April, we begin our planting, with the trees spaced 8-10" apart and the rows 54" apart. We prefer not to use any herbicides to control the weeds, mainly because there is little information on the effects of herbicides on bud "take," so as much of our weeding as possible is done by machine and the rest manually.

Budding is started approximately the 20th of July with *Prunus americana, Gleditsia, Sorbus* and *Fraxinus* being the first species budded. These are followed by *Malus* in early August, *Acer* around the middle of August and the flowering and fruiting cherries approximately August 20th. *Betula* and *Cornus* are always the last to be budded, this being done the last week of August and the first week of September. In our field-budding we find it preferable to work in pairs, consisting of the technician (or budder) and the bud tyer.

All rootstock stems are wiped clean of dust and dirt with a clean rag. Before budding, buds are wrapped in burlap to keep them from drying out, and are also dipped in a solution of Benlate prior to taking them out to the field. Knives, as noted, are razor sharp and are kept clean the simplest possible way, by spitting on

them and wiping them off as often as necessary, usually about every 6-10 buds. We use Tina or Knuda brand knives which are manufactured in Europe and have the finest tempered steel blades. The blades must be able to hold a finely honed edge in order to cut a perfect bud. We cut our buds thin, leaving just a sliver of wood in the shield bud. The size of the T-cut is made in proportion to the size of the buds being used, the overall length being 1-1¼". Speed is of the utmost importance in cutting, placing and wrapping the bud. Six years ago we budded *Acer palmatum* 'Ornatum Dissectum Atropurpureum' and *Acer palmatum* 'Dissectum Nigrum' around the 10th of July. In two weeks time we stubbed them just above the shield bud. By the first week of September the growth was 15-18" long, and the bud take was highly successful, with 95% success. Unfortunately they were very susceptible to frost and the first early frost killed them out. We tried this three years in a row, with the same initial success and eventual failure as a result of the early frosts. I believe that in a warmer climate, where there is no danger of frost, this method would undoubtedly be highly successful.

ACER GRANDIDENTATUM AND ITS PROPAGATION

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Abstract: Acer grandidentatum is practically a diminutive of *Acer saccharum* to which it is closely related. Widely distributed throughout the Intermountain region of the United States, its attributes include outstanding foliage coloration in the fall and tolerance of drought and alkaline soil conditions. There was highly significant variation in number of seed-filled samaras harvested from 86 plants in 1972; also from plants at different elevations. Empty samaras resulted from aborted embryos and infestation by larvae of a *Euclyptus* weevil. By March 9, 1973, 36 seed lots had germinated out of 76 that had been stratified. The radicle length means of these germinated seed lots ranged between 2.6 and 25.4 mm. The mean height of the seedlings grown from seven representative seed lots ranged between 4.34 and 5.98 cm at 1-year age and 16.35 and 29.10 cm at 2-year age.

The dazzling spectacle of scarlets and oranges imparted by the bigtooth or canyon maple, *Acer grandidentatum* Nutt., is a major component of the autumn scene in many parts of Utah. Yet few people elsewhere seem to know about it or its nobility. Apparently Li (5), who mentioned it in his comprehensive paper on the cultivated maples, was unaware of its attributes.

Discovering its fall coloration is a dramatic experience. Gene Bauer, an artist living in southern California, who, with her husband, first saw canyon maples while traveling through Utah in October 1970, described the experience in a letter:

> "I couldn't wait to jump out of the car and run over to them. I was spellbound by their beauty . . . They were the exact same gorgeous color of the sugar maples of the eastern United States, the very trees we were journeying across the country to see . . . The leaves were basically the same shape but smaller and the trees themselves were very much like the eastern tree but again smaller. They were dwarf sugar maples. The brilliant color of their leaves could not be surpassed. These particular trees had retained their lower branches so the lower leaves barely skirted the ground. What a thrill to step under the canopy of leaves and see the sun rays streaming through them . . .. The sides of the mountains looked like a marvelous patchwork quilt . . .. The ravines especially were covered with [them], some yellow, some yellow-orange, some apricot colored, some scarlet, some blazing red and some still green."

Taxonomy. Experimental evidence of a number of workers, based almost entirely on leaf characters, suggests that *Acer grandidentatum* Nutt. is one of several subspecies of *Acer saccharum* Marshall (4).

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[1] Plant physiologist stationed in Provo, Utah, at the Shrub Sciences Laboratory, 735 North 500 East, maintained in cooperation with Brigham Young University. Stationed in Logan, Utah, at the Forestry Sciences Laboratory (maintained in cooperation with Utah State University) at the time this study was done.

Distribution. Besides occurring in solid stands along a north-south axis through central Utah, the continuous range of *A. grandidentatum* includes southeastern Idaho and southwestern Wyoming, Arizona, New Mexico, and the Guadalupe, Davis, and Chisos Mountains of southwestern Texas (7). It is also a disjunct species in the Wichita Mountains of southwestern Oklahoma, its easternmost limit (6), and in the northwestern corner of Montana, its northernmost limit.

A. grandidentatum occurs on a wide range of both moist and dry sites, and from limestone-talus slopes where the pH is alkaline to sites where the soil is a fertile loam of moderately acid pH. Soil pH at 10 canyon maple sites in the mountains surrounding Cache Valley, Utah, ranged from 6.2 to 7.5 with a mean of 7.17 in 1975. The species is hardy at sustained winter temperatures of −35° C (−25° F) and tolerates summer temperatures well above 38° C (100° F).

One of its principal ecological niches is the sides and bottoms of canyons, hence my preference for the name "canyon maple," a name as western as the plant itself.

Form and Size. This maple is typically a 2- to 6-meter (6- to 20-foot) multistemmed shrub, but single-trunk trees as high as 12 meters (40 feet) exist. The widespread variations in form and size are believed to reflect genetic differences evolving from site selection pressures.

Current Research. My study of the canyon maple, which began in 1970, has centered in northern Utah near the northern limits of the maple's continuous range (1, 2). The objectives of this research were to assess the pattern of the fall foliage coloration, select and eventually cross superior individuals (phenotypes), and develop propagation and other silvicultural information about the canyon maple. This paper describes results of studies relating to its propagation.

PROPAGATION BY SEED

Procedures. Fruit yield in *A. grandidentatum* in northern Utah is frequently meager, but in 1972 it was unusually heavy; likewise in 1975 in Logan Canyon and other canyons east of Logan, Utah. We harvested the 1972 crop from late August through early October from 86 plants that had unique form, unusually brilliant fall foliage coloration, or both.[2] These seed-source plants and about half as many nonfruiting ones were permanently tagged for future observation and as sources of seeds in succeeding years. All are located at elevations between 1,550 and 2,280 meters (5,100 and 7,500 feet), primarily in canyons draining into Cache Valley of northern Utah and southeastern Idaho in which Logan, Utah, is the principal city.

[2] Grateful acknowledgement is expressed to M. Guy Durrant, Keith Peterson, and Mark Larrabee for their diligent field assistance.

We handpicked the fruit, bagged it separately in polyethylene bags for each of the selected plants, and delivered it daily to the laboratory where it was immediately stored at 1° C (34° F). Within a few days after collection, the number of samaras filled and empty of seeds was estimated by the usual cutting test. We drew two 25-samara samples from each seed lot (tree source) for this purpose. In late November each of 76 seed lots was mixed with an equal volume of moist sand or a moist 50-50 v/v peat-perlite medium, either repackaged in polyethylene bags or sealed in glass jars and stored at 1° C until planting time the following spring. With both kinds of media, there was adequate moisture for after-ripening and the samaras remained free of fungi.

Filled samaras were not sorted from empty ones before storage, but radicle elongation in some of the seed lots by early March 1973 made sorting possible. This also made it practical to use Jiffy-7 peat pellets[3] planted with only filled samaras. This was done by inserting the radicle of the seed into a hole made into the expanded pellet and then gently pressing the hole closed. Seed of some of the germinated lots was planted in "1-quart" plastic pots, also in early March.

Following planting, all of the planted pellets and pots were held in a greenhouse for several weeks at 18° C (65° F) during the day and 14° C (57° F) at night. The seedlings started in both the pellets and the "1-quart" pots were shifted into "1-gallon" plastic containers at age 6 weeks and into "1½-gallon" metal containers at the beginning of the second growing season. Each shift was into a medium of equal volumes of Canadian peat, fine sand, and a fine sandy loam soil. Seedlings were fertilized with a water-soluble, 20-20-20 fertilizer three times during each of the two growing seasons. Iron chelate also was applied once each season.

RESULTS AND DISCUSSION

Seed Quality. An analysis of variance mean squares (table 1) showed significant differences in the amount of filled samaras harvested in 1972 from different plants and from different elevations. Filled samaras from the 86 plants ranged between 92.0 and 2.0 percent with mean and standard deviation percentages of 43.2 and 23.8, respectively. Samaras with the most seeds came from plants growing at elevations between 1,800 and 1,900 meters (5,900 and 6,200 feet). Samaras with the fewest seeds were from plants located below 1,600 and above 2,000 meters (5,300 and 6,500 feet).

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[3] Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture of any commercial product or service.

Table 1. Analysis of variance mean squares for effects of elevation (Analysis A) and plants (Analysis B) on quality of samaras of *Acer grandidentatum* growing in northern Utah that were collected in 1972 from plants located within 30-meter (100 foot) elevational zones (54 plants in three nearby canyons) for Analysis A and from an additional 32 plants (N=86) for Analysis B.

		Mean square for condition indicated		
		Empty samaras		
Source of variation	Degrees of freedom	Aborted ovary	Insect infested	Filled samaras
		(Analysis A)		
Elevation	17	56.8**	194.6**	107.2**
Error	90	10.3	28.6	17.0
		(Analysis B)		
Plants	85	39.9**	98.8**	64.8**
Error	86	3.1	6.1	2.8

**Statistically significant at the 1 percent probability level.

Ordinarily, when only a few of the trees in a stand bear fruit, most of the seeds are consumed by late August by tiny larvae of a *Euclyptus* weevil (1) and occasional moth larvae. But in 1972, with weather presumably favorable for pollination of the flowers followed by the development of an abundance of fruit, there were proportionately more filled samaras than usual because insect infestation lagged behind the abrupt rise in host populations. Insect infestations were present in 37.0 percent of all samaras in the 86 seed lots.

Failure in propagating *A. grandidentatum* from seed has not been an uncommon experience among the few nurserymen and others who have tried to grow it. These failures are apparently due in part to planting empty samaras that had been infested by insects or had aborted ovaries, even when the presence of a heavy fruit crop may have suggested otherwise.

Seed Germination. By March 9, 1973, 36 of the 76 seed lots that were in stratification storage had germinated. A seed was considered germinated if the radicle was visible. The radicle length mean for these 36 seed lots was 10.42 mm (standard deviation 5.62 mm). The seed lots with the longest radicles probably germinated the earliest (3).

The absence of germination in more than half of the seed lots and the different magnitude of radicle elongation in the seed lots that did germinate support the idea that changes in endogenous hormones during stratification proceeded at different rates in

seeds from the different plants. A particular rate of such change could be a desirable selection criterion for genetic improvement work with this maple. Differential radicle elongation also suggests the possibility of using seed from an array of these plants in assessing the presence and differential levels of endogenous germination inhibitors and promoters (8, 9).

Seedling Development. Several lots of the germinated and ungerminated samaras that had been in stratification storage were sown in seed flats and the bare-root seedlings were shifted into 1-quart plastic pots at age 4 weeks. There was high mortality among these seedlings after shifting and the survivors had no further growth that year. This problem corresponds to that described by Kenneth Taylor for this maple taxon and by Ed Wood for some other maples in personal communications (1975). The reason for it is not apparent, although Wood reported that some of the maples require an overwintering before they are bare-rooted.

Seven of the seed lots that germinated in storage were used in an experiment to assess seedling survival and growth when planted in Jiffy-7 peat pellets. The experiment comprised five 20-germinant plots per seed lot. Results are shown in table 2. The germinants from seed lot 10 (tree 10) lacked vigor and had high mortality. The reason for this is not apparent. The few germinants in this seed lot that did survive grew as well as the others.

There was very little internode elongation in these seedlings during the first growing season. This is attributed to the presence of a survival mechanism that favors root elongation at the expense of shoot elongation in first-year seedlings of this species. On dry sites, where canyon maple often grows, this may be a desirable attribute. But under more favorable moisture conditions, such as in nursery cultivation, it could be a liability in terms of production time requirements. Therefore, the use of an exogenous phytohormone to promote shoot elongation in first-year seedlings of canyon maple should be explored.

Height growth of the seedlings at the end of the second growing season averaged 23.84 cm (9.39 inches).

The pattern of growth of the seedlings in the foregoing experiment typifies that of the seedlings produced from the other seed lots collected in 1972.

Table 2. Size of *Acer grandidentatum* seedlings at 1 and 2 years and other growth indices at 1 year[1].

Seed lot (plant No.)	Age 1 year					Age 2 years	
	Germinant survival rate, %	Pairs of leaves	Height		Growth index	Height	
			cm	inches		cm	inches
	(A)	(B)	(C)		(A×B×C)		
61	92	6.76	5.44	(2.14)	3.45	26.77	(10.54)
140	99	5.00	5.82	(2.29)	2.91	25.43	(10.01)
38	72	7.22	4.86	(1.91)	2.52	24.83	(9.78)
7	88	5.18	4.48	(1.76)	2.15	23.30	(9.17)
64	90	5.24	4.34	(1.71)	2.03	16.35	(6.44)
29	91	4.72	4.27	(1.68)	1.94	21.10	(8.31)
10	12	7.48	5.98	(2.35)	0.48	29.10	(11.46)
Mean	77.7	5.94	5.03	(1.98)	2.21	23.84	(9.39)

[1] Each seed lot value is a mean of 100 observations × the germinant survival rate ÷ 100.

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PROPAGATION OF ACER PALMATUM CULTIVARS FROM HARDWOOD CUTTINGS

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Traditionally, *Acer palmatum* cultivars in the Northeast have always been propagated from dormant hardwood grafting. This method has assured the grower of successful stands of grafts which can be planted out in the spring and which will be winter hardy during the first season outside the greenhouse. The increasing scarcity of *Acer palmatum* seedlings for understocks and the rapidly escalating labor costs have prompted some growers to search for less expensive and more expeditious means of propagating *Acer palmatum* cultivars. A review of the literature within the IPPS indicates that growers have been experimenting with both softwood and hardwood cuttings of Japanese maples (1, 2, 3, 4, 5). Unit costs have always favored cuttings over graftage but many of the problems related to cuttings production have discouraged the commercial grower. I have achieved good results with softwood cutting production of *Acer palmatum* 'Atropurpureum Bloodgood'[1] but the problems incidental to taking and maintaining cuttings in mid-May more than outweigh the savings to be gained from this method.

Consequently, during the winter of 1972 I proceeded to experiment with hardwood cuttings of *Acer palmatum* 'Bloodgood,' 'Dissectum' and 'Dissectum Nigrum.' This experimentation was a supplement to our normal winter grafting operation; it was an attempt to utilize surplus scions and to search for a less expensive means of production.

Timing. Cutting material was gathered from field stock plants during the first week in January. Wood was stored in our cooler at 34° F until we were ready to process the cuttings. All material was from current season's growth and varied in thickness from 3/16" to 3/8".

Preparation of Cuttings. Cutting material was taken out of the cooler and brought into the work room as needed. Side branches were cut or trimmed from the wood and all cuttings were sized to lengths of 6"-8", with two or three pairs of nodes. Heavy cuttings root as readily as thin ones but we prefer cuttings of ¼" diameter. All cuttings were given a double wound by removing a thin slice of epidermis about ¾"-1" long on opposite sides of the basal end. We then made a clean, straight cut across the end of the cutting and set it aside for hormone application.

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[1] *Acer palmatum* 'Bloodgood' - Selected from a seedling bed by Bloodgood Nursery, Long Island, New York.

Hormone. Although I have used dry hormone preparations of 0.08% and 1.5% IBA, I have found that Jiffy Grow[2] gives consistently better results. Cuttings were gathered together in bunches of 10 to 12 and are given a 10-second dip in a solution of Jiffy Grow, 1:4 (1 ounce Jiffy Grow in 3 ounces of water). Cuttings were immersed so that the wound was covered and after the 10-second dip were allowed to dry before sticking.

Media. I selected three different media in 1972 and have by process of elimination ruled out all but the peat/perlite mix. Initially, I stuck cuttings in a peat/sand mix, a John Innes compost potting mix and in a peat/perlite mix. Apparently the first two media did not provide sufficient drainage and most of the cuttings rotted within 4 weeks. The peat/perlite (2 parts peat, 1 part perlite) medium proved to be the most successful and I have been using it every winter since 1972. Wood flats, 24"×16"×4" with ¼" spaces between the bottom slats were used in the rooting operation. The flats were filled with the medium, slightly firmed and thoroughly watered. Cuttings were inserted directly into the medium in rows of 15, 150 cuttings to the flat. The flats were then placed on greenhouse benches, watered once again and *ignored*. Temperature in the rooting medium should be between 60-68° F and the air temperature should be maintained below 60° F at night. Excessive top heat and/or overwatering will lead to complete failure, thus my statement to the effect that the cuttings should be ignored. The medium should feel almost dry to the touch and at no time during the first 4 weeks should you be able to squeeze water from a handful of the mix. Frequent underwatering is preferred to occasional overwatering.

Rooting. Callus formation was visible after about 15 days and roots began appearing in 4 weeks from date of sticking. Vegetative buds will begin swelling at this time and new growth will be evident by mid-February. Overwatering can be disastrous at this point since the roots will rot very quickly if the rooting medium becomes too wet. I prefer to syringe twice daily with a fog type nozzle. The foliage should not be exposed to bright sunlight after syringing since the new growth is very tender and will burn quite easily. A weekly drench with a mild Captan solution is beneficial in controlling any *Botrytis* infection.

Potting. By mid-March the rooted cuttings may be potted or canned. Caution should be exercised in lifting the cuttings from the flats since rooting is extensive and many roots will extend through the bottom of the flats. I have found that the cuttings respond more successfully if the roots are *not* trimmed prior to potting.

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[2] Jiffy Grow - Ingredients: IBA - 0.5%; NAA - 0.5%; boron - 0.0175%; phenylmercuric acid - 0.01%. Manufactured by G & W Products, Estacada, Oregon.

During the 1975 season, I carried several flats of cuttings through the spring season and planted them directly in nursery beds in mid-May. Other cuttings were potted in 2½" clay rose pots and will be planted in field rows in the spring of 1976. Those cuttings which were canned directly in one-gallon and two-gallon containers have responded remarkably well and were 15"-18" branched plants by late August. I definitely plan to continue this method of containerizing from the rooting flat during 1976.

Planting. Rooted cuttings were either planted directly from the flats into beds or were handled as previously discussed. Bed plantings took place in mid-May and all plants were mulched with "Serve-All" (sugar cane). Lath shades were placed over the beds to provide 50% shade during the first growing season. After two seasons in the bed, the plants were lifted, trimmed and planted in field rows during early May. The plants were now 12" to 15" and will be field-grown for 3 years until saleable.

Observations. After experimenting for 3 years with hardwood cuttings of *Acer plamatum* 'Atropurpureum,' I find that the advantages of this method favor a continuation of this program. Cuttings can be gathered leisurely during the winter months and do not require the careful handling necessitated by softwood cuttings. Since misting is not required during winter propagation, the facilities for rooting hardwood cuttings can be less elaborate than those required for summer cuttings. Growth commences in early spring so that hardwood cuttings are in "phase" with a normal growing cycle and we are not faced with forced growth which is sometimes difficult to maintain when plants are moved to the field.

SUMMARY

Many cuttings may be rooted with minimal care and limited facilities when they are taken as hardwood cuttings in early January. Unit cost of production is far less than that from softwood cuttings and is considerably less than that from graftage. Great care must be taken in watering during the early weeks when cuttings are forming callus. Overwatering will inhibit rooting and encourage basal rot. With proper care and minimal attention, a 60% to 70% rooting and survival rate is easily attainable.

The 'Dissectum' cultivars of *Acer palmatum* 'Atropurpureum' are more difficult to root and percentages as low as 25% are not unusual. I have rooted *Acer palmatum* 'Dissectum' and *Acer palnatum* 'Dissectum Nigrum' from hardwood cuttings but with no great degree of success. I am continuing to experiment with these cutlivars in an attempt to improve rooting percentages. I am also continuing with hardwood cuttings of *Cornus florida* 'Rubra' and *Fagus sylvatica* 'Riversii.'

The results I have obtained from hardwood cuttings of *Acer palmatum* 'Bloodgood' are sufficiently encouraging to justify a continuation of this program. Plants growing in the field have withstood three winters without appreciable injury and are displaying a growth rate at least equal to grafted plants. Although I have not completely discarded the practice of grafting the Bloodgood cultivar, I feel that it is only a matter of time before we discontinue grafting in favor of hardwood cutting propagation.

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MODERATOR STAN SORENSON: We are now ready for questions for our first panel.

BRUCE BRIGGS: There has been a lot of research in the East on the effects of Ethrel in rooting cuttings. The work done was mostly with softwood and herbaceous plants. Basically, after dipping for 24 hours and 48 hours there was an accumulation of Ethrel in the tissues rather than removing a substance. My question is — do hardwood cuttings accumulate Ethrel within its wood — or are they slow to accumulate Ethrel?

BOB TICKNOR: The question may be — is there an accumulation of Ethrel or is there a leaching of inhibitors from the cuttings? This we can't answer, Bruce. We have had some variable results with pines; sometimes we have good results with Ethrel and, in another year, it doesn't work. So we are not real sure what the mechanism is, or whether it is a useful treatment. Ethrel releases ethylene, which is a growth regulator itself and it could be triggering root initiation.

VOICE: Bob, have you tried the quick-dip method? You said that you were not pleased with it on *Cornus florida*.

BOB TICKNOR: We did use quick-dip with Dip-N-Grow and actually it was equal to Hormodin No. 3 in its effectiveness. The one that did not work was when Benlate was added to the hormone.

BILL CURTIS: A question for Larry Carville. Have you used the method you described on *Acer palmatum* 'Dissectum,' either the green, or the red?

LARRY CARVILLE: Yes. I have to tell you that these cultivars don't respond successfully. They are much harder to root, even from a hardwood cutting. We also tried softwood cuttings, and didn't have the response with *A. palmatum* 'Dissectum' that we get with *A. palmatum* 'Atropurpureum.' I don't know what the reason is, but as we continue the operation we will probably stay with grafting for the 'Dissectum' cultivars and go with cuttings for the 'Atropurpureum' cultivars. One other thing that I would like to mention. We have been trying rooting of *Cornus florida* and we have had good success — not outstanding success. They are essentially the same methods as used for *Acer palmatum*, such as use of peat-perlite mixture. We are also trying *Fagus sylvatica*, Riversii cultivar — and that is a toughie; the rooting percentage is very low. But I think that practically anything will root. It is just a question of timing and hormones and rooting medium. This is what Bruce Briggs has been doing for 15 or 20 years — finding out what time of the growth cycle to take cuttings and what application of hormone to give them. We can root most things. But it is a question of perseverance and I don't know if we have the time to accept the challenge.

HUDSON HARTMANN: I would like to ask Phil Barker if he has tried vegetative propagation of the canyon maple and, if not, does he plan to do so?

PHILIP BARKER: We tried propagating canyon maple from 6-inch and 12-inch softwood cuttings taken in August from plants that had been severely pruned in April. The 12-inch cuttings rooted very well and, treated with Jiffy Grow, 100%. They rooted partly when treated with Jiffy Grow, diluted 50% but we got practically no rooting in the control. The 6-inch cuttings rooted likewise but not nearly as well as the 12-inch cuttings. I plan to try hardwood cuttings because softwood cuttings have certain drawbacks, principally that of availability of material.

RALPH SHUGERT: Following up Dr. Hartmann's question, Phil; looking at this from a commercial standpoint, what about budding? Many of the nurseries, particularly in the East, are geared for a good long budding program starting in late June. Now a two part question: part one, what rootstock should be used; and part two, have you had any budding experience with canyon maple? From a commercial standpoint I can't see stratifying and germinating seeds, picking up the seedlings, and putting them in Jiffy-7's, then going out in the field with them. That plant would cost about $50 before you ever got it out. Economically, from a production standpoint, unless there is something that you have not shown in the slides, that would not be a feasible commercial operation. What about a budding operation?

PHILIP BARKER: I have had no experience in budding canyon maple. I told about this maple at the IPPS meeting in Tulsa

last December (1974). Several people were interested in getting some propagation material so in August, 1975, I sent budwood to about 10 different persons throughout the United States. Recipients were to try budding on *Acer saccharum* or any other *Acer* species that they were interested in. So in another year we will have more information to answer your question.

RALPH SHUGERT: What about compatibility with, say, *A. platanoides*?

PHILIP BARKER: I have no idea at all. I have no reason to doubt that it will be compatible with *Acer saccharum, but Acer platanoides* is in another group, and I have a question about it.

RALPH SHUGERT: But there has been no work done on it?

PHILIP BARKER: No work at all that I know of.

VOICE: I would like to ask Mr. Barker if he knows anything about *Acer grandidentatum* in a mild or, at least, a wet climate so we can speculate on its fall coloring.

PHILIP BARKER: I don't know how it is going to color elsewhere. I do know that the trees that are larger, which have deeper roots, do not color as well as do the younger trees. However, those trees that are in moist sites do tend to color quite well, too. So I believe that we can expect good coloration of this tree even in moist sites.

JOLLY BATCHELLER: What about temperature, wouldn't temperature be a factor in fall coloration?

PHILIP BARKER: I think coloration is controlled by temperature, as well as other factors. I can find very little information in the literature where fall coloration of any plant has really had very much study other than a physiological study to determine why it colors. But I don't find anything in the literature where stands of trees have actually been monitored to determine what environmental conditions may contribute to fall coloration. We are studying this now.

VOICE: What minimum temperature will *Acer grandidentatum* stand?

PHILIP BARKER: We have temperatures, where it grows naturally, that go to 30° F below zero.

JIM HINES: This is a question to Larry Carville on hardwood cuttings. At what temperature do you hold the tops of your cuttings?

LARRY CARVILLE: We try to maintain a top heat in the greenhouse of between 50° and 55° F. It's an old greenhouse so all our heat is underneath the benches. It is hot water heat. There is no heat in the air other than what the sun's rays will give us. We maintain a top heat at night at 50° to 55° F. We try to slow down the top development of the buds on new growth.

VOICE: Same in the day?

LARRY CARVILLE: Yes, if at all possible. We don't try to vent those houses during the day to cool them down and, as you know, when the sun comes up you're going to get the warming effect in the houses. So it is a night temperature that we are trying to maintain. The bottom heat is between 65° and 68° F.

RICHARD VAN KLAVEREN: This question is for Larry. I would like to know if you are using a fertilizer during your cutting rooting period?

LARRY CARVILLE: Absolutely not; there is no fertilizer in any of our greenhouses. I don't adhere to it in propagation. The medium is sterile; it's new peat and new perlite. We don't apply any fertilizer to the rooting medium and we don't apply any foliar feed to the cuttings when they begin growing or breaking top growth in the rooting medium. The only fertilization that takes place is when the plant goes into a potting mix, into a pot, or a container as it goes outside the greenhouse.

BARRIE COATE: Is it going to be possible to correspond with you to get cuttings from you again. If so, will the cuttings be from selected plants which could be later referred to by an accession number, or something, to get identical material later on?

PHILIP BARKER: Possibly, please write to me at my present address, I do keep the plants identified so that we can go back to those plants. There is great variability within this genus, within this species, and it is important I think to note precisely from which plant any budwood or seed material has come.

CURTIS ALLEY: In your budding operation you say you soak your buds in Benlate. At what concentration? This is for Mr. Mathies.

JOHN MATHIES: At a rate of ½ teaspoon per gallon. We just dip them in; we don't soak them. We cut the buds the night before.

CURTIS ALLEY: How long can you save your buds after you cut them?

JOHN MATHIES: Well, it depends, I would say 3 to 4 days. Cherries not so long — 1 to 1½ days. *Acer palmatum*, can go 3 to 4 days.

CURTIS ALLEY: Do they start turning brown? Do they give you some indication they are deteriorating?

JOHN MATHIES: That's right.

RALPH SHUGERT: John, have you had any experience with frozen bud stucks? The reason that I ask this — this practice is used somewhat in the West — some people have tried it and say they will never do it again; yet one of the largest wholesale nurseries, I guess in the world, the bulk of their bud sticks are all cut

and frozen. I was wondering if you had any experience out here with frozen bud sticks.

JOHN MATHIES: No, I am sorry, I have never used frozen bud sticks. It would be very interesting to try.

BOB TICKNOR: I know that some Western rose growers use frozen bud sticks. The early budding is all done with frozen buds that are shipped up from California.

STAN SORENSON: What do they do? Put the bud sticks in cold storage? Do they cut and defoliate them?

RALPH SHUGERT: I can speak just a little bit to this. I have never done it myself. I have seen it. The nursery referred to is Mount Arbor Nursery in Shenandoah, Iowa. While they do not have a member in the Society, if anybody would be interested they could contact me and I can give them a name to write to there. Their technique is to cut sticks just as if you were going to bud the next day, defoliate them, wrap in paper, slip them into a polybag and hold at 27°-28° F. Then they can go out in June and bud — primarily on stocks that were fall-planted. There is a short paper on this that Daryl Holmes gave to the Society in 1957 — (Volume 7, page 164). There is a reason for doing this. Quite often in the Middle West there is inclement weather so you cannot plant your stocks until maybe the first week in May, and then that throws you pretty far behind in your budding. So a lot of Prunus rootstocks will be fall-planted — *P. americana, P. tomentosa, P. besseyi*, and a lot of *Malus*, etc.; then they will be able to go in and bud using the frozen budsticks. Their stands have been good; you just drive through their fields and there they are. They have been doing this about 25 years, so it is not a new technique.

MIKE SMITH: What were the bottom and top temperatures used in the *Cornus* rooting studies?

BOB TICKNOR: The temperatures were essentially the same. We are using a propane heater. But it is set for 50° F in the plastic house and we are using 70° F bottom heat. So it is essentially the same temperatures that Larry Carville is using, except we do run into problems. On a bright day the temperatures can go up in that plastic house and I think this is where we can get into trouble. We can get a high temperature of 90° F in there.

MIKE SMITH: Are some of the *Cornus* rooting failures due to decay at the base of the cutting?

BOB TICKNOR: Yes, much of the failure is due to decay of the base of the cutting. Occasionally we will lose one that roots but the failure starts right at the soil line rather than at the base of the cutting. We have used Benlate drenches to try to prevent this but so far that hasn't worked out too well.

PAUL GREIBER: Don't some fungicides cause a problem in preventing rooting?

BOB TICKNOR: When we use Benlate in the hormone mix, we had less rooting than when we didn't include it, but we have had variable results with other things too. Sometimes we get better results in rooting some pines with Captan in the hormone mix. Benlate doesn't work on pines. Benlate is used on some of the rhododendrons. Some people are just dipping cuttings in a Benlate solution, like John Mathies is using with his bud sticks. They feel they get a benefit from Benlate without any added hormone. So it will vary with plant materials and the fungicide.

LARRY CARVILLE: On the subject of Benlate, we have been using a Benlate addition to our rooting powder. On softwood cuttings of azaleas we find that Benlate does inhibit root formation but those that do root are healthier plants. We prefer to take that sacrifice in order to get a healthier stand of rooted plants, although we are taking out some that don't root because of the Benlate in the rooting powder. On the hardwood maple cuttings which we are doing now we are not using Benlate at all in the operation. We have found the same decay at the surface of the rooting medium that Bob Ticknor referred to on *Cornus florida* and this bothers us somewhat. It is a question of overwatering, poor drainage, or a fungus, I don't know? We have used Captan, we are using Ban-Rot, or Truban, and we are using Terraclor in various proportions. We are trying to find out what will control this tissue breakdown.

VOICE: I would like to ask Phil Barker what the stratification procedure is for canyon maple.

PHILIP BARKER: The seed was gathered in late August, September, and October. We brought it into a cooler at 1° C for a few days. Once we had the seed all collected we dried it for 2 or 3 days, then we rubbed the wings off for bulk reduction purposes, and then put the seed into moist sand or moist peat-perlite, 1:1, and stored it at 1° C until planting in early March.

RALPH SHUGERT: Why stratify, why not fall sow?

PHILIP BARKER: I think you can do that. This maple bears seeds so infrequently that when 1972 came along with a good crop I wanted, primarily, to produce some seedlings for the next year. From what I could read in the literature and in previous *Proceedings* of the Plant Propagators' Society it seemed to me that the most successful method would be to overwinter it in stratification boxes and plant it out in the spring.

VOICE: Why is vermiculite not being used more?

BOB TICKNOR: Well, in my experience vermiculite, on a long term basis, tends to collapse and become soggy, whereas perlite is more stable. Also in rooting in flats, perlite is easier to carry in and out than is sand.

GRAPEVINE PROPAGATION — FIELD BUDDING, A MODIFIED CUT, AND THE USE OF PLASTIC TAPE

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Field budding of grapevines onto nematode and phylloxera resistant rootstocks was the most common method of establishing vineyards (in the non-irrigated areas) in the coastal counties of California in the past (4). This was done in midsummer, preferably in August, and completed prior to harvest. The three limiting factors to the success of this method were: (a) the availability of mature budwood in early August; (b) having the rootstock in an actively-growing condition at budding time and (c) having at least 6 weeks of warm weather after budding to satisfactorily "callus-in" the bud.

Prior to development of certified grapevines (1, 2) mature budwood could easily be obtained from the non-irrigated hillside vineyards where the vines matured their wood early. The newer vineyards using certified stock were made in the flat, deep fertile soils in valleys where irrigation was available. Under these conditions it was not possible to obtain mature budwood from these vineyards for clean-stock as early as from the older noncertified hillside vineyards, and not much earlier than before the middle of September. In many areas this delay made it too late to bud and get a satisfactory take. In order to use clean budwood, growers resorted to summer budding. Budwood was collected in December and January and placed in refrigeration. In late June, July and even August the rootstocks were budded using this refrigerated budwood. The early budding appeared to be more successful than the later budding. The standard budding technique (5) involves much care and labor and success is not always achieved. A better technique is desired.

The work of Alley (3) indicated that the use of plastic tape instead of budding strips and a modified cut was an improvement over the standard method and gave very satisfactory results at Parlier, California. The modified cut (Figure 1) consists of making about a 25° angle first cut into the rootstock instead of the standard 45° angle cut. This forms a deeper slot into the rootstock when the second cut is made. Similar cuts are made for the bud which gives a longer, more tapered point in front of the bud and allows for a deeper insertion of the bud into the rootstock, permitting a tighter fit. In this study, rootstocks were budded at the end of July by making a deeper cut and using plastic tape. Vines were irrigated the following day, a practice that is not recommended

when using the standard technique. Three buds out of 180 inserted failed to grow. In the spring of 1974 in another experiment using the modified cut and plastic tape 89% successful take was obtained with Cabernet Sauvignon and 88% successful take was obtained with Zinfandel.

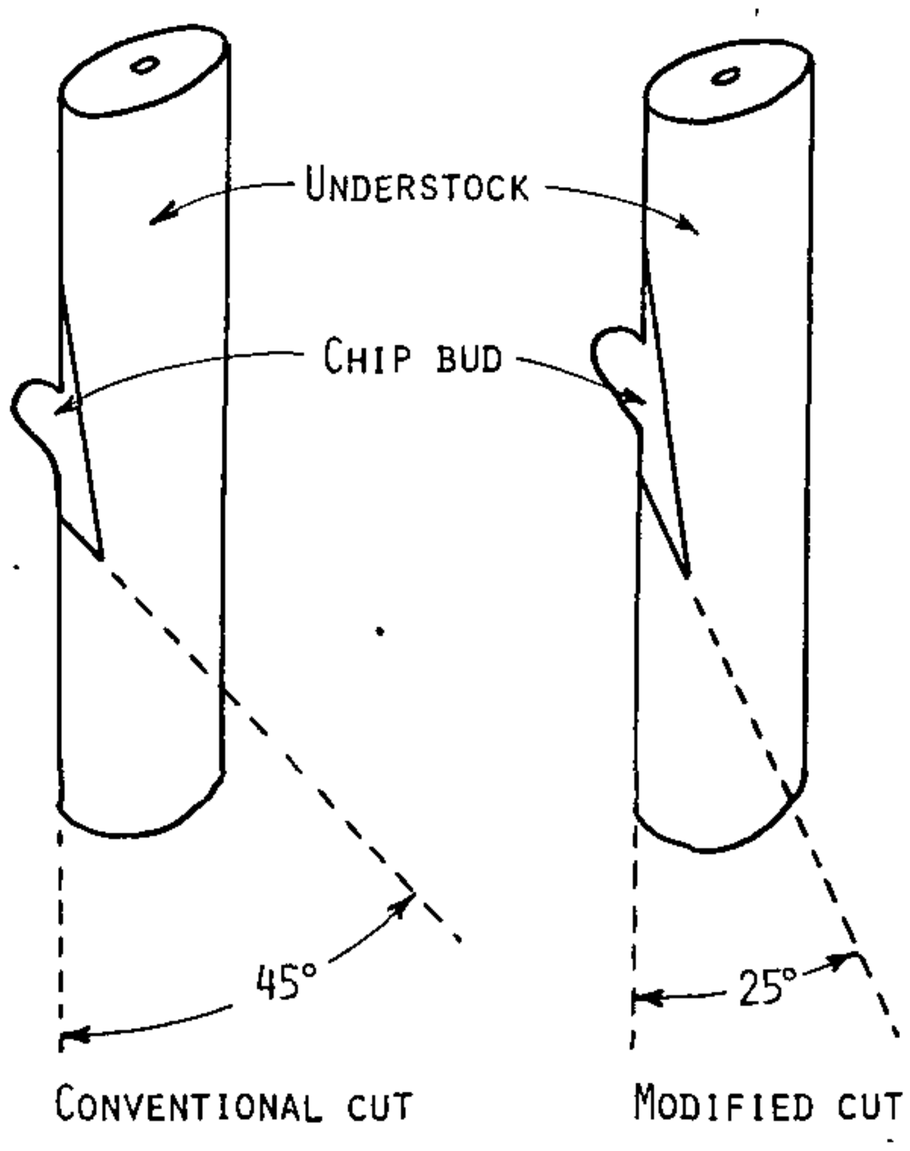

Figure 1. Different angles of cut below bud

In all this work no comparison was made of the take by the use of tape and the standard method. Experiments were made in the fall of 1974 and spring of 1975 to compare the successful take using plastic tape versus the standard technique of using a rubber budding strip (3). Also a comparison was made between the standard technique of tying with a rubber budding strip, both above and below the bud with tying above the bud only.

Fall Budding, 1974. The resistant rootstocks '1613' and 'Harmony' were budded on August 23 using refrigerated budwood; and on September 16 using freshly-cut budwood. There were 20 replications of three vines each per treatment. Treatment consisted of: (a) tying with a rubber budding strip above and below the bud (standard or control); (b) tying with a rubber budding strip above the bud only; and (c) tying with plastic tape above and below the bud. Those rootstocks that were tied with a rubber budding strip were mounded over with soil which is the standard practice, whereas, those budded with plastic tape were left uncovered.

The results in Table 1 indicate that when using refrigerated budwood and plastic tape, the successful take was poorer than the standard method of using a rubber budding strip. However, when fresh budwood was used, plastic tape was as successful as the control.

Table 1. Fall field budding 1974 - Davis, California. Percent successful take. Values represent mean for 20 replications of three rootstocks budded per treatment. Rootstocks used: '1613', 'Harmony'. Budwood used: 'Zinfandel'

	Type of Budwood		
	Refrigeration[6]	Fresh[7]	
Method of Tying Buds	Percent[1] Buds Growing	Percent[1] Buds Growing	Mean[2]
Rubber[4]-above & below bud	86.7[a]	91.7[a]	89.2[c]
Plastic[5] tape	63.3[b]	78.3[ab]	70.8[d]
Rubber-above bud only	93.3[a]	91.7[a]	92.5[c]
Mean[3]	81.1[e]	87.2[e]	

[1] [2] [3] Different superscripts are significant at 1% level.
[4] Rubber budding strip 6 inches long, ⅛ inch wide.
[5] White plastic nurseryman's tape ½ inch, 4 mil.
[6] Rootstocks budded August 23, 1974.
[7] Rootstocks budded September 16, 1975.

The use of a rubber budding strip above the bud only was just as successful as the standard technique. This has considerable significance since it means that the grower does not have to cut the budding rubber in the spring when growth begins, a practice which is necessary when using the standard technique to prevent girdling the shoot. If the budding strip is not cut when the bud starts to grow, as is the case when the bud chip is tied above the bud only, this prevents the bud chip from pulling away from the rootstock if it has not callused in well. Also, it offers added support to hold the bud firmly in place and support the young shoot.

Spring Budding, 1975. The rootstock vines were budded May 1st using the same methods as for fall budding. At this time there were 10 replications of three rootstocks per treatment. The Zinfandel budwood was collected in January and held in refrigeration at 32-34°F until used

The results in Table 2 show that 100% take was achieved by all three methods. Those rootstock vines that were tied with plastic tape and had the tops cut off early (May 12), had formed shoots close to 16" long by June 6. Those rootstock vines whose tops had not been cut off until June 6 had various stages of bud growth from "pushing" to 6" long. On June 18 the rootstocks that had been decapitated on May 12 had shoots 24-36" long, whereas those vines that were not decapitated until June 6 had shoot growth only 2-10" long.

Table 2. Spring field budding - 1975 data on bud push and growth. Rootstock: '1613'. Budwood: 'Zinfandel'.

Method of Tying	Total Vines Budded	Total Buds Growing	Number Buds Growing & Length of Shoots	
			June 6	June 18
Rubber-above & below bud	30	30	29. Buds pushed to 3", one bud to 16"	30 Bud pushed 2-6"
Plastic Tape	30	30	27 see[1]	30 Early-pushed buds 24-36" Late-pushed buds 2-10"
Rubber-above bud only	30	30	23 Buds pushed to 5"	30 Buds pushed 2-10"

Rootstocks budded May 1, 1975; all tops cut off June 6.

[1] Where rootstocks cut off early (May 12) buds pushed 12-16". Where rootstocks cut off June 6 buds pushed to 6".

DISCUSSION

The use of plastic tape greatly reduces the time and labor necessary to bud a rootstock. After budding with tape a grower may irrigate the rootstock vines immediately and not be afraid of a poor take, a practice that is not recommended when using the standard method. Since the take is higher in the spring than in the fall, a grower should strongly consider spring budding when it is easy to obtain mature budwood and climatic and physiological conditions for growth are more favorable.

The use of a deeper cut permits the bud to be placed more firmly into the rootstock making a tighter fit.

From what has been observed by spring budding and using plastic tape the author feels that the following practice can be followed: the vines can be budded, the tops of the vines cut off, and a collar or milk carton placed over the budded vine at one operation. About one month later those vines that have not pushed can be easily seen and rebudded. It is possible to rebud rootstocks 3 to 4 times the same season (up until July 15), so it should be possible to get the vineyard established in one year.

Chip budding using plastic tape has been found to be successful to change over cultivars or correct mixed cultivars in a vineyard that has been trained up the stake and cane-pruned or cordon-trained for the first two years. One or two buds are placed 10-12" below the lower wire and tied securely with plastic tape. The tops of the vines may be cut off at the time of budding or 2-4 weeks later. It takes about 3 weeks before the bud starts to push. If two buds are inserted on opposite sides of the vine trunk, each

bud will form a branch of the cordon. If one bud is used the resulting shoot may be bent to form one branch of the cordon. As soon as the shoot is bent a lateral bud generally pushes at the bend so it can be used to form the other branch of the cordon. Experience of the author with both budding and grafting indicates that chip budding is more successful than the various forms of field grafting.

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PROPAGATION OF WALNUTS, ALMONDS AND PISTACHIOS IN CALIFORNIA

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Walnut Propagation. Our walnuts are started from seed, using the Northern California black *(Juglans hindsii)* or 'Paradox' hybrid (*J. hindsii* × *J. regia*). The latter is an F_1 hybrid from the black walnut naturally crossing with the English walnut.

In selecting our seed we start with vigorous trees which produce seed which grows into a rootstock which is compatible and will give us a high percentage of bud "take". This takes some time in determining these factors because our walnut production takes two years from the time seed is planted until the tree is dug in the nursery and delivered. So our "roughing out" effort of a good seed source takes some time.

We plant our seed in October, by hand, 1½ inches deep, 6 inches apart. We then cover the seeds with 6 to 8 inches of soil where they lay through the winter and stratify naturally.

The following spring, about March 1, when the seed has cracked and the root is about 4 inches long, we take the soil off the top of the seed with an Illiston cultivator, being careful not to go too deep. This cultivator takes off about 6 inches of soil, mulching the soil above the seed and cultivating the weeds out all at the same time.

Four to 6 weeks later, when the seedlings are 4 to 6 inches tall, we undercut the seedlings 8 to 10 inches deep with a sharp blade mounted on a tractor. This operation requires a cool, cloudy, day and irrigation immediately after to prevent wilting. In doing this undercutting we produce a branched root system rather than a "carrot root." The seedlings grow through the summer and about August 20th we start our fall budding.

We are using a large T-bud rather than the patch bud. The T-bud has given 15% to 20% better stand than the patch bud. We prefer budding over grafting because of the labor costs and it makes a much nicer union and cleaner looking tree.

In the process of budding we like to have the seedlings irrigated 6 days before budding and immediately after budding. We also like to have the budwood trees irrigated 6 days prior to collecting the wood. In collecting the budwood, we use the current summer's growth from the desired cultivar of English walnut, trim the leaves off, and store the wood in a cold box at about 38°F. We don't like the budwood to get more than 4 days old before using.

Figure 1 shows the five steps we use with a large T-bud when budding walnuts:

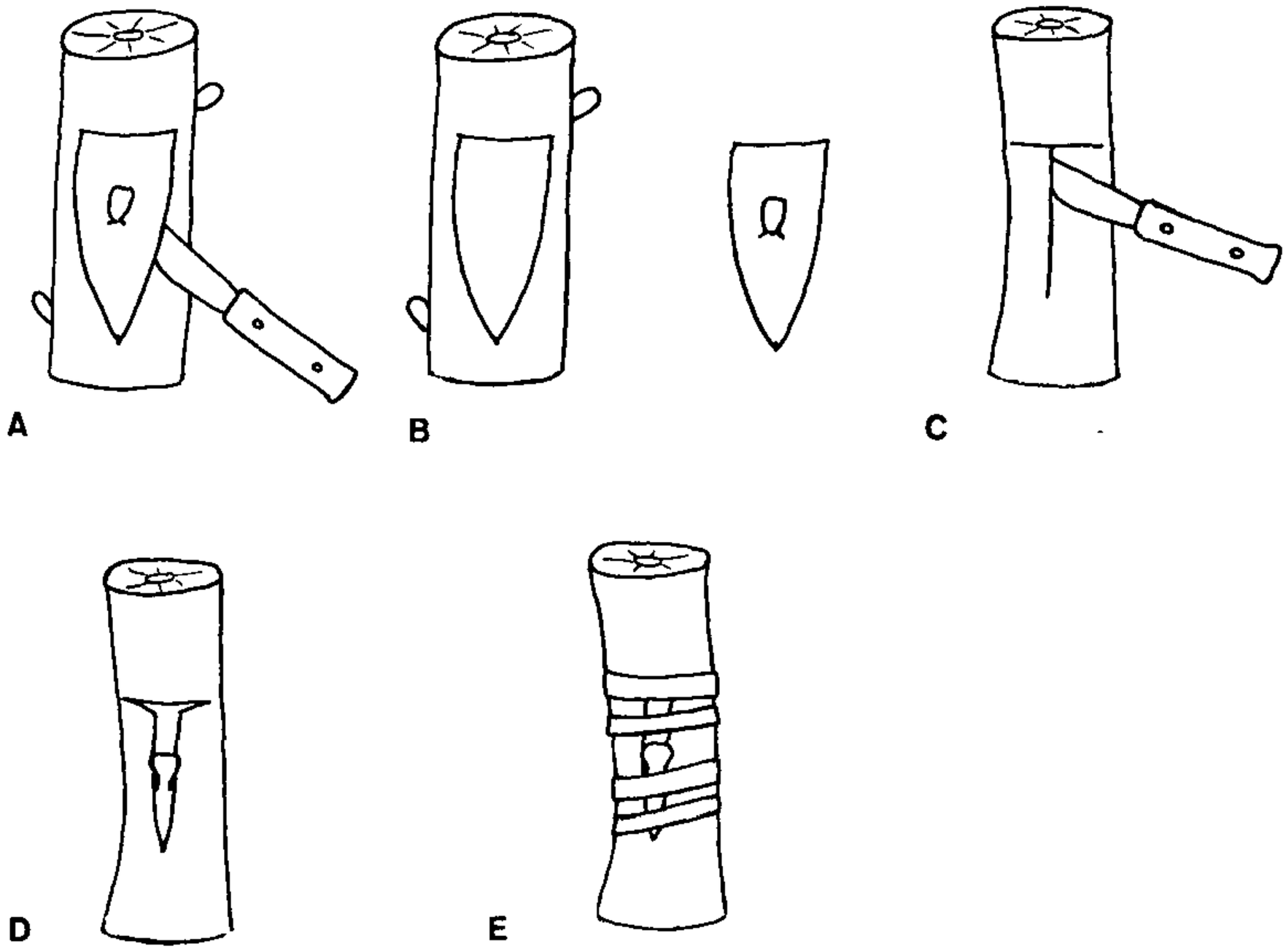

Figure 1. A. Make the horizontal cut ¾" above the bud. Make one cut on each side of the bud and bring the cut to a point 1½" below the bud. **B.** By pushing from one side of the previously cut bud piece with the thumb, snap the bud off, being careful not to lose the "eye" of the bud. **C.** On the rootstock make the usual "T" cut with the budding knife. **D.** Push the shield piece with the bud down into the "T"-cut, making sure the horizontal cut at the top of the bud matches the horizontal cut on the rootstock. **E.** Tie the bud in tightly with an 8 × ⅜ × 0.02 budding rubber, leaving a small opening at the bottom of the bud for possible sap drainage.

Nothing else is done to the seedling or bud until the following spring. When the bud starts to push about April 1 we cut the seedling back to about 8 inches above the bud. The extra height gives us something to tie the bud to while it is very tender in order to get the maximum amount of straightness started with the new shoot.

When the bud has grown to 8 inches we cut the seedling back to the bud and stake the new shoot for the remainder of the season.

We also graft in the spring for follow-up work and for additional orders we take during the winter months.

When grafting we use the whip graft. We have found one important thing in the past two years of propagation which has proven to be very successful. Because the bark of the scion is thinner

than that of the rootstock we do not match the wood of the two pieces perfectly together. We match the two in such a manner that the cambiums match, but the outside barks do not so, in effect, the scion is a little smaller than that of the rootstock, as shown in Figure 2.

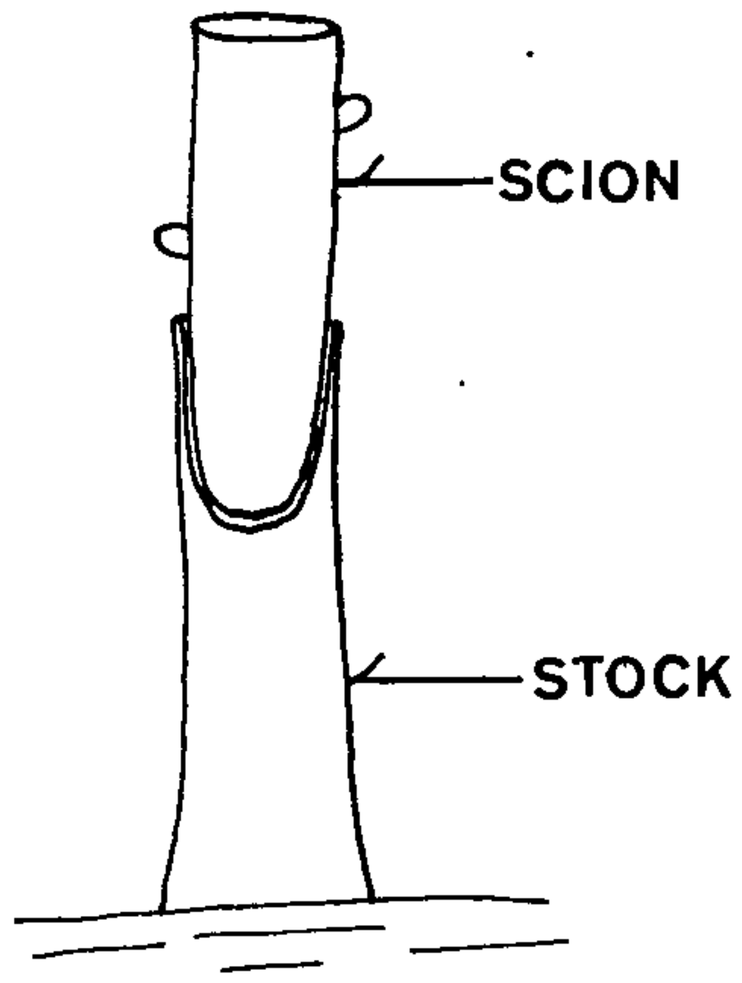

Figure 2. Appearance of completed walnut whip graft before taping. Note smaller size of scion in relation to the rootstock to permit matching of the cambium layers.

I think the most important thing in the propagation of walnuts is in the timing of water to all the plant material concerned and the air temperature difference during budding and grafting.

Almond Propagation. In California 95% of the almond trees are propagated on peach root. Peach, compared to almond roots, provides more vigor, earlier production and, in the case of the 'Nemaguard' peach, a rootstock resistant to nematodes.

Our peach seed is planted by hand with the apex end of the seed pointed down to produce a straight root.

The seeds are planted in October. We plant them 4 to 5 inches apart, 1 inch deep and cover them with 6 to 8 inches of soil, where they lay through the winter for natural stratification.

The following spring around March 1, we uncover the seeds with the same method described to uncover walnut seeds.

We hope to start budding around May 10th. The starting time is determined by the size of the seedling and the maturity of the budwood. For almonds we use June budding. With this method we use the T-bud technique. With this kind of propagation we can produce a salable almond tree from 5/16 to 5/8 inch caliper in 5 to 6 months for sale to commercial orchards.

When June budding, using the T-bud technique, we snap the

bud off the bud stick. In this way we can bud a very small seedling — as small as 3/16 in diameter.

When collecting budwood for June budding one must be careful, because of the early growth, to watch for blank "eyes." Also we have to watch the "eyes" on the budwood later, when the wood becomes over-mature and dryer. In this case the "eye" of the bud will remain on the wood when we snap the bud shield off. Generally we have about 40 days of ideal budding time.

If the budwood becomes too mature to snap the wood off, generally the seedlings will be large enough to slice the bud in, but at this point we generally will get a poorer stand.

Three days after we bud we cut the tops off the seedlings 8 to 10 inches above the bud with a mechanical mower mounted on a tractor. By doing this we stop the growth of the seedling and begin forcing out the inserted bud. During the summer training we sucker each tree 2 to 3 times to produce a good looking quality tree. In June budding it is very important to irrigate 3 to 4 days ahead of budding and 3 to 4 days behind budding.

Some of our budders can bud up to 4,000 seedlings per day with a tyer behind him. We should expect a 90% bud take with this kind of propagation of almond trees on peach root.

Pistachio Propagation. Of the nut trees we grow, pistachios are the most difficult to propagate. For commercial sale to orchards most pistachios are grown in a long tubular pot as seedlings, planted directly in the field, and budded later in the orchard.

We do have one program in our nursery which has been successful for the production of pistachios for backyard sale.

We plant our seed directly in the field, using either *Pistacia atlantica* or *P. terebinthus*, *Pistacia atlantica* being the easier of the two for propagation.

In planting seed directly in the nursery, a very light soil is needed so that there is no crusting during seed emergence; many times we have to sprinkle to get the seed up through the soil. We plant around May 1, after stratifying the seed for 30-40 days in damp peat moss at 35° to 40°F. The first summer we merely try to get the seedlings to grow large enough so that we can bud the following spring or fall.

The first winter after planting we undercut the seedlings about 8 inches deep to force a branched root system; otherwise we would have only one long tap root which is undesirable for replanting bareroot stock.

If the seedlings are large enough to take the large bud on the budwood we can bud the first spring after planting the seed. If not we have to bud the following fall.

In budding pistachios we use the T-bud technique. In collecting the budwood it is very important to collect the right kind of material. The wood should be from vigorous growth of a shoot having small buds. The hardier, more mature wood, has a problem of losing its buds because of the wood being drying and less vigorous. The bud itself, in most cases, is too large to insert into the seedling.

We have found that we can bud pistachios at any time during active growth. We get our highest percentage of bud take by budding in the fall, making sure we have plenty of active growth in the seedling. A pistachio will not "take" a bud if the seedling is too dry or the bark is too tight. When handling pistachios bareroot, it is very important not to let the roots get too dry or expose the roots to the air for any length of time.

We find it is cheaper to propagate in the field and plant the trees in a container when they are ready to dig. In some years we will get as high as a 30% loss from replanting, but normally it will run around 10%. We also find that the older the tree the higher the loss in replanting into a container.

DWARFING ROOTSTOCKS FOR STONE FRUITS

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In recent years there has been an increased need for smaller sized fruit trees for high density plantings in commercial orchards and for the home garden. Reduced tree size can be obtained by several methods, such as the employment of genetic dwarfs, use of growth retardant sprays, heavy pruning — particularly summer pruning, and by the use of dwarfing rootstocks. The latter may be the most satisfactory means of reducing tree size of present desirable cultivars.

A peach breeding project has been initiated at the California Agricultural Experiment Station aimed primarily at developing genetically dwarfed cultivars which will produce high quality fruits. There is also underway a screening test of a number of private plant breeder's genetic dwarf seedling selections (6 to 8 feet tall) set at various planting distances to determine per acre production as well as fruit quality. Such breeding projects could ultimately best solve the problem of reduced tree size, particularly if a dwarfing gene can be introduced into otherwise desirable cultivars. Dwarfing in genetic dwarf selections is due to the short internodes of the fruiting cultivar. Such trees are budded onto the usual peach rootstocks, such as 'Nemaguard' or 'Lovell.'

For some tree fruit species there are available one or more clonal or seedling vigor-controlling rootstocks that result in reduced tree size. For apples, the Malling and Malling-Merton rootstock series, together with seedling stocks, provide almost any desired degree of tree vigor. For pears, several clonal quince rootstocks are available to reduce tree size, although some scion/rootstock combinations are incompatible and require an interstock. For citrus species, *Poncirus trifoliata* seedling rootstocks give reduced tree size, although other clonal dwarfing rootstocks have also been developed.

For the stone fruits — peaches, apricots, almonds, plums, and cherries, widely accepted and utilized dwarfing rootstocks are not generally available. Certain ones do exist, however, that have given good results with certain scion/rootstock combination. .

Peaches. Following studies by Sax (17) some 25 years ago, *Prunus tomentosa* (Nanking cherry) seedlings have been used experimentally (1) to give dwarfing of peach cultivars, reducing tree size, as compared to peach seedling rootstocks, by about 50%. Although *P. tomentosa* has bene known for many years to exert dwarfing of peach trees, it has not as yet been widely used for this

purpose. In spite of this, *P. tomentosa* is still considered (15) to be one of the most likely candidates for dwarfing peaches or, perhaps, *P. tomentosa* × *P. persica* hybrids. *P. tomentosa* however, is quite susceptible to root-knot nematodes which would eliminate it as a useful stock in many areas.

Prunus besseyi (Western sand cherry), too, has been known (1) for many years to exert a dwarfing influence on peach cultivars. Due to its cold hardiness, possible resistance to crown gall, and relative ease of clonal propagation, it would seem particularly promising for future use. Dwarfing of peaches from *P. besseyi* roots is slightly less than obtained with *P. tomentosa*. *P. besseyi* is currently being used to some extent as a peach rootstock, 1.2% of commercially-propagated peaches in the north Central U.S. in 1966 and 1967 being on *P. besseyi* roots, compared to 97.7% on peach seedling roots (19).

Both *P. tomentosa* and *P. besseyi* are reported (1) to carry latent viruses, so in any research with these plants as dwarfing rootstocks it would be necessary to start with heat-treated material.

Certain clonal stocks of *Prunus domestica* will dwarf peaches; the varieties 'Ackerman' and 'Pershore' ('Yellow Egg') being recommended in Germany (13) as producing dwarfed trees. Limited studies by Brase in New York (1) using seedlings of these two cultivars as rootstocks showed that good bud take with four peach cultivars was obtained, as was growth restriction, in comparison with peach seedlings as rootstocks. However, the late Carl Hansen, of the University of California, tried many *P. domestica* plums as possible dwarfing peach rootstocks under California conditions but without success.

Prunus hortulana will cause some dwarfing of peaches (3, 4, 12). The use of seedlings of the 'Wayland' plum, a *P. hortulana* cultivar, has been studied for a number of years at the California Agricultural Experiment Station, Davis, as a possible useful dwarfing peach stock (10). 'Wayland' seedlings appear to be compatible with most peach cultivars and they do not produce undesirable suckers. They are quite uniform and give uniform dwarfing effects. Hardwood cuttings have been very difficult to root. In California, 'Wayland' seedlings are now considered to be more promising than either *P. tomentosa* or *P. besseyi* for dwarfing peaches. A clone of *Prunus subcordata* 'Klamath 1' was selected by A.N. Roberts at Oregon State University as a suitable interstock between peach and *P. americana* roots to give semi-dwarfed, productive trees (10).

Two clonal *Prunus insititia* cultivars, 'Mirabelle' and 'St. Julian EM, type C', when used as rootstocks for peach cultivars are reported (13) to give a dwarfing effect.

Two peach rootstocks, 'Siberian C' and 'Harrow Blood', developed at the Harrow (Ontario) Research Station show tree dwarfing of peach cultivars during early growth but final tree size is reported to be about the same as obtained with peach seedlings (15). Apricot roots have long been known (4) to produce dwarfed peach trees but incompatibility has been a problem, seeming to vary with the ecological source of the apricot seed (5).

Some dwarfed or semi-dwarfed seedlings from peach breeding projects may be useful for developing clonal dwarfing rootstocks for the peach (18).

Cherries. Both sweet [*Prunus avium*] and sour [*P. cerasus*[cherries are conventionally grown on either seedling Mazzard [*P. avium*] or Mahaleb roots [*P. mahaleb*]. The clonal Mazzard stock from East Malling, England — F12/1 — produces uniformly vigorous trees. Mahaleb roots will give slightly smaller trees than Mazzard but the trees cannot be considered as being dwarfed.

In California 'Stockton Morello' [*P. cerasus*] has been used for many years as a semi-dwarfing clonal rootstock for sweet cherries (3), giving a tree substantially smaller than one on either Mazzard or Mahaleb roots. Formerly it was propagated by suckers arising from the base of the tree, but with the advent of new propagation methods it was found to be readily propagated by leafy terminal cuttings under mist if treated with IBA (7). The 'Stockton Morello' clone, as used in past years, was known to carry necrotic rusty mottle virus, thus infecting all trees for which it was used as a stock. By heat treatment techniques this virus was eliminated so "clean" stock became available. Although cuttings taken from such material rooted more readily than infected cuttings there are reports that the non-infected rootstocks do not result in the degree of dwarfing obtained with virus-infected material.

Prunus fructicosa, the Mongolian, or ground cherry, has been tested in New York (1) as a potential dwarfing stock for both sweet and sour cherries with rather encouraging results; it gives very dwarfed trees but it tends to sucker quite badly and may be better utilized as an interstock. Vegetatively propagated selections have been made for testing as cherry rootstocks (2). However, it was not considered to be a suitable cherry stock in trials in Washington State (20). One clone of 'Vladimir' [*P. cerasus*] (a group of sour cherries introduced into the U.S. from Russia about 1900 (9)) has shown distinct dwarfing of sweet cherries in California (16). It also enhances fruiting precocity, but graft incompatibility with some fruiting cultivars appears. Other defects are overgrowth at the graft union, root suckering, and poorly anchored trees. However, by using a hedgerow system of training trees to horizontal supporting wires, together with naphthaleacetic acid sprays to overcome suckering (14), it is believed (16) that commercial use could be made of this rootstock.

Interstock pieces of the Morello-type 'Northstar' [*P. cerasus*] cultivar are reported to produce dwarfed cherry trees (21).

There is considerable interest in the development of dwarfing rootstocks for sweet cherries and field trials are in progress in several countries (6).

Apricot. Apricot is conventionally propagated on either apricot or peach seedling roots. Peach roots are widely used commercially in California for the 'Tilton' and 'Blenheim' cultivars but in the eastern U.S. with other apricot cultivars incompatibility has occurred and peach roots are not recommended.

Although not used commercially, *Prunus besseyi* roots will produce semi-dwarfed trees, which are usually healthy and productive. *P. besseyi* can also be used as an interstock to dwarf apricots, giving even more dwarfing than when used as a rootstock (11). An interspecific hybrid between apricot and *P. besseyi* named 'Yuksa' has shown promise at the Vineland Station, Ontario, Canada (11) as a semi-dwarfing, compatible interstock between myrobalan [*P. cerasifera*] roots and apricot scion cultivars.

Plums. Myrobalan [Prunus *cerasifera*] plum seedlings may be considered as a standard plum rootstock, producing vigorous trees of European plum [*P. domestica*] cultivars.

There are a number of clonal rootstocks available giving varying degrees of dwarfing. 'Myrobalan plum B' produces a vigorous tree; 'Brompton', semi-vigorous; 'Pershore', an intermediate tree. 'St. Julian A' gives a semi-dwarf tree, and 'St. Julian K' a dwarfed tree. These rootstocks were developed in England (21).

Both *Prunus besseyi* and *Prunus tomentosa* will dwarf certain plum cultivars to about ⅓ size but the trees may not be well anchored and would possibly need to be supported. More experimentation is needed to develop information on cultivar behavior on these stocks, although some studies of these combinations has been done at the New York Agricultural Experiment Station (1). They report that 'Stanley' prune on *P. besseyi* started bearing at 2 years and fruited continuously during a 12 year test period.

Almonds. *Almonds would be included among the stone fruits* but there is no record of the development of dwarfing stocks for this species. Almond or peach seedlings or certain plum seedlings or clones are commonly used as rootstocks. Interest at present in almond rootstocks centers on the development of peach-almond hybrid roots, which are more invigorating than either almond or peach roots (8).

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KIWI PROPAGATION

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The kiwi or Chinese gooseberry, *Actinidia chinensis* (Planch) may be propagated by various means (1). Budding or grafting desired cultivars on seedling rootstocks is the most usual practice. Owing to rootstock variability and the longer time required to obtain planting stocks, several propagators desire to grow kiwis from stem cuttings. As with most trees and vines, seedling variation makes necessary vegetative propagation using selected scion cultivars. Suitable ones are available for topworking or for cuttings.

Seed extraction. Soft, mature fruits yield large numbers of viable seed. The simplest way to handle seed fruit is to store it soft ripe at about 4.0°C until the seed is to be planted. The fruit is then peeled and the pulp liquified in an electric food blender. This pulp may be evenly spread on the planting medium without further treatment or the seed sieved, dried and returned to storage in a plastic bag.

Seed germination. Seed planted directly after extraction germinates readily. Stored seed becomes dormant and thus fails to germinate satisfactorily. To break dormany either of two methods may be used. (1) Subject seeds to temperatures alternating between 10°C by night and 21°C by day for 2 to 3 weeks (before or after sowing), or (2) store moist seed 3 weeks continuously at 4°C. Germination takes 2-3 weeks after planting at 20°C.

Raising seedlings. Seed sown in January under hothouse conditions produce seedlings that may be pricked out and planted in flats or small peat pots later to be moved into containers or in the nursery row about 46 cm between plants and 76 cm between rows. As with most seedlings, kiwis are subject to "damping off" fungi and should be planted in a suitable medium, adequately watered and fertilized. Transplanting in outdoor nursery rows must be delayed until all danger of frost is past.

Budding seedlings. With favorable growing conditions, stocks should be large enough (ca. 6 mm in diameter) for budding in September or early October. Matured shoots of the current season's growth makes suitable budwood. For convenience in handl-

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ing, a short stub of the petiole is left when the leaves are cut from the budstick. Utilizing the shield (T) bud, the stocks are budded about 10 cm above ground level.

After the buds have "taken" the stock is cut back about 2.5 cm. above the bud union. (If the stock is cut in the spring to "force" the bud, the vines "bleed" copiously and may result in bud loss.) Bud ties are removed during or soon after cutting back the stocks.

Grafting seedlings. Grafting wood is cut during the dormant period and held in damp sphagnum or sawdust in a cool, shaded area until it is used. Scionwood, like budwood, may also be stored under refrigeration at 4.0°C in sealed polyethylene bags.

Grafting is best done in late winter. If grafted when spring growth starts, excessive bleeding may cause a poor "take". Two or three good buds per scion, about the same thickness of the stock, is suitable for whip and tongue or cleft grafting. As with budding, the stocks are grafted about 10 cm above the ground level and firmly tied. All cut surfaces require a suitable sealer to prevent drying. To avoid constriction of growth, the binding material is cut with a sharp knife as soon as the graft union has healed.

Care of topworked seedlings. Bud and graft shoots require staking and tying to produce suitable straight trunks. Stakes should "face" the bud, preferably on the windward side. All rootstock suckers must be rubbed off and undesirable lateral scion shoots "pinched" in order to maximize growth of the young vine main stem.

Stem cuttings. To hasten establishment of suitable planting stock and to eliminate rootstock variability, softwood cutting propagation appeals to both nurserymen and growers. Only lately have California kiwi propagators seriously considered utilizing this type of reproduction.

Limited experience indicates that softwood cuttings can be taken from new growth throughout the growing season until about September. Each cutting should have one fully expanded leaf (cut in half, if necessary, to conserve space in the rooting bed). The basal cut should be just below the node and treated with indolebutyric acid (IBA). (Most satisfactory concentration of IBA appears to be about 8000 ppm.) The cutting is then placed in a well drained propagating medium with intermittent mist and bottom heat.

Under favorable conditions roots appear in 3 or 4 weeks. After root initiation sufficient to sustain the transplant, the cuttings are potted in a well-drained, fertile loamy soil mixture and held under humid, shady conditions until it is safe to move them into well-illuminated hothouse or lathhouse. If they are to be lined out in

the nursery row, it should be done after danger of frost is past in the spring and after the rooted cutting is sufficiently hardened.

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MODERATOR DON DILLON: Now, we are ready for questions for our second panel of speakers.

VOICE: On kiwi's; how long does it take from a cutting until they fruit?

KARL OPITZ: Well, they will be in production in a couple of years. Fruit is borne on current season's shoots from wood that matured the year previously. It depends on how much vegetative growth they make. They come into production rather rapidly but will not be in full production for about 6 to 7 years. This could be maintained for a long time, since the kiwi is a long life plant — if you don't rot it off by excessive "good" care.

LARRY CARVILLE: A few years back I wrote to a friend and he sent me some plants of kiwi which he was growing. Are kiwis bisexual or unisexual? He sent me a male and a female plant and I have been rooting them and growing them along.

KARL OPITZ: There needs to be a male plant to about 7 females. They are dioecious. That is about the correct ratio. So when you are planting them out you must know what the sex is of each plant.

VOICE: Are there selected clones of kiwi?

KARL OPITZ: Yes, the 'Hayward' is the best clone grown in New Zealand. There are several other clones that they use — 'Bruno' and several others. We have a 'Chico' selection that was made at the USDA Plant Introduction Station at Chico, California. As far as we know, it is identical with 'Hayward'. There are some other cultivars but it looks like the 'Hayward' (or 'Chico') is the one to grow. They do very well under the right condition.

VOICE: Are there selected understocks that seem to be best with the kiwi? In other words, are there rootstock advantages in terms of increased production?

KARL OPITZ: We know that if you grow the selected clones on their own root they do well and are uniform. There may be rootstocks more resistant to diseases, which may influence productivity, and which make them more resistant to late spring frosts and early fall frosts, but that is a wide open thing. We don't know anything about rootstocks for kiwi.

VOICE: How about hardwood cuttings for propagating kiwi?

KARL OPITZ: They will root from hardwood cuttings. Some of the more knowledgeable nurserymen root both hardwood and

softwood cuttings in the same area at the same time. The softwood cuttings start growth much more rapidly but hardwood cuttings will root.

BARRIE COATE: I have two questions — one for Mr. Opitz and one for Mr. Hall. First, do you find that there is a relationship between the female cultivar and a male cultivar for best possible pollination?

KARL OPITZ: Several male cultivars exist but 'California' male (from Chico) blooms at the same time as 'Hayward'.

BARRIE COATE: A question for Mr. Hall. About the use of the tape in budding: It seems a silly questions, perhaps, but do you wrap the green plastic tape starting from the top or from the bottom?

JOEL HALL: On the walnuts, start wrapping from the bottom and work to the top, they make a tie at the top.

BARRIE COATE: What type of tie? Do you actually make a knot?

JOEL HALL: No, we use the same type of tie that we use with budding rubbers. We slip it through a slip-knot type tie.

HUDSON HARTMANN: In California we have a problem with walnuts called "black line." This is related to the rootstock, where there is a degeneration of the tissues at the graft union. I am wondering what Joel recommends as the best rootstock to overcome this "black-line" problem?

JOEL HALL: To avoid "black-line" we are working with seeds of some cultivars of *Juglan regia*, particularly Eureka and Serr, but we do have one problem as far as nursery production goes. Such seedlings are very slow growers. We find that for propagation, use of *J. regia* seedlings slows the program. We have a farm advisor who is working with the University of California on this problem. Walnut black-line in Contra Costa County, California, has just about destroyed the walnut production there. It seems to be a problem in compatibility. We don't know really what it is. Some growers plant a *J. hindsii* seedling, then bud different limbs with budwood from several different trees. I have seen orchards where this has worked — where one of the limbs would get black line and they would cut it off. The other limbs did not have the problem.

CURTIS ALLEY: Joel, in the last two years we have been planting California green with grapevines; growers have also been fumigating the soils, especially old vineyard soils. They have been getting into trouble with tie-up of phosphates when they fumigate. Have you had experience with this in your fumigation?

JOEL HALL: Yes, we have; in fact, this is why we only use 200 pounds of methyl bromide per acre. This is the minimum requirement. We go with 200 pounds of methyl bromide and then

get a root sample for our inspection program. But methyl bromide, of course, does tie up, particularly, the metallic elements — iron, manganese, phosphorus, zinc, etc. Particularly zinc and phosphorus. We have to use massive amounts of phosphorus and zinc — more than we would otherwise — particularly after using methyl bromide fumigation. So it is very important to follow methyl bromide fumigation with a good program of phosphorus and zinc fertilization.

RALPH SHUGERT: Hudson, about 6 years ago in Oregon we met some growers who were working on Mahaleb × Mazzard crosses hoping to come up with some new cherry rootstocks. I wonder what has happened in the last 6 to 8 years in that regard?

HUDSON HARTMANN: Dr. Al Roberts of the Oregon State University at Corvallis has been interested in the cherry rootstock situation and has a collection of *Prunus mahaleb* from all over the world. I really don't know much more about it than that. Maybe some of the people here from Corvallis could fill us in on the status of the Oregon cherry rootstock studies.

CURTIS ALLEY: Hudson, in our vineyards every year we spend a lot of money suckering the vines. You said to use NAA to stop suckering of cherry rootstocks. What concentration is used?

HUDSON HARTMANN: I think about 500 ppm. This hasn't been in nursery work, though; it has been on older trees. This work has been done by Jim LaRue, Steve Sibbett and others in the Extension Service at the University of California. They tried it on olives, crepe myrtle, and various things like that. But as far as I know, they haven't tried it in nurseries or on more tender material. They published an article in *California Agriculture* not too long ago about their work, but I don't believe that they have experimented with nursery material or grape vines.

JOLLY BATCHELLER: In rootstocks for dwarf peaches, why aren't they using seedlings of the dwarf flowering peach? What is the problem there? I have such trees about 10 feet tall grafted 8 or 9 years ago.

HUDSON HARTMANN: These are genetic dwarf flowering trees and could be grafted on a vigorous rootstock. Seedlings propagated from seeds taken from the dwarf clonal tops may or may not be of a dwarfing type. However, cuttings taken from these dwarfed clones could be rooted and tried as a clonal rootstock.

RICHARD NELSON: Dr. Alley or Joel Hall. Have you used mycorrhizal fungi to overcome phosphorus and zinc deficiency at all? In grapes or in the tree fruits?

CURTIS ALLEY: In grapes it is just being tried this year. The results should come out in a year or two.

JOEL HALL: No, we haven't used mycorrhizal fungi in our nursery for this purpose.

PROPAGATION OF MAHONIA AQUIFOLIUM

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Successful vegetative propagation of *Mahonia aquifolium* 'Compacta' depends a great deal upon favorable natural conditions. In Mendocino County, in the Fort Bragg area of the coast of northern California, we apparently have conditions ideally suited for this work. Soil conditions are acid; water is acid; summer temperatures are mild, rarely exceeding 70 degrees, and the annual rainfall is between 40 and 70 inches. These conditions allow cutting wood from field-grown stock plants to "cure" properly, and in the late summer we are able to place our cutting flats under intermittent watering. Ideally, this should be done in late September, though we have made cuttings of *M.a.* 'Compacta' as late as November. The percentage of our rooting varies from 30 to nearly 90, depending more upon mechanical vagaries than upon the ability of the plant to respond consistently to our professional efforts.

While this paper deals primarily with the clone 'Compacta', we grow other mahonias including the species *Mahonia pinnata*. We treat all of the mahonias alike, selecting cutting wood when ripe. Generally we take the 'Compacta' first, then the *M.* × 'Golden Abundance' and then 'Ken Hartman'. Our experience with rooting 'Golden Abundance' and 'Ken Hartman' has all been at Fort Bragg, but we are not without experience in attempting to root 'Compacta' in other climates, namely the Chino area of Southern California. There, we had no success whatsoever, sticking as many as 10,000 cuttings and rooting only a few hundred. We concluded that the cutting wood we were using was unsatisfactory and there was no way we could economically cause a change. Summer temperatures in the Chino area are in the high 80's, often reaching over 100°F. We felt that the wood was simply too green, as plant growth was nearly continuous. Taking cuttings earlier was not successful because we then ran into difficult high temperature problems while cuttings were in the rooting medium. We used both cold frames and propagating greenhouses.

So while we gradually accumulated data on what mahonia plants will not tolerate, we moved a block of stock plants to Fort Bragg for field planting. We next took cuttings after we had constructed a propagation greenhouse duplicating our southern California facilities. Electric cables were installed in the benches and cooling was by convection. This was later changed to an evaporative type of cooling system. Our medium was the same as we used for rhododendrons: sand and peat. We used the conventional shallow southern California nursery flat as a rooting con-

tainer placed on the heated greenhouse benches under mist. Our first effort was a 100% failure. We stuck nearly 500 cuttings and they were all dead within one month.

We sought advice from mahonia experts and they added bits of information to our growing knowledge of what mahonias do not tolerate. We learned at about this time that no part of the cutting should be torn or ripped away; rather, one should use shears. This was supposed to prevent fungus infection, not necessarily assist rooting. The following year we made another effort to root mahonias. Extreme precautions to prevent fungus infections were observed, and we continued with the same medium, conditions, and facilities. Results were the same. Complete failure. But by a stroke of luck, a passing electric company lineman, making a routine inspection of the power line over our property, observed what we were doing and asked for a few cuttings because he appreciated our compact plants and wanted to root some at his home in town. He took no more than 6 cuttings and put them in his pocket. Fortunately, the person in charge of our operations had the good judgment to ask him if he knew anything that we didn't about rooting mahonias. He said he stuck them in a flat of vermiculite and watered them when he had time and they most often rooted. About 6 months later this same man said he rooted all of his 6 plants. A visit to his place confirmed this, and we started to summarize mentally the things we might be doing wrong, for we knew we were doing nothing correctly.

Immediately, we recalled our southern California experience with heat. Mahonia plants do not stand heat while rooting. We also realized our medium should be changed to vermiculite. The next year, we took our cuttings in late summer when the wood had properly firmed and placed them in flats of vermiculite in our lathhouse. Water was provided by overhead Rainjet sprinklers turned on by hand several times an hour for a week or so, and then later when the flats needed watering. Of nearly 10,000 cuttings, we rooted about 5000. We felt, at last, that rooting could be accomplished. Now, for the last seven years, we have been attempting to refine this procedure but basically we are doing only what the lineman suggested. Because of our unique climate, it is doubtful if all that we report will be successful for those working in areas with a harsher climate. Currently, our procedure at Fort Bragg is as follows:

The rooting medium we use is a coarse #1 vermiculite. This grade may vary with manufacturer. Fine grade is unsatisfactory, and the very coarse material is not apt to be properly expanded or graded. We have constructed well-drained deep 4'' flats for rooting and they have proved to be an improvement over the conventional shallower depths. We dip flats in copper naphthenate each

season and are able to use them over and over. Rooting is in a lathhouse with minimum shade, on gravel beds under hourly water provided by "Spray Stakes", a time clock, and solenoid valves. No bottom heat is provided. Cuttings taken in late summer are trimmed, sanitized, and stuck 100 cuttings per flat. A hormone, Hormex #8, with Benlate added, is used. Selection of proper wood had always appeared to be more significant than choice of hormones, fungicides, or dwell of the water on newly-stuck cuttings. Prior to sticking, flats are filled with vermiculite, and these are placed under a sprinkler to be thoroughly saturated. Precautions are taken that the vermiculite is of uniform firmness in all flats and no air pockets exist. We do not pack the vermiculite under pressure nor disturb it after it is soaked. We make several thousand cuttings per day with a crew of four. If all goes well, cuttings commence rooting within about one month and may be potted off at this time. In actual practice, we rarely do this, generally delaying making cuttings until nearly too late — sometimes in November. Potting is then delayed until spring. While cuttings are being rooted, we spray with Benlate, and, if required, with Zectran to keep off chewing insects. Prior to taking cuttings, our stock fields are sprayed with lindane for weevil control, Zectran and Sevin for chewing insect control, and with Benlate. These sprays are repeated as required. Weed control is a major problem. Sheep sorrel is the most troublesome weed. We have damaged our stock block several times with herbicides and this has affected rooting. However, the plants are persistent, and come back strong the next season. So do some of the weeds. We fertilize the stock block several times a year with a complete food. Sometimes we believe we fertilize too often, as our plants elongate and become too heavy. We prefer a light cutting, about ⅜". Cuttings may be stored overnight and processed the next morning, but keep in mind that it is cool in Fort Bragg and all evenings, all year, are cold. We use only tip wood of 'Compacta', but have used stem cuttings of 'Golden Abundance' and 'Ken Hartman'.

We have caused occasional damage to our cuttings by injecting too much chlorine into the water supply. Fortunately, on these occasions, most cuttings had already commenced rooting, but a great portion of the cuttings did defoliate. We have learned that a rooted cutting, if it defoliates, will start growth again in the spring. However, it should remain in the cutting flat until new growth commences and be watered and fertilized as required, and then transplanted. If a defoliated cutting is removed and potted off, it generally will perish.

We fertilize all of our cuttings in the flats after they are well-rooted; but this is generally in the spring, and a long growing period is ahead. We would prefer to pot off the cuttings in the fall, but our program of getting started each year with mahonias is im-

precise, and we often find ourselves sticking cuttings as late as November. They root, but we hesitate to pot them off as we lack shelter for the pots. We do plan to construct quonset shelters for the newly-potted cuttings, but will approach this procedure carefully, remembering that mahonias do not do well in unusually warm artificial conditions. It appears the best procedure would be to attempt to pot off the rooted cuttings in the fall, place the liners in a quonset structure without a poly cover but light shade only and then, after they are established and are dormant, place a poly cover over the quonset and force an early cycle of growth.

We pot off the rooted cuttings into 4" pots rather than 2½" because of the large root system. Our customers have complained about this increase in size and price, but we feel that we are offering a better plant. We were required to shear off most of the roots of each cutting in order to squeeze them into the 2½" pots, and then discovered there was really no medium left in the pot in which the plant could establish itself. It was also difficult to water and feed the plants in smaller pots. We also grow rhododendrons, pieris, and ferns, and the growing medium we use for mahonias is the same as for these plants — fir bark, peat moss, and perlite. Our fertilizing program is also the same, though the schedule may vary.

At present, we are growing five mahonia cultivars. Three are of the compact type, and they are all equally more difficult to root than the standards. But in spite of these difficulties, we feel we do make progress each year, as we discover conditions best for the plants. We feel that the production of cutting-grown mahonias is worth the effort for the sake of uniformity and reproduction of truly superior clones which deserve a prominent place in the beautification of our environment.

THE MYSTERIES OF RHODODENDRON PROPAGATION

TED VAN VEEN

Van Veen Nursery
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In a 1932 Van Veen Nursery record book there is a listing of 44 rhododendron cultivars, totaling 3,125 cuttings, which were set in an outside ground bed — the old fashioned hotbed type. The uniqueness here is one of the first installations of lead cable for electric bottom heat, and a rooting record of 78%. This percentage is a remarkable achievement for an age when rooting of rhododendrons was so little known. Hormones, fungicides and misting were yet to come.

Since that time the production of rhododendrons has accelerated to many millions each year. However, the overall percentage of rooting has improved relatively little, in spite of our more modern production methods and the research efforts employed over the years. Our rooting percentage at Van Veen Nursery today is seldom much better than 85%.

Briefly, I will review our present method of rhododendron propagation starting with a few cuttings taken as early as the first part of June. The bulk of the production starts around the first of July, however, and we take some cuttings as late as January. During the heat of the summer, one greenhouse is set aside to store the overflow of gathered cutting wood. Saran cloth is stretched across the top of the empty benches and the intermittent mist system is used to keep them turgid.

In the preparation of the cuttings one crew removes excess leaves and trims back those remaining. These are placed in plastic baskets and dipped in a Clorox solution (1:20) for five minutes. Then they are rinsed in fresh water and passed on to another crew who cuts and wounds the stems. The cuttings are then dipped in a hormone preparation, which may be a powder or a quick-dip solution of varying strengths depending upon the cultivar and time of year. We have stopped using Benlate both in solution and in a powder mix. There is reason to believe a rapid breakdown of the Benlate takes place when in contact with moisture, which then inhibits rooting.

Cuttings are stuck in open benches in glass greenhouses equipped with 72°F bottom heat and intermittent mist. The medium used is 60% peat and 40% coarse perlite. The houses are completely cleaned out once a year and fumigated with formaldehyde. As the cuttings are rooted they are transferred to growing-on greenhouses into a peat and bark mix. Overhead gas heaters are used here. Cuttings not sufficiently rooted are reset.

As alluded to in my opening remarks, the mysteries of rooting rhododendrons are still with us. While we know more, have new

chemicals, and enjoy elaborate testing facilities, in actuality we have not greatly improved the rooting percentage in the last 40 years.

In deference to ourselves we must admit there are a tremendous number of variables which may influence rooting. Conclusions of successes and failures under the many trials reported could very well be influenced by one or more other factors. I would like to briefly review some of these:

1. Condition of the stock plant. Is it healthy, or weakened by disease, insect damage, lack of fertilizer, or water stress?

2. Time of year cuttings are taken. There would be considerable variation in maturity by locality and seasonal weather conditions within a particular area. Is a cold period beneficial?

3. Amount and kind of fertilizer used on the mother plant — and then what is actually in the tissue, including trace elements?

4. The influence of herbicide residuals in the stock plant on rootability.

5. Maturity of the cutting, location on the plant, caliper, first or second growth, terminal or side shoot, presence of flower bud; juvenility.

6. Length of cutting, number of leaves left on, and type of wound.

7. Strengths and types of hormones and fungicides. Has it been properly mixed, or has there been a loss of potency through dilution?

8. Type of rooting medium. Is pH a factor?

9. Bottom heat temperature. How close a tolerance must be maintained for maximum rooting? What happens when heat is lost for a day or two?

10. The moisture requirements of the medium. How much mist should be used? Would the installation of fogging nozzles to maintain 100% humidity be better?

11. The benefits of sunlight or darkness. Is the amount of greenhouse shading a factor?

12. How beneficial is the use of sawdust in the rooting medium? Is it advantageous to use an antidessicant to maintain quality of soft cuttings? Why does storage in a plastic bag seem to speed up rooting? To maintain moisture in heated beds they must be soaked periodically. The cold drench reduces temperatures and this must have some effect on the rooting.

When we know the answers to all of these mysteries we will have learned our lesson well. As propagators we can then pursue new problem areas as yet unthought of. Our work will never end.

PROPAGATION OF ARCTOSTAPHYLOS UVA/URSI BY CUTTINGS

VERL L. HOLDEN

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Silverton, Oregon 97381

Landscapers and gardeners have found kinnikinnick [*Arctostaphylos uva-ursi*] to be a very useful ground cover for dry, sandy, rocky or poor soil. The difficulties in getting the plant propagated and established are limiting factors to its wider use. In over 20 years of propagating, planting, and transplanting kinnikinnick, I have been at the bottom of dismal failure and to the peak of fantastic success. The last few years have settled down to a series of successes, and we are finally on the right track.

As in propagating many plants, I believe timing is of utmost importance. Cuttings can be rooted earlier or later than my schedule, but one has to consider transplanting from the cutting bed into pots. Losses of 50% or greater can take place at this critical time. Kinnikinnick seems to have two times of the year when root initiation is at a peak. One period is in the fall, from about September 15 to October 15, and the other from March 1 to April 1. In following these time periods then, the cuttings are stuck from September 15 to October 15, and transplanted from the cutting bench into pots from March 1 to April 1. In following this time schedule we have often had 85% or more saleable plants from the number of cuttings stuck. We recently went through a block of 2,500 plants during pinching operations and we found only 3 dead plants.

Our procedure is as follows: First, the old propagation medium from the year before is removed from the bench and the heating cables are rolled up. The saran shade cloth and cross boards are removed from the bottom of the bench. The entire area is then hosed down with high pressure water. The floors of my propagation house are solid concrete with a 4-inch drain tile at the lower end, and all of the old medium is washed out of the house. The sides and bottom supports of the bench are then retreated with copper naphthenate. The entire greenhouse is then sprayed with LF-10 solution. The cross boards are dipped in copper naphthenate solution and replaced in the bottom of the bench, and spaced from ½ inch to ¾ inch apart.

The saran cloth is then placed on top of the cross boards and the rooting medium is placed about 1 inch deep on top of the saran cloth. The heating cables are then put back in place after soaking in LF-10. The rooting medium is placed 3 or 4 inches deep on top of the heating cables. I do not pack the medium down, but keep it moist. I use a close spaced mist system. The

overhead pipes are 24 inches above the bench and run down the middle of 38 inch wide benches. The nozzles are spaced about 3 ft. apart. I use Monarch F110C nozzles which are supposed to have a 6 ft. coverage, but do not. I also have Flora-Mist nozzles with the 1/32 in. orifice. I consider the Flora-Mist nozzles the best of the two systems. The misting cycle is 5 minutes, with 15 seconds on and 4 minutes 45 seconds off during daylight hours. On cool, cloudy, rainy days, I cut down on the number of misting hours. I like to see the leaves moist during daylight hours.

Cuttings are made from the current season's growth. Short cuttings seem to root better, but we go from 2 to 6 inches long. Tip cuttings are best, but we also use runners clear back to the old growth. Strip leaves only from the part of the stem that will be stuck in the medium. The more leaves, the more food manufactured for root growth. We retain 6 to 8 leaves on some cuttings. After stripping, cuttings are bundled about 50 per bundle (not counted) and held together with a rubber band. The cuttings are placed upright in a plastic dishpan with about 1 inch of plain water until they are ready to be stuck. Prior to hormone treatment, the cuttings are placed in a dry dish pan for about 15 min. We use "Dip and Grow" at one part "Dip and Grow" to 9 parts of water. After quick dipping — in and out — the cuttings are placed in a dry dishpan and allowed to dry out. I do this because "Dip and Grow" contains DMSO and I don't like to get it on my hands.

The cuttings are stuck with the mist system on, so sometimes it gets to be a wet job. I really prefer sticking cuttings at night with the mist off. The cuttings are stuck in rows about ¾ in. to 1 in. apart, and ½ in. apart in the row. With this spacing I can put about 150,000 cuttings in our 1,000 sq. ft. glass house.

Cuttings from *older* plants root better for me. Cuttings from young plants or plants that are well watered and fertilized seem to turn black and die for no apparent reason. I think this is physiological rather than pathological. Healthy cuttings from older plants root perfectly well right next to cuttings from young plants which turn black.

The rooting medium is basically washed mason's sand. I have tried perlite, concrete sand, sharp Columbia River sand, and have found that the fine mason's sand works best. To every yard of sand, add one 4 cu. ft. sack of vermiculite and one 4 cu. ft. sack of perlite, ½ bale of fine grind peat moss, 1½ oz. Benlate, and 1½ oz. Truban. The medium is not sterilized. I don't have the facilities for steam sterilizing, but if we are careful about sand selection we end up with very few weeds. Benlate and Truban should keep other pathogens out. This mixture is mixed with a soil shredder and placed in the bench.

Bottom heat is supplied with Roberson Y-227, 1,400 watt ca-

bles. The cables are spaced about 3 inches apart. I want all the heat I can get out of this arrangement, so I plug the cables in without thermostats and let them run all the time. Bottom temperature stays close to 72°F. Kinnikinnick cuttings do well in full sun and I have had best results propagating them in a glass house with little or no shade.

After the cuttings are in, I spray with Benlate about once every 4 weeks, and with Plantvax about every 4 weeks. Plantvax really does a good job of stopping the reddish spots that get on the leaves.

Transplanting is a very critical time. First of all it should be done during the month of March. The rooted cuttings are potted into 2½", 3" or 4" peat or plastic pots. I think the French "Fertil Pots" work very well for *Arctostaphylos*. We put the cuttings in the pots one at a time and pour the potting mix around the roots. Do not tamp the soil around the roots. The flats of potted cuttings are then taken to the greenhouse and watered down by hand with a hose. After hand watering once, the overhead sprinklers and mist system are used to keep the soil damp at all times. This is hard to achieve, but I would be inclined to give newly-potted kinnikinnick plants more water than less. I like to keep the leaves wet during the initial transplanting period. Kinnikinnick plants are extremely sensitive to lack of water, or to too much water. Watering should be as even as possible. I haven't found a sprinkler system yet that will give even distribution of water, so I use two watering systems over a bed of plants. One system is for heavy watering and the other system is for light watering. I like the Floral-Mist nozzles with the 1/32 in orifice, plus overhead Thompson sprinkler heads spaced about 8 ft. apart. With two watering systems you can more easily balance large amounts of water with small amounts of water to give the evenness of watering you need. I keep trying different nozzles because I am still not satisfied with the coverage I am getting.

Any medium used for growing kinnikinnick should have very good air circulation and very good water drainage. There are a few more things I am going to try. Volcanic sand, pumice, or volcanic cinders, I think could be used with good success. My present potting medium is 4 large contractor wheelbarrow loads of washed mason's sand, 1 standard bale of fine ground peat moss, 2 cu. ft. of vermiculite, 2 cu. ft. of perlite, 1 lb. (454g) fine Mag Amp, 1 lb. (454 g.) 9 month Osmocote 18-9-13, 4 oz. (112g) Sequestrin 330 Fe, 1 lb. (454 g.) limestone flour, 1½ oz. (42 g) Benlate, and 1½ oz. (42 g.) Truban. Later feeding is done with 4 month 18-9-13 Osmocote about once a month, and liquid feed with 24-18-12 Peterson's soluble fertilizer mixed with Sequestrin 330 Fe. I feed to keep the plants growing fast with a good dark green color.

Summer sprayings of Plantvax are continued to keep the leaf spot down.

In summary then, I attribute my success in propagating kinnikinnick to the following factors: 1) timing; 2) proper rooting medium; 3) good air and water draining; 4) use of Truban and Benlate; 5) proper selection of cutting material; 6) use of "Dip and Grow" hormone; 7) not packing the rooting medium down; 8) A short misting interval, but close spaced nozzles; 9) keeping as much rooting medium on the roots as possible during transplanting; 10) not packing or tamping the soil mix during transplanting operations; 11) proper water control; 12) fungus and leaf spot control; 13) continuous feeding with Osmocote after transplanting; and 14) liquid feeding as needed with heavy emphasis on iron.

PROPAGATION OF *GAULTHERIA SHALLON* (SALAL)

MORRIS VAN METER

18221 S.E. Richey Road
Portland, Oregon 97236

Gaultheria shallon is perhaps the most common shrub in the understory of the Pacific Northwest forests. It reaches its largest size in the fogbelt along the Pacific coast where dense, extensive patches of the species often hinder the establishment of forest reproduction on cut-over and burned-over areas. Related species are found in northeastern Oregon and in the Rocky Mountains. The flowers are pink, about ¼" long, borne in loose clusters. The fruit is bluish-black, edible, and approximately 5/16 in diameter. Plants are found on dry to moist, well-drained sites in the sun or shade in the western part of the states from British Columbia to southern California (1). It is a handsome broadleaf evergreen shrub, usually growing 1' to 3' but occasionally to 8' to 10' in height.

Because of the habit and range of *Gaultheria shallon*, it became of interest to the Washington State Highway Department as a candidate for roadside planting. In 1971 we contracted to grow 60,000 plants in 4" pots of salal for this use. As there was no information available concerning propagation techniques to insure such quantities, we experimented with three basic methods as follows:

(1) **Collecting clumps and rhizomes.** Small clumps of salal were collected in the dormant season. The stems were pruned back by two-thirds, and the roots trimmed enough to fit the 4" containers. These were drenched with Vitamin B_{12} and Benlate. Maintaining the house temperature at 70°F, we observed root initiation in 3 to 4 months. We found this method most cumbersome, along with the inherent disease problems.

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(2) **Propagation from seed.** The seed is collected in June to July on the Coast and one month later at higher elevations. It is then cleaned and stored in a cool, dark and dry place until used. This very fine seed is sown in a mixture of ½ peatmoss and ½ fine perlite with a small amount of dolomite lime added. The seed is broadcast on the surface of the flat and covered with a thin layer of fine perlite. A drench of Terraclor and Benlate is applied and the flats placed on bottom heat at 68°F, with overhead shade provided. We found the seed to germinate in approximately 30 to 45 days. The seedlings were very slow growing even under a constant fertilizing program. The seedlings were left in the flat for up to 5 months before transplanting. The seedling at this stage is approximately 2" in height and sensitive to transplant shock. After applying a drench of Benlate a minor loss due to disease was experienced. These newly-planted plants in 4" pots were grown under greenhouse conditions and ready for market in 5-6 months. This method was the most economical and gave us the most control in producing a marketable product.

(3) **Propagation by rooting cuttings.** We chose to use the current season's growth in a semi-hardwood condition; this is determined in large part by the reddish cast of the stem color. The cuttings were made 6" in length. The leaf surface was cut back one-third. Two 1" scars were made, cutting just through the cambium layer on either side of the base of the cutting. The cuttings were then dipped 2" into Hormodin #3. These were laid in flats, covered, and left overnight before sticking. They were stuck in fine perlite and both bottom and top temperatures maintained at 68°F. Root initiation was noted within 30 days. Although we were well satisfied with the rooting percentage, there was a significant problem in that the leaf buds were slow to break dormancy, thereby delaying marketability.

It has been our experience since 1972 that propagation from seedlings is the far superior method. This method afforded us the optimum utilization of labor and greenhouse space and developed a healthy, uniform product for market in the quickest time possible.

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PROPAGATING MAGNOLIAS

W.D. CHRISTIE

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Aldergrove, B.C., Canada

We usually start take cuttings about the third week in June and continue off and on during the summer as cutting material is available, up to the third week of August.

We start out with the stock which is being grown in gallon cans in the greenhouse from last year's cuttings, then take a crop of cuttings from our outdoor stock plants, and end up with more material from the greenhouse.

We like to take our cuttings first thing in the morning while it is still cool and, if possible, we try to pick a day when it is overcast. Ideally, when using soft cuttings from the greenhouse it is best to have a period of a few days when the temperatures are not too high.

Cuttings of *Magnolia* × *soulangeana* cultivars are usually 6 to 8, and sometimes 10 inches long, with 3 nodes. We first remove the bottom leaf, then reduce the size of the second leaf, and pinch out the soft tip. The cutting is given a one-inch basal wound and dipped in 0.8% IBA.

The rooting medium is 3 parts coarse sand and one part medium grade perlite. We use 4-inch flats and put ½ to one inch of coarse sawdust in the bottom. It is a mistake to try to crowd too many cuttings into a flat as this greatly increases the losses from *Botrytis* and other pathogens. With *M.* × *soulangeana* we get usually 120 cuttings in a 12" by 18" flat, but with plants having a very large leaf form, such as *M.* × *soulangeana* 'Lennei', we get only 100.

Flats are placed on the heating cables and settled in by hand watering. Bottom heat is kept at 75°F until rooting occurs and is then reduced to 70°F and finally to 60°F before the flats are taken off the bench and placed on the greenhouse floor.

Only enough misting is used to keep the cuttings from wilting. A great deal of attention is given to this part of the cutting management and we will often have the mist on for only an hour or so during the day and perhaps on a very dull day, not at all. The mist is always turned off at night right from the start. Under our conditions we find that a fairly long misting period — 24 seconds — and a fairly long cycle — 12 minutes — seems to be about right.

Within a few days of sticking a thorough Benlate spray is applied and this is repeated as necessary during the time the plants are on the bench and until leaf drop. If decay does show up

in the cuttings — and this is almost certain to happen to a small extent when very soft material is being used — we remove any affected cuttings from the flat.

After the cuttings have been placed on the greenhouse floor and when weather cools down and leaves start to yellow and drop, we go over the flats several times, removing the dropped foliage. If left in place the dropped leaves will mat and keep the base of the cuttings soggy and, if this happens, no amount of spraying will prevent the occurrence of disease.

The cuttings are over-wintered in the greenhouse with only enough heat to keep out the frost. In the spring, as soon as new growth commences to show on the cuttings they are then potted into peat pots. We used to use a 2¼ inch pot but switched to a 3 inch as we found that this gives the cutting a little more room to develop and gives us a better plant.

PROPAGATION OF DWARF CONIFERS

JOHN MITSCH

Mitsch Nursery
Aurora, Oregon 97002

On a small nursery of 10 acres employing 20 to 25 individuals, over a thousand cultivars can be found at the present time, including conifers and a broad range of azaleas, camellias, heathers, rhododendrons, some selected deciduous stock and a few perennials. During our 28 year history, we have come more and more to specialize in dwarf conifers until now over 500 cultivars can be found on the grounds.

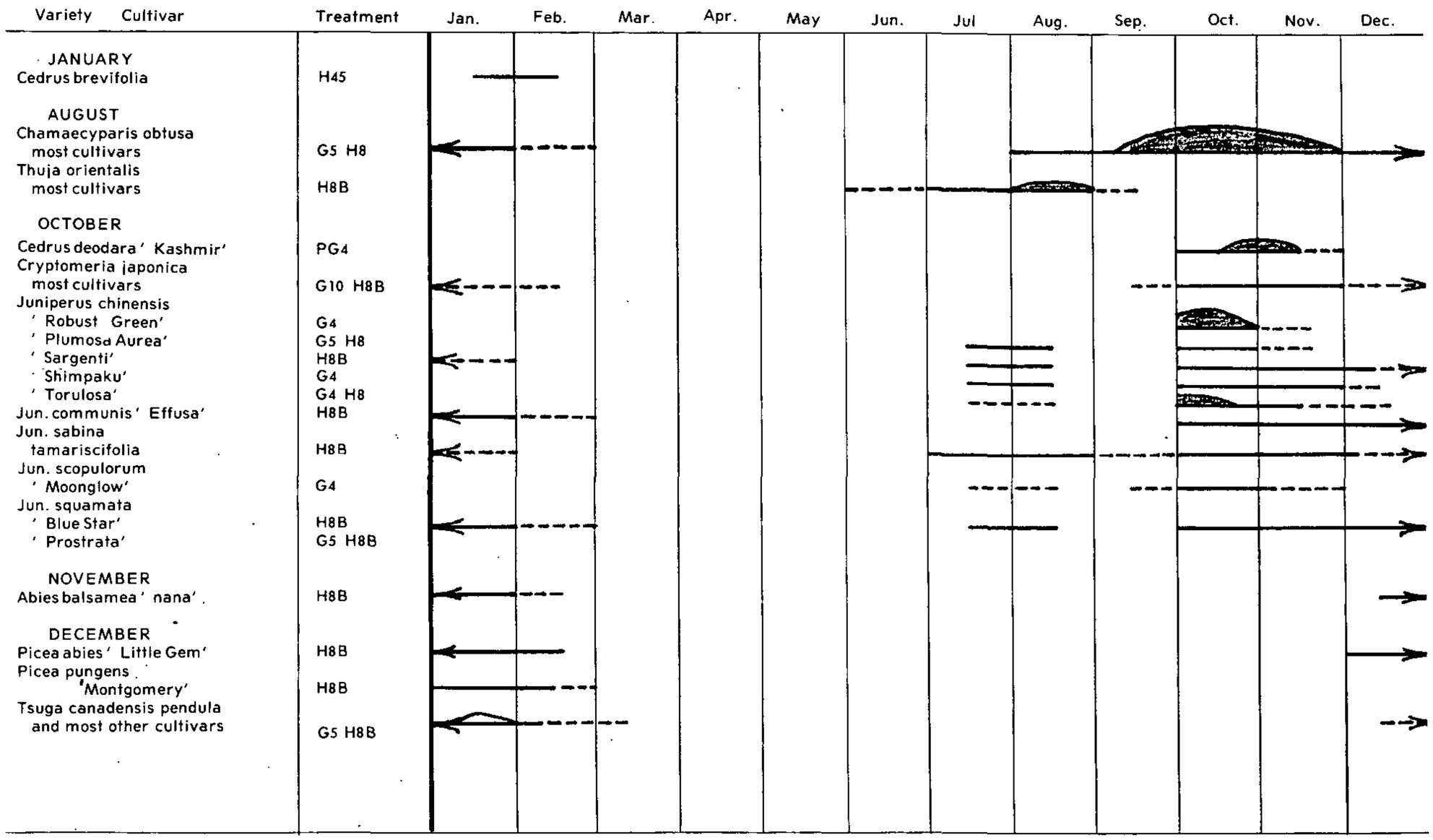
Continuous experimentation and observation have helped us formulate some ideas about specific times and methods of propagation — although we still get surprises! Gradually we have worked out a general time schedule which helps in propagating such a diverse collection. This schedule is frequently updated as we continue to experiment and learn from fellow propagators.

Cultivars (or species) are listed the month propagation is started. (See the following sample Propagation Schedule). Shaded areas are prime time; solid line, good; broken line, "risky but possible" if our schedule prohibited our doing them at a better time. Being able to see the whole month at a glance enables us hopefully to juggle the work loads to get the most plants in at the best time for as many as possible.

After determining the specific item to be propagated we give instructions to our workers by means of a 5" × 8" Propagation card which is made out either by myself or a foreman. These are color coded (green for conifers; salmon for azaleas, pink for camellias, etc.) as there is less chance of error in recording quantities on the backs of the cards as propagation is done, particularly when we are working on several different items in the cutting room at the same time.

The "Actual Total" is filled in at the end of the day or propagation period. This information is then recorded on a Master File (we use a 5" × 8" visible Kardex file) which is color coded to correspond with the Propagation Cards. (See Master File Card.) The Master File lets us see at a glance the history of a plant. When rooted cuttings are lifted for shipping later on, we make notations indicating the success of the propagation as a guide in the future. This works better on paper than it does in actual practice. We have yet to figure out what to do when identical treatments on the same day produce conflicting results. After the information is recorded on the Master File, the Propagation Cards are filed chronologically, thus giving us a day by day record of what went in.

ROPAGATION SCHEDULE FOR MITSCH NURSERY, AURORA, OREGON Shaded area: best time. Solid line: good. Broken line: do only if impossible to do at a better time.



Legend:

H45 = Indole-3-Butyric Acid 4.5

G5 H8 = Double dip: 1 part Dip' n Grow, 5 parts water; followed by H8, 0.8 Indole-3-Butyric

H8B = 8 oz. 0.8 Indole-3-Butyric Acid, 1 oz. Benlate.

PG4 = 1 part Dip' n Grow, 4 parts water. (Pre dipped; allowed to dry for 30 minutes).

G10 = 1 part Dip' n Grow, 10 parts water.

G4 = 1 part Dip' n Grow, 4 parts water.

PROPAGATION CARD

DATE: 1-20-75

VARIETY: *Picea abies 'Little Gem'*

Stock plant location if needed: A 30

Color of label W

needed _____ OR: (All possible) All cut off

ACTUAL TOTAL 4275

CUTTING SIZE: tip (1-2") 2-3" 3-4" 4-6" 6-9" See sample

TREATMENT:

H_8 (H_8B) $H_{16}B$ $H_{30}B$ $H_{45}B$

None

G_5 G_{10} G_{15} G_{20} G_____

Same as last time

G_5+H_8B $G_{10}+H_8B$ _____

PG —5 —10 —15 —20 PG _____

Submerge:

B D (B+D)

PLANT IN:

MIX:

Totals

Flats: # rows per flat 10 # plants per row 25 (1750)

Pots: size of pot _____ (_____)

Bed location: C-3 # in row 100 (2525)

WATER ROOTING MEDIA BEFORE PLANTING; WATER AFTER PLANTING.

MITSCH NURSERY, Aurora, Oregon

For some cuttings, which in the propagation stages look very much alike, we are trying something new this year. On the Propagation Card, above the "Actual Total" we now have a place to indicate the color of the small identification label (name of cutting, treatment, date) to be placed in the flat or bed. Since there are only five colors of these labels available, we consequently have to use the same color over and over again. Thus we might use a green label for *Chamaecyparis obtusa* "Nana' and a yellow label for *Chamaecyparis obtusa* 'Gracilis', etc. Since *Juniperus* does not look like Chamaecyparis, we can again use green for, say, *Juniperus horizontalis* 'Plumosa Compacta' and yellow for *Juniperus horizontalis* 'Aunt Jemima' etc. We are anticipating that this color coding will also help speed the locating of rooted cuttins during the shipping seasons. The color for the label is noted on the Master File. If the system works, we will use the same color of labels next year.

In making the sample Propagation Schedule, we selected those items which we hope will be of particular interest. Basic propagation information is given there for each one. The "G" in the treatment is "Dip'n Grow", whose chemical components are: 3-indolebutyric, 1.0%; a-naphthaleneacetic acid, 0.5%; Phygon (Dicholne), 0.1%; Rutin, 0.2%; Boron, 0.0175%; Dimethyl sulfoxide, 20.0%; Alcohol + deionized water, 78.18%.

Nearly all of our conifers are also treated with a fungicide such as Benlate and an insecticide, usually Diazinone (indicated on the Propagation Card by "B & D"). Most of our conifers are rooted in 1 part washed concrete sand, 1 part fresh fir sawdust, 1

part perlite, and 1 part peat moss. We find the greenhouse grind seems to give the porosity essential for good aeration. The "B & D" treatment referred to is made up of 1½ tbsp. Benlate and 1 tbsp. Diazinone 50W in 3 gallons of water.

Cedrus brevifolia is a little known tree which has patio and bonsai potential with its short, Alpine-looking needles. I think it should be better known. We have rooted this from January 15 to February 15 with H45. Most of the dwarf forms of *Picea abies* root quite readily during January to about February 15, using H8, including *Picea abies* 'Pendula' although it is slower and the percentage of "take" is not as high. We have put in very soft green cuttings of *Picea glauca* 'Conica' in May, using the same treatment under mist with good results. We have had varying degrees of success when we propagated this during late summer or in the fall; however, we have the best success during January to about February 15. For the most part, winter cuttings are propagated without mist over 72°F heat.

The majority of *Tsuga canadensis* cultivars are propagated January 1 to February 15 over bottom heat of about 75°F. We have also had good results with soft cuttings in July under mist.

Picea orientalis 'Aurea compacta' is another cultivar which is beginning to respond slowly to treatment of H8B after soaking overnight in B & D for rooted cuttings.

Our all-season sport is watching for negative and positive signs of sports on our dwarf conifers. Any variation or especially loose or long growth is carefully watched. Dwarf conifers are sometimes difficult to keep true to form because of sporting or as a result of propagating mainly from vigorous tips. They tend to *lose their dwarf habits. However, occasionally a worthwhile var-*iant appears to be sufficiently interesting to start propagating it.

Within the next year we hope to find some method of using solar energy with PVC pipe. Electric coils would supplement this as needed.

WEDNESDAY EVENING, SEPTEMBER 3, 1975

QUESTION BOX

MODERATORS: James O'Friel and Bruce Usrey.

MODERATOR O'FRIEL: Here is the first question. Why do you use only peat and perlite in rooting mixes? There are others just as good.

HOWARD BROWN: I think one of the reasons for using peat-perlite more and more is that they are fairly standard and lightweight, and they are fairly uniform throughout my experience. If you take compost or sand, you may get different grades of sand and some are not really clean. Peat-perlite mixes have proven to be fairly standard over a period of time.

MODERATOR O'FRIEL: Has anyone had a successful experience using Osmocote as a fertilizer in the rooting medium?

BARRIE COATE: I can't say that I have had good results, but the requirement of the IPPS to contribute a paper every few years brought forth a paper that told about a terrible success with Osmocote. We tried Osmocote at two different levels — that is, scattered on top and incorporated all through the mix; we tried also blood meal; and some directly on the bottom of the flat; and a control, of course. We used *Magnolia grandiflora* and *Rhamnus alaternus*. With all treatments we had equally poor rooting results with *Magnolia* and equally good results with *Rhamnus*. In other words, addition of Osmocote and blood meal did not show any beneficial results. Of course, there might have been other things involved that had more effect that the Osmocote.

VOICE: Could I disagree with the previous gentleman? We use Osmocote 14-14-14 in all our rooting media. And we get extremely good results. Maybe our rooting medium is different. We are using at least 50% sawdust in our rooting media. And we incorporate 5 pounds of Osmocote 14-14-14 per yard and we get 95% rooting. We grow general ornamental nursery stock.

BILL CURTIS: What kind of sawdust do you use?

VOICE: Any kind of sawdust.

BRUCE BRIGGS: One thing that you might consider is that in these two cases you are looking at two different environments and two different media. First of all, sawdust ties up the excess nitrogen so you don't get burning from it. In the South, where Barrie Coate is, the weather is warmer. Nitrogen release from the Osmocote may come quicker than it can be used up, before the roots are formed, and there may be burning from it. So there are two different conditions. In the Eastern Region, IPPS meeting, last year there was a paper on Osmocote. It had experimental data and there was an improvement in rooting with Osmocote. They were

working in a cool climate under cool conditions. I think what we need is the release of nitrogen just about the time the roots come out, but without a substantial increase. Going back further to work that was done 20 years ago by Art Myhre in Washington State on blueberries, he found a substantial rooting increase with fertilizer in the medium, but here again he was working under cool conditions.

VOICE: I would like to contribute something, irrespective of climate, on Osmocote. We have been working with the Osmocote people on some tests. Their own chemist claims from all the work he has done with it that there is no significant release of material, under almost any conditions, no matter how hot or cold, for at least a couple of weeks. Under cooler conditions, probably a couple of months is required; this is irrespective of the amount of water applied. This is the way the material acts. It is actually water vapor absorbed into the capsule that is significant. You can actually have the material in a bucket of water with no release of material for this length of time. So, for very fast rooting plants, it really couldn't be any significant aid; but if you want to leave the plants in the medium for a lenth of time afterwards, you can certainly give them a boost.

LES CLAY: I can add something to this. We have used Osmocote in most of our mixes for a while now. We have tried some with, some without, and we have noticed a significant increase in plant condition, a better root system, a much better looking plant. We use about 4 pounds of Osmocote per cubic yard in the medium.

BRUCE USREY: At our nursery we don't use any nitrogen in the rooting media. We don't want the plants to grow until they are rooted. A lot of times we root something but we may want to keep it for a couple of years in a flat, at least a year until we need it.

VOICE: I just want to tie this information together. First of all, in the greenhouse, working with sawdust in varying amounts but with the same amount of other nutrients, including Osmocote, we found that we had high salt level always, with higher amounts of peat. Mixes with very low peat, largely sawdust, we had a lower salt content all the time. With the same water practices, the same plants, and everything, we got different salt levels in the peat and peat-sawdust mixes, depending on the amount of peat. I think this might clear up some discrepancies in the description of the results which have been discussed here.

BRUCE USREY: This is directed to Bruce Briggs and Bill Curtis. It is a question about *Acer palmatum* cultivars. Are the cutting-grown ones more susceptible to root rot in the Pacific Northwest than comparable grafted cultivars?

BILL CURTIS: We have had no problem with damping-off in the field. We couldn't see any difference.

BRUCE BRIGGS: A good nursery shouldn't have root-rot. But if you do have root-rot — then that is a big problem. We have not seen any difference between cutting-grown and grafted maples in this respect. Here again, maples are not bothered too much by root-rot problems. But don't water your maples too much; once you get them growing they will take a tremendous amount of water. It is when you first transplant them that you may have conditions causing infection. That is the critical time to keep the water down. In our fields, we never have root rot problems with maples. Our only problem with maples is verticillium wilt — the type which affects the top. it is not, in any way, connected with the root disease. One of our major problems in rooting maples is verticillium wilt.

BRUCE USREY: The cultivar I had in mind was 'Dissectum.' Once it is put in the homeowner's yard the trouble can start.

BRUCE BRIGGS: On 'Dissectum,' we have propagated it both ways, but we lost more grafts than rooted cuttings. You have to watch that first year for winter damage in the container. Apparently they seem to be tender until all the roots mature. Maybe up to two years.

VOICE: We are growing several cultivars of Japanese maples in the field which were rooted from May-stuck cuttings. Once planted in the field we can see no difference in the growth against those which were grafted. We feel that on their own roots they are just as good as anything produced by grafting. I think, too, that climatic conditions have a direct bearing on the results achieved with *A. palmatum.*

RAY BURDEN: We have grown large numbers of Japanese maple. The first year we put them in the field we lost about 2,000 in very well drained soil. We found that a lot of this agricultural land has been used to grow berries. Verticillium wilt is soil borne; it is in the soil. It does come through the roots and attacks up through to the top. Japanese maple does best in a neutral to slightly alkaline soil condition. Pete Vanderbaum, at Portland Camellia Nursery, used to grow thousands of maples and he would always put lime in the containers. We do the same thing with specimen Japanese maples in big bosses. Any specimen maples — if we plant them in heavy soil conditions where the pH is low — we place the plant on a mound of sterilized or fumigated soil. We use methyl bromide in a regular potting or planting mix with lime added and we never lose any of the Japanese maples. But if we plant them in heavy wet soil with a low pH, kiss them goodby.

BRUCE USREY: The next question I have here — when is the

best time to cut magnolia 'St. Mary' and what is the best propagating technique?

BILL CURTIS: I have grown *Magnolia grandiflora* 'St. Mary' for a number of years. We always take cuttings around the first of November. We have used a rule of thumb that when the tip, the growing tip, hardens — that is the time to take them. If you put them in when the wood is too soft, many times you will lose the tip; you will get a plant with a "dog-leg". If you take cuttings when the shoot matures, you don't generally lose the tip. Now, a lot of people say if you use heel cuttings that is old-fashioned; but I found that *Magnolia grandiflora* cuttings, with a heel, root well if you take the cuttings off 2-year old plants in the field. You use these for cuttings 4 inches in length, up to about 6 or 8 inches. The plants with a heavy pith, to me anyhow, always root better when you use a heel. A plant with a stem like *Magnolia grandiflora* has more pith than wood, so that is one reason, I think, that we have better success with the heel cuttings on this plant. Another thing; we put the cuttings in deep flats and use straight sand, or sand and perlite. We leave them in the medium until we see the roots coming through the bottom of the flat. It takes about 120 days. If you can't get them out without injuring the roots tear the flat apart and throw it away because you must not injure the roots. The plants are set back and won't start growth quite as well. If they have a large root system we put some of them in 2 gallon cans from a 4" flat. We pot them all by hand into gallons and two-gallons, normally 5 or 6 hundred a year.

One thing about *Magnolia grandiflora*; they like a stiff bottom heat. We have used as high as 80°F temperature on *Magnolia grandiflora*. But when you use that much heat, you have to pour the water on them; we saturate them every day. With stiff bottom heat you won't have any problems with rooting. We make about a 2-inch wound on one side only. We found that about a 6 or 8 inch cutting is the most desirable because you can get more in a flat, but we have a lot of cuttings a foot long. If you want to come by the nursery we have 5 or 6 hundred in gallon cans now. You can see what the growth is this year.

BRUCE USREY: Do you have a recommendation on the hormone?

BILL CURTIS: We use Hormodin No. 3. We never cut the leaves. We take some leaves off the cutting and leave about 5 or 6; but we never cut the leaves back.

BRUCE USREY: Do magnolias do best in an acid or an alkaline environment?

VOICE: Well, we know that most magnolias do grow very well at a pH of around 6.5. I think if you got much lower than 6.0

you might be in trouble. But I know they grow very well at 6.5 to neutral to slightly alkaline — up to 7.0 and 7.5. Anywhere in that range. I don't feel that they are fussy plants. We grow 8 to 10 thousand a year.

BRUCE USREY: Has anyone evaluated the effect of Ban-Rot in comparison with Benlate as a fungicide treatment on cuttings at time of hormone treatment?

VOICE: Ban-Rot and Benlate are not inter-substitutable. Benlate itself covers one range of pathogens — *Rhizoctonia*, *Fusarium*, and *Verticillium*. Terrazole and Truban are for *Phytophthora* and *Pythium* problems. The advantage of Ban-Rot is that it combines Terrazole with a chemical that gets *Rhizoctonia*. You cannot precisely compare the two.

VOICE: Benlate is completely ineffective for the geranium diseases, as far as I am concerned. Ban-Rot gives you complete control of *Pythium* and all of the other usual disorders associated with rooting geraniums.

VOICE: I have tried Benlate on a few things; it doesn't seem to be very effective. I use Captan on ferns and it doesn't seem to disrupt the fern. I don't find Benlate very effective at all.

BRUCE USREY: Today someone mentioned that Benlate was not good for azaleas, that it inhibited rooting. Please elaborate; did you mean for hardy evergreen, deciduous, or forcing azaleas? Also was it used as a dip, soak, or spray? Does anyone have an answer?

LARRY CARVILLE: We are using Benlate as an additive to a dry-rooting compound. We mix it with Hormex No. 8. We dip our deciduous Exbury azaleas in this. We find that the use of Benlate in the rooting compound does delay somewhat the formation of roots. I don't mean inhibit in the sense that they do not root but it does delay them. It is only a quick-dip dry formulation; 5% Benlate added to Hormex No. 8 rooting compound.

BRUCE USREY: Has anybody tried open-bench grafting of *Juniperus* 'Ames' or 'Wintergreen'? We use a cover tent and have a lot of problems with disease on these cultivars; we have been trying to get more air circulation, more light to them. They seem to dry out before the graft takes. I wonder if anyone has used open bench grafting of junipers in their greenhouse?

RAY BURDEN: We personally don't graft them, but West Oregon Nursery grafts a great many conifers. The grafting is open bench. They graft low and put a layer of sawdust and peat over the union; they are grafted in open air with bottom heat under and seem to have very good success. We graft the scion and unrooted stock, then stick them in the bench. The understock roots and the graft takes at the same time — the way we do it.

BRUCE USREY: We open the rooting frame quite a bit but we

still have a lot of disease problems. The next question is to Bob Boddy. Have you had any success with spring cuttings of Mahonias? We want to accelerate the growth of rooted cuttings by getting them rooted early in the growing season and have had promising results with trial blocks taken just as the first part of growth is finishing its April and May cycle. So the question is — have you had any success with spring cuttings of Mahonia?

BOB BODDY: No.

BRUCE USREY: This is to Larry Carville and Bob Ticknor. Have you had any experience with hardwood cuttings of *Viburnum carlesii, macrocephalum,* or *carlcephalum?*

LARRY CARVILLE: We handle all our viburnum cuttings as softwood cuttings, taken in June, and stuck outside in the sand under mist beds. We pull them in late fall, when they have ripened up and rooted well and store them dry, in polyethylene bags in the cooler at 35°F. We plant them out in the field the following spring. We have not made hardwood cuttings of those viburnum species.

RALPH SHUGERT: Appending Larry's comments, concerning three of the species he mentioned; we take them very soft, use a very light hormone treatment and intermittent mist. Now *V. carlcephalum* in Ohio does not over-winter well. We treat it the same as we do the *Syringa* cultivars on their own roots. We leave them in the mist beds with, of course, the water off. They winter there under poly, but with no heat. Then they are lifted the following spring. The same comment on *V. carcephalum* as Bill Curtis said regarding magnolias. If we damage the root then we are in lots of trouble. We then take bare root liners but we do not run them through a pot but go out in the field through a planting machine. The French lilacs are carried a second year in the beds, and then you have got a nice 9-12 mail order grade — two years in the mist bed.

BRUCE USREY: Next question has to do with germinating modin No. 3?

VOICE: It is 8000 ppm or 0.8% indolebutyric acid (IBA).

BRUCE USREY: Next question has to do with germinating *Mahonia aquifolium* seed. We pick a lot of it in southern California when it is half green and half blue or purple. Then we soak it and clean it. I think we have picked a hundred pounds this year but if we get a couple of thousand plants we will be doing good. So I am looking for someone who has had a little better success at it than I have.

BRUCE BRIGGS: Apparently you have a problem in the southern states that we don't have here, but you are not the only one in the California area that has this problem. I know some

members of this group have asked me about it. We find no problem at all. As soon as the seed is ripe, we pick it and clean it and immediately sow it in boxes. We sow it right away. Along about February or March, when the weather turns warm it germinates — no problem at all. So it must be in the southern states you are not getting sufficient cold stratification or your seeds have some other problem. I am not sure what it is, but apparently you have a problem in your area that is not typical here in the north.

VOICE: What temperature do you use for Mahonia seed stratification?

BRUCE BRIGGS: We take our outdoor winter temperature. We do clean the seed, take off the pulp, and immediately store it in shallow boxes. We put them outside — freezing is OK — through the winter, and by February the seedlings really come up. There is no problem at all under our conditions.

Friday Morning, September 5, 1975

DIRECT CANNING OF ROOTED CUTTINGS INTO ONE GALLON CONTAINERS

BARRY A. EISENBERG

California Polytechnic State University

San Luis Obispo, California 93401

Abstract. *Buxus japonica. Raphiolepis indica* 'Rosea'. *Trachelospermum jasminoides. Viburnum tinus* and *Weigela florida* were used to determine if rooted cuttings could be directly potted into one-gallon containers. Direct potting of rooted cuttings offers a grower a production operation that could reduce labor and materials costs. Direct potting of rooted cuttings was successful with four of the five species used in this study and demonstrated that a grower may be able to achieve an equal or better quality one-gallon container plant by direct potting. The condition of the root system at time of transplanting, the soil mix and conditions used to reduce dessication are the primary concerns a grower will need to evaluate for his specific growing conditions. The type of root system, either fibrous, stiffly branched or wirey, appears to be a root characteristic that lends itself to determining if a plant can be directly potted.

Much of the work involving direct canning of rooted cuttings has been done with deciduous plants. Worth (11) reported that direct canning of *Spiraea* and *Syringa* cuttings saves the labor equivalent to 8 or 10 persons.

Hill (5) observed that some *Salix*, *Prunus*, and *Pittosporum* species initiated growth earlier when canned directly in one-gallon containers than when placed in ground beds. In addition, he noted that direct canned cuttings had twice the growth of ground bed cuttings, which he attributed to less root disturbance during the growing period.

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Vermeulen (10) reported the importance of a well aerated soil with high moisture-holding capacity for direct canning. In addition, Vermeulen (9) noted that increasing labor and materials costs are causing nurserymen to find ways of cutting expenses and offered the concept of direct canning of rooted cuttings into one-gallon containers as a practical solution to this problem.

Numerous persons have stated the disadvantages of direct canning of rooted cuttings. Anderson (1) noted that a grower can control environmental factors better in a liner pot than in a one-gallon container; pots need less checking for chlorotic conditions; and the Jiffy-Pot is easier to pot because the roots are confined to a specific area which reduces root damage. Blyth (2) agrees that direct canning of rooted cuttings may not be a beneficial practice. He stated that direct canned cuttings slowed the hardening-off process after transplanting when compared to plants grown in Jiffy-Pots.

The purpose of this study was to evaluate root characteristics of direct canning rooted cuttings vs those grown in liner pots prior to canning in one-gallon containers.

MATERIALS AND METHODS

The experiments involving direct planting of rooted cuttings into one-gallon containers was carried out at the Ornamental Horticulture Unit, California Polytechnic State University, San Luis Obispo. Two structures were used; a 50% shade house and a mist propagation house. The shade house was used to harden-off the cuttings after they had rooted in the mist house. After the rooted cuttings were planted in one-gallon containers, they had a 2 week period in the lath-house to reduce transportation so that dessication would not occur.

Thirty rooted cuttings of each of the following, *Buxus japonica* - Japanese boxwood; *Raphiolepis indica* 'Rosea' - India Hawthorn; *Trachelospermum jasminoides* - star jasmine; *Viburnum tinus* - Laurustinus; and *Weigela florida* - Rose weigela were rooted and ready to transplant May 25, 1974. Fifteen plants of each species were potted into one-gallon containers on May 25, 1974 and were placed in the 50% shade house for 2 weeks. The 15 remaining plants were placed in 3'' clay pots, left in the mist house out of mist for 1 week then moved to the shade house. The liner pots were then placed into one-gallon containers on July 11, 1974. The one-gallon containers were placed in full direct sun for the remainder of the growing period. On September 18, 1974, 5 plants from each treatment were evaluated.

The rooting medium consisted of 9 parts grade #2 perlite and 1 part fine peat moss. The soil for the liners was 2 parts coarse washed sand, 1 part peat moss and 2 parts pumice. For the one-

gallon containers a soil mix which consisted of 2 parts Cal-Poly Soil Mixture[1], 2 parts fir bark, 2 parts pine shavings and 1 part coarse washed sand was used.

In analyzing the root development, three characteristics of the roots were used: length, symmetry and number of roots. Root length refers to the longest root from the terminal tip to its origin from the stem. In referring to root symmetry, the author used a 1-4 rating system, to evaluate that area of the stem most of the roots occupied. A root system that had roots primarily in one quadrant of a circle would be given a rating of 1, thus showing that the root system was unbalanced. A rating of 4 was used if the root system occupied all four quadrants of a circle thus indicating that the root system was more evenly developing in the container. A rating of 2 or 3 were used accordingly. The number of roots is the measurement of the number of primary roots originating from the stem.

Table 1. Comparison of roots of plants by direct potting vs. liner potting in the production of nursery crops.

	Direct Potted in 1 gallon containers			Liner Pots		
Species	Length (inches)	Symmetry	No. of Roots	Length (inches)	Symmetry	Length (inches)
Buxus japonica	5.6	4	31.6	5.0	4	27
Trachelospermum jasminoides	10.2	3.2	19.2	3.8	3.4	16
Raphiolepis indica 'Rosea'	9.6	2.6	6.0	7.8	3.2	10.8
Viburnum tinus	5.8	3.25	8.4	3.4	3.25	8.4
Weigela florida	8.0	3.6	36.7	5.6	3.25	21.4

[1] Symmetry - Values refer to the four quadrants of a circle which the roots of the plants occupied. A rating of 1 is very poor and a rating of 4 is excellent.

RESULTS AND DISCUSSION

All species except *Raphiolepis indica* could lend themselves to direct potting into one-gallon containers. With *Raphiolepis rosea* the reduction in number of roots and symmetry outweighed the increase of length rooted in the direct planted rooted cuttings. If the number of roots were similar, then root length would have helped in evaluating the difference in the cuttings (Table 1).

Both *Trachelospermum jasminoides* and *Weigela florida* responded favorably to direct potting. The symmetry did not differ significantly between the two treatments, but the number of roots and length of roots were greater with the direct potted cuttings (Table 1).

Buxus japonica and *Viburnum tinus* showed few differences between the two treatments, except that the *Viburnum tinus* did show an increase in length without a decrease in number of roots.

[1] Cal-Poly Soil Mix: Baywood sand: fir bark: clay loam: aged manure (2:2:1:1 by volume) with 3 lb superphosphate; 2 lb hoof and horn meal: 1 lb K_2SO_4: 1 lb dolomitic lime per cu. yd.

It should be noted that if no differences between the two treatments occurred, it would favor direct potting as this is a savings in labor and materials.

While recording the results of this experiment the author noticed three distinct types of root systems: fibrous, stiffly-branched and wirey. *Trachelospermum* and *Weigela* roots fibrous; *Buxus* and *Viburnum* roots were stiffly branched and *Raphiolepis* had a wirey root system. This could be a key that a grower could use to estimate whether a plant could be used for direct canning of rooted cuttings. The two species that were fibrous-rooted showed the best results, with the stiffly branched material showing some increases in root length. The wirey type root system of *Raphiolepis* showed adverse effects from being direct canned and this could indicate that plants with a wirey root system might not lend themselves to being directly canned.

The author believes that the root system should not be overgrown. Smaller roots would permit the plant to grow into the pot with little root damage. Using cuttings with too large roots may be the major reason why some growers have had poor results with direct cannings (1, 2).

There are three major factors that a grower will have to deal with in deciding whether or not he will be successful in direct canning: the environmental conditions, the condition of the plant and roots, and the soil type used.

Vermeulen (10) has done work with soil mixes for the direct canning process. The same requirements of a good rooting medium: aeration, moisture holding capacity and support of the cutting are the three basics that also must be maintained in a mix for direct potting (4) so that the transition between the rooting and growing medium will be small. Soil mixes for direct canning depend upon the region and the materials available. Any mix will work provided adequate care is taken during the growing process.

The environmental conditions that affect water loss are of primary importance. Misting the foliage, shading the plants, using anti-dessicants, and reducing wind velocity all have beneficial effects in reducing water loss. When a root system isn't fully developed when planted into a gallon container, water uptake will be less, thus the grower will have to offset this by using the above-mentioned methods. In a large scale operation misting of the foliage and shading offer the best means to reduce transpiration. Since most nurseries have some type of irrigation system the misting would not add extra cost to the direct canning process.

The condition of the root system at time of planting is critical. Anderson (1) stated that one problem with direct sticking of cuttings relates to the root damage that occurs. Anderson is assuming that the roots will be overly-large during transplanting.

In this brief discussion of direct planting of rooted cuttings many points have not been mentioned or looked into that could offer some benefits. The use of nutrient mist of which Usrey (8) has commented on, as a benefit to propagation could be useful. Also the use of mycorrhizal fungi might add extra water and nutrient absorbing area (7). The use of mycorrhizae in this manner has not been fully researched and no one really knows what benefits will be achieved.

In conclusion it should be noted that some nurseries do direct-pot rooted cuttings. Oki Nursery in Sacramento have gone as far as directly-potting rooted cuttings into five-gallon containers (3), while Green Thumb Nursery has used direct potting of rooted cuttings with some herbaceous, fibrous materials. Only by further study will this method of producing one-gallon container plants be adapted to the present nursery operation scheme.

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WINTER PROTECTION OF NURSERY STOCK WEBFOOT STYLE

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In winter protection, "Webfoot" style, we are striving for saleable nursery stock in the spring that will bring the buyer to our nursery again and again. We are also looking at costs — a major part of our costs is labor; in fact, the greatest cost of winter protection is LABOR. We must so structure our winter protection facilities to keep this cost to a minimum. A great deal of labor cost can be eliminated if the stock can be grown in the structure used to protect the plants during cold weather. For the most part we leave our plants where they are grown, covering them prior to winter. We do move some stock from the canned area to larger structures before severe winter weather arrives.

We have for years used steel reinforcing concrete mesh. It is known in the trade as 6×6×8. This wire reinforcing mesh comes in a 7' wide roll, 150' long. Cut into 10' wide sections it will give a quonset frame 105' long. A foot can be left between each section, gaining an additional 14'. This material, on today's market, will cost $8.20 per 100 sq. ft. Some labor is involved in cutting this 8 gauge wire. A 24" bolt cutter will do the job. We unroll the mesh, placing a plank on either end to hold it flat. As we cut off each 10' section we move the plank. Cut a 10' measuring stick which will speed up the job. Cut in between the spaces; this will leave a 3" end to stick in the ground. A man on either side of the row of containers spreads the mesh, setting it down over the stock; pressure of the foot sets the mesh in place. We space our cans 5½' to 6' wide. This gives an arc that during a normal winter will shed the snow. If you are in an area of heavy snow fall, drive a stake through the mesh, setting it under one of the wires, holding it in place with a small staple or bent-over nail. We use the same method for 3's and 5's. The section of wires are longer so, of course, you do not get as many pieces out of a roll. We always use a stake under the higher sections or snow will collapse them. We use 4 mil × 12' plastic to cover the lower quonsets. The sides are covered with soil or sawdust of sufficient amount to keep the edges in place.

The end plastics are left open until we know it is going to be cold, then we drop the ends, setting a couple of cans or anything handy to hold the ends down.

We begin to set the wires over the stock in mid-October when it is too wet to work in the fields, perhaps placing the plastic over the wires at the same time, only covering one side, then throw the

plastic off the wire to let the rains get every plant good and wet. We watch the weather forecast. In early or mid-November we put the plastic in place, covering the quonset. We do not drop the ends until we know it will be cold. The stock must be wet — this is MOST important.

The only source of heat in these low structures is the ground. A low ceiling perhaps 3' at the most traps the heat. If stock is wet we have never had any losses. During a mild spell of weather in late January or early February we uncover the plants, throwing the plastic between the two rows of quonsets. We do this when we know we are to have heavy rains. If necessary, we recover at night if it looks as if it will get enough cold to harm the stock.

We have other structures that we grow in for one year before setting stock in the fields. One is a quonset structure 17'×100', covered with saran cloth but also covered with 4 mil polyethylene during the winter.

The balance of our growing houses have fibre glass roofs, with saran cloth for shade around the sides. All are enclosed with 4 mil polyethylene before cold weather sets in. All have overhead watering but no heat. We keep them closed tightly during cold weather. We also keep the 5'×7' door open until we know it will be cold enough to hurt the stock. We used to heat these houses with Hi-Low heaters — burning kerosene — but we found that we do not get any winter injury if we just keep the houses closed tightly when it is cold.

MATERIALS HANDLING AND MECHANIZATION OF HARDY NURSERY STOCK

RICHARD FLINT[1]

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The decision to mechanize any one aspect of a nursery must be tied to various other factors if it is to be effective.

1. A production flow line should be worked out.
2. Be sure of worker participation.
3. Can any of the equipment be used to advantage elsewhere?
4. If extra production is envisaged as a result, can it be sold?
5. A carefully planned training program.
6. A costing system.

The benefits that can be achieved are:

1. To reduce the heavy work done by staff.
2. To speed up work done by staff and thereby reducing the number of staff required, or increasing the volume of production with the same staff.
3. To reduce the number of menial and unpalatable jobs performed by staff, thus making the total job more desirable.

An efficient approach to the "manufacture" of plants will help to encourage the right type of people to come into the industry. As with farming, it should not be the type of job that school leavers decide to take up because they can find nothing else. We should aim to make horticulture one of the most desirable and attractive of professions as it is certainly possible for it to be.

The concept of mechanization is discarded by some because it sounds as though it involves the spending of considerable sums of money. There are however a number of ideas which cost very little but can be very useful; for example: hand-operated tying machines, the square pot "fork" and the ring knife, etc.

Other larger and more expensive items include a variety of planting machines, lifting machines, potting machines and internal handling systems such as the Tilhill Nursery pot standing trailer and the Nisula Roll system. Other U.K. innovations are the Hillier tractor-mounted seed picking platform and the National Institute Agricultural Engineering gantry system. Each of these sys-

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[1] Richard Flint is a Nuffield Farming Scholar to whom the Management Council of the United Kingdom Farming Scholarships Trust awarded the Eric Gardener Memorial Fund traveling scholarship to study commercial horticulture and production.

tems can increase the efficiency of a nursery and thereby help to produce a product which is more competitively priced in the leisure industry market.

Automated irrigation, liquid feeding, ventilation and temperature controls, etc. all have a place in freeing labor for other tasks and will probably do the job more efficiently.

Grafting machines and budding guns etc., mean that long years of expensive and intensive training are not necessary.

All this does not mean that skilled persons will no longer be required. On the contrary, the skilled man or woman must be even better and will have much more responsibililty. If, for example, an automated irrigation system is not programmed correctly considerable damage could occur. If the mechanical grafting is not done at the correct time the "take" may be worse than if done by hand. When a large number of plants are grafted by hand the prolonged duration of the job will mean that at least some of the plants are handled during the optimum period. When done mechanically the time taken will be much shorter and must therefore be done at the correct time — timing is critical.

One of the potential benefits that I have not yet mentioned is the sharing of ideas on mechanization. On individual nurseries throughout the world, individual people have their individual problems and solutions. As IPPS members are already convinced of the benefits of sharing ideas on propagation I would like to make a proposition:

Would it be possible to form a "register" of current ideas and systems? Anyone who had an idea or a problem could approach the register. Would IPPS, as a respected, unbiased, international idea-sharing Society be prepared to be "caretaker"?

If we as an industry are not prepared to help each other, nobody else is likely to come to our aid, nor can we hope to become a more dynamic, enlightened and progressive industry. Any nursery worthy of its name must be a well organized unit, displaying not only the excellence of its products but also the well thought out systems of planning, operation, mechanization and good husbandry. These things are the "Shop Window" on the business generally and are vital to the trade and the general public we seek to interest.

MODERATOR SHUGERT: We now have time for questions for the first panel of speakers on this morning's session.

HUDSON HARTMANN: On the Nisula roll used in England, are unrooted cuttings put in there to root, or are they rooted cuttings, or seedlings?

RICHARD FLINT: They are seedlings.

MODERATOR SHUGERT: The roll technique that Richard nicely described in his paper was observed by several of us who attended the 1973 conference in Great Britain. They are rooted seedlings that I refer to as a "jelly roll wrap." They would wrap plants for storage for winter and then take them back out into the field. The tops are sticking out; the seedlings are merely rolled in polyethylene and a slicing machine slices the roll right in half. And then you set each half on the truck. It has tremendous amounts of advantages, as Richard pointed out in his paper, for storage as well as the handling of the plants. They can stay in these rows for a good number of months; they pick up the roll, take the whole roll through the reforestation area, which saves a lot of flat and lug handling. Only one small roll of plants has to be carried.

BARRIE COATE: Regarding the tilt bed trailer that Richard demonstrated; was that a motorized trailer, or was just the weight of the cans used to tip them off the trailer with the belts to help them — or is that belt motorized?

RICHARD FLINT: No, I think it is a hand-operated mechanism.

JOHN TRAAS: Would heat inside the air-supported structure prevent the snow collapse which we saw in the slide?

BRUCE BRIGGS: Actually we didn't try heat in this house. There has been a lot of basic research done over at Washington State University at Pullman on air-supported houses. Dr. Charles Pfeiffer worked on this when he was a teacher there. They recycled the warm air under the house but they had the same problem. Whenever you have a snow fall you have to sweep it off. I am not sure how warm you have to go to get the snow off but in their work at Pullman there was not enough heat to melt the snow. The house would go down with the snow. We use the air-supported house in the spring after the snow is over.

LARRY CARVILLE: Just a comment on those doublewalled air-inflated houses. We are using them in New England quite successfully both for propagation and for growing. They are typical quonset houses. We have a lot of slope at the sides of our houses. The ones in Bill Curtis's pictures look to me to be very flat on the top. I can see where you might get into problems with snow. We do get snow in New England; we get wet snow. But with the quonset house it will shed off.

JEAN WHALEY: I would like to ask Dr. Anderson about his cuttings that have the roots emerging from just one side. Do they develop from the other side, too? We have always discarded cuttings of conifers that were what we call one-rooted. We take the root off and start over again.

DR. ANDERSON: We are getting a much better rooted cutting

if we put them in a peat pot and put them in gravel. We get a much more fibrous-rooted cutting than the ones with tap roots you saw in the pictures.

MODERATOR SHUGERT: About the polyethylene container that Richard Flint showed. That is not a rigid wall container as we know it in the states. Are there any questions about this type of container?

JOLLY BATCHELLER: What are the costs as compared to gallon cans?

RICHARD FLINT: Approximately $30.00 per thousand in England for the polyethylene containers; 3¢ apiece as against 23¢ for a gallon can here.

VOICE: Will these poly containers with plants stack one upon the other in a truck without damage — or do you have to shelve them?

RICHARD FLINT: Well, they will, in fact, stack at least 2 or 3 high — but we do normally shelve them.

VOICE: First of all, about actual handling of the poly containers, is there any way of carrying more than one at a time? Do they carry them by the rim of the container without having the poly just tear? If you are to set them out in beds where you want spacing — say, you are growing something like junipers — that are spreading wide around the container. Can they stand up by themselves without each other for support?

RICHARD FLINT: The polythene is really quite strong. You can easily carry two in each hand with your fingers; the poly doesn't tear. As far as spacing is concerned, they are heat-sealed and it has a square base.

VOICE: Do you have problems with ripping of the seam?

RICHARD FLINT: No — maybe an individual one.

MODERATOR SHUGERT: We saw a very large rose operation — potted roses in full bloom. We saw them in the growing state and we saw them loading the lorries (trucks) and moving them into the containers. The slide Richard showed was one which I had never seen before showing the loading of the bed of his truck — backing the truck under the bed. They have these all lined up so that the truck would go out, unload the carriage of the truck, if you will — the actual bed right out from underneath it; then swing on back, picking up another one, and leaving the sold containers in a customer's yard. Beautiful way to ship stock.

VOICE: I would like to ask Barry Eisenburg what his mortality rate was, and what was the replication on that project that he did.

BARRY EISENBERG: None.

VOICE: How many plants did you actually use in the experi-

ment? How much replication did you have?

BARRY EISENBERG: Thirty plants in each group. That is what I started with. Then I took 5 that were showing the best characteristics out of any of them to use as the samplings.

VOICE: Has it ever been used in large replication?

BARRY EISENBERG: This is the San Fernando valley of California that we are talking about — just north of Los Angeles. Summer temperatures are 85° to 110°F. We used direct rooting with oleanders and we have tried it during the winter months with some of the junipers and we did it also with all of our perennials — Marguerite, Shasta Daisy, etc. We have had real good success with direct rooting, but the owner of the operation is hesitant to change methods because he has been successful using Jiffy Pots. This seems to be the biggest drawback. Everyone is already satisfied with what they are doing. In the San Fernando area everything they are growing they are selling anyway. So why change?

MYCORRHIZA EFFECTS FOLLOWING SOIL FUMIGATION

D.A. NEWCOMB

Willits & Newcomb, Inc. – Citrus Nursery
Thermal, California 92274

Fumigation of citrus nursery soils has come into general use during the past 10 or 15 years. The increasing difficulty of finding suitable citrus soil which is free from harmful nematodes and phytophthora fungus has made it necessary to treat nursery sites in order to grow disease-free plants.

The first attempts at soil fumigation of seed bed soil at our Thermal, California nursery resulted in a near disaster. Citrus seed planted in either methyl bromide or Vapam-treated soil sprouted and grew normally at the start, but when the seedlings reached a height of 3 to 4 inches, growth stopped or was retarded in large areas of the beds. In some small areas of varying size the seedlings grew normally. Similar stunting of citrus seedbeds has been observed following soil fumigiation in Spain, Peru, Venezuela, and Florida.

Studies made at the Citrus Research Center of the University of California at Riverside showed a deficiency of phosphorus as well as some of the micronutrients in the stunted plants. A pro-

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Studies made at the Citrus Research Center of the University of California at Riverside showed a deficiency of phosphorus as well as some of the micronutrients in the stunted plants. A pro-

gram of preplant application of 1200 lbs. of phosphorous per acre resulted in improved growth. In fact, plants of some rootstocks, such as Rough lemon and troyer citrange, responded with 80% to 90% of normal growth; but others, such as sweet and sour orange, only grew to 40% or 50% of normal size.

Samples of roots of the affected plants were sent to Dr. J.W. Gerdemann at the University of Illinois, who had made studies of the effect of mycorrhiza fungus on growth of woody plants. The stunted plants were found to be non-mycorrhizal.

In every case, the healthy plants were mycorrhizal. This led to trials of field inoculation. The first effort in our Thermal nursery was made on *Citrus amblycarpa* Ochse by Harold Lembright of Dow Chemical Company with inoculum supplied by Dr. Gerdemann. This inoculum had been grown on Sudan grass roots. The plants inoculated were growing in methyl bromide-treated soil that had not received the heavy application of phosphorus fertilizer. These trial plants had been transplanted from fumigated seed beds which had received the heavy phosphate fertilization, but had failed to grow after transplanting. The inoculation was made six months after transplanting by mixing the mycorrhiza culture into the top two inches of soil around the plants. The result was spectacular. The inoculated plants started to grow normally while the untreated remained dormant or died (see Figure 1). Also, taking soil from around healthy plants in fumigated seed beds and working it into the soil around stunted plants in the same seed bed has consistently resulted in a quick growth response.

Subsequent experimental data obtained under controlled conditions has confirmed the dependence of citrus on mycorrhiza for adequate nutrition. Fumigation or other soil treatments usually reduce and may completely eliminate the natural occurring mycorrhiza. Spots in fumigated seedbeds where the plants grow normally result from failure of the fumigation to destroy the mycorrhiza.

The question remains, how can lack of mycorrhiza in fumigated nursery soils be overcome? One method is the inoculation of the citrus seed. Work by Dr. Gerdemann and Dr. John A. Menge with seed inoculation has resulted in successful growth of seedlings in fumigated soil with normal levels of fertilization. Mycorrhiza-inoculated seed of sour orange, *Citrus aurantium* L. grew normally in fumigated soil, while noninoculated seed showed greatly depressed growth (Figure 2). The inoculation of seed seems to be a promising approach to a solution of the problem.

The successful use of mycorrhiza in citrus nurseries may suggest its application to other tree crops.

Figure 1. Mycorrhiza inoculation of *Citrus amblycarpa* Osche. Trees on left noninoculated. Trees on right with black band on wrapper inoculated with mycorrhiza culture by mixing into top 2 inches of soil 6 months after transplanting.

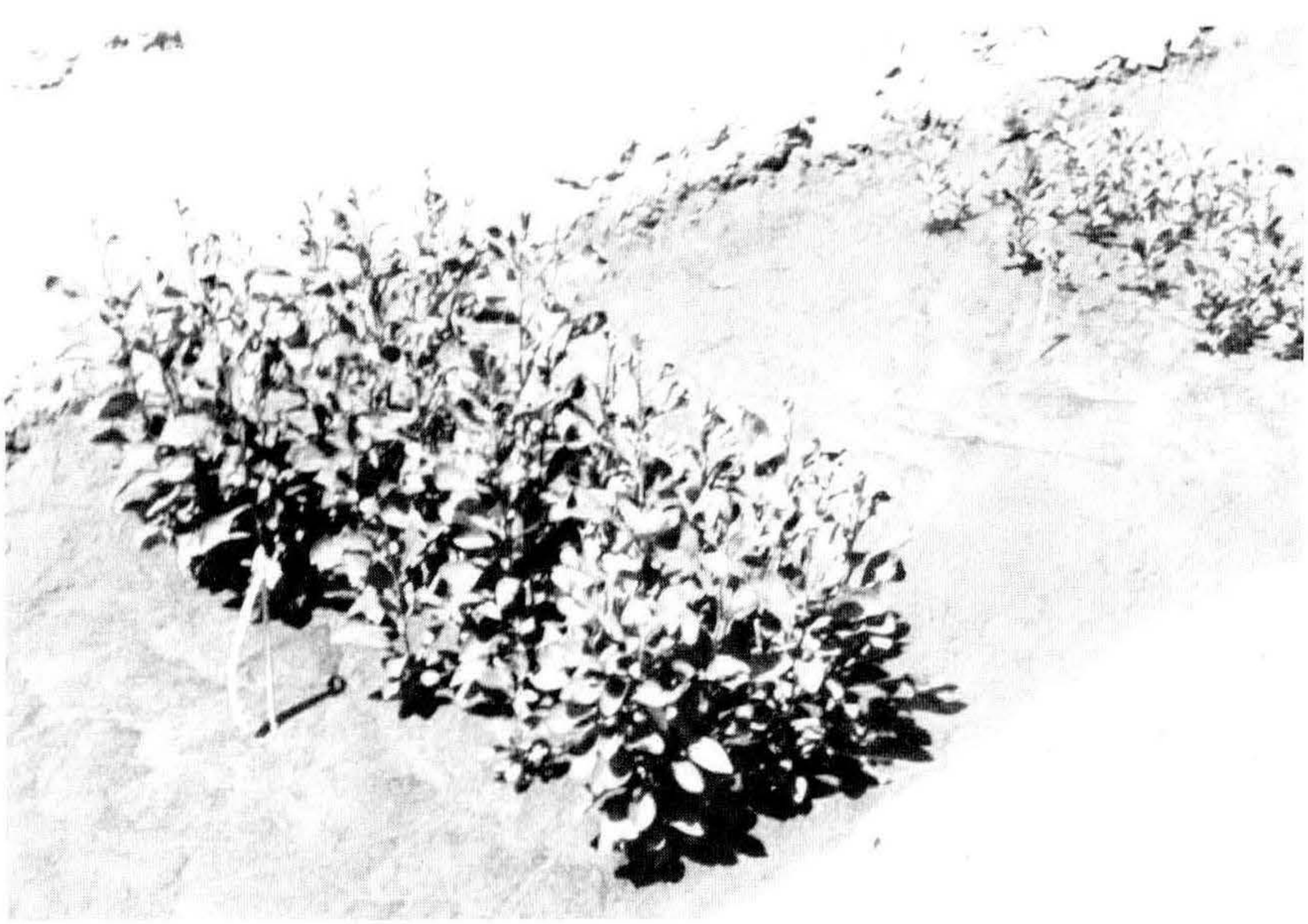

Figure 2. Inoculation of Sour orange seedlings (*Citrus aurantium* L.) with a culture of mycorrhiza. Plants on left from inoculated seed. Plants on right from noninoculated seed. Grown in fumigated soil.

MYCORRHIZAE-PLANT RELATIONSHIPS

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Abstract. Greater than 80% of all plants are reported to form either ectotrophic or endotrophic mycorrhizal roots in a symbiotic association with fungi. This association modifies the biology of the plant and provides a beneficial effect by increasing nutrient uptake, deterring root pathogens and increasing plant resistance to environmental stress. The influence of the mycorrhizal associations will vary with the different fungal symbionts and as environmental conditions at different planting sites change. For these reasons, scientists and practicing nurserymen are now combining their efforts in an attempt to obtain maximum potential from selected manipulation of the mycorrhizal association.

A complex of divergent microorganisms (fungi, bacteria, actinomycetes, nematodes, etc.) is associated with all plant roots. This association varies from being extremely specific, exemplified by the legumes and the associated nitrogen fixing bacteria (*Rhizobia* sp.), to the relatively loose associations found in the rhizosphere where organisms appear to have no specific function, but are adapted to the unique soil environment created by the presence of the plant root.

The symbiotic association of fungi and plant roots results in the production of a root structure referred to as mycorrhiza ("fungus root"). Only a limited number of fungi can form this association, yet greater than 80% of all higher plants are believed to exist in this symbiotic association.

TYPES OF MYCORRHIZA

Ectotrophic mycorrhiza can be recognized by the swollen short roots, often richly branched, lacking root hairs and, as a rule, surrounded by a thick hyphal sheet. This hyphal sheet effectively isolates the root from direct contact with the soil. In this association, the fungal hyphae which enter the plant root, are intercellular only in the outer root cortex. Higher fungi, belonging to the Hymenomycetes and Gasteromycetes, are responsible for forming this association (18). The ectotrophic mycorrhiza are the type most frequently developed in association with coniferous forest vegetation. In the natural environment, nearly all feeder roots will be mycorrhizal.

Endotrophic mycorrhiza can be recognized by loose network of hyphae in the soil surrounding the root and by extensive hyphal growth within the root cortex. In the endotrophic mycorrhiza, the hyphae which enter the plant root are intracellular and are confined within the cortical tissue only by the digestive activity of the plant root cells. Lower phycomycetes are responsible for the

formation of endomycorrhiza. This is the most widespread mycorrhizal association and is of particular interest because of the large number of agricultural crops on which it occurs.

Ectendotrophic mycorrhiza are similar to the ectotrophic type but have both inter- and intracellular hyphae occurring in the root cortex. In this way, they are somewhat of an intermediate form to the previously described types.

There are differences in the life cycles of the fungi producing ectotrophic and endotrophic mycorrhizal roots which could have ramifications in nursery management practices. Fungi forming endomycorrhiza produce spore forming structures only within the soil matrix and do not produce aerial fruiting bodies, hence little or no distribution of material occurs by normal air currents. Fungi forming ectomycorrhiza do produce aerial fruiting bodies (the common mushroom) which release spores that may be transported over considerable distances by normal wind currents. Repeated sterilization of nursery soil will therefore restrict the potential for mycorrhiza formation to the ectomycorrhizal type. The reintroduction of infective particles will normally be limited to aerial transport unless corrective inoculation procedures are instituted.

MYCORRHIZAL INFLUENCE ON PLANTS

The mycorrhizal association modifies the biology of the plant root and consequently the whole plant, morphology, physiology and ecology. As a result of this modification, the mycorrhizal fungi benefit plants by a) aiding in the absorption of inorganic nutrients, b) deterring root pathogens and c) increasing host plant resistance to drought and extreme soil temperature.

(a) Absorption of Inorganic Nutrients. In the formation of the mycorrhizal root, the development of root hairs is suppressed. The fungal mycelium which produces a sheath around the rootlet and penetrates the root cortex functionally replaces the root hair. Growth of this mycelium into the soil provides an extension of the plant root system enabling it to exploit a greater soil volume and obtain the associated nutritional benefits (17). For this reason, it is logical to expect the greatest benefit from mycorrhizal association to occur under conditions of nutrient deficiency or with plants which do not have a vigorously branching fibrous root system. The beneficial nutritional effects have been demonstrated primarily for phosphorus (11) but have also been noted for nitrogen (19), sulfur (3) and several other elements (11). All the mycorrhizal fungi are not equally efficient in producing this effect. Table 1, taken from the work of Mejstrik and Krause (10), outlines the variable effect of two symbionts on the uptake of different phosphorus forms by radiata pine. From this, it appears that there are conditions under which it would be ecologically advantageous to establish specific mycorrhizal formers.

(b) Deterring Root Pathogens. Systematic investigations of the role of mycorrhizal roots as opposed to nonmycorrhizal roots in the resistance of plants to feeder root disease, have shown that mycorrhiza on plants decrease the incidence of feeder root disease (7). The description of the ectomycorrhiza noted that the hyphae isolated the root from the soil. This same hyphal sheath could therefore present a physical barrier to the invading root pathogen. In addition, the fungal symbiont could produce an antibiotic which inhibits pathogen development, or the fungal symbiont might induce the host to produce compounds toxic to the invading pathogen.

Table 1. The effect of different treatments upon absorption from different solutions (results expressed in relation to uptake by uninoculated controls).

Source of Phosphorus	Symbiosis	Total Uptake (%)
Resin - available phosphate (0.1 ppm)	No mycorrhiza	100
	Cenococcum graniforme	99
	Suillus luteus	147
Humus - organic phosphate in humus (0.58 ppm)	No mycorrhiza	100
	Cenococcum graniforme	194
	Suillus luteus	408
Nutrient solution with H_3PO_4 (7.2 ppm)	No mycorrhiza	100
	Cenococcum graniforme	87
	Suillus luteus	146

Both the fungal symbiont and the pathogen receive the organic compounds necessary for their growth from the host. Part of these are made available as root exudates, i.e. products which leak from the root as a result of the normal growth process. The presence of a mycorrhizal fungi utilizing the root exudates would make them unavailable for the growth of a pathogen. Another possible control mechanism could result from the selection of a unique population of organism around the mycorrhizal root (mycorrhizal rhizosphere) (13) which was antagonistic to the invading pathogen. In the soil system, probably no single mechanism is effective but control comes from a combination of several interacting processes. Table 2 (7) indicates the response that could be expected from this control.

Table 2. Growth of *Pinus echinata* with and without Ectomycorrhizae in the presence and absence of *Phytophthora cinnamoni*.

	Nonmycorrhizal		Mycorrhizal with *Pisolithus tinctorius*	
Measurements	Without *P. cinnamoni*	With *P. cinnamoni*	Without *P. cinnamoni*	With *P. cinnamoni*
Stem dry wt. (mg)	99	81	185	203
Root dry wt. (mg)	124	86	131	134
Lateral roots	22	10	23	21

(c) Increased Host Resistance to Drought and Extreme Soil Temperature. The ecological diversity of the specific mycorrhizal association can best be demonstrated under conditions of marked environmental change and stress. Marx and Bryan (8) subjected nonmycorrhizal and mycorrhizal loblolly pine seedlings to temperatures in excess of 45°C. *Pisolithus tinctorius* was the fungal symbiont in this study. They reported that 90% of the mycorrhizal seedlings survived, whereas only 45% of the nonmycorrhizal plants survived. Safir *et al.* (14) demonstrated that endomycorrhiza enhanced water uptake and transport in soybeans, thus improving the drought tolerance of these plants. The reduced moisture stress is a combination of improved nutrient status and expanded root system utilizing a greater soil volume.

From the preceding discussion and examples, it is apparent that the mycorrhizal association, which includes a specific plant and a specific fungi, has a unique set of ecological capabilities that dictates that the association be considered only as a unit. If this is done, we may be able to develop plants more able to adapt to different environmental stresses.

FACTORS INFLUENCING MYCORRHIZAE FORMATION

The *advantages of this association can be obtained only if* mycorrhizal root formation occurs. As a very general rule, conditions that allow optimal growth and balanced plant metabolic process will produce the largest quantity of mycorrhizal root. An imbalance in the many factors controlling plant metabolism will reduce intensity of mycorrhizal formation.

The fungal symbiont obtains much of the organic material required for growth from the host plant (19). As a result, it is logical to expect that full sunlight, which allows for maximum photosynthetic rate, will maintain high levels of mycorrhizal root formation (4). A second requirement for maximum mycorrhizal root formation is an adequate supply of soil moisture. Care must be taken to prevent excess buildup because the fungal symbiont is an obligate aerobe. Under the conditions which develop as a result of flooding, the association will be destroyed (2).

Nutrient levels must be adequate for good plant growth to obtain maximum mycorrhizal formation. Lister *et al.* (6) demonstrated this after examining mycorrhizal formation in white pine under a varying combination of nitrogen and phosphorous levels (Table 3). Sinclair (16) indicated that the nutritional effect on formation frequency will vary for different mycorrhizal formers. In his study, he noted fewer tomentose mycorrhizae on 20-week-old seedlings that had received 200 KgN/ha than on unfertilized or superphosphate fertilized (200KgP/ha) plants. With the smooth ectomycorrhizal forms, no difference in frequency of occurrence was

noted under the three different nutritional regimes (unfertilized, 200 KgN/ha and 200 KgP/ha).

Table 3. Effects of various levels of nitrogen and phosphorous on mycorrhizal abundance (arbitrary units) in *P. strobus* L. seedlings

N (mg/l)	P (mg/l) 0	173	692
0	−	++	++
2.5	−	++++	++
53	+	+++	+
265	+	0	0

PRACTICAL CONSIDERATIONS

Certainly the potential exists for a beneficial growth response from controlling the specific mycorrhizal former. This is probably best demonstrated by work of Theodorou and Bowen (21) which is summarized in Table 4.

Table 4. Response of *Pinus radiata* to different mycorrhiza.

Inoculum	Height[1] (cm)
Suillus granulatus	482
Rhizopogon luteolus	454
Suillus luteus	414
Uninoculated	334
LSD 40	P = 0.05
58	P = 0.01

[1]Mean of 27 trees 60 months after planting.

The different levels of growth stimulation produced by the different fungal symbionts should be noted. It has further been demonstrated (5) that the effect of a given inoculum will vary as the outplanting site is changed.

With this in mind, is it possible to manipulate the associated mycorrhizal flora at the practical level? In many nursery operations, sterilization of seed buds is a necessary practice to control fungal pathogens, nematodes and weeds. Sinclair (15) stated "Potential opportunities for manipulating mycorrhizal fungi in previously fumigated soil exist during the first several weeks of seedling growth, before indigenous fungal symbionts extensively colonize the root systems". Nursery soil could therefore be inoculated but at present there are no proven practices available. A few government and private nurseries in the Southeastern U.S.A. are in the initial stages of carrying out large-scale inoculation of loblolly pine with a selected symbiont, *Pisolithus tinctorius* (Marx, per. comm.). They will be using a basidiospore inoculum. At present, there are few fungal species where an adequate number of spores could be collected for such a large-scale nursery operation.

Because of the lack of suitable quantities of inoculum for nursery bed application, the container production system offers the greatest opportunity for selected mycorrhizal manipulation. A much smaller volume of soil must be sterilized and re-inoculated, hence the associated costs of providing inoculum in high densities are reduced. The inoculum required for such a program can be grown on an artificial nutrient medium added to a peat-vermiculite carrier mix (9) or on a variety of cereal grains (12). This material can be easily incorporated within the container soil mix to provide a high density of selected inoculum.

Nevertheless, the problems must not be underestimated. Any inoculation hastily executed is bound to fail. Such failures will serve only to discredit a potentially effective technique. Accordingly, before a decision is made to inoculate a large number of plants, we must select the appropriate fungal stock, determine the best time for inoculation, establish optimal conditions for the development of the organism and the association, and develop adequate test methodology.

The mycorrhizal association has developed through a long period of selective ecological pressures and is now an important feature of the adaptation of plants to a range of natural sites. Failure to take advantage of such a symbiotic association will result in the use of increasing quantities of fertilizers and pesticides without an appropriate return in quality of plant produced, if the ability to establish on and utilize a natural site is the accepted quality standard.

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FUNGICIDES AND THEIR SPECTRA

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Financially successful plant propagation requires a conscientious effort to reduce losses due to pathogenic fungi and bacteria to a low level.

Three basic steps are involved: (1) use of disease-free plant material (2) use of pathogen-free rooting media (3) prevention of infection or contamination.

Fungicides have a place in each of the three steps:

In **Step 1**, to ensure that seeds, cuttings, etc. are free of pathogens up to the time they are placed in the rooting medium, *broad spectrum fungicides* have long been used. Two methods of application are involved here:

A. Seed Treatment Chemicals:

1. *Mercurials*, very effective against a wide range of seed and soil-borne pathogens, can no longer be used because of environmental contamination problems.

2. *Captan 75W* (*Orthocide*) controls most fungi which happen to be on the outside of seed and prevents early damping off due to organisms in soil.

3. *Thiram 75W* (*Arasan, Panoram, Tersam 75, Thylate, TMTD*) is similar to captan in its broad spectrum effectiveness.

B. Bench & Tool Disinfectants:

1. *Mercurials*. Various mercurial compounds were widely used because of their broad spectrum effectiveness. However, these uses have been withdrawn and most manufacturers have ceased production.

2. *Phenol disinfectants* (*Lysol, Amphyl, LF10*). Effective for surfaces and tools but not for flats or benches where fungus sclerotia or resistant spores may be lodged.

3. *Quaternary ammoniums* (*Roccal, Hyamine, Bactericide #10*). Usefulness similar to phenols, less objectionable to use.

4. *Chlorine* (*Perfex, Javex, Clorox*). Effective for tools; solutions tend to lose effectiveness rapidly.

5. *Formaldehyde* (*Formalin*). Effective for sclerotia and resistant spores but is unpleasant to use due to toxicity of solutions and vapours.

Step 2, the preparation of pathogen-free rooting media, also utilizes fungicides of a *broad spectrum* — in this case of the fumigant type.

Whenever soil, manure or similar material is used in a rooting or potting mix it is advisable and often essential to partially sterilize the media either with heat or fumigants. The most commonly used chemicals in this category are:

1. *Methyl bromide* (*MC-2, Brom-O-Gas*). It has the shortest aeration period following treatment, but is hazardous to the operator and is not recommended for carnations, snapdragons, or to control *Verticillium* wilt.

2. *Chloropicrin* - (*Larvacide, Picfume, Terr-O-Gas*) broadens spectrum of control, when combined with methyl bromide, but has a two week aeration period.

3. *Formaldehyde*. May be applied in water by watering can method, but requires long aeration period — similar to chloropicrin.

4. *Vapam, Vorlex, Mylone*, etc. These materials all perform in a similar fashion and have similar effectiveness and require a 2 week aeration period.

Step 3 utilizes both *broad and narrow spectrum fungicides*. In some cases these are mixed or drenched into the rooting or potting soil. In other cases foliar applications are involved.

For convenience we'll consider the soil applications first and divide those into broad and narrow spectrums.

A. Soil Fungicides — Broad Spectrum:

1. *Captan* - a number of fungicides including mercurials have been used in the past for control of damping off and other disorders of a general nature. The only one of these which is still commonly used is captan. Captan can be added to the rooting or potting medium at the rate of about 500 ppm to prevent recontamination by fungi such as *Pythium* and *Fusarium*. It is weak against *Rhizoctonia*.

B. Soil Fungicides. Narrow Spectrum

1. *Terraclor* (*PCNB, Brassicol*). Terraclor was the first fungicide to gain wide use in soil applications. It is useful where damping off or root disorders due to *Rhizoctonia, Sclerotium*, or *Sclerotinia* are likely to be a problem. It is not effective against *Fusarium* and water molds such as *Pythium* and *Phytophthora*.

2. *Benlate (benomyl)*. Benlate is a fairly new fungicide which has many uses in crop protection. As a soil additive it is effective in preventing diseases caused by *Fusarium, Verticillium*, and *Rhizoctonia*. It is totally ineffective against the water molds, *Pythium* and *Phytophthora*.

3. *Thophanate-Methyl (NF-44), Topsin M, Cercobin M)*. Frequently referred to as "Japanese Benlate," it has similar activity and similar spectrum of effectiveness.

4. *Dexon (diazoben).* Dexon was the first fungicide specific for the water molds. It effectively prevents establishment of *Pythium* and *Phytophthora* in the root medium but is short-lived and must be applied as a drench of 50-100 ppm at regular intervals where contamination is likely to occur. It has lost favor because of its unpleasant and unstable nature.

5. *Truban (ethazol, Terrazole, Koban).* Truban also controls *Pythium* and *Phytophthora* and has the advantage over Dexon in being more stable so that it can be incorporated in the root medium at the rate of 25-50 ppm during preparation. It also gives some control of *Fusarium* and *Rhizoctonia*.

6. *Mixtures:* Due to their specific nature it has been found beneficial to use 2 or more of the above fungicides in combination to give a broad spectrum of activity. The most commonly used of these are:

Terraclor + Terrazole (Terraclor Super X)
Dexon + Terraclor
Truban + Topsin M (Banrot)
Benlate + Dexon
Benlate + Truban

C. Foliar Fungicides

Fungicides which are normally applied to the tops of growing plants can be grouped in either of two ways: (1) by fungicide, listing the pathogens controlled or (2) by disease, listing the fungicides useful against it.

Either method has its advantages and disadvantages but I have chosen the first and have listed the most useful fungicides in that manner in Table 1.

Table 1. Fungicides and their uses and disadvantages

FUNGICIDE	ALTERNATIVE NAMES	USES	DISADVANTAGES
Acti-dione	cycloheximide	Powdery mildews and rusts of various ornamentals; blights and leafspots including *Keithia* blight of *Thuja*	highly toxic to mammals
Benlate	benomyl	Scab of apple and flowering crab; brown rot of stone fruits; grey mould (*Botrytis*) and powdery mildew; *Fusarium* and *Verticillium* wilts; Juniper twig blight (*Phomopsis*)	Some fungi are becoming resistant; not effective against *Pythium, Phytophora, Alternaria,* peach leaf curl
Bordeaux	—	Dormant spray for cherries, lilac, forsythia, etc. which are susceptible to bacterial blight or canker	difficult to mix; incompatible with other chemicals, often phytotoxic

Table 1. continued

Bravo	Daconil Exotherm Termil	Control of *Alternaria* and *Botrytis* in greenhouses	possible allergic reaction
Captan	Orthocide	Scab of apple and flowering crab; brown rot of stone fruits; *Botrytis*; many other diseases	—
Difolatan	captafol	Dormant spray for peach leaf curl; several foliar diseases	possible allergic reaction
Dodine	Cyprex	Scab of apple and flowering crab; brown rot of stone fruits	—
Ferbam	Fermate	wide spectrum	unpleasant odor and residue
Fixed Copper	Basicop Tricop Coprantol etc.	For bacterial diseases in place of Bordeaux esp. in growing season	not effective against many fungus diseases
Karathane	Dinocap	powdery mildews	—
maneb	Dithane M-22 Manzate D	broad spectrum protectant against many foliar diseases including rusts. The fungicide to use when in doubt	—
mancozeb	Dithane M-45 Manzate 200	Same as maneb - contains zinc as well as manganese	—
Parnon	parinol	powdery mildew	—
Pipron	piperalin	powdery mildew	—
Plantvax	oxycarboxin	systemic control of all common rust diseases in greenhouse and nursery	
streptomycin	Agristrep Agrimycin	alternative to coppers for bacterial diseases	limited registration compared to coppers
sulphur	wettable sulphur, lime sulphur Orthorix	wettable sulphur is useful in growing season for powdery mildew. Lime sulphur is useful as a dormant spray for powdery mildew, pear scab and certain other diseases	phytotoxic under certain conditions
Thiophanate-methyl	Topsin-M Cercobin-M NF-44	same as Benlate	same as Benlate
Zineb	Dithane Z-78	broad spectrum against many foliar fungus diseases; protectant action against rusts. Interchangeable with maneb and mancozeb	

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NURSERY UNDERSTANDING OF TISSUE CULTURE

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The type of tissue culture which we are considering may be defined as the development of new plants in an artificial medium under aseptic conditions from very small pieces of plants. Propagation may be accomplished from embryos, seeds, tissues, stems, shoot tips, root tips, callus, single cells or pollen grains (1). For successful propagation, new roots and/or shoots or small embryos must develop in order to produce the new plants. The kind of growth pattern which develops depends upon the genetic potential of the plant cultured and upon the chemical and physical environment to which it is subjected.

We nurserymen are accustomed to using other methods of propagation but should keep our minds open to the the many new future possibilities of this technique. It can accomplish a much more rapid mass production of limited propagating stock, it can recover disease-free plants, and it can show us new ideas and methods which we can apply to our current ways of propagating plants.

There are many fine publications on the general premises and techniques of tissue culture which may be studied further (2). It is helpful to keep in mind a few terms which we are not normally using in the nursery industry, but which will appear when you start working with tissue culture:

IN VITRO: under artificial conditions.

IN VIVO: under natural conditions.

TRANSFER: the process of relocating cultured tissue to a fresh nutrient medium.

PLANT PIECE. The size of the plant tissue used in vitro is usually very small, ranging from the size of the head of a needle to a single cell. The general trend is to use as large a tissue as can be sterilized and kept clean. Every known condition of the tissue which might favor rooting should be closely watched. For instance, juvenility is a factor which usually enhances the chances of success. Juvenility does not mean a soft or tender cutting, but rather tissue like that from germinated seed which has not reached an adult stage.

MEDIUM. To develop a satisfactory technique for growing small pieces of tissues, scientists have adapted some of the methods used for many years in medicine and pathology. A small

piece of the plant tissue is placed in a sterile container with a small amount of a sterile medium to encourage and nourish growth. The various rates of development and growth can then be carefully measured and recorded.

The basic medium used must be sterile. It can be a liquid solution of chemicals diluted with distilled water, or agar can be added to make it solid. Agar is a gelatinous substance derived from certain sea weeds which may be purchased from chemical or medicinal supply houses.

It is important to keep the total volume of the medium small to maintain an effective chemical balance with the leachings from the small piece of tissue. After rooting has been accomplished, both in vitro and in vivo, cuttings usually increase growth by having a greater volume of the medium. Because of the small size of the plant tissue and the small amount of the medium, everything we do to it becomes more critical. The small piece of tissue does not have much storage capacity, so whatever else is needed for growth and division must be supplied by the medium.

The chemicals in the medium can range from a simple NPK formulation to one of 40 or more elements. Minerals, auxins, cytokinins, vitamins, amino acids and sugar may all be needed to form a balance to produce optimum results. Some of the needed undefined ingredients have been found in such things as coconut milk, tomato juice and brewer's yeast. Apparently, many of these ingredients are supplied on the rooting bench in the rooting medium, the water, or are already in the tissue, originating from the stock plant.

The sugar is added as a replacement for photosynthesis. It must be used with careful sanitation practices, as it also will allow a rapid spread of any contamination. The use of small containers in vitro makes it possible to completely isolate an infected tissue without infecting the other cultures.

In vitro, the pH of the media seems to be critical to the point of actually killing the tissue when the correct range is not maintained. If solid agar is used, it is also necessary that the level be kept above the point which liquifies agar. As time goes on, we may find that pH is a more critical factor in rooting plants on the bench than we had realized.

Charcoal added to the medium will cause a reaction which prevents browning of the tissue. We have used charcoal for many years in the bench rooting medium for some of the hard-to-root plants, thinking that we were getting mainly a structural change. However, it now seems that this antioxidant function may have additional value in the bench rooting medium also.

In bench propagation, we usually use only one medium and leave the plant in it until rooted. To accomplish mass production

in vitro, two and three stages are used. The first stage is that of introducing the plant tissue into a sterile growing environment. The second stage is that of causing additional shoot formation or division. And the third stage is the conversion of these shoots to root and the conditioning for transplanting into bench growing conditions.

LIGHT AND TEMPERATURE. The temperature level is close to that used on the open bench, but the light intensity is quite different. More of the lighting in stage I is furnished by supplemental light sources with an intensity of 100 to 200 foot candles. On the open bench, it is not uncommon to reach up to 2,500 foot candles when propagating under mist. Some tissue, like embryos in culture can utilize between 500 and 1000 foot candles. Many growers of tissues in stage II are using light to the top point of tolerance for increased growth and conditioning for the outside.

SUMMARY. We are involved in the chemical reactions in the tissue leading to shoot and division formation as well as root formation; the addition of cytokinins, like benzyladenine, generally increase shoot formation. Auxins like IAA, IBA, NAA, and 2,4-D stimulate root formation. Successful tissue culture requires a greater knowledge of the tissue to be propagated. At least with our present knowledge of in vitro techniques, varietal differences are critical with regard to specific photoperiod, pH, reaction to chemicals, growing peaks, juvenile stages, disease, etc. Each species and cultivar seem to require a custom mixed medium and special handling procedures.

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USING TISSUE CULTURE FOR VEGETATIVELY PROPAGATING AND IMPROVING ASPARAGUS PRODUCTION AND QUALITY

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Abstract. Tissue culture of asparagus provides a technique for mass production of superior clonal material for increasing production by mass production of staminate clones; increasing proven parents that result in superior crosses for the production of large quantities of high quality F_1 seed; and for developing pathogen-free stock.

REVIEW OF LITERATURE

Asparagus officinalis L. is a dioecious crop of pistillate and staminate plants occurring in equal numbers when grown from seed. Because of the heterogeneous nature of asparagus, propagation by seed results in individual plants of varying yielding ability (3, 4, 7, 10, 11, 18, 28). By establishing a field of a superior selection of genetically-identical staminate plants yields should be markedly increased (11, 18). We have found the growth of such plants to be very uniform and a tendency for new spears to emerge together after removal of all above-ground asparagus. Such a development would promote mechanical harvesting of this crop if mass production of clonal material becomes commercial feasible.

Prior to the development of the asparagus tissue culture (TC) techniques vegetative propagation by crown division only resulted in a few additional plants. The propagation of asparagus by TC not only makes it possible to propagate genetically-identical plants for production, but provides a means of increasing parents of superior crosses for commercial seed production.

Propagation of asparagus plants by callus and cell culture has been demonstrated (12, 19, 20, 21, 23) but some tetraploid and aneuploid cells have resulted. It has been shown that normal diploid plants can be developed from stem tips (1, 5, 6), meristem (2, 15), shoot apexes (8, 16), and stem lateral buds (13, 14, 24, 25, 27). Meristem and shoot apex cultures have proven to be better methods for developing normal plants, but require rather delicate techniques in excising the minute apical meristem of the shoot apex. Much time is required and the survival of propagants is poor. However, this technique does provide a method of developing disease-free plants of asparagus and other horticultural crops (9).

METHODS AND RESULTS

We have developed a more simple method of vegetative propagation that avoids the problems involved in callus formation (24, 25, 27). By using the TC technique aseptic stock plants are established from lateral buds of asparagus spears. From these stock plants buds are taken and developed into rooted plantlets under sterile conditions.

After these complete plantlets are developed they are removed from the sterile environment and placed under mist in Jiffy-7 peat pots (26). When shoots start to grow they are transplanted into pots containing soil. This is followed by maintaining these growing plants in the greenhouse for 3 to 4 months until they become well developed. They are then acclimated in a 50% shade lathhouse 1 to 2 weeks before setting into the field. Early spring or late fall planting has resulted in the best crown survival.

The nutrient medium and culture environment for TC techniques have been described by Murashige (16) and modified by Yang and Clore (24, 25, 27). A plentiful supply of aseptic stock plants is necessary for mass clonal multiplication. To do this it is important to consider stem vigor, bud age, bud position, implantation techniques, and concentration of plant growth substances.

The propagation time table using stock plants for mass production of asparagus crowns is as follows:

a) *6 to 8 months to develop stock plants from asparagus spear* buds;

b) 2½ months to develop complete plantlets from bud cultures;

c) 1 month to develop complete plantlets from non-rooted plantlets;

d) 1-2 weeks in mist chamber after transplanting from sterile culture to Jiffy-7 peat pots;

e) 3-4 months in greenhouse to develop plant size for field planting;

f) 1-2 weeks acclimation in lathhouse before transplanting to the field.

Thus the total time required from spear bud to field planting of large numbers of clonal asparagus is 13 to 16 months. It has been estimated that with an adequate supply of aseptic stock plants and adequate facilities one person working 200 days in one year should be able to produce approximately 70,000 plants.

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MASS PRODUCTION OF BOSTON FERN THROUGH TISSUE CULTURE

RANDALL W. BURR

Transplant Nursery, Inc.
Oxnard, California

I will discuss the practical aspects of tissue culturing for the purpose of mass-producing plants for a commercial nursery. It has just been in the last few years that the work of tissue-culturists, such as Dr. Tosh Murashige at the University of California, Riverside, has been tried in practical applications by commercial nurseries. This discussion will concern the application of tissue culture for the mass production of Boston fern [*Nephrolepsis exaltata* 'Bostoniensis']. We have learned much from Dr. Tosh Murashige at the University level, but we have found that their procedures and techniques must be amended when applying them to a commercial lab. We haven't the funding, time, nor the high quality of personnel that a University has, so we have adopted their techniques to our own special requirements.

The actual proliferation of the ferns begins with the stolon tips, or runner tips, from a parent plant. The tips are collected and brought to the "clean air" station where they are sterilized by placing them in a bleach solution for a given amount of time, then they are run through sterile water baths to assure the removal of any bleach residue. At this time they are then placed on the medium which is enclosed in a culture tube or flask. From here they go to the culture room for growing. The initial growing time from this tip to plants large enough to divide takes about 2 to 3 months. After this initial 3 months the plants are divided into individual plants and placed back on fresh medium. It now only

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takes 6 weeks before the plants are ready to be divided again. The process of sub-dividing the cultures can be repeated as many times as desired but it is not necessary to do this.

Since this article is about mass production, I will indicate the actual numbers that can be produced. A good technician could turn out about 600 stolon tips in a day. If we did 600 tips a day, the final numbers would be much too large to handle; a lab staff of 20 to 30 people would be needed to handle such quantities. If the plants were grown to 4" pot size, six acres of houses would be needed to house the volume. At the transplant stage we have six trained people to do the sub-dividing of the cultures. One person prepares the media, and one person takes care of the culture room. So, for practical reasons, we keep the initial numbers more conservative. Let's say the technician does 100 stolon tips on a given day. Three months later these 100 plants are divided up for the actual division. I'll use a conservative number. Cultures can be sub-divided to as many as 30 plants, but let's say every culture yields 5 new plants so we now have 500 plants in the first generation. Six weeks later they are divided again to obtain 2500 plants in the second generation. In another six weeks the process is repeated to obtain 12,500 plants in the third generation. From here they are placed on a medium which is designed to slow down their multiplication and initiate root growth in preparation for planting out in the nursery. This growth period is also 6 weeks, at the end of which the plants are placed into soil in a special room or greenhouse for adaptation to soil and greenhouse conditions. At this stage they only multiply about three times — so when they are placed into soil, we've obtained about 37,500 plants in a span of about 9 months. This can be put on a schedule to allow that many plants a day to be produced, which would result in about 750,000 plants per month. This figure is too large for most nurseries to handle but it is possible. For smaller numbers the initial number of plants can be adjusted to meet any number that is desired. With this technique a certain amount of plants can be programmed to be produced every day or at any time interval desired. With preplanning, larger crops can be produced for special times when sales are high, for example, the various holidays.

The last phase of the operation is the process of hardening off plants from a sterile artificial environment to a greenhouse environment and ultimately the home environment. This process is a relatively simple one. When the cultures are removed from the flasks or jars they are rinsed in water to remove any agar medium and then they are placed into soil in cell packs. These ferns are very small, less than ½ inch in height. The cell packs are placed into high humidity tents for about two weeks or until they establish some roots into the soil, after which they are taken out of the

tents and placed in a greenhouse for further growth and hardening off. They become a good size cell pack fern in about 6 to 8 weeks at which time they are stepped up into a 4-inch pot. The room which houses these high humidity tents also needs to be kept clean to reduce the introduction of any unwanted pathogens and resultant disease losses.

In summary, I have outlined the practical application of tissue culturing in a commercial lab. Large numbers of plants can be obtained and be on a regular schedule through proper programming and management.

There are many other plants in the foliage industry which can be mass produced through a tissue culture lab. We have worked on media for Dieffenbachias, a variety of Dracaenas, Red and Green Marantas, Calatheas, Kalanchoes, different succulents, Cordylines, and a variety of other ferns. We are able to grow all of these in a culture, but only about half have shown promise on a commercial level for the mass production of the plant. Some of the plants stll are propagated faster through conventional propagation methods, but as time goes on we will be able to produce larger numbers of any plant desired. All plant growth can be preprogrammed to obtain a given number of plants on a given day. Continuing into the future we may expect to see rapid increases in the variety of plants cultivated by sterile techniques and, in consequence, extensive benefits for man's need of food, lumber, medicine, and ornament.

DIFFERENTIATION OF ADVENTITIOUS BUDS ON DOUGLAS-FIR EMBRYOS IN VITRO

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Abstract: Conditions for obtaining adventitious buds on embryos of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) are given. These buds have been excised and rooted to produce plantlets.

Problems inherent in the genetic improvement of trees are linked to their long generation time, heterozygosity, and the difficulties of vegetatively propagating mature individuals. Possibly, the propagation of selected trees can be accomplished through tissue culture. For other plants, such as orchids, tissue culture has proved to be a practical means to the rapid multiplication of selected cultivars, but although the literature contains many references to the tissue culture of gymnosperms (1), there are few recorded instances of organogenesis. Recently it was reported that plantlets of *Pinus palustris* Mill. had been obtained by rooting adventitious buds differentiated on embryos grown in vitro (i.e., embryo cultures) (5). However, when the method described by Sommer, Brown and Kormanik (5) was tested using embryos of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), adventitious buds were obtained only sporadically. Subsequently, investigations were undertaken to improve the frequency of their development.

MATERIALS AND METHODS

In general, the culturing procedures have been described previously (5). The composition of the basal media is given in Table 1. NAA and 6-benzyl adenine were added to the basal media at the concentrations indicated and the cultures maintained at approximately 25°C. Illumination was approximatley 500 ft.-c. from Gro-Lux lamps, with a 15-hour photoperiod. Wild seed lots were used.

RESULTS

Initially the NAA and 6-benzyl adenine concentrations were varied widely to obtain a broad index of embryo response. In all, 35 combinations were tested with 10 embryos in each combination. As might be expected, differentiation of adventitious buds was favored by no or low auxin (Table 2). Results were more consistent, most rapid, and the buds better formed at lower cytokinin levels.

Using a different seed lot, the response to NAA and 6-benzyl adenine was investigated using lower concentrations. Twenty-

eight combinations were tested, with 25 embryos in each combination. The response for basal media I and II were also checked (Tables 3-4). Again, the lower concentrations of NAA favored the differentiation of adventitious buds with the lowest (0.01 ppm) producing slightly more buds per embryo under most conditions than no NAA. Basal medium I appeared superior to medium II with respect to both the percentage of embryos producing buds and also the number of adventitious buds produced at favorable hormone concentrations. Adventitious buds from these cultures were excised, placed on different media and, in some instances, rooted to form plantlets; shoot extension followed.

DISCUSSION

The method here described is not a means of mass-producing clones of planting stock from selected individuals but it does represent a significant step in that direction. It demonstrates that a high percentage of Douglas-fir embryos can form adventitious buds, and that plantlets can be obtained. In time, the technique may be modified and expanded as a means to producing plantlets from callus.

Table 1. Composition of basal media

Component	Medium I	Medium II
Major salts	Gamborg and Eveleigh (2)	Witham, Blaydes and Devlin (6)
Trace salts	Gamborg and Eveleigh (2)	Gamborg and Eveleigh (2)
Iron	Murashige and Skoog (4)	Murashige and Skoog (4)
Vitamins	Greshoff and Doy (3)	Greshoff and Doy (3)
Sucrose	20g/l	20g/l
Agar	7g/l	7g/l
pH	5.6-5.8	5.6-5.8

Table 2. Embryos producing adventitious buds after 1 month on medium II.

NAA Concentration	Percent of embryos with adventitious buds[1]						
	0.0ppm BA[2]	0.5ppm BA	1.0ppm BA	2.0ppm BA	4.0ppm BA	8.0ppm BA	16.0ppm BA
0.0 ppm	0	100	89	80	60	78	80
0.1	0	70	67	80	67	30	43
0.5	0	10	50	20	22	30	0
1.0	0	10	0	40	30	0	0
2.0	0	11	0	0	11	0	17

[1] 10 embryos per treatment at start
[2] 6-benzyl adenine

Acknowledgement: These experiments were performed with the help of Miss Mary Wright and Mr. Ray Haung.

Table 3. Adventitious bud differentitation on medium I.

NAA Concentration	Percent of embryos with adventitious buds[1]						
	0.0ppm BA[2]	0.1ppm BA	0.25ppm BA	0.5ppm BA	0.75ppm BA	1.0ppm BA	4.0ppm BA
0.0 ppm	0	92 (3.5)[3]	80 (3.7)	96 (3.8)	88 (4.5)	80 (3.7)	88 (4.6)
0.01	0	84 (4.6)	92 (3.9)	92 (3.4)	84 (4.6)	80 (4.2)	80 (4.0)
0.5	0	76 (2.7)	80 (2.7)	80 (3.3)	88 (3.7)	72 (3.6)	84 (3.7)
1.0	4(1)	44 (2.2)	84 (3.4)	56 (2.8)	64 (2.6)	80 (3.7)	88 (4.6)

[1] 25 embryos per treatment at the start
[2] 6-benzyl adenine
[3] numbers in parenthesis are average of adventitious buds/bud bearing embryo

Table 4. Adventitious bud differentiation on medium II.

NAA Concentration	Percent of embryos with adventitious buds[1]						
	0.0ppm BA[2]	0.1ppm BA	0.25ppm BA	0.5ppm BA	0.75ppm BA	1.0ppm BA	4.0ppm BA
0.0 ppm	0	80 (2.1)[3]	75 (2.8)	80 (3.1)	64 (3.3)	76 (3.4)	42 (2.0)
0.01	0	64 (4.7)	68 (4.4)	80 (3.6)	72 (2.7)	76 (4.0)	52 (3.2)
0.5	0	60 (2.5)	68 (3.4)	60 (2.6)	52 (3.5)	48 (2.4)	48 (2.8)
1.0	0	52 (1.9)	64 (2.0)	56 (2.1)	40 (2.7)	40 (2.8)	36 (1.6)

[1] 25 embryos per treatment at the start
[2] 6-benzyl adenine
[3] numbers in parenthesis are average number of adventitious buds/bud bearing embryo

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MODERATOR BATCHELLER: We have time now for a few questions for our last panel of speakers.

BILL BARR: I have heard reports of health problems with Benlate, of it building up in your body. Does anybody know anything about this? We aren't using Benlate now. We have stopped using Benlate because of this.

VOICE: Nothing specific on the buildup of it, but you want to be aware that a lot of people do have a severe allergic reaction to Benlate and it is not limited to dermatitis. I had some folks working for me using it in propagation and getting severe headaches which indiciates some kind of absorption into the body.

BRUCE BRIGGS: If you will check in the 1974 *Proceedings*, I believe you will find in the Eastern region meeting last winter that this problem occurred in Australia. They did show that it was very toxic in that area. There are more details in the *Proceedings*. There have been other people in the United States that have said there were adverse reactions but from that I cannot quote any data where there has been research done.

RALPH SHUGERT: Adding to this Jolly, Bill Flemer, of Princeton Nurseries, Past-President of the IPPS Eastern Region, had some employees become quite ill last winter. If anyone wants to explore it a little further, they could write to Bill personally.

PROPAGATION OF RHODODENDRONS BY-TISSUE CULTURE: PART 1. DEVELOPMENT OF A CULTURE MEDIUM FOR MULTIPLICATION OF SHOOTS[1] [2]

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Abstract. It was necessary to reduce the potassium concentration in the Murashige and Skoog (MS) formula (3) for sustained shoot growth of rhododendron seedlings and shoots. The KNO_3 concentration was reduced to 950 mg/l and the NH_4NO_3 increased to 2000 mg/l. Other constituents required in the basal medium for the Stage II shoot multiplication phase were: adenine sulfate dihydrate 80 mg/l; IAA 4 mg/l; and N^6 (Δ^2-isopentenyl)-adenine (2iP) 15 mg/l. This medium supported the development of 6.2 new shoots per culture in 8 weeks. The new shoots arose from axillary buds of the original shoot explants and axillary buds of new developing shoots.

INTRODUCTION

Three distinct stages were described by Murashige (1) for rapid plant propagation through tissue culture. Murashige, et al (2) developed the basic principles for these three stages with their research on gerbera propagation that is now a commercially accepted procedure. Stage I involves establishing an aseptic tissue culture from shoot tips or other plant organs. During Stage II, conditions are altered to cause a rapid increase of shoots or other organs that will ultimately produce complete plants. Stage III involves changing cultural conditions to promote root development on the shoots and to harden these plants in preparation for successful transfer to soil.

The development of a tissue culture method for vegetatively propagating rhododendrons has commercial value in reducing the time required to increase stock plants of new clones. It is estimated 10 years are required to develop sufficient stock of a new clone for large volume sales. A technique for rapidly producing stock plants in the initial period could shorten development by several years.

The tissue culture method also has potential in propagating clones that are hard to root by the normal cuttage methods.

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[1]Scientific paper 4521. Project 0178, College of Agriculture research Center, Washington State University, Pullman, Washington, 99163.

[2]Acknowledgements: This research was partially supported by grants from the American Rhododendron Society. Plant materials were generously supplied by Briggs Nursery, Olympia, Washington, and Harts Nursery, Mount Vernon, Washington.

Preliminary experiments on establishing rhododendron tissue cultures showed that the MS formula (3) contained something toxic. Tissue in contact with the medium rapidly turned brown and browning progressed up the seedling stem until the cultures were completely killed. Sub-culturing the green portion of the shoot on a 3 week schedule kept them alive. The browning problem was eliminated by reducing the nitrogen-containing compounds in the MS formula to one-half.

This paper is concerned with the establishment of Stage II culture conditions for rapid multiplication of rhododendron shoots.

MATERIALS AND METHODS

Plant materials were obtained from aseptically-grown rhododendron seedlings and from shoot tips of 'Rose Elf' plants. Seed was collected and stored in the following manner in order to avoid severe culture contamination. Green capsules were collected and surface sterilized either for 1-2 minutes in 70% ethanol or for 20 minutes in a 10% water solution of laundry bleach, with a small amount of Tween 20 (polyoxyethylene sorbitan) added. The capsules were then air dried. Seeds were hand shaken out of the dehisced capsules with care not to cause capsule fragmentation since small pieces of this tissue were a major source of contamination. Before germinating, 20 mg lots of seeds were surface sterilized for 20 minutes in a water solution of 10% laundry bleach containing 0.1% Tween 20. The surface sterilization reaction was stopped by decanting off the sterilant and rinsing the seeds several times in sterile water. The seeds were suspended in 5 ml of sterile 0.2% water-agar. The seed suspension was poured into 16 oz. French squares or 125 ml Erlenmeyer flasks containing 50 ml of basal medium. The containers were then swirled to spread the seed evenly over the medium surface. Seedlings grew to sufficient size for further culturing or transplanting in 2-3 months.

'Rose Elf' shoot-tip explants were prepared by removing the expanding leaves and washing the shoot tips in soapy water. They were then soaked for 2-3 hours in an antioxidant solution consisting of 150 mg citric acid and 100 mg ascorbic acid diluted to 1 liter with water. Shoot tips were surface sterilized for 15 minutes in 10% laundry bleach water solution containing 0.1% Tween 20, then were rinsed several times with sterile water. The shoot tips were then aseptically placed on the medium. The explants started a new flush of growth after 6-9 weeks in culture.

The basal nutrient medium consisted of the following constituents and concentrations:

Constituent	Concentration mg/l
Inorganic salts	Modified Murashige and Skoog formula (low K)
Additional phosphate as $NaH_2PO_4 \bullet H_2O$	170
Sucrose	30,000
Difco Bacto-agar	10,000
i-inositol	100
thiamine HCl	0.4
IAA	0.25

Organic compounds, including the auxins and cytokinins, were dissolved in 1-2 ml dimethyl sulfoxide before dilution with water. Aliquotes of these stock solutions were added to the medium before autoclaving. The medium was adjusted to pH 4.5 by adding in NaOH or HCl before autoclaving. The medium was dispersed at 25 ml per 25 x 150 mm culture tubes and autoclaved 15 minutes at 121°C. Polypropopylene tube closures (Bellco Kaputs) were used to close the tubes. After autoclaving, the tubes were routinely cooled with the medium solidified on a 45° angle.

Cultures were kept in a room with temperatures that ranged between 19° and 23°C. Lighting was by cool white fluorescent lamps with an intensity of ca. 1000 lux on the cultures, and with a daylength of 16 hours.

RESULTS

Varying the concentrations of NH_4 and NO_3 concentrations in the MS formula (3) had no effect on the toxic tissue browning condition in shoots. However, a large proportion of the total N concentration in the formula is KNO_3. When it was reduced, the browning and early culture death symptoms were eliminated. The KNO_3 treatment with maximum growth was 950 mg/l (table 1), one-half the concentration in the MS formula. The total N concentration of the modified medium remained the same as the MS formula as an equivalent amount of N was added as NH_4NO_3.

An addition of 170 mg/l $NaH_2PO_4 \bullet H_2O$ was found to be beneficial for growth of all rhododendron cultures. Adenine sulfate dihydrate at 80 mg/l was important for axillary bud breaking and sustained shoot growth in Stage II.

Critical for the best Stage II culture conditions is the determination of optimum combinations and concentrations of auxins and cytokinins. Initial experiments indicated that indole-3-acetic acid (IAA) gave growth superior to that from β-naphthaleneacetic acid (NAA). Normal growth of shoots occurred at 0.5 to 5.0 mg/l IAA. Comparing kinetin and N_6-benzyladenine (BA) on bud differentiation showed that BA was slightly more effective than kinetin at concentrations of 2.5-5.0 mg/l (table 2). BA generally seemed to be quite toxic to rhododendron tissue.

The most effective concentrations for developing the maximum number of shoots were 4 mg/l IAA and 15 mg/l N^6-(Δ^2 isopentenyl)-adenine (table 3). At this optimum concentration 4.1 shoots were obtained in 5 weeks and 6.2 shoots in 8 weeks. Shoot development on the explant reached a maximum in 7 weeks as the shoots showed some senescence and deterioration in 8 weeks.

Shoot tips from 'Rose Elf' rhododendron were established in culture and tested on the Stage II medium. After five weeks an average of 3.2 shoots per explant was obtained.

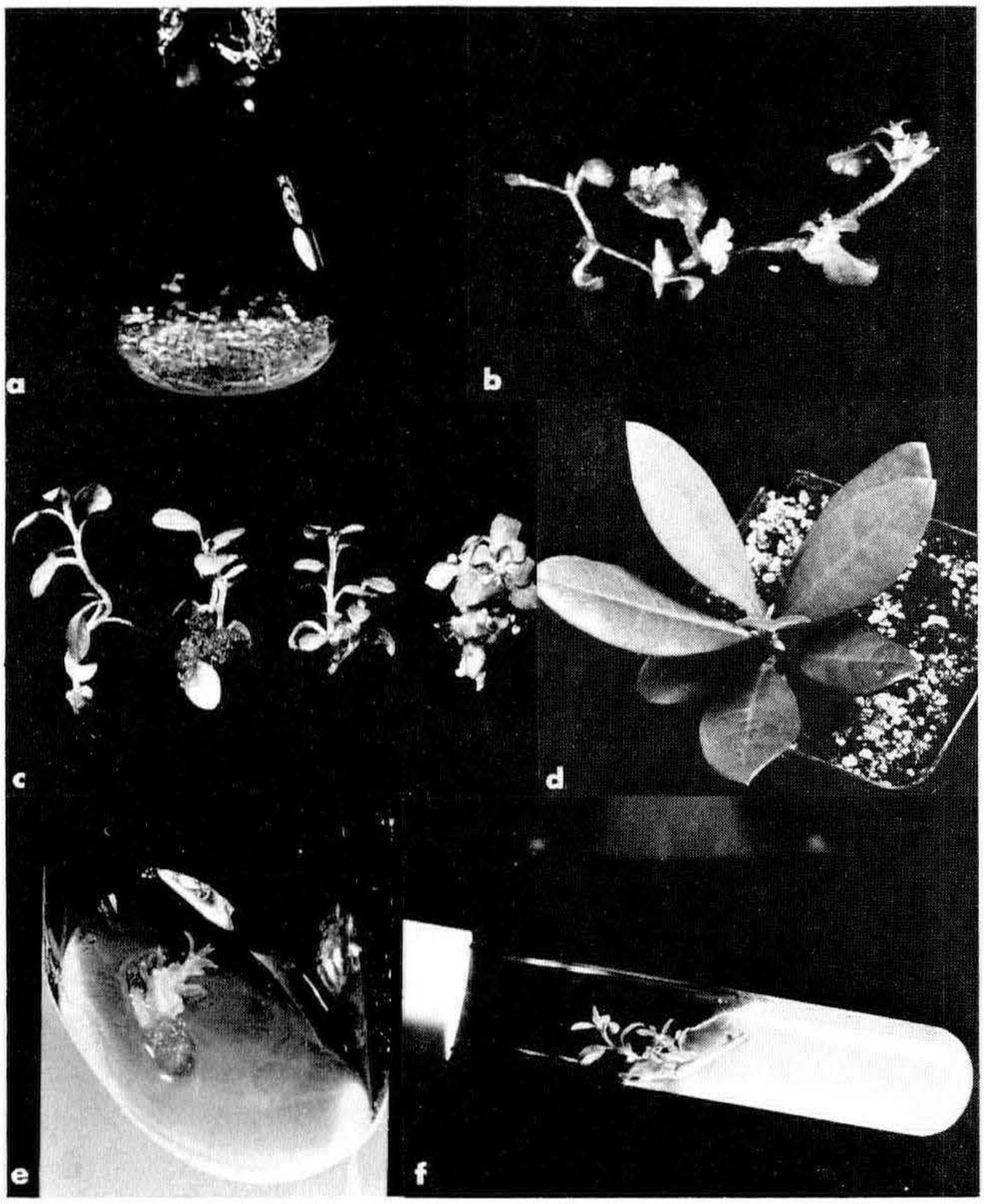

Figure 1.

(a) Rhododendrons developed from seeds after 3.5 months in culture.

(b) Shoots developed from the seedling explant cultured for 5 weeks on medium containing 2iP.

(c) Shoot development after 8 weeks of culture as affected by IAA (4 mg/l) plus various concentrations of 2iP. Left to right: 0, 5, 10, 15 mg/l 2iP.

(d) Seedling plant developed from tissue culture 3.5 months after transplanting in soil.

(e) Rose Elf shoot apex culture 6 weeks after explanting.

(f) Rose Elf shoots 6 weeks after subculturing on the basal rhododendron medium.

Table 1. Effect of varying K concentration with total N remaining constant on the survival rate of rhododendron seedling explants and shoot growth after 6 weeks of culture.

Medium Composition			
KNO_3 mg/l	NH_4NO_3 mg/l[2]	Survival %	Fresh wt[1]/ mg
0	2400	100	6.6±0.8[2]
475	2200	100	9.0±1.8
950	2000	100	9.6±1.5
1425	1800	100	6.4±1.1
1900[3]	1600[3]	70	4.7±1.0

1/ 10 replicate cultures per treatment. Fresh wt. of explants was 4.4±0.6 mg.

2/ Standard error of the mean

3/ Concentration of KNO_3 and NH_4NO_3 in MS formula

Table 2. Effects of kinetin and BA concentrations on the survival rate of rhododendron explants and the numbers of shoots after 7 weeks in culture. The IAA concentration was 1 mg/l.

Cytokinin	mg/l	Survival %	No. of Shoots/ Culture
	0	90	1.3±0.1[2]
Kinetin	2.5	60	1.0±0.0
Kinetin	5.0	70	1.6±0.3
Kinetin	10.0	60	1.5±0.5
Kinetin	20.0	70	2.7±0.7
BA[1]	2.5	30	3.0±0.6
BA	5.0	60	2.0±0.3
BA	10.0	50	1.4±0.2
BA	20.0	30	3.0±1.2

1/ N_6 - benzyladenine

2/ Standard error of the mean

Table 3. Effect of IAA and 2iP concentrations on the number of rhododendron shoots arising per explant.

IAA mg/l	after 5 weeks 2iP mg/liter				after 8 weeks 2iP mg/liter			
	0	5	10	15	0	5	10	15
0	1.2±0.1[1]	2.8±0.3	2.8±0.2	3.0±0.2	1.6±0.2	4.4±0.4	4.0±0.7	4.2±0.7
2	1.0±0	1.8±0.4	2.6±0.4	2.6±0.3	1.6±0.2	2.4±0.7	2.6±0.4	4.2±0.6
4	1.6±0.3	2.7±0.4	2.8±0.3	4.1±0.4	2.0±0.4	3.0±0.3	3.6±0.6	6.2±1.0
6	1.1±0.1	2.6±0.2	2.5±0.3	2.2±0.3	1.0±0	3.2±0.6	4.4±0.2	3.8±0.7

1/ Standard error of the mean

Table 4. The composition of Stage II rhododendron medium.

Mineral Salts	**mg per liter**
NH_4NO_3	2,000
KNO_3	950
$CaCl_2 \cdot 2H_2O$	440
$MgSO_4 \cdot 7H_2O$	370
KH_2PO_4	170
$NaH_2PO_4 \cdot H_2O$	170

Table 4. continued

Na_2EDTA	37.3
$FeSO_4 \bullet 7H_2O$	27.8
$MnSO_4 \bullet H_2O$	16.9
$ZnSO_4 \bullet 7H_2O$	8.6
H_3BO_3	6.2
KI	0.83
$Na_2MoO_4 \bullet 2H_2O$	0.25
$CuSO_4 \bullet 5H_2O$	0.025
$CoCl_2 \bullet .6H_2O$	0.025
Organic Constituents	**mg per liter**
Sucrose	30,000
Bactoagar	8,000
i-inositol	100
adenine sulfate.dihydrate	80
2iP (N^6-(Δ^2-isopentenyl)-adenine)	15
IAA (Indole-3-acetic acid)	4
Thiamine. HCl	0.4

DISCUSSION

The potassium concentration in the MS formula was toxic to rhododendron tissue and a reduction of the KNO_3 concentration by one-half eliminated tissue browning. Pierik and Steegmans (4) reported ½ strength Knops solution was best for rooting of rhododendron stems and attributed the lower salt concentration in Knop's formula to be the major factor. The MS medium has a 16 fold greater salt concentration based on millimoles (mM) /l (3,5). The K concentration of ½ strength Knops formula is 1.1 mM/l compared to 10 mM/l in the modified rhododendron formula. Possibly the high salt concentrations in the MS medium have a buffering effect that reduced the toxicity of K on rhododendrons.

The essential compounds required for shoot development in the basal medium were 80 mg/l of adenine sulfate dehydrate, 15 mg/l of 2iP and 4 mg/l of IAA. This combination of compounds resulted in an average increase of 6.2 shoots per culture in 8 weeks.

The cytokinin 2iP was the preferable chemical as it caused the greatest number of axillary buds to develop into shoots without any toxicity effects.

Rapid rhododendron shoot multiplication arising from axillary buds has been demonstrated. However, parameters for Stages I and III remain to be thoroughly investigated.

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WATER QUALITY AND PLANT GROWTH

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As Daubenmire (2) has observed water is the closest approximation of a universal solvent. It has the capability of dissolving soil minerals and is the medium through which both organic and inorganic solutes enter the plant and move from cell to cell. It is a reagent in photosynthesis and is essential for the maintenance of plant turgidity.

As well as being a necessary factor for plant growth water is also used in nursery operations to manipulate climatic factors through such practices as frost protection and for cooling in periods of extreme heat.

The quality of water is often beyond the control of the nurseryman; however in many situations the nurseryman is able to monitor and alter some aspects of water quality.

The contamination of water used for irrigation purposes can occur through physical, biological, or chemical means.

Physical contamination of a water supply with sand or larger soil particles or from organic debris can result in clogged sprinkler and mist lines and subsequently prevent uniform water distribution. It is thought by many that a better plant growth response is achieved through the use of warmed water than from the use of very cold water. The application of cold water (40° to 55°F.) to plants growing in air temperatures above 75°F. appears to provide some measure of physiological stress that is detrimental to growth. I think we get a better growth response in our nurseries when the water source has had exposure to air temperatures (i.e. lakes, reservoirs) than in those nurseries that irrigate directly from wells, although I have no data to substantiate this observation.

Biological contamination of irrigation water by pathogens and weed seeds can be a problem, particularly when water is drawn from sloughs and lakes. Mosses, algae, and liverworts are continuing problems at several of our nurseries, particularly on containerized stock. At Surrey the irrigation water is thought to be the vector for a blue-green algae that is a problem on container stock.

There are increasing reports of *chemical contamination* of irrigation water. The gradual entrance of salt water into fresh water aquifers has become a serious problem in many parts of the world. In British Columbia the problem is minimal except in several areas where water is drawn from rivers or streams adjacent to a

tidal influence and in several areas on the coast where salt water has permeated ground water sources. In its broadest sense saline water is defined as water that contains more than 1,000 ppm of the salts of sodium, calcium, magnesium, potassium, and other rarer elements (5). All of these elements, with the exception of sodium, are essential for growth; however an excess of any of them can be detrimental to plant growth.

The origin of excess salts can be from fertilizers, soil, or water. Over-application of fertilizers, or use of inappropriate fertilizers, can be overcome and soils containing excess salts can be leached. It is much more difficult to remove salts from an irrigation water supply, although where high value crops such as ornamentals are produced the use of demineralizing, ion-exchange resins can overcome the problem. The use of domestic water softeners is not adviseable as they act by replacing the Ca, Mg and other cations with Na which is toxic to most plants; Na also breaks down soil structure. The measurement of salinity through conductivity readings has become a standard monitoring operation at many nurseries. The problems of salinity and the related testing techniques are well outlined in the Western Fertilizer Handbook (6) and in a University of California publication on producing container-grown plants (1).

The concentration of salts in irrigation water is rarely so high as to cause immediate injury to plants but continuous use of water with a moderate salt concentration can create problems. If a thorough leaching of the soil in the root zone does not take place, the concentration of salts in the soil solution may increase through the loss of soil water by plant uptake and evaporation, until the soil water reaches the limit of solubility of each salt (3).

The quality of irrigation water can also affect the soil reaction. Most species of conifer seedlings do best under acid soil conditions (pH 4.5-5.5). In mineral soils, acidity is commonly defined as a condition of low base saturation. The continued use of irrigation water high in mineral cations can increase the degree of base saturation and raise the soil pH, particularly in soils with a low buffer capacity. The development of plants, particularly conifers, is greatly influenced by soil reaction which affects soil flora and fauna populations and the availability of most nutrients. In bareroot conifer nurseries the use of acid organic amendments such as peat, the use of "acid type" fertilizers, and leaching may be necessary to maintain or reduce soil reaction. In the Pacific Northwest the high annual total precipitation provides a natural means of maintaining acid soil conditions.

Pesticides are often the cause of water contamination. If the number of fish killed each year in the streams and lakes of North America was the only criterion of water quality, pesticides would

occupy first place among water pollutants (4). Similarly if losses and damage to nursery crops were tabulated I am of the opinion that pesticides would be very high on the list of causal agents. The application of fungicides, insecticides, and miticides through irrigation systems has gained more acceptance in recent years. Problems with the use of these chemicals in this manner on plant materials have not been widespread but there have been reports of phytotoxic affects that in all probability would have occurred had these materials been applied using conventional methods. When chemicals are applied through irrigation systems there is danger of contaminating the water supply in the event of a sudden drop in the main line pressure although this potential means of contamination can be prevented through the installation of a reduced pressure backflow preventer between the water source and the point of chemical injection.

The application of herbicides through irrigation systems has gained some acceptance in recent years, particularly in the central pivot system.

The contamination of irrigation water with fertilizers, fungicides, insecticides, or miticides, while not desirable will in most instances not result in plant damage provided the amount of contamination is minimal and short lived. Contamination of irrigation water with herbicides, on the other hand, can have disastrous effects on plant growth.

The following is a summary of an incident at the Surrey Nursery in 1974 that resulted in substantial crop losses. I hope that it will serve as a warning to all nurserymen of the hazards of using herbicide-contaminated water for irrigation purposes.

The Surrey Nursery is the largest of the eight principal nurseries operated by the British Columbia (Canada) Forest Service. There are a number of smaller establishments operated in conjunction with the major nurseries and several nurseries are currently in the developmental stage. The total annual production of the organization currently runs around 75 million seedlings, of which 80% are grown as bareroot and 20% as plugs in containerized styroblocks. The species grown at Surrey include Interior spruce (*Picea spp.*), Douglas fir (Pseudotsuga menziesii [*Mirb.*] *Franco*), and Western hemlock (*Tsuga heterophylla* [*Raf.*] *Sarg.*)

The irrigation water for the nursery is drawn from a 14-acre lake which is located on municipal property ½ mile south of the nursery. The lake is being developed by the municipality as a recreational area. As a result of a number of drownings in recent years in which the submerged aquatic weeds, mainly *Elodea canadensis* were implicated, the municipality, after an unsuccessful attempt to reduce the weed population by mechanical means, solicited and received the assistance of the provincial Department of Agriculture in an attempt to control the weeds with herbicides. In 1973 some preliminary aquatic weed control trials and conifer seedling phytotoxicity trials were conducted with Diquat (Reglone A). The phytotoxicity trials on the conifer species produced no damage but the rates of Diquat used did not provide adequate weed control in the lake. In 1974, at the urging of the municipality to resolve the problem as soon as possible and after consultation with aquatic weed specialists elsewhere in Canada, a proposal was made to treat the lake with Diquat (Reglone A) and Paraquat (Gramoxone S) to provide an

effective concentration of ½ ppm of each material in the lake. The municipality's proposal was reviewed and approved by an interdepartmental committee that oversees the application of pesticides to public lands in this province.

The lake was treated on July 30th and, prior to the herbicide application, the nursery replenished its two reservoirs (capacity 2.8 million gallons) in anticipation of the 5-day waiting period between treatment and use of water. The lake water was not used for irrigation purposes until 7 days after treatment; however one of the reservoirs was partially recharged 3 days after the treatment and the contaminated water was allowed to stay in the reservoir for a further 4 days prior to use.

The Canadian distributor's specifications indicate that where Diquat or Paraquat are used for aquatic weed control it is safe to use the water for irrigation purposes 5 days after treatment. In subsequent discussions with the distributor's technical representatives it was indicated that these materials are normally deactivated to safe levels for irrigation within 48 hours and the additional 3 day delay is built in as a safety factor. The cationic behaviour of Diquat and Paraquat provides for their deactivation through contact with anionic materials such as clay, silt, and living or dead organic matter. In retrospect it may have been better to further delay the use of the lake water for irrigation but the seedlings were under drought stress conditions at the time and no alternate source of irrigation water was available.

A herbicide residue analysis of the lake indicated a total Diquat-Paraquat concentration of 3.3 ppm two hours after treatment, 2.4 ppm at six hours, 0.7 ppm at 24 hours, 0.3 ppm at 48 hours, and 0.33 ppm after one week, indicating that most of the deactivation occurrred during the first 48 hours and that there was no appreciable change in the level of herbicides present during the next five days.

Those familiar with Diquat or Paraquat are aware that when these materials are used for conventional weed control purposes at rates between 500 and 1200 ppm results are usually evident within 48 to 72 hours. With the sub-lethal levels of the herbicides present the damage to the conifer seedlings did not become evident until two weeks after the use of the contaminated water on some species and several months later on others. Two weeks after commencing to use the water foliar damage to container-grown hemlock and Sitka spruce became evident. The container grown white spruce did not appear to be affected and both the coastal and interior fir appeared to be only slightly damaged at that time. In the field-grown stock there was some tip damage to 2-0 Sitka spruce but a severe out-break of aphids that went unchecked for some time made it difficult to ascertain whether the contaminated water or the aphids were responsible for the damage.

Analysis in late August indicated the continued presence of trace amounts of both herbicides in the lake and reservoirs (0.06 ppm Diquat and 0.09 ppm Paraquat) and healthy bracken ferns *(Pteridium aquilinum pubescens)* used as indicator plants continued to show foliar damage after being irrigated well into September. We had been working on the assumption that the herbicides had been deactivated by this time and that the damage to the container-grown stock resulted from the initial irrigations following the treatment of the lake. By late August only the container-grown hemlock showed serious signs of damage. With the continuing damage to the bracken ferns and the evidence of trace amounts of both herbicides still remaining, clay was added to the reservoirs and charcoal filters were installed in the irrigation mainlines.

It was not until late September, eight weeks after the lake was treated, that the presence of serious injury to both the 1-0 bareroot and container-grown Douglas fir became evident. Examination of the fir seedlings revealed the presence of a constricted area on the lower stem. Foliar damage was confined to the hemlock and analysis of dead foliage indicated residues of Diquat and Paraquat.

Fortunately, damage to the 1-0 and 2-0 white spruce, which is the nursery's principal species, was negligible. There was no damage to the 1-0 Sitka spruce; however there was substantial culling in the 2-0 Sitka spruce at lifting time as a

result of the herbicides and/or aphid damage to the terminals. There was some damage to the 2-0 Douglas fir but buds appeared intact and no losses were recorded.

The constriction on the 1-0 bareroot and container-grown Douglas fir had seriously damaged the cambium tissue and it was postulated that the cambium would either heal or eventually result in the death of the upper portion of the seedlings. During the winter of 1974/75 the latter occurred. By the spring of 1975 the fields of Douglas fir were orange with dying or dead foliage, a condition not uncommon in Douglas fir nurseries that have received winter desiccation injury or a late spring frost; however in this instance the damage extended much farther down the stem than normally occurs from desiccation or frost injury. With diligent use of irrigation and an enriched fertilizer programme the seedlings have been brought back to good health. Of the 10.3 million bareroot Douglas fir seedlings grown we anticipate shipping 70 to 75% of this number, which is approximately 10% less than in a "normal" year. The damage to the bareroot portion of the nursery was minimal although the delay in the availability of about 3.5 million Douglas fir seedlings which were to be shipped as 1-0 for mud-packing caused considerable inconvenience to consignees.

The inventory of planable bareroot species of all age classes at Surrey in August of 1974 was 56.2 million. The total figure will be down by 10% by the time all of the stock is shipped. Total bareroot shipments out of Surrey during the past planting season were 22.7 million, compared with 18.3 and 17.5 million in the previous two seasons and approximately 33 million will be available for the coming fall and spring planting season.

As a result of the more intensive water requirements, damage to the container-grown stock was very severe. A total of 4.9 million were culled. The only container-grown species suitable for shipping were lodgepole pine and interior spruce and 1.2 million of these two species were shipped. It is probable that a good percentage of the culled container stock could have been salvaged but the nursery had no facilities to carry the crop in containers for a second year and the costs associated with transplanting this stock in the field with no guarantee of success was not justifiable.

Container shipments from Surrey in the previous years were 7.9, 2.2, and 5.1 million respectively and a crop of 5.9 million is anticipated this year.

While we have attributed most of the damage to the 1974 crop to the contaminated irrigation water it is acknowledged that some portion of it may result from diseases, insects, over-winter injury, and poor cultural techniques which plague every nursery operation.

We have had some difficulty in convincing herbicide specialists that such trace amounts of herbicides could cause such extensive damage. The fact that the seedlings were under drought stress conditions at the time and the interactions with fertilizers, insect injury, insecticides, and other herbicides may have been contributing factors.

Contamination of irrigation water supplies by herbicides is something many of us would rather not think about and because of the sophisticated techniques necessary for pesticide analysis and the time involved it is not practical to carry out a continuous monitoring programme. The use of sensitive indicator plants and the experienced eye of the nurseryman to stock abnormalities are perhaps the most practical means of monitoring water quality.

I would hope that our misfortune would alert plant prop-

agators to the necessity of maintaining and protecting the quality of their irrigation water supply.

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PRESENT POSITION AND FUTURE PROSPECTS FOR THE BRITISH NURSERY INDUSTRY

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Prior to selecting a sample of holdings for a national costing of ornamental trees and shrubs, which was commissioned by the Ministry of Agriculture and is currently in progress, the Agricultural Economics Research Unit of the University of Bristol, as co-ordinating centre for the study, obtained details of hardy nursery stock (HNS) acreages relating to the June 1971 census. These data were analysed and the results published in August 1974[1]. It is this report, brought up-to-date and supplemented, which forms the basis of this article.

Setting the Scene (Table 1). There were in England and Wales in 1971 nearly 3,000 producers and some 16,000 acres of hardy nursery stock. Of this area, 2,700 acres were occupied by fruit trees and bushes, and in the discussion of demand which follows later, this section of the industry has been deliberately excluded as being unrepresentative. A considerable proportion of its output is by and for commercial fruit-growers and, in contrast to ornamentals, the acreage of fruit trees and bushes has been declining steadily since this category of HNS was first separately identified in the June census of 1954.

Table 1. Distribution of hardy nursery stock acreage and holdings, 1971[1]

	Number of holdings	Area of HNS	HNS acres per holding
		acres	acres
All HNS	2,908	16,030	5.5
Of which:			
Ornamentals	1,365	6,199	4.5
Roses	872	4.071	4.7
'Other' nursery stock	1,548	3,062	2.0
Fruit trees and bushes	792	2,698	3.4

[1] Source: Hardy Nursery Stock in England and Wales, AERU, University of Bristol (1974); based on data supplied by the Ministry of Agriculture, Fisheries and Food.

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[1] "Hardy Nursery Stock in England and Wales — a brief study of scale, location and structure." J. Rendell & S.R. Wragg, Agricultural Enterprise Studies in England and Wales, Economic Report No. 29, University of Bristol, Agricultural Economics Research Unit.

Table 1. continued

	Number of holdings	Area of HNS	HNS acres per holding
Degree of specialisation:			
No. of categories: One	1,916	6,417	3.3
Of which:			
Ornamentals	485	1,642	3.4
Roses	266	1,762	6.6
'Other' nursery stock	826	1,605	1.9
Fruit trees and bushes	339	1,408	4.1
Two	528	2,821	5.3
Three	251	3,140	12.5
Four	213	3,652	17.2

			Percent of total	
			By *holding*	By *area*
Size Group:				
Less than 1 acre	1,066	431	36.6	2.7
1 to 4.99 acres	1,266	2,724	43.6	17.0
5 to 19.99 acres	429	3,759	14.7	23.4
20 acres or over	147	9,116	5.1	56.9

While only 13 percent of holdings growing HNS are exclusively devoted to this activity, and 65 percent of growers use less than half their acreage for HNS production, there is some degree of specialisation *within* the HNS sector. Although two-thirds of the holdings produce only one of the four separately identified categories of HNS, "specialisation" in this sense is a relative term. Obviously "rose" and "fruit-tree and bush" production is far more specialised than say "ornamental tree and shrub" production. In fact, it will be apparent later that the United Kingdom industry is not specialised enough.

A further point to be noted from the figures presented in Table 1 is that although small-scale growers of HNS are numerically important, their share of the total HNS acreage is comparatively very small.

Regional Distribution (Table 2 and Figures 1 and 2). Although hardy nursery stock is grown to some extent throughout the United Kingdom, there are only certain parts where it is of considerable importance, in particular South East England, East Anglia and the East Midlands. That this is not just a question of demand, as measured by the size of the population, is clear from the figures presented in Table 2, for "HNS acres per 10,000 population" is higher for these three regions than for all other parts of Great Britain. In contrast HNS is poorly represented both in relation to population and in absolute terms in the whole of England north of a line from the Mersey to the Humber, and in Wales.

Table 2. Regional distribution of hardy nursery stock acreage in 1971[1]

Region or county	Area of HNS	Population	HNS acres per 10,000 pop.
	acres	million	acres
England			
South East	6,922	17.0	4.0
East Anglia	2,348	1.8	14.1
East Midlands	1,913	3.3	5.6
West Midlands	1,500	5.1	2.9
South West	1,166	3.9	3.1
Yorks/Humberside	610	4.8	1.3
North West	606	6.7	0.9
Northern	417	3.3	1.3
Scotland	888	5.2	1.7
Wales	548	2.7	2.0
Total	16,918	53.8	3.1
Surrey	2,390	1.0	23.8
Norfolk	1,345	0.6	21.8
Hampshire	1,153	1.7	6.9
Western Europe			
West Germany	33,600	61.7	5.4
France	24,200	50.8	4.8
Holland	9,400	13.0	7.2
Belgium	4,400	9.7	4.5
Total W. Europe (excluding UK)	71,600	135.2	5.3

[1] Sources: Hardy Nursery Stock in England and Wales, AERU, Bristol University (1974) and Statistics Office of the EEC, Agricultural Statistics Series, 1972, No. 8.

When one considers individual county data, Surrey, Norfolk and Hampshire are very important for HNS production, contributing as they do 29 percent of the total acreage in Great Britain. The accompanying maps are of interest in that they clearly show that even within Southern England, HNS holdings are not randomly scattered. They tend to cluster in certain restricted areas of suitable soils and in particular, avoid the chalk downlands of that region.

In the rest of Western Europe, both West Germany and France possess large areas of HNS, as one would expect from their size, but even in The Netherlands, HNS acreage is considerable in relation to the population. These comparisons should, however, be treated with caution since the definition of HNS used in the various countries to determine the acreage devoted to that enterprise, is not necessarily identical in each case.

To summarise, HNS production, although widespread, is not evenly distributed in relation to demand as measured by population numbers, and there are considerable movements of nursery

stock both internally and across national frontiers. That there exists a large Dutch export trade in HNS is consistent with the high density per 10,000 population of HNS in that country.

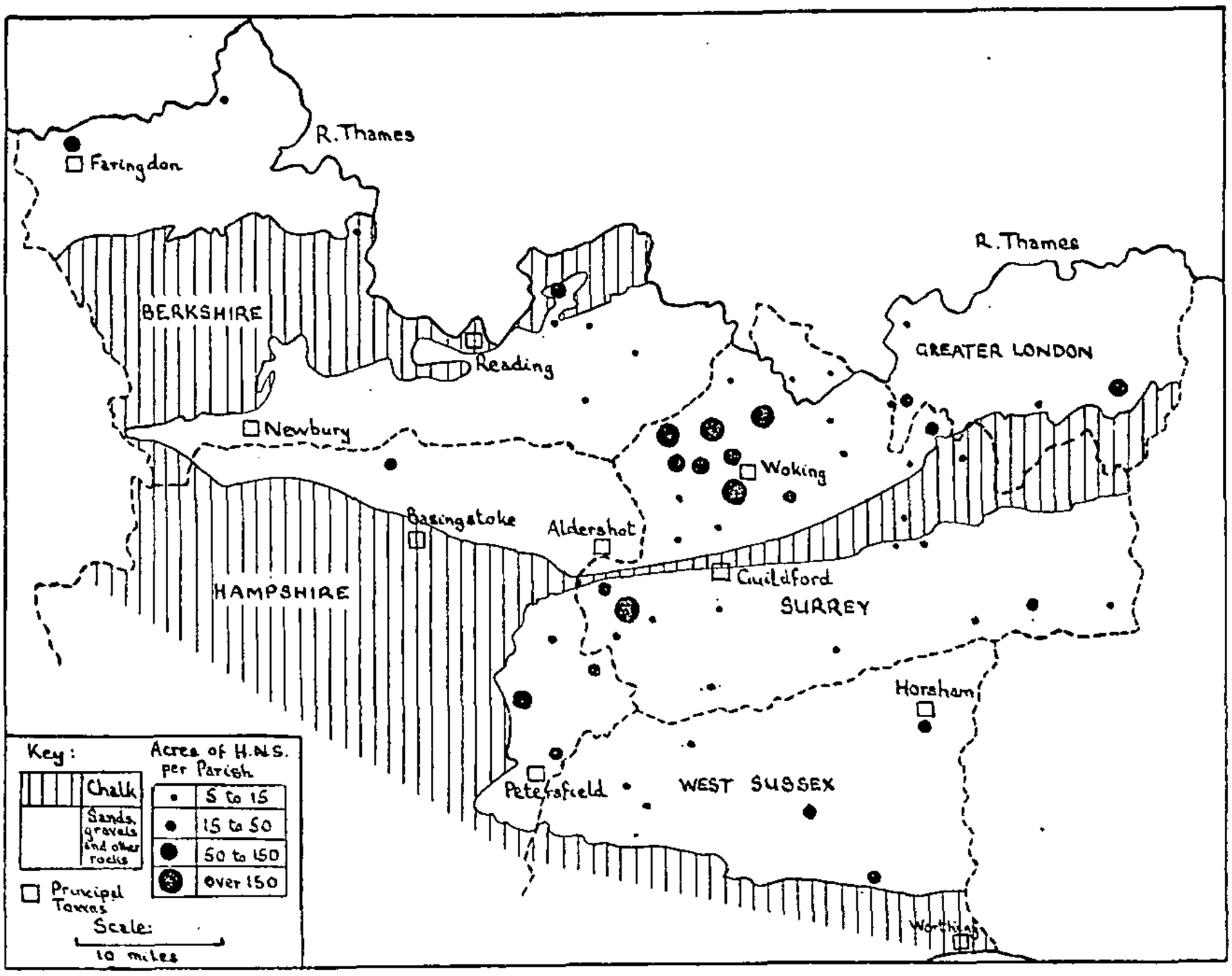

Figure 1. The London Basin and the West Weald

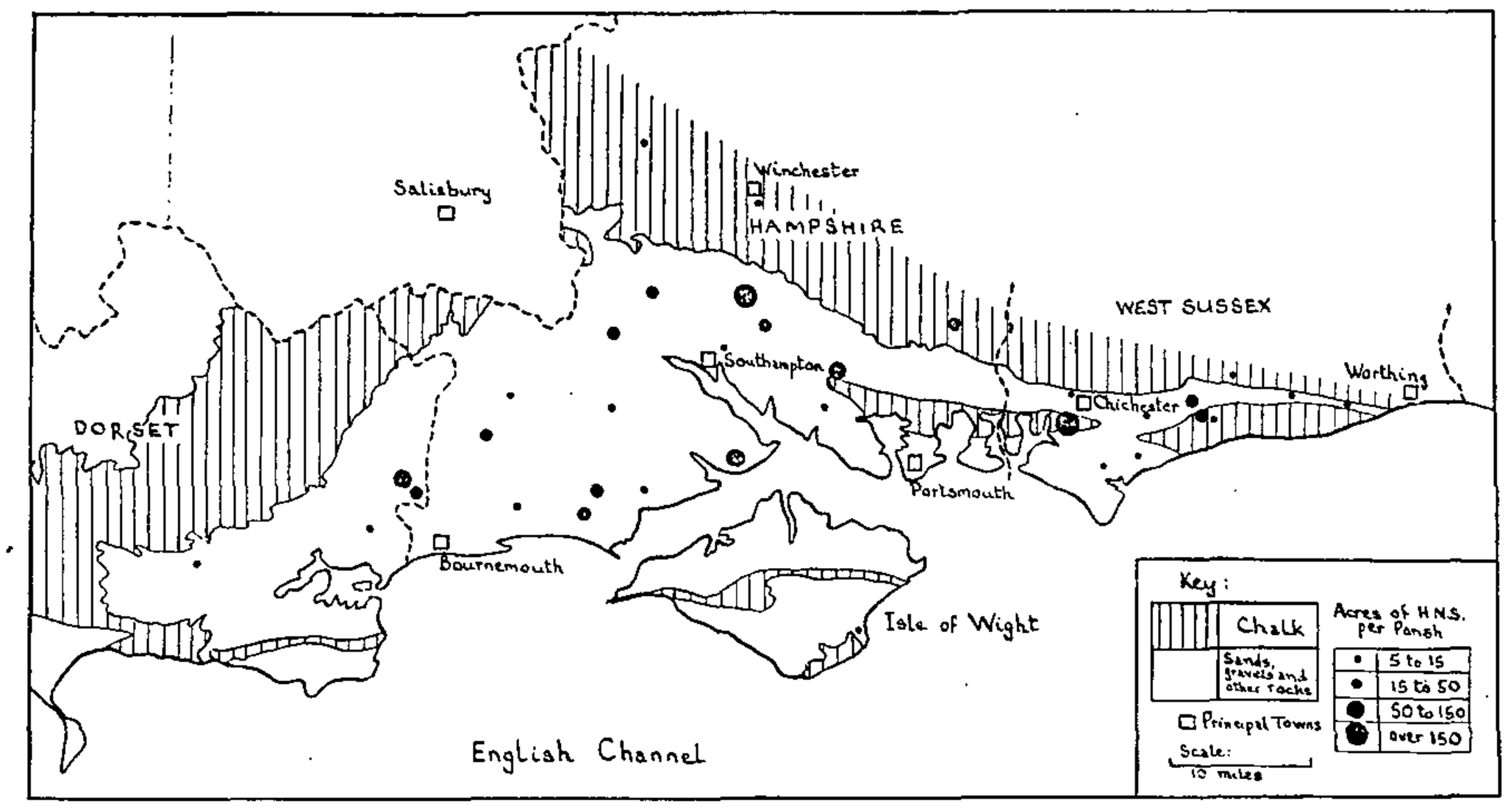

Figure 2. The Hampshire Basin.

Regional Specialisation. An appendix to our report included tables showing for the principal HNS-producing counties in 1971, the acreage and number of holdings for each of the 4 categories of HNS at that time separately identified. These data were presented both as totals and as percentages of the county HNS in each case.

Due to changes in the categories of HNS now detailed, the lack of data on holding numbers, and alterations in local government boundaries it has not been possible to fully up-date these tables. Nevertheless, it is clear that certain of the various "specialisations" within the HNS industry are associated with different parts of the country to an even greater extent than is the industry as a whole.

"Fruit tree and bush" production and "rose" production are more regionalised than the other specialisations. The former, as one would expect, tends to be concentrated in those counties with a substantial acreage of cropping orchards and fruit plantations, particularly West Sussex and Essex, the latter in the East Midlands, East Anglia and Clwyd. It is interesting to note that, comparatively speaking, rose production is of minimal importance in the Southwestern counties. This is probably due to unfavorable climatic circumstances.

The "shrubs, conifers, hedging plants and Christmas trees" category is of particular importance in Dorset, presumably for heathers. Devonshire, Derbyshire, Surrey, Staffordshire and Cornwall, should perhaps, also be mentioned here, although private information indicates that some growers of *Pittosporum* spp. for cutting as foliage have erroneously included their acreage of this crop under HNS. Ornamental tree production dominates the HNS industry of Lancashire, Cheshire and Hampshire, and is also important in Surrey. Herbaceous plants are associated with rose-growing in Norfolk and Cambridgeshire, probably in connection with the mail-order bulb firms of that area, and Somerset is also an important source of herbaceous plants. The use of the term "other" as a basis of classification is a convenient convention when the content of the group so described is relatively unimportant. But it sometimes happens, as in this case, that this is not so. Even after separating herbaceous plants, "other" accounts for 15 percent of the total HNS acreage, while it also exceeds the acreage of fruit trees and bushes.

Overproduction of HNS (Figure 3). In our report we pointed out that there had been a "steady and long-term expansion in ornamentals and roses" and stated that "this was obviously the grower's response to increasing demand." In attempting to provide an explanation for this post-war expansion we concentrated our attention on two explanatory variables, namely, the annual rate of completion of new houses and flats, and the level of con-

sumer expenditure at constant prices, because these two variables could be readily measured and data were available.

We found that the first of these two variables, namely new house building, did not add significantly to the explanation of annual change in the acreage of HNS, and we established that a one percent change in consumers' real spending was accompanied by a one percent increase in the acreage of HNS.

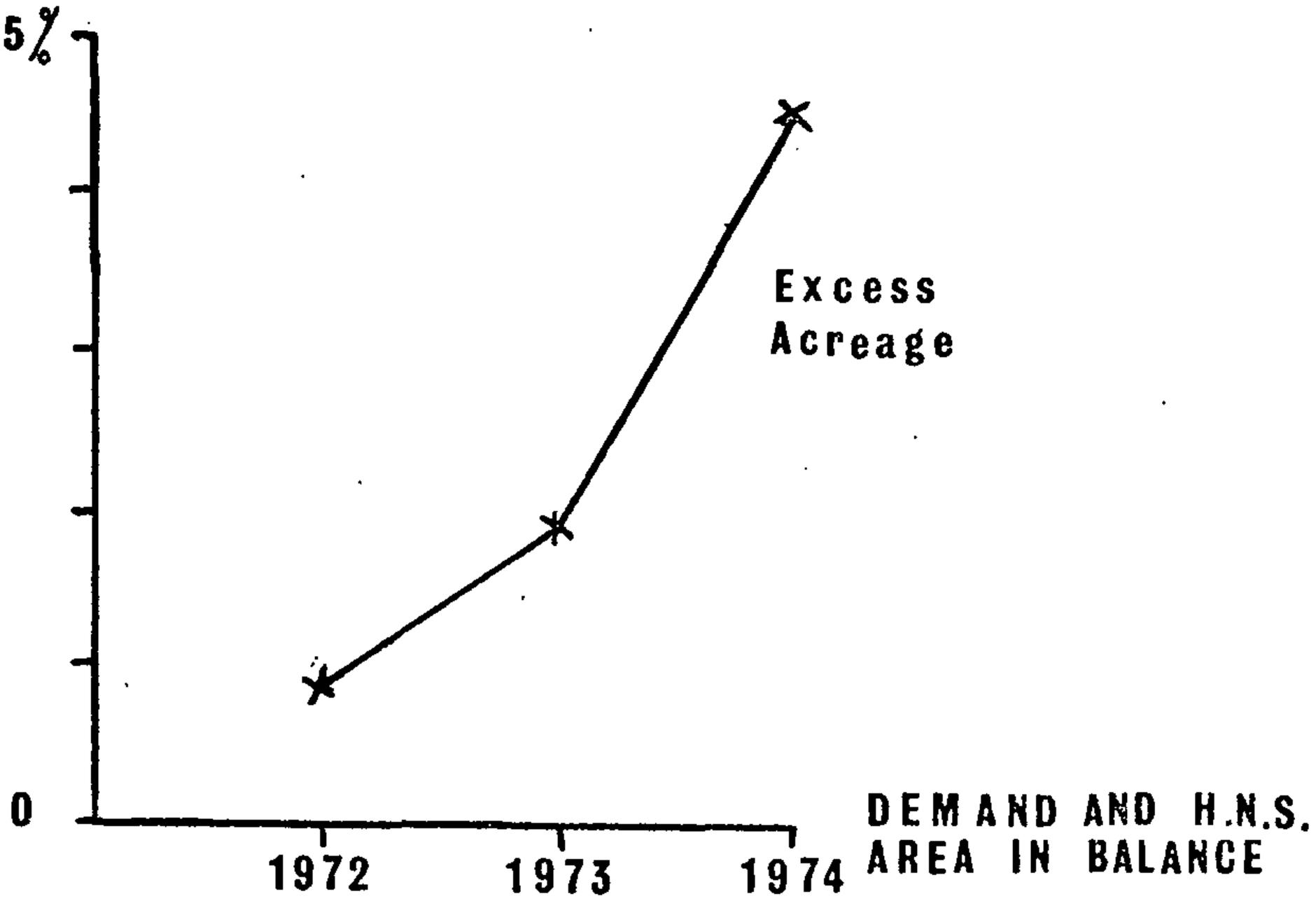

Figure 3. Overproduction of H.N.S.

Using this established relationship it is possible to calculate the expected acreage of HNS for those levels of consumer expenditure at constant price actually experienced in 1972, 1973 and 1974. The differences between actual and expected acreages, expressed as percentages of the expected, are shown in Figure 3. It is clear that during the last three years HNS acreage has increasingly exceeded that acreage which in the past one would have expected to have satisfied demand. In particular the acreage of HNS continued to rise in 1974 despite an actual fall in consumer expenditure at constant price. This coupled with a recession in the building industry and a clamp-down on public expenditure, points very clearly to a present state of overproduction, and the likelihood that rapidly increasing production costs can no longer be offset by price increases sufficient to maintain profitability.

The NEDO report of May 1973, even at that time, speaks of the difficulties faced by rose growers, largely because of overproduction. This is confirmed by the June census data for "roses" which show that since 1971 an appreciable decline in acreage has

taken place, and it seems likely that a similar situation is now facing the nursery trade as a whole. That there has been an even steeper decline in the number of rose stocks imported from the Continent, from some 50 million annually in 1969 to about 30 million annually at the present time, suggests that production of home-produced stocks has actually increased.

Recent changes in the HNS industry. Due to changes in the 1973 census in the categories of HNS, separately distinguished comparisons with earlier years are somewhat difficult to make and subject to a certain amount of estimation. For instance the category "shrubs, conifers, hedging plants and Christmas trees" for 1973 and 1974 may include some areas previously classed as "other hardy nursery stock", and similarly "other hardy nursery stock" may include mixed areas formerly divided between the separate categories. Such distortions are unlikely to be serious, and are to some extent self-compensating.

A study of the data for the 4 years, 1971 to 1974, is of some interest as it reveals considerable changes within the HNS industry which are concealed in the overall acreage figures. During this period "fruit trees and shrubs" and "roses" both show a steady decline in acreage despite the continued rise in total HNS area. The latter has been due to that section of the industry comprising "ornamental trees and shrubs" which has expanded considerably. It is perhaps significant that within this group "shrubs, conifers, hedging plants and Christmas trees" fell from 4,039 acres in 1973 to 3,858 acres in 1974. An interpretation of changes in the "other hardy nursery stock" area is difficult as the 1972 figure is inconsistent with data for the remaining years.

Plant movements within the nursery trade. In 1969, the only year for which appropriate data are available, output of HNS in Great Britain was valued at some £ 17½ million[1] of which only £ 10½ million was sold retail, and probably £ 2 million at least represented movements of plants within the nursery trade itself. For the nursery trade is a very complex business with some plants being propagated on one holding, "grown on" on a second and bought for resale by a third, increasing in value at each stage.

[1] Ed. Note: In 1969, the British pound was equal to about $2.80. (In November, 1975, it was equivalent to about $2.10).

It is evident that any increase in the area of HNS in Great Britain might increase the import expenditure on stock-plants and plants for "growing-on". However, this increase would be considerably less than the increase in total value of the home industry and in any case could not conceivably support a rate of growth in imports greater than the rate of growth in the United Kingdom acreage.

The role of imports (Figure 4). Imports of HNS in terms of value at constant price have been increasing since 1966 by an average 10¼ percent per annum, whereas the increase in the England and Wales acreage of HNS has been on average only 4¼ percent per annum. Even a cursory glance at Figure 6 shows that imported HNS has been capturing an ever larger share of the United Kingdom market. This is presumably at the expense of the British producer, for only a relatively small proportion of this increase in imports could be for filling the needs of the commercial UK nursery for additional young plants and cuttings.

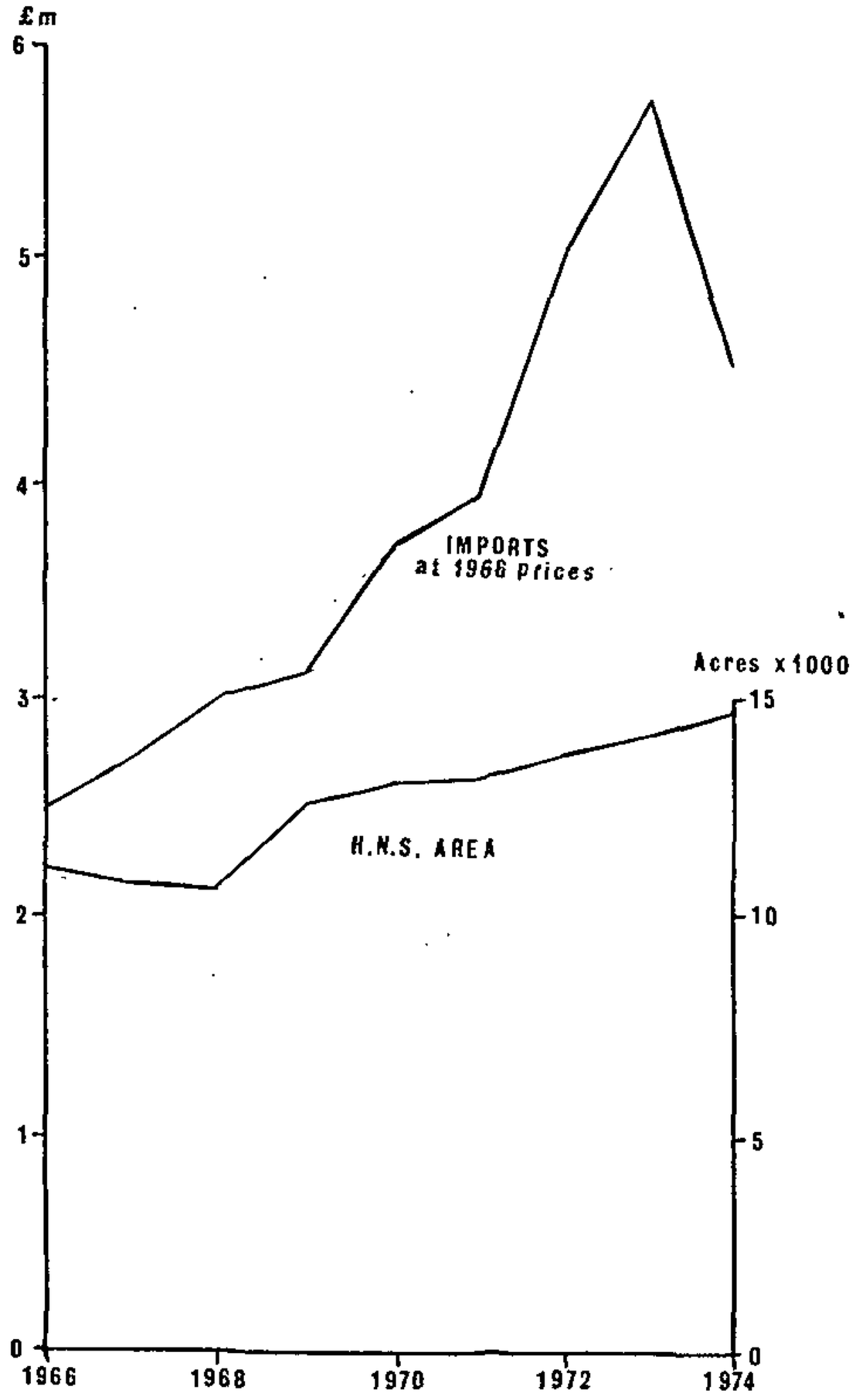

Figure 4. Changes in H.N.S. area and imports. (Sources: MAFF, June census data. Annual Statement of UK trade.)

It is unlikely that this trend will continue, however, since it is clear that demand in this country will decrease, or at least will rise more slowly than in other parts of Western Europe, and our own stage of overproduction will make the United Kingdom market less attractive to Continental producers than hitherto. Certainly the input of plants and cuttings for growing-on will decline with any substantial fall in the United Kingdom HNS acreage in the same way as has in recent years the import of rose stocks.

European trade in nursery produce The Netherlands is the principal country in Western Europe for the export of HNS and about two-thirds of our HNS imports originate there. West Germany is the largest importer of HNS, although in contrast to the United Kingdom, it also has a sizable export trade. In consequence, in 1971 at least, its net import bill for HNS was less than that of the United Kingdom. Belgium and Denmark are other net exporters of HNS, although this trade is very much less than that of the Dutch.

Future Prospects. The UK is climatically in a favorable position for the production of HNS compared with many parts of the European Economic Community. Although the dispersed nature and small-scale of the industry can be of advantage when supplying small retail outlets, the industry is not so well placed for providing large numbers of a restricted range of plants for landscape work and so on. This point is made specifically by B.T. Barrett in a "Survey of the demand for hardy nursery stock in Scotland." He quotes Scottish Local Authorities as saying repeatedly than they "would prefer to buy Scottish-raised plants because of their better acclimatization, if price, quality and availability were at least as good as those from English and Continental sources." "The advantage in all these factors is with the Continental suppliers, even allowing for transportaton and packing" and "the establishment of large-scale cooperative growing is urged."

Similarly P.R. Thoday of the University of Bath, in a report to the National Health Service on the demand for and best method of growing hardy nursery stock used in the landscaping of hospital grounds, says of the Continental producer that "rigorous grading to export standards ensures reliable, high quality material which is often available in larger quantities than from British producers. Most significant is availability of very young nursery stock sold immediately after the propagation stage for growing-on in the nursery. As this stock is very small it is relatively cheap but is often the result of highly skilled specialist propagation techniques. The purchase of such "whips" and "liners", particularly some grafted trees, is strongly recommended." Surely there is no overriding reason why this market need remain in the hands of the Continental producer and, although the history of horticultural cooperation in this country is not one of unqualified success, HNS producers would, at this time of increasing competition, be well advised to work more closely together in an attempt to capture their fair share of this market.

Replies to a questionnaire sent by Thoday to ten local authority parks departments indicated that "home production is extremely unlikely to prove cheaper than purchasing." In a time of limited and curtailed public expenditure it might be thought that many non-commercial propagating units, for example those run by

parks departments, would be closed and that plants urgently required would be bought-in. Unfortunately for the industry this may not be the case, since to quote Thoday, "the choice between purchase and home production may not ultimately be a matter of expenditure but of accounting. It is evident in some cases that at present it is far easier to get money for the provision of nursery stock via the wages of the ground staff than it is by orders placed with commercial firms."

THE SIGNIFICANCE OF NURSERY ECONOMICS

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Nursery accounting and nursery economics are subjects which, in my experience, do not excite the majority of nurserymen. Perhaps it is that most nurserymen have come into their profession because of a natural inclination to work with plant material rather than with pieces of paper on a vast executive desk. The prospect of being chair-bound is anathema to many plantsmen and is something to be avoided at all costs.

There is also the possibility that people who call themselves accountants or economists are people who speak a strange language not at all like that of the nurseryman. Conversely, the nurseryman probably sounds strange to the accountant! Each has his own jargon which to the uninitiated appears as a barrier to understanding. In almost any situation where 'jargon barriers' occur, it is highly likely that a certain amount of mutual misunderstanding will develop between the groups involved. At worse, misunderstanding leads to distrust.

May I say that if the picture I have painted is a true one then I think it is a pity. For it seems to me that the accounting profession has an enormous amount to offer the nursery industry; and given better nursery accounting and records the economist could start making a lot more sense of the problems which confront the industry today. It is true that an awakening is occuring in some nursery firms and a grip is being taken on the accounting[1] this hopefully with better management in mind.

"The significance of Nursery Economics" will be interpreted in this article in three different ways: (i) at the international level, (ii) at the inter-company level, and (iii) on the intra-company scene.

The international level. Whether we like it or not the British Nursery Industry is inextricably linked with that of mainland Europe. Until recently it has been very much a one-way trade, with Britain absorbing various nursery products from nearby countries, notably Holland. In particular we can think of the importation of millions of rootstocks each year as well as large numbers of lining-out stock. But although we have become used to this pattern of trade over the last three or four decades this has not always been the case.

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[1] Accounting should be interpreted here to include not only financial accounting but also the measuring of labour and material inputs as well.

Frederick Street in his 'History of Goldsworth Nursery' has stated that in the 20's Goldsworth Nursery exported as many as 4.5m rose stocks (Manetti) to the United States in one year — a fairly substantial number even by modern standards. But this trade is now as dead as the Dodo. And as I see it, we may well be on the verge of another major shift in the pattern of international nursery stock trading. The point is that relative economic advantages change over time as, of course, does production technology. In consequence it is possible that rootstock production, until recently the prerogative of the Dutch, may once again become established in Britain.

It is noteworthy that the Dutch nation has recently become progressively more industrialised and less dependent on agricultural/horticultural production. Labour has been drawn from the land into industry and in turn the agricultural worker looks for wages on par with his industrial counterpart. This, of course, has resulted in some fairly steep rises in Dutch nursery-stock prices over the last few years.

The international economic scene is therefore relevant to our thinking and the nursery manager, with planning horizons beyond the present year, would do well to develop a strategy for taking up the opportunities as they arise.

The inter-company scene. What do we mean by this? At any given point in time there will be various nursery companies competing for a share of the market for nursery stock. Whether it be rose trees, fruit bushes or clematis there is a roughly defined market place in which firms compete at least to a degree.

For the moment we will stay with roses since these make a readily understood production group. Some of you may have experience of the vagaries of the market for this product over the past few years.

Consider with me for a moment four possible producers of rose bushes: (i) the large, wholesale producer who prepacks for the supermarket trade; (ii) a farmer who grows roses on contract or as a speculative venture into a new crop; (iii) a large grower/retailer; (iv) a small grower/retailer.

An interaction, via the market place, is going on between these groups as a result of the cost/price framework within which they are each working. As every nurseryman knows — production techniques have developed such that mass production has become feasible. In particular we can mention the use of herbicides, purpose-built machines, and budding techniques.

The effect on the four classes of rose producers has been tabulated for ease of reference in Table 1.

Table 1. Economics of production and marketing of roses for four categories of rose growers.

Type of Rose grower	Production costs/acre	Marketing costs/acre	Profitable selling price	Overall effect
Large, wholesale grower	low	low	low	Large numbers of cheap bushes available with a tendency to overproduction.
Farmer	low	v. low	low	"
Large grower/retailer	low	high	medium	Looks for a separate higher priced market segment.
Small grower/retailer	high	high	high	Unable to compete, probably goes out of business.

Although the picture presented in Table 1 has been somewhat dramatised in the rose trade it is, in fact, being repeated to varying degrees in many sectors of the nursery trade. Innovation alters the pattern of production and marketing which often results in some firms benefiting whilst others suffer. This phenomenon has always been part of the business world and there is no reason why the nursery industry should be an exception. Clearly it behoves us to be aware of the inter-company situation such that competitors do not gain a rapid economic advantage over us.

The intra-company scene. 'Matters' and 'things' are 'significant' when they affect us personally. We may not be greatly aware of what goes on in Europe; we may not even be greatly aware of inter-company competition; but we are highly conscious of the economics of our own business. We know that books have to balance and at the end of the year we wish to see total income exceeding total expenditure. As someone who has spent the best part of four years looking at the economics of nursery stock production, it seems to me that a nurseryman can best be likened to a juggler. Imagine, if you will, one hand juggling three balls labelled, 'numbers', 'grades' and 'prices' and the other hand juggling three more balls labelled, 'labor costs', 'material costs' and 'overheads'. Somehow or other all the balls have to be kept in the air, and when the juggling act is over for the year, a final conjuring trick transforms all the balls into one big ball which is labelled 'profit'. The greater the size of the last ball the more the audience, including the Bank Manager, applauds.

Now it seems to me that to juggle the balls successfully requires a lot of experience and intuition. There are good and indifferent jugglers and the indifferent ones are quite hopeless at performing the final conjuring trick. Either the profit ball fails to ap-

pear or else the juggling act collapses at an earlier stage. The result is that the audience sits glumly silent and the Bank Manager looks exceedingly gloomy.

Now the question is, has the study of economics anything to teach us so far as the ball juggling game is concerned? I feel it probably has in that it helps to indicate the size of ball for optimum performance. And although the juggling act will never reach perfection, there is, no doubt, that some optimisation of ball size can make the last conjuring trick a good deal easier and a lot more successful.

Now where a nurseryman grows simply bush roses his juggling act is a relatively simple one. All his costs relate to one crop and income will depend on the number and grade of his plants which relate in turn to the price obtained for each grade.

Many nurseries, however, are involved with several plant groups and it is here that the juggling act is often carried out more by good luck than informed judgement. The result is rather like an experience I once had of being driven down a country road on a foggy night on a bone-shaking lorry with poor headlamps. The vehicle meandered from one side of the road to the other narrowly avoiding disaster at every turn.

What I believe we need in such a situation is more information about the inputs and outputs of each plant group. With this in hand an economist or accountant can examine more helpfully the pattern of nursery production and in many cases advise on ball size for a better juggling act. Let me give you an illustration of what I mean: two nurseries I have studied produce a range of plant groups. In one analysis, I tried to determine whether, under normal conditions, some of these crops are profitable or unprofitable. My criterion has been whether the rate of return to capital employed has been positive or not. Table 2 shows some of results obtained.

Table 2. The rate of return on investment shown by different plant groups on two mixed wholesale nurseries.

	Percentage saleable		
Plant group	100%	80%	60%
Nursery A			
Bottom-worked trees	38	28	17
Bush conifers	40	40	35
Standard roses	32	15	loss making
Nursery B			
Bottom-worked trees	40	32	20
Bush roses	30	15	loss making
Standard roses	7	loss making	loss making

As was expected, considerable variation was exhibited in profitability between different groups of plants. Some proved very profitable and others less so. The net result, which often shows up in the annual profit and loss account, is that a business as a whole does less well than it might. The significance of nursery stock economics in this context is that given a carefully conducted analysis from which conclusions can be drawn, a start can be made on reorganising the nursery for greater profitability.

I would now like to deal briefly with one other aspect of intra-nursery economics. Quite often a nursery propagates stock, grows it on, and then transplants it once again so that the stock (or at least part of it) grows to a larger size. In many minds a clear enough distinction is not made between these different functions. The plant emerging from the propagating unit should have a price on its head. What is more, it should be a profit-making price such that the propagating unit is seen as a 'cost and profit centre' in its own right. If the propagating function is not operated profitably it may pay to buy in young stock from elsewhere to grow on.

In much the same way a nursery standard tree which is moved on to the heavy-standard tree unit should go with a price on its head. The outgoing price from one function then becomes the input cost for the next phase. Treated in this way each part of the nursery is looked at critically and made to not only pay its way but also contribute to the overall profitability of the nursery.

Conclusions. Nursery stock economics, as indicated in this paper, has significance at three levels: internationally, at an inter-company level and at an intra-company level. For most nurserymen the greatest rewards will come from a better understanding of the economics of his own undertaking. In particular, the choice of plant groups is important for within a given price/cost framework, partially imposed by outside forces, some nursery crops are more profitable than others. A better understanding of nursery economics will help in the formation of price policy and cost budgeting such that the full potential of the nursery can be realised.

THE IMPORTANCE OF COSTINGS FOR EFFECTIVE MANAGEMENT

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When I first joined the nursery business in the 50's I was introduced to pricing of nursery stock by my boss saying, "Find out what other nurseries are charging? What is our stock availability? What is the availability within the trade? How many did we sell last year?"

Having sweated blood to obtain this, very little notice was taken of it as each proprietor played his hunch — "Oh, that plant will stand another shilling".

Nobody could tell me what contribution that plant made to the business. The attitude was, "We are making money, so what the hell". Now that margins are being squeezed, further information must become available to enable management to plan ahead of inflation. Once a nursery reaches the slippery slope to Financial Trouble there is nothing that can be done unless the details and reasons are obtainable quickly. This applies to a general nursery more than the specialist grower.

Most well run nursery businesses produce an annual trading budget with profit forecast. A simple but important exercise:

	Sales
Purchases	
Production cost	
Direct expenses	
	Gross contribution
Central costs	
	Net profit on trading

This will be followed by the introduction of a cash flow forecast — probably the most important financial information, especially today with interest charges so high and a seasonal sales pattern.

Maybe at this stage the picture looks satisfactory but have the following points been thoroughly examined? (a) Proper valuation of saleable stock. (b) Are the products available in the right mix? (c) Are the returns expected sufficient for the capital employed? (d) What will be the effect if the sales targets are not achieved? (e) Immediate action in the case of (d) above.

I would expect that very few nurseries today are achieving the right return on capital employed which must be in the region of 30%. The main problem is in assessing the capital employed par-

ticularly with regard to nursery growing stock. By doing a thorough job on costing this will come to light and give management a good idea of the actual capital invested in the business. But let's start at the beginning and then I can bring out all the important by-products produced from a good costing system and how they can assist management.

Firstly, the relevant data must be obtained from what is going on in the nursery. There are many ways of doing this, but we found individual employee daily time sheets to be most satisfactory in conjunction with foreman's weekly report sheets. Eighty-two different operations were identified and listed and, therefore, time could be attributed to each. Standards of achievement had been agreed previously with all the staff so, from this exercise, management could see: (a) the time consuming jobs; (b) the efficiency of each operation against standards.

The next step was to code all plants grown on the nurseries, for simplicity's sake, and then group all plants with similar production techniques into a product group. With labour costs identified all that was necessary to add was the material content of each group/item to give the total production costs.

The important fact that emerged here was that costs had been built up on an annual basis which gave management the opportunity to determine whether there was a case for buying in at the one or two-year stage, or not continuing to grow that particular item at all.

However, before confident decisions could be taken it was necessary to complete the picture by costing in two more highly important factors — (1) The loss rate between rooted cutting stage and saleable (or bad grading); (2) Overhead costs apportioned at wages percentage rate and labour-hour rate. Example — overheads attributed to Rhodo is 15p

At this stage there were no reliable figures on losses so mathematical calculations were provided at various levels of survival. This illustrated the fact that although stock records were kept they were not sufficiently detailed to keep management informed as to what was or was not coming on, so a simple plant recording system was started and is still in operation. The data collecting is no longer continued for no other reason than there is now a wealth of information gained over two years, so at any time it is quite a simple matter to check on a particular operation and up-date the costs.

The final costing to produce a rate of return pricing policy gave some surprises, viz:

(1) Although there are certain differences in the difficulty of producing some of the plants within a group, the production

methods are similar. The effect of this is that one should be able to say that all plants in a particular grouping cost the same. However when it comes to the selling of deciduous shrubs produced in the same method prices vary from 45p to £ 2.25p.

(2) Early expenditure in a plant life, like soil sterilisation, although in itself not very expensive, related to the crop (say £ 300 per acre) becomes a major part of the selling price due to the cost of financing this expenditure for 4-5 years. As far as *Malus* 'John Downie' is concerned the effect is to put up the cost of the tree by 12p per saleable unit.

(3) Across the board there is a considerable change in pricing structure and consequently the contribution will vary considerably within any group. The ideal would be to grow one line by the million that shows the best contribution which obviously is not possible. Rhododendrons, dwarf conifers, trees from seed, and certain shrubs can produce a reasonable return, barring major losses. However, trained fruit trees and other worked trees which were always thought to be profitable have proved to be the reverse. A detailed investigation into cutting production costs and obtaining higher productivity is proving quite successful as far as trained fruit is concerned, i.e. training *in situ* (not transplanting). Small drill for staking — two-men team of tyers, one highly skilled to shape the tree, the other to follow up. Even then the price will have to be increased.

(4) Before deciding to dispense with a particular line, management has to consider the total volume of sales of any plant group and its value as a sales aid for other types of production. Potted herbaceous is a classic example and only represents 2½% of the total sales.

(5) To go flat out for the high yield groups, such as common trees, could produce other management headaches like marketing and distribution. The main market for those being Public Authorities, where there is liable to be a considerable reduction in expenditure.

(6) Product group No. 5 (156 kinds of deciduous shrubs) were costed out, open-ground-grown, and pot-grown, the difference being 11p more expensive to pot-grow. A further exercise proved that containerising a saleable shrub was cheaper but the loss was higher and yet to be established. More money has to be asked for container-grown shrubs, probably in excess of 15p.

(7) Popular cries, "like it doesn't matter if we have not sold these conifers, rhododendrons, etc.; they will grow into money", at the present time is a load of "Cod's wallop" unless, of course, the price for bigger stuff can be considerably increased. This costing data has enabled management to build up a programme of work well in advance which has had a two-fold effect: (1) that the

timings for each operation can be adhered to (very important in container growing); (2) that there would not be the labour on the land/standing ground to properly attend to the stock that is so-called "growing into money". By all means grow 5/6' rhododendrons and conifers, but programme and cost them.

That, then, is the broad picture as to how I see the importance of costing for effective management. A lot more I know will come out of this as time goes by. But like all forms of accounting, it is an aid for management and has to be interpreted by those in command in the light of the prevailing circumstances. It was not so costly to operate as it may sound — it is possible and worth considering, applying a system to a section or line of plant about which there is doubt as to their value to the business.

I would recommend the Wye College publication on managerial and economic aspects of hardy nursery stock production by Hugh Nunn and Mr. Folley at £ 1.25p, including overheads, National Insurance, family allowance, and a 30% return to me. Personally, I agree that further research is warranted on capital investment and rates of return marketing nursery stock.

BENEFITS FROM METHOD STUDY IN CUTTING PROPAGATION

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Method Study as a branch of *Work Study* makes better use of time and energy by developing the most effective method of working. What I am about to describe is not how to work faster and faster but better.

Every job should really be observed and recorded on its own, since where I insert cuttings today may be entirely different to next week or where you root your own material. However, the principles that I have used in this example can be applied right through the complete range of propagation from cuttings.

I want you to ask yourselves and select what is the key *doing* operation required to root the more common material which is to be handled in large numbers? . . . To me, it is the insertion of the prepared cuttings to permit the best conditions for rooting to be applied quickly and effectively. Skill is required for selecting and making cuttings — though we might argue that one — but once our criteria are set others should be able to follow the example of what makes a suitable cutting. We can make a lot of good cuttings but the delays of insertion and poor after-care can waste a percentage of this skilled output.

A study of making the actual cuttings can also be of value, but there would be very many effective methods according to the time of year and the species to be handled. So this study concentrates on inserting cuttings. The location is outside in late summer under white polythene in what is often called the "strawberry tunnel." I have worked up the improvements on this over several years on my own ground cover nursery using my own labor, or that of untrained teenagers.

At Merrist Wood we allow nursery students to insert cuttings in such a bed and to develop their own improved methods. Almost 100% naturally work across the bed as shown at right angles to the length of the bed using marker boards, with or without spacings, or pre-forming the holes in the bed with nail dibbers, etc. The cutting material used is *Cotoneaster salicifolius* 'Saldam', purposely using soft shoots to demonstrate that even soft-stemmed material does not have to be dibbled into the rooting medium.

It is a hot day, the material must be protected, in this case in a polythene sack, but the operator wastes a lot of effort having to pick out the material which was thrown into the bag anyhow. You would have the material laid out in the same direction and would

probably take up a handful in the left hand and then push the individual cuttings in with the right hand, having dispensed with the dibber and making sure that each row is firmed up afterwards.

At this stage various minor improvements are made for the convenience and comfort of the operator. A lined box to store the cuttings, a box and board to sit on. In one study we found that as much time was taken to move these boards as was taken to insert a row of cuttings from the sack.

From the squat or crouching position we can observe that the person inserting cuttings, even when close to the work, has to make several trunk twisting movements, to replenish his hand with cuttings. He or she probably moves the store of cuttings every row and this study indicates an exceptionally short row. (14 cuttings per row across the bed).

A breakdown of all these movements, and *only one operation actually gets the cuttings into the bed,* in a *Man Type Flow Process Chart* reveals how complex and disjointed the insertion of a thousand cuttings per hour can really be. By examining our method we can reduce the time from 54 minutes down to about 30 minutes and have enough time to water-in and cover up more carefully than before.

By looking at repetitive jobs frequently and analytically, we can record what is happening by examining the essential DOING operations and reducing the MAKE READY and PUTTING AWAY operations and delays, we are able to develop an improved method. In our example, I can best quantify the benefits by recording on a STRING DIAGRAM to find out the distance travelled by a thousand cuttings being inserted, and then comparing any improvement against this. After all, you do not pay workers to 'travel' cuttings — only to insert for rooting. Even more critical would be the distance each hand travels, and to highlight the incredible waste we put our left hand to, if it is only used as another cutting store!

Present Recorded Method:

Distance: Cuttings travel from the box, each one inserted by the right hand at 14 cuttings per row. Distance travelled by cuttings for one row = 4.6m. Distance per 1000 cuttings = 1000/14 × 4.6m = 328.6m

Time: To insert one row, set up next row, move cutting store, boards, and seat = 0.75 minutes; 1000 cuttings take 1000/14 × 0.75 = 54 minutes

Proposed Improved Method:

Distance: Two-handed cutting insertion; cuttings taken from box store behind middle of long rows down bed, 25 cuttings per

row. Distance travelled by cuttings for one row = 6.6m. Distance per 1000 cuttings = 1000/25 × 6.6m = 264 m = 20% improvement.

Time: To insert one row of 25 cuttings with both hands and move store of cuttings and kneeling board every two rows, firm up and mark out = 0.75 minutes. 1000 cuttings take 1000/25 × 0.75 minutes = 30 minutes = 44% improvement.

Defects of the Existing Situation. Within the confines of the polythene tunnel, or any other cutting bed area, the reach and dexterity of the operator is not being used effectively. The rows are too short and time is wasted when moving back for each row. The hands and trunk are used in a discontinuous process with one valuable hand unproductive; it is either holding cuttings in a 'temporary store' or making separate holes with a dibber.

Both hands and cuttings travel unnecessary distances and delays are caused when prepared cuttings are not layed out all one way in a box or other rigid container. The delay is caused by looking for the tops and bottoms when the eyes should concentrate on the row being inserted.

Recommendations:

1. Use the full radius and span of arms and fingers as is comfortable to the operator and insert long rows of 25 cuttings.

2. Provide a central store of layed-out cuttings which can easily be picked up in both hands.

3. Place this box over the inserted rows directly in the front view of the operator, i.e. one box resting on an upturned tomato tray (peg box). In this position the supply of cuttings does not have to be moved for every row, so speeding up the work and reducing the distance the cuttings will travel.

4. Kneel on a soft padded board on the bed facing the row and cut a mark deep enough for the depth of the cuttings with a sharp edged board or angle iron.

5. Using both hands, pick up a cutting simultaneously in each hand.

6. Insert both cuttings working out from the centre of the row each time. Concentrate the eyes on the left or right, then the other end of the row can be inserted without looking from side to side! In this way a fast rhythm can be obtained.

7. Firm up complete rows with both hands using plenty of arms-outstretched pressure. Again the operation is completed with one simple continuous movement.

Advantages. Although the improved method is not by any means the final improvement, there is 20% improvement on travel that the cuttings make for insertion. Next the time is reduced to

give a 44% improvement, in the example studied. Given the motivation, it is not difficult to train ourselves to use both hands and although the kneeling position may sometimes be more tiring, the method allows more time for relaxation or other work, such as helping the cutting-makers to catch up!

REDUCING COSTS BY CHANGING FROM INTENSIVE TO EXTENSIVE PROPAGATION METHODS

JANICE ANSTEY

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Tunbridge Wells, Kent

When we speak of reducing costs we usually think in terms of cutting down on the use of our resources — reducing our use of land, labor and capital. But, by contrast, the propagation methods we are using require *more* space, *more* labor, *more* time and therefore *more* cost — but they do reduce the overall cost of producing a saleable plant.

I should say, however, that none of these ideas is new. We have merely adapted the methods used by other people or, in some cases, our own methods used by other people or in some cases our own methods but we think that they are useful. We have selected four examples to illustrate what we are doing.

(1) For a start consider pyracantha. We used to put the cuttings in seed trays in a conventional mist house and, being economical people, we put 54 cuttings in a tray. When they were rooted we knocked them out and potted them into 3" pots to overwinter in the glasshouse ready for containerizing the following spring.

There were two problems with this system — firstly, it meant double handling so we considered how we could cut out one operation. And secondly, we were getting a very high rate of loss. So we tried putting the cuttings directly into small pots. But using 2¾" square pots we only get 15 to a seed tray, which takes up a great deal more space, so we moved them out of the mist house and placed the trays on the floor of the glasshouse. Over the cuttings we have an ordinary irrigation line linked to a solenoid and a time switch (no bottom heat) and the cuttings root here in 3 to 4 weeks. They are then left *in situ* until they are ready for containerizing in the spring.

Of course it costs more to put the cuttings in pots than it did to put them in seed trays — more in terms of labor, compost, pots and space but we do save one potting operation. The comparative costs are:

Cuttings in seed trays:

collect, make and put in 100 ph @£ 1.40[1]	1.4 p.
seed trays @ 13p for 54 cuttings	0.25
compost, including mixing 3.6p/tray	0.67

[1] Ed. Note. In November, 1975, the British pound was equal to about $2.10.

mist, 2.5/tray/wk for 3 weeks	0.14
weaning	0.14
potting 100 ph	1.4
pots	1.0
compost	0.25
watering	0.25
glasshouse space @ 10p/sq. ft/ann	0.5
	6.00p.

Losses up to 50% - overall cost 12p.

Cuttings in Rapidex pots:

collect, make and put in 100 in 110 mins	1.54
seed trays (used at least twice)	0.50
pots @ £ 16 per 1000	1.6
compost	0.25
sprayline, solenoid and time switch	0.01
glasshouse space	0.5
	4.40

Losses 5% - overall cost 4.62p.

So we save a little by using the second method but the really significant difference is in the losses.

This seems to be a useful method of rooting many of the plants which will not tolerate root disturbance. We use it with slight modifications for viburnums, large-leaved cotoneasters and *Ceanothus* 'Gloire de Versailles', etc. as they can put on a bit of growth before being containerized.

(2) Another subject which now takes up a great deal more space than it once did is *Hypericum calycinum*. We used to put our cuttings into seed trays — about 50 cuttings to a tray (or 450 to the square metre) and then plant them out. We estimate the cost of this method as:

collect, make and put in	1.4
seed tray, compost and house	0.5
knock out, prepare and plant	1.0
weeding, etc.	2.0
	4.9

losses 40% - overall cost 6.86p.

Now we put out cuttings (unrooted) directly into the field and get just over 40 to the square metre! As I said before, this method is not new, in fact, our friends across the Atlantic were using it at least 20 years ago. But we haven't yet seen anyone else using it in quite the same way that we are.

The land is first cultivated and treated with Basamid and then a layer of sand is spread over the entire surface. If we were on lighter soil this probably wouldn't be necessary - in fact we have

omitted it on one occasion elsewhere — but the soil on this particular site is heavy and clayey; the sand makes it easier to insert the cuttings, helps to hold down the polythene and improves the soil for future use. The bed is then marked out, the cuttings collected and put in (we don't bother to "make" hypericum cuttings these days — just cut them off and put them in) about 150mm apart, give them a good watering and cover with weldmesh and polythene. The weldmesh is cut into short lengths from the roll so that we are left with "legs" which push into the soil and we dig out a small trench along each side in order to bury the edges of the polythene to hold it down. We used to use white opaque polythene, which was much better, but as we can't get it to our specifications now we either cover the tunnel with thick layers of lenoweave or brush on ordinary glasshouse shading. (Incidentally, shading won't stick on new polythene but as we use the sheet two or three times we use lenoweave the first time and shading on subsequent occasions.)

The cuttings usually take 3 to 4 weeks to root, then we hook up the sides of the polythene at intervals to let in some air and after a week or so take the sheet off and use it again. If the cuttings are put in in May, as soon as the shoots are long enough to handle, they don't need watering until they are rooted. Some of the plants are big enough to sell in the following winter — 7 to 8 months from cuttings. We grade out the biggest and leave the others for another year. If we don't get the cuttings in until June we have to put in a sprayline which increases the cost and, as they don't get away so early, the percentage saleable in the first year is very much lower.

The cost of this method is:

Basamid @ 10p/sq metre (42 cuttings)	0.3
Sanding £ 10/bed (1600 cuttings)	0.7
collect and put in @ £ 1.40/hour	1.4
polythene and weldmesh	0.2
weeding, stopping, etc. 10 hours	1.0
	3.6

losses 20% - overall cost 4.32 - compared with 6.86 for the original system.

By the same method we are also rooting other hypericum cultivars and laurel, including the dwarf laurel cultivars, putting the cuttings in during the autumn and winter. And during the summer we put in any easy rooting subjects such as *Forsythia*, *Philadelphus* and *Potentilla*, but these need a sprayline which is hand-operated three times a day, gradually reducing the amount and frequency of watering as the cuttings begin to root. This increases the cost by 0.5p per cutting, but by spacing the cuttings we aim to undercut the plants and sell directly from the bed.

This is all right for plants which will be sold bare-root but basically we don't like the idea of putting cuttings in the ground and then digging them up and potting them so we looked at the possibility of putting the cuttings directly into a pot in a similar tunnel — and the results are as follows:

(3) Frames were constructed using concrete blocks for the paths with the whole thing being on a slight slope for drainage. A sprayline was placed along the centre of the frame, the pots stood down and filled with compost, the cuttings put in, watered, then covered with weldmesh, polythene and shading as before. Once rooted, the polythene, weldmesh and sprayline can be moved away and used again and the plants sold directly from the frame.

The alternative, of course, is to root the cuttings in a cold frame and dig them up and pot them. The comparative costs are:

Cuttings in cold frame —	
collect, make and put in 100/hour @ £ 1.40	1.4
cost of frame and dutch lights	0.2
compost and frame preparation	0.05
watering, shading, etc.	0.6
lifting	0.014
potting	2.8
3½" poly pot	0.3
compost	0.8
	6.164
Cuttings directly in pots —	
collect, make and put in	1.54
pots (2¾" square)	1.6
compost	0.25
watering	0.3
frame construction	0.2
weldmesh, polythene and sprayline	0.1
	3.99

We found that many subjects such as cotoneasters, *Euonymus* and *Hebe* rooted very well like this but we then had several frames full of liners which still needed containerizing so we now confine this method to ground covers, such as *Vinca* and *Hypericum calycinum* which can be sold in a small pot, sub-shrubs such as *Pachysandra*, rosemary, *Salvia* and *Santolina*, which can be put in a 4" pot, and a few liners which we want for our own use.

(4) The other subjects which rooted well under these conditions now go into a larger pot. We tried senecio in poly pots in these tunnels and they did reasonably well provided that the weather was coolish and we didn't have to give them too much

water. However, poly pots are not ideal in these small tunnels as it is difficult to see what is happening without taking the top off two or three times a day so we moved back into the glass house. We would prefer to use a walk-in poly tunnel but did not have one available at the time. Here we put unrooted hydrangea cuttings directly into a 5" poly pot (2 cuttings per pot) with a sprayline operated by a time switch; they rooted in about three weeks. The same method is particularly successful with *Caryopteris*, *Fuchsia*, hebes and *Ampellopsis* . . . all of which we used to root in seed trays and then pot on.

The comparative costs of the two methods are:

Cuttings in seed trays:

collect, make and put in 100/hour @ £ 1.40	1.4
seed trays	0.5
compost, including mixing	1.4
mist	2.5
weaning	0.14
potting — 40/hour @ £ 1.40	3.5
5" poly pots @ £ 5/1000	0.5
compost	3.00
glasshouse space	0.62
	13.56

Cuttings directly into poly pots:

collect, make and put in 30 pots/hour	4.7
5" poly pots	0.5
compost	3.00
sprayline, solenoid, time switch	0.3
glasshouse space	0.62
	9.12

However, like any other system there are problems:

(i) First of all, there is the problem of additional cutting material as we are putting two and three cuttings to a pot; and it is difficult enough sometimes finding material for one cutting per (hoped for) plant.

(ii) Secondly, there was the unexpected problem of over-production because some of the plants we produce in this way are saleable earlier than those rooted in seed trays and because we didn't suffer the losses to which we had become accustomed.

(iii) Thirdly, there is the problem of timing; because we are pushing more and more of our propagation into the summer months, we run into difficulties with holidays and other outside jobs which demand attention. If one is not careful there could also be the problem of what to do with the propagation staff in the

winter; although I don't see that as being much of a problem for us as we have several other ideas lined up.

(iv) Finally, there is the problem of space, which is an ever-increasing concern as we think of more and more subjects which we would like to try on the extensive system.

Once we were content with a small mist house and a few cold frames; now our propagation area extends to nearly three acres and we're still looking for more but if it reduces the cost of production it will be well worth it.

A TECHNICAL DESCRIPTION OF THREE PROPAGATING UNITS IN GUERNSEY

ROY BISSON

Victoria Vineries Limited,
St. Andrew, Guernsey

The past four years in Guernsey are remarkable from a plant propagation point-of-view because a large and concentrated horticultural area — some 2000 acres on a small island — took a great leap into the propagating business; because there was little experience in any aspect of this particular field there were many unexpected problems. In any event, out of over 30 nurserymen initially interested, less than 10 remain in business. However, one of the benefits of this lack of experience was an open mind — uncluttered by previous conceptions. We were fortunate in having a large equipment industry backing up the existing tomato and flower crops, and so the open mind and technical expertise got together and produced some most interesting and advanced propagation units. These units only worked when they had been evolved with the closest co-operation of someone experienced in propagating the particular plants concerned.

I shall describe the technical side of three propagating units that were built for very different purposes. You will notice many similarities in them because we all came to the same conclusions on many basic design points.

John Allen had the idea, which he developed with George Thorburn, of establishing from scratch a large wholesale business for hardy nursery stock. The site was a not too old tomato nursery in a fairly exposed situation. George Thorburn's experience stemmed from Holland and Germany and he knew only too well the importance of an extensive plant list. He embarked on the production of a wide range of plants including rhododendron, camellia, deciduous azalea, skimmia, mahonia, magnolia, miniature roses,

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hamamelis and so on. His propagation unit would have to cope with rooted cuttings and grafting. He has a 200 ft long by 30 ft wide 'traditional' Guernsey greenhouse on which he uses Rocolene shading.

Inside the house there is a wide central path for motorised trucks and the beds are placed on each side. The 6 ft wide beds are simply asbestos sides set into the soil with 18-inch gravel paths between. The ½-inch polythene heating coils were set directly into the soil, 2 inches below the plant boxes. The lack of drainage has recently caused problems and the use of sand would probably now be recommended. A main hot water feed pipe goes through a motorised valve into the flow manifold. The motorised valve is controlled by a detector set in the bed. The house is divided into several sections in case of different heat requirements. The ½-inch polythene tube is looped under the beds to ensure even temperature distribution. The return is sited on the opposite side of the house, the loops extending across the full width — under the central path. This very simple and cheap system has only one drawback in that the temperature cannot be accurately controlled. A more sophisticated system would require mixing valves and separate circulating pumps for each manifold.

There is no mist in this unit and all propagation is carried out on a closed case basis. The cuttings are covered with thin clear polythene film and the beds are covered with white polythene tunnels sealed at each end. This is very similar to methods used in the most advanced German nurseries. After rooting, the plants are weaned off in a greenhouse next door. A wide range of containers is used depending on the particular crop.

A 65 ft wide by 200 ft long Frampton Ferguson house was used by Eysturoy Nurseries Limited to produce rooted *Begonia* 'Elatior' cuttings. The entire production cycle was based on similar units in Denmark and was mounted on benches constructed to Danish plans for ease of working. The 1.8 metre wide benches were made from timber and asbestos. They were covered with Vattex and watered by a special Volmatic system. Vattex and similar systems have had problems in Guernsey because of the high salt levels in our water supply. The benches were raised off the floor on 4'' cast-iron or terra-cotta drain pipes. Hot water heating pipes were suspended under the benches and controlled from a mixing valve. Aluminum strips were sprung across some of the beds and covered in white polythene or Dralon to provide the rooting areas. Dralon gives shading without high humidity and is useful during weaning.

Inside one of these mini-tunnels were several important features. The mist was supplied from galvanised mains and 50 cm plastic standpipes through DGT nozzles. The whole system

worked at 4 atmospheres at the nozzle (60 lbs. per square inch) and the mist or fog produced was very even. Control was by a DGT mist controller activated by a piece of blotting type paper on a sensor. Heating was by four ½ inch polythene pipe loops set into 4 inches of sand and controlled by a mixing valve. The sand was covered with polythene sheet and 3 inches of peat. The sand was kept moist to ensure efficient heat transfer. The cuttings were rooted in open mesh OS pots held in the rack and could be quickly moved to the weaning benches. The rooted cuttings were thus produced at about 10,000 per week from this 1/3 of an acre greenhouse.

The control panel for the whole unit consisted fo a DGT mist controller which incorporated a timed delay so that a degree of "drying-out" could be achieved if desired. A Sarnia Controls unit sequenced the weaning and motherstock spray units and was started by the DGT Sol Integrator. I shall describe the detailed workings of this equipment when discussing my own nursery. There was a unit for controlling the automatic shading system by light intensity. Regrettably the market was not ready for the scale of production achieved at this nursery and the whole unit has been dismantled and sold.

Finally I come to my own nursery, Victoria Vineries Limited, where Raymond Evison and I have designed and built a specialised unit for the large scale productions of young clematis plants. Raymond described at last year's Conference the propagation techniques we use, so I shall confine my comments to the systems, equipment, their design and working.

The young plants are grown-on on the floor of a 30 ft wide greenhouse and here, for economic reasons, we have had to use the existing 4 inch cast-iron hot water heating system although it does affect the overall space utilisation. The overhead irrigation system uses DGT nozzles and a Volmatic barrel diluter — an even distribution of 1 millelitre per 3 inch pot per minute is achieved across the whole area. The floor is covered in black polythene and the tomato trays holding 18 three-inch pots rest on bamboo canes to ensure good drainage. Cuttings are taken from these plants using one-sided razor blades and placed into specially made aluminum trays. The trays are lines and covered with Captan soaked linen to inhibit flagging of material. The label is written at this stage. Optimum working conditions are important in any production unit; the girls can sit comfortably whilst making the inter-nodal cuttings. The prepared cuttings are placed in specially made nylon coated trays which are dipped in Captan before the cuttings are struck in seed trays. Once full, the trays are stock-piled on a two-tier slotted angle trolley before being moved out, 10 at a time, to the 4 mist beds. These are arranged so that we can change the climate every 2-3 weeks without moving the cuttings.

The plant density is over 100 per square foot and as nearly 100% rooting is achieved, we have not been able to find a more convenient system, although we have looked at modular types including rockwool blocks, Jiffy strips, peat blocks and so on.

The beds are 9 feet wide and have a 500 gauge polythene base to give weed protection. This is covered with 1-inch thick expanded polystyrene to discourage vertical heat transfer; this material is cambered to provide drainage at the bed edges. Two inches of sand were then laid on top and levelled forming a base for the loops of ½ inch polythene pipes. These pipes are covered with a further 2 inches of sand. They are 9 inches apart and have a return and flow arrangement to ensure absolutely even heat distribution. One man did all the pipe laying and fitting alone, taking approximately 1 hour per bed. The mains congregate at the flow and return manifolds which are valved for isolation in case of damage and so that during weaning, bottom heat can be lowered against the 'control' bed. It is cheaper to run the polythene tube to a compact manifold than to extend the manifold to the bed, and more flexible in case of change.

The hot water is supplied from the boiler through a 'DGT' mixing valve and circulated continuously through the pipe system. The calculations for the heat required are based on giving the greenhouse itself a 30°F lift. We also have 4 inch perimeter pipes for air heating. The controller has a string of five detectors spread across the bed to ensure that a representative temperature is maintained and this can be moved to each of the four beds as the 'control' bed moves during the production cycle. These are normally covered by trays of plants.

The mist nozzles are set in two rows, 2 metres apart, into the roof of the greenhouse at 1½ metre intervals. A Grundfoss CP 8-60 draws filtered rainwater from a hundred gallon tank through a 2 inch polythene pipe and, running continuously, supplies water under pressure at 6 atmospheres to this manifold. There is a capillary bleed-off returning to the tank to prevent the pump overheating. When the controller turns on the Danfoss solenoid valve for a particular bed to be misted, the water flows into two ¾ inch polythene pipes, one for each row of nozzles. The header pipe, as it is known, is punched at 1.5 metre intervals and a capillary tube takes the water to the DGT nozzle through a specially made plastic block.

All the fixings are push fit and in fact we did all the fitting work ourselves without skilled labor. The block is held in position by a ¼-inch aluminum rod pushed through a hole drilled in a 2 by 1 wooden batten. A small capillary tube leads down from the header to provide a drain off, thus preventing excessive drips. One of the beneifts of this system is its flexibility, lack of corrosion

and, of course, its cheapness, about £ 1.50 per nozzle, excluding the pump. We have already moved the system once and expect to do so again. The overhead mist is 1½ metres above the cuttings and gives the most even distribution that we have achieved after trying many types of nozzles in various positions.

The shading materials is a Scandinavian dacron which allows 80% of the light to pass through but only 50% of the heat.

We have a most sophisticated control system. A DGT Sol Integrator unit measures the calorific value of the available light — or in other words the energy reaching the greenhouse from the sun, even on cloudy days. This is totalled on a counter and in turn operates a count-down procedure against pre-determined levels on two other counters. In other words, if we set one of these counters at 15 calories, for every 15 calories of energy received a pulse will be initiated by the unit and this will trigger the timing mechanism in a specially made Sarnia Controls unit. A sophistication is a filter which cuts the count-down on a second channel on dull days — we use this for our weaning programme. On the timing unit we can set a length of mist pulse from 2 to 30 seconds; we can also set the time clock for night misting, which we use. We therefore have four programmes available to us and we can switch any one of our four beds into any programme.

We have a continuous programme of research both in Guernsey and Tenbury Wells and lighting is a most promising feature. It is always difficult to evaluate results on a commercial trial but an eight tube gantry enables us to root even normally difficult cuttings in 10 days. We use other lighting systems for day length extension in the autumn — thereby extending our season well into winter.

Finally, I would like to say that much of the equipment has not been readily available. I have been assisted by many skilled and experienced technicians who willingly produced special units for our needs. I believe that we, as propagators, must not feel restricted by the equipment currently on the market, but that we must go out and develop whatever we think will fulfill our future requirements.

SPEEDING UP OAK PRODUCTION WITH EXTENDED DAYLENGTH

S.J.F. MAXFIELD

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In 1956-57 R.J. Downs, H.A. Borthwick, B. Waxman and J.P. Nitsch carried out experiments on the effects of photoperiodic stimuli on trees. Various things were discovered including the fact that oaks (the species they used was *Quercus rubra*) responded to continuous daylength and, as a result of their treatments, grew to 8 ft. in one year.

In 1974 I tried a rough experiment using four different species, namely *Quercus rubra, Q. robur, Q. cerris* and *Q. ilex* to discover whether there was any application of these results for the commercial grower. I used reasonable quantities of each species, to wit: 1,750 *Q. rubra*, 1,500 *Q. robur*, 1,000 *Q. cerris* and 750 *Q. ilex*. In all cases 1 year seedlings were used potted into 7''×9'' polypots in a soilless compost. There was no control. The lighting used was 40 watt tungsten filament bulbs 3 ft. apart suspended 3 ft. above the crop. They were placed in an 'old' cold greenhouse which had a polythene skin inserted inside to make it waterproof.

After growth commenced the plants were fed weekly (this was at the end of April). Lights were turned on at the end of January and the plants were subjected to continuous daylength until October when they were given short nights, gradually lengthening until the end of October when the lights were turned off altogether.

Briefly, the results were that *Q. robur* and *Q. cerris* failed to respond; *Q. rubra* responded and certainly grew to the 8 ft. suggested. The *Q. ilex* responded very well and it was to this species that I turned my attention this year.

Principally my object was to substantiate the findings of the previous year with controls. I also wanted to find out what the effect was on seedlings; i.e. if the growth could be obtained in the first year, and what happened to the plants subjected to light in the previous year, i.e. whether they grew normally or not.

The results I can give at this time are, of course, mid-season and so do not show the final potential of the plants. This is aggravated by the fact that *Q. ilex* seedlings put on most of their growth after the middle of July and continue growing right into October (or, of course, longer if one maintains lights on them). From what I can discover this year, it appears that the larger the plants in the beginning the more they grow with lights on them.

Briefly the results to date are these:

A. *First year seedlings:* about 1" difference.

B. *Small 9 month old seedlings.* (2" high at commencement of experiment): 9" for controls compared with 1'4" under lights.

C. *Well established 18 month old plants* (7" at commencement of experiment): 1'10" for control plants compared with 3'4" for plants under lights.

D. Plants from last year averaging 5' now average 8'6".

I expect plants in group B to top 3' at the end of the season and those in group C to top 5'. Last year with established 1 year seedlings 6" high, the final results were between 2½ to 5'8", averaging 4'.

Accurate costings are not valuable in this case as inevitably being an observation, these plants had more attention than would normally be warranted. However the operations that should be considered are: potting, caning & trimming (2 or 3 times in the season), regular watering and weeding.

Our entire crop was sold last year with apparent satisfaction. It may be of interest that the last time Slocock's offered *Q. ilex* at 3½ ft. was in 1907. We have *never* offered them at 6-8 ft. which we are doing this year.

RE-USE OF POLYTHENE IN MECHANISED STERILISATION OF SOIL[1]

H. JACKSON

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In the present uncertain financial situation the emphasis is on economy in the nursery. If thought and time are given, machines can be adapted and produced not only to ease the job in hand but also to enable the product to be re-used. This is relevant with soil sterilisation as polythene used in sealing the soil can be re-rolled and re-used, so reducing the cost per acre quite substantially.

For the sterilisation of the soil Basamid is used. This product is supplied in prill form and I have used two methods of application:

(1) A Sisis Lospred fertilizer spreader fitted on the rear of the tractor which applies the material at the correct rate.

(2) Horstine Farmery applicator fitted to the front of the tractor. This can be hydraulically controlled if required, but in our case it is in a fixed position.

The advantage of the second system is that only one tractor is required, as a rotovator may be fitted to the rear of the tractor enabling the chemical to be incorporated into the soil.

A disadvantage at the present time is that as the material is dropped on the soil and as the tractor passes over it the draught from the tractor fan tends to draw the material into the tractor cab. This can be a problem. One idea which I have tried, and which is partially successful, is to stretch a piece of hessian or polythene under the tractor. The ideal would be a means of incorporating the material before the tractor passes over it. I am at present looking into the possibility.

Once the tractor has applied and incorporated the material a seedbed former and roller makes the seedbed. This operation is followed by a polythene laying machine, designed and produced at our nursery which can be operated by one man. This machine functions in the following manner:

Two small reversed mouldboards pull soil away from the edge of the bed; the polythene is laid and held in contact with the sides of the bed by two rubber rollers tensioned by shock absorbers, followed by two small mouldboards which throw the soil on to the edge of the polythene. In four minutes 190 yards of seedbeds can be covered.

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[1] *Editor's Note:* Slides were shown in conjunction with this paper and only visual appreciation will give an indication of the author's ability and ingenuity.

Now that polythene is becoming more difficult to obtain and also with the increasing cost I decided that it was essential to develop a machine which would re-roll and re-use it. I had previously produced a machine which would roll the polythene but in such a way that it was not re-usable and so had to be destroyed. Using a scrap hay crimping machine I now have a unit which will transmit power in two directions. Operation of this machine is as follwos:

A cardboard core is placed on a quick release roller; at the ends of the roller there is a cone, one cone being adjustable, the other fixed. The sliding cone forces the cardboard core on to the fixed cone by tightening a wing nut. This means that the cone is gripped on the inside thus enabling the polythene to be rolled. The machine is carried on the three-point linkage of the tractor. The polythene is then stapled to the cardboard core, the tractor is reversed down the bed with the power take-off in operation and, as the polythene is rolled, a rotating brush removes surplus soil from the polythene so that it is ready for re-use.

THE PROPAGATION UNIT: LAYOUT AND EQUIPMENT TO AID HANDLING

B.E. HUMPHREY

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Abstract. The significant role of labour costs in the propagating unit are discussed, and the main demands on labour are identified. The scope of the materials handling problem in the unit are then investigated. Equipment and equipment design factors are then described for: (a) permanent or semi-permanent structures, (b) handling machinery, and (c) handling smaller units. Existing layouts and their particular problems are described and, finally, general guidelines for the design of new units are laid down.

Labour costs represent the biggest single item of expenditure for all general nurserymen; it seems highly unlikely this situation will change in the forseeable future. No area in the nursery has a greater labour input that the propagation unit. Most propagation departments have a higher proportion of skilled to unskilled staff than any other sector of the company. The problems of reducing labour input by mechanisation are greater in the propagation unit than any other.

DEMANDS ON LABOUR

Most units place demands on labour in three main ways:

(a) Manipulative manual skills which notably include the craftsman operations, such as bench grafting, preparing and inserting cuttings, etc. In many units this probably accounts for the largest single labour input.

(b) Maintenance operations such as watering, shading, etc. often involving measurement and human judgment as well as manual labour. Probably least demanding in labour in most units.

(c) Materials handling — this accounts for a significant proportion of the total labour content in the unit and covers all forms of handling from movement of the individual cuttings to bulk handling of cutting trays, etc.

MATERIALS HANDLING /SCOPE OF THE PROBLEM

The most complex nursery propagation units carry out propagation by seed, cuttings and grafting. In these are found diverse handling problems.

Seed — Large quantities of seed, perhaps several hundredweight, may be involved, some of it perishable, some requiring specialised treatments. The seed may arrive in small or large quantities, usually over an extended period of time.

Cuttings — Many of the large units in Great Britain and Ireland may be handling in excess of one million cuttings annually. For much of the year cuttings are highly perishable, and frequently timing of various operations, notably collection, is thought to be critical. The importance of timing can result in severe labour peaks at certain periods and this, in turn, can often lead to a failure to obtain material at the optimum stage for rooting. Handling of the individual cuttings during preparation, treatment, and insertion needs to be especially well planned or labour output can be very poor.

Grafting — Scion handling is very similar to that of cuttings. The understock which is normally pot-grown can represent a very difficult handling problem, particularly if 'drying off' of the stocks is the normal pre-grafting routine. Two individual transportation handlings of the pot grown understock can account for 22% of the total time taken in bench grafting.

Seed and cutting containers and associated media normally represent the bulk of all materials to be handled in the propagation unit. The weight of material involved can be enormous. A single 100 ft. × 40 ft. propagating house when housing filled cutting boxes may represent the movement of 30-40 tons of material. When it is realised that each complete crop represents a double handling of this weight and that the house could hold four or five crops per year, a potential handling in weight alone could amount to 400 tons of compost. In commercial practice, with losses due to access paths and a three-crop turn round, a figure of 200 tons of material or 1 cwt. per sq. ft. per year is more realistic.

EQUIPMENT AND ASPECTS OF EQUIPMENT DESIGN WHICH MAY AID HANDLING PROCEDURES

(a) **Permanent or semi-permanent structures.** Permanent structures should always be built as large as possible and in design be as simple as possible. Structural members (walls, etc.) should be designed to last 50 years.

(i) *Propagation house.* A large single span structure with a completely clear floor space and all other fittings, mist lines, ventilator arms, etc. fitted well above head height (preferably 8 ft. or more) is advisable. If bottom heat is required this should be built into the floor, selecting a system which is likely to last indefinitely (i.e. polythene heating pipes and warm water). Ideally the whole of the floor space should be capable of being heated and misted so that maximum utilisation of floor area is possible.

(ii) *Working Shed.* Efficient heating, good light provided by numerous transparent roof lights supplemented by fluorescent lighting is essential. Plenty of ventilation should be provided; this can be ensured by large sliding doors to eaves height on at least three of the walls. Clear unimpeded floor space is, of course, essential.

(iii) *Cold Store.* For technical reasons the jacketed store is ideal. Few companies can justify the cost of this for propagation requirements only, and a cheaper direct cold store is therefore a good alternative. Under direct store

individual wrapping of separate batches is essential to prevent dessication of the material, but this is often a convenient means of separating varieties of numbered batches. The value of the cold store as an aid to the short and medium term storage of propagating material has been undeservedly neglected. Intelligent use of the store can help greatly in reducing labour peaks, can reduce losses in productive time due to adverse weather conditions, and can improve utilisation of handling machinery by enabling bulking up of small individual batches, and can aid in many other ways, many still to be discovered.

(b) **Handling Machinery.** This falls into two major groups, propelled and non-propelled equipment. Propelled machines may have their own power source or be manually propelled. There is an enormous and bewildering range of equipment concerned with handling in all the possible categories and it is obviously impossible to attempt to cover it all. To keep informed of latest developments in this sphere, propagation managers may be advised to take one or more of the specialists' magazines on the subject, which are often available free of charge.

(i) *Fork lift and pallet systems.* These systems, for so long the mainstay of materials handling in industry, are slowly becoming accepted as part of normal equipment in the British nursery industry.

Fork lifts may be attached to conventional tractors, and in modern units designed with mechanical handling in mind the robustness, power and weight of the tractor may commend this system. In general, the poor manoeuverability and bulk of the tractor makes it unsuitable for use in the propagation unit. By utilising the smaller dimensions and greater maneuverability of the vineyard versions of some popular tractor models the disadvantages noted may be to some extent offset. Tractors have the advantage over most fork lifts that lifting forks may often be fitted to the front and rear of the machine, thus doubling the carrying capacity and making them most suitable for horizontal travel over some distance.

There are literally hundreds of different versions of fork lift trucks available. The choice of model will depend on numerous factors, but it is unlikely that most requirements cannot be met in at least one model. In our own case we have selected a fairly compact maneuverable cross country truck capable of lifting one ton to 9 ft high.

For handling pallet loads of filled cutting boxes inside the restricted space of the propagating house we use a hand pallet truck. This has proved to be extremely maneuverable, and does not put the structure in so much jeopardy due to accidental ramming of main structural members.

(ii) *The pallet.* If numerous types of fork lift are available, even more types of pallet can be obtained. Pallets to hold almost every conceivable type of material have been designed and manufactured. In the propagating unit the most important design is almost certainly the multi-tier pallet. These can be manufactured from a range of materials, but box section steel is to be recommended. The number of tiers can be varied by making them removable, and clearances can be changed by sliding the individual shelves into variously spaced side supports. It is quite feasible by using the multi-tier pallet to pack lorry-sized loads into a compact space which can become a highly maneuverable mobile unit.

Pallet bins can be used to speed up the handling of large quantities of loose material such as rooting media or potting compost. We have in mind to ask our supplier to produce rooting media in paper lined pallet bins

loaned to him by ourselves. We expect great labour savings over our present system of hand shovelling and wheel barrow handling.

(iii) *Tractor/trailer systems.* These can occasionally have an application, but normally the unit must have been designed with the system in mind as 'trains' comprising a tractor pulling a string of trailers is lacking in manuverability. The system is seen at its best where very large volumes and weights of material are to be moved in a linear set up, notably on the growing beds in the container unit of Darby Bros. A further refinement seen at Darby Bros. is the use of the Jack Tug which enables individual trailer loads to be detached and maneuvered separately from the main batch.

(c) **Handling smaller units.** These are normally containers of some sort for the handling of relatively small batches of seed, cuttings or scions.

Polythene bags — These are ideal where the material being handled has no need to be orientated, either because it requires subsequent sorting, or because it grows satisfactorily regardless of orientation, e.g. seed.

Once sorting and preparation of material has occurred the maintenance of correct orientation can result in great savings in subsequent handlings. We always stack prepared cuttings or scions carefully so that their bases are all level and facing one way in a plastic tray. Usually each tray contains a specific number of items. The tray is then taken to the rooting area for cutting insertion or, more commonly, placed inside a polythene bag which wrapped around to prevent moisture loss, the whole then being put into the cold store. Batches of cuttings are stored at 36-38°F for a convenient time (up to 3 weeks) prior to insertion. This system ensures that labour planning and utilisation can be best achieved. The handling of small lots by small teams of people or individuals can result in serious inefficiencies.

PROPAGATION UNIT LAYOUT

Unfortunately, this aspect is nearly always an 'after the event situation', in that many of the main characteristics of the unit have been built in, and therefore are fixed. Old units usually suffer from paths which are too narrow for access by self propelled vehicles. The site may not be level and working surfaces poor. It may be possible to purchase a quite small, cross country fork lift which may overcome the problems just mentioned, as in our own case. Such machines are not cheap, but it is false economy to consider the purchase of a mini-type tractor with a fork lift 'tacked on'.

Another alternative in the above example might be to concrete paths which are too narrow for all but hand trucks, and use a hand pallet truck in conjunction with a pallet handling system. The use of this type of arrangement has advantages over the use of hand-pulled barrows. Any developments made for the hand pallet system may at some later date be converted to a fully mechanised handling system if the opportunity for re-building occurs.

In many of the older units the engine-powered flat-bedded truck with a small carrying capacity in relation to its cost is the traditional system of materials handling. Replacement of this system by a multi-tier and bin pallet system could be well justified on reduced running costs, even if paths would need to be levelled and concreted to enable small battery-powered fork lifts to operate.

If a completely new unit is to be designed, then every opportunity exists for efficient materials handling to be designed into the system. Avoid gimmickry, keep the layout very simple for maximum long term flexibility; avoid committing yourself to a particular and specialised handling system, and allow copious access to all the major components of the unit.

Take plenty of advice from materials handling specialists, and try to see as many other well designed units as possible before finally deciding on your layout.

FACTORS AFFECTING THE USE OF MUNG BEAN CUTTINGS AS A RESEARCH TOOL IN VEGETATIVE PROPAGATION

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A requirement in the study of vegetative propagation is a research technique which will facilitiate the detection of internal root promoting or inhibiting factors within the plants being propagated. Bioassay techniques are appropriate because their function is to detect growth factors by measuring responses induced in biological material. A bioassay for rooting substances is one in which an extract from the plant under test is applied to cuttings whose adventitious root development is measured as the response to the extract.

Went (5) published the first description of a bioassay for rooting factors using etiolated pea seedlings while Hemberg (1) and Luckwill (4) described bioassays using cuttings of dwarf bean seedlings. Hess (2) used the mung bean, *Phaseolus aureus*, as his test object and subsequently modified the technique (3). Seedlings are grown for 9 to 10 days in a controlled environment and then cuttings are prepared with 3 cm of hypocotyl, epicotyl, primary leaves and trifoliate bud. Ten cuttings are used per vial with 4 ml of test solution which is replaced by distilled water after 24 hours. Roots are recorded 5 to 6 days after treatment.

Characteristics of test material suitable for a bioassay. Test plants must be readily available, germinate uniformly, grow quickly and be easily handled, requirements which the mung bean fulfills adequately. Equally important is the need for uniformity of response in the test subject so that observed reactions can be attributed to the effect of the extract under test and not obscured by the natural variability within the bioassay. A criticism of the standard mung bean bioassay is the variable response among individual cuttings.

Sensitivity, defined as the ability of the bioassay material to respond quantitatively to a small amount of rooting factor, is another prerequisite. Ideally, mung bean cuttings should have inherently low rooting ability to avoid masking the response to the extract under test.

Sources of variability within the mung bean bioassay. Seeds from different sources were found to differ in size, and when cuttings from these were rooted under uniform conditions of daylength, temperature and IBA, cuttings from the larger seeds produced more roots than those raised from smaller seeds (Table 1).

Table 1. Seed size and cutting rootability related to seed source

Seed source	Weight of 500 seeds (grams)	Mean root number per intact cutting (mean of 12)
A	26.3	29.3
B	23.8	31.5
C	21.2	17.9
D	19.3	12.6
E	18.0	12.8
F	17.0	15.1

Cuttings from seedlings harvested between 2 and 8 days after sowing showed differing abilities to root in the same environment (Table 2).

Table 2. Age of cutting as related to mean root number

Age (as days from sowing) of cutting when treated	Mean root number (mean of 48)
2	29.0
3	23.7
4	42.4
5	38.2
8	33.4

Because cotyledons represent a high proportion of the mass of a seed and therefore might be expected to differ in size in different seed sources (Table 1), and because cotyledons degenerate within a few days of preparing the cuttings while primary leaves expand, effects of cotyledons and leaves were investigated to determine their influence on the rooting process. Cotyledons were found to be a source of root promoting factors and their removal caused a reduction in rooting (Fig. 1). This was especially evident in cuttings prepared from very young seedlings (2-4 days old). Removal of cotyledons from cuttings prepared from different seed sources reduced the range of roots per cutting from between 12.6 to 31.5 (Table 1) to between 5.7 and 10.8.

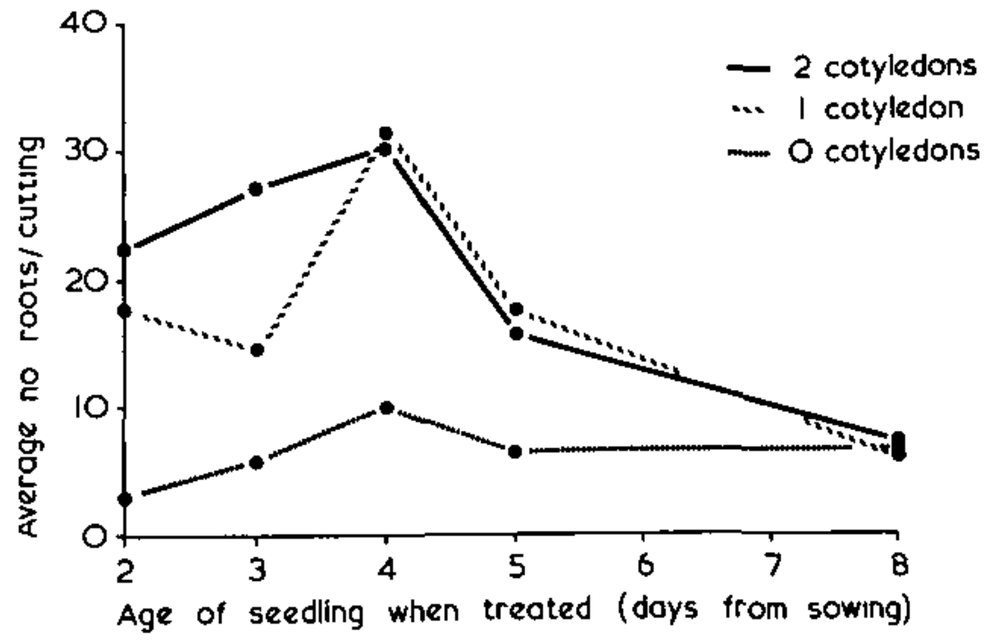

Figure 1. The effect on rooting of removing cotyledons from seedlings of increasing age.

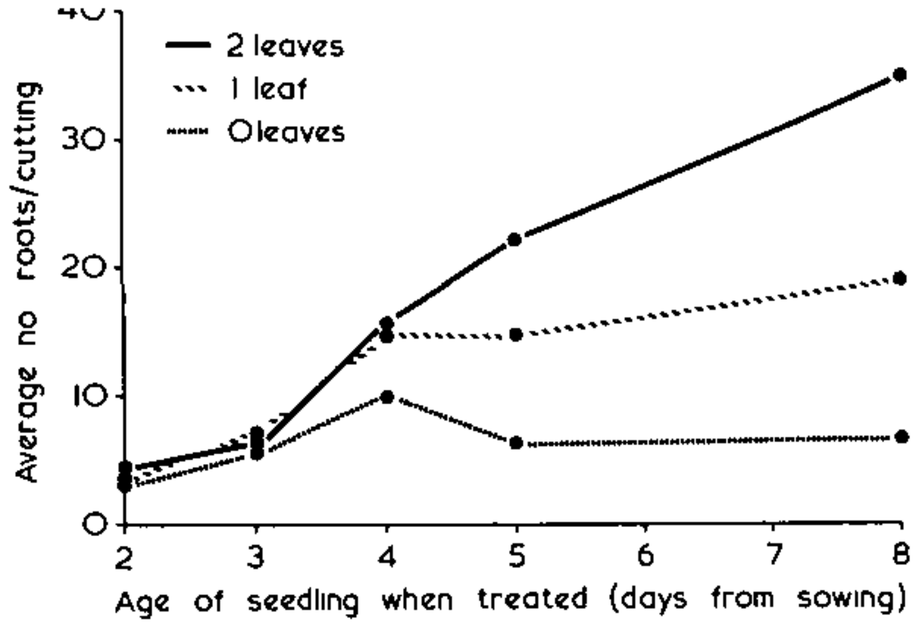

Figure 2. The effect on rooting of removing leaves from seedlings of increasing age.

Removal of leaves, especially from cuttings prepared from 4-day or older seedlings, depressed rooting (Fig. 2), suggesting that the root promotive effect of the cotyledons is taken over by the leaves as the material becomes older, although the stimulus may not be the same.

The effects upon rooting variability of removing cotyledons and leaves were measured by plotting the standard deviation (SD)[1] from the treatment means (Fig. 3). Standard deviations diminished as cotyledons aged and increased with increasing age of leaf.

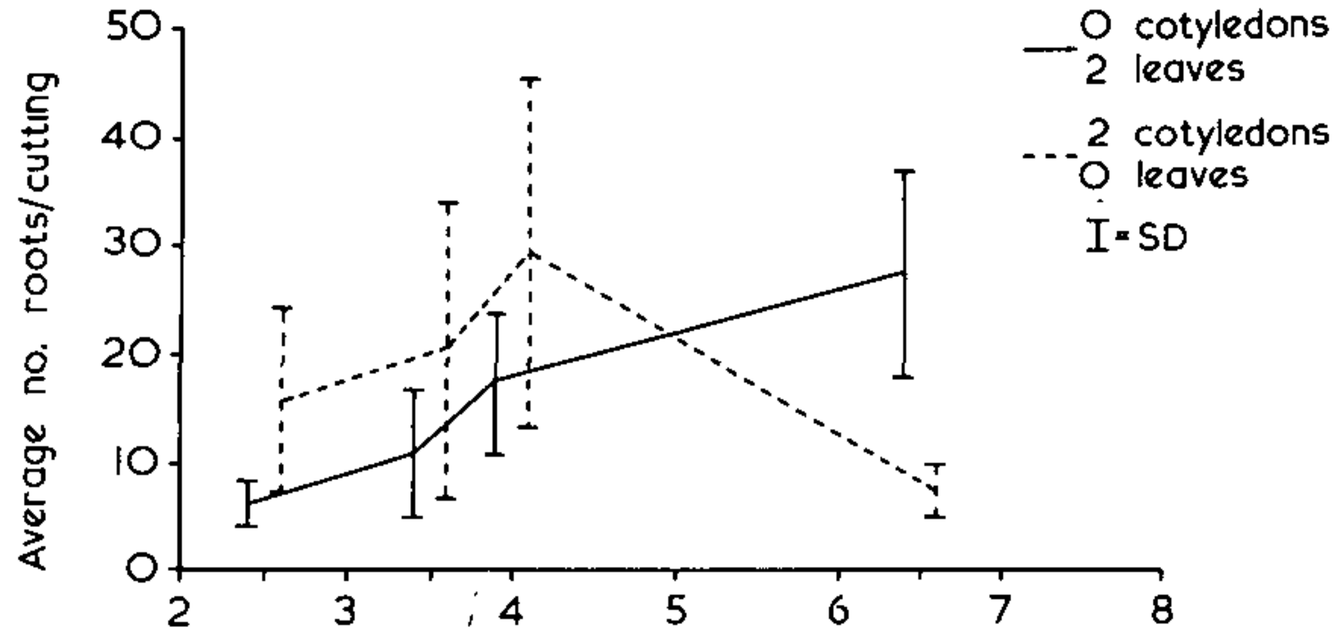

Figure 3. The effect on treatment variability due to cotyledons and leaves with increasing age.

Conclusions. It appears possible to improve the mung bean bioassay test object by removing the masking effects of rooting factors already present in the cutting and, in doing so, reduce the associated sources of variation, by either removing the cotyledons at an early stage, or the leaves at a later stage of cutting preparation. Removing cotyledons at an early stage is preferable both because the test can be completed sooner with a saving of about 5 days, and because the development of leaves assists uptake of test solutions and provides a low background level of rooting.

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[1] Standard deviation is a statistical measure of the range of values, shown as root numbers, obtained from individual cuttings in a similarly treated sample. Small standard deviations indicate uniform material and increase the precision of the test.

Preliminary results from using cuttings from seedlings about 3 days old, with cotyledons removed, suggest that they provide a sensitive system. Extracts of cotyledons applied in the modified bioassay have induced rooting responses whose magnitude was closely related to the amount of cotyledon extract present.

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NURSERY PRACTICE IN RELATION TO THE CARBOHYDRATE RESOURCES OF LEAFLESS HARDWOOD CUTTINGS

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Hardwood cutting technique. The hardwood cutting technique, as developed at East Malling Research Station, essentially consists of rooting leafless shoot cuttings by applying a synthetic auxin to their bases and placing them in covered bins containing a peat-grit compost where their bases are warmed by heating cables (3). After rooting, the cuttings are transferred to the nursery where shoot growth commences in the following spring; they are dependent on stored carbohydrates until the new leaves produce carbohydrates surplus to their own requirements. If the cuttings do not have adequate carbohydrate reserves to carry them over until this occurs they will die. Experiments investigating this aspect are discussed in this paper.

Problems of clonal and season rooting difference. A period of 4 weeks in heated bins with a basal temperature of 21°C has been recommended to obtain rooting in apple hardwood cuttings (5), but not all rootstocks root with equal facility (3), and rooting may fluctuate depending on when they were collected, being poor in mid-winter (2).

Effect of extended exposure to basal heat on carbohydrate and establishment levels. Improving rooting by extending the period of bottom heat has had varying effects on subsequent establishment (4). In these experiments extending the duration of exposure to basal heat from 4 to 8 weeks increased the rooting percentage of *M.25 apple rootstock cuttings collected in mid-winter.* However, the proportion of the initial carbohydrate left in the cuttings at the time of planting out in the nursery was significantly lower in the cuttings which had remained in the heated bins over the longer period, and this was correlated with a significantly lower level of establishment than with those heated for 4 weeks (Fig. 1).

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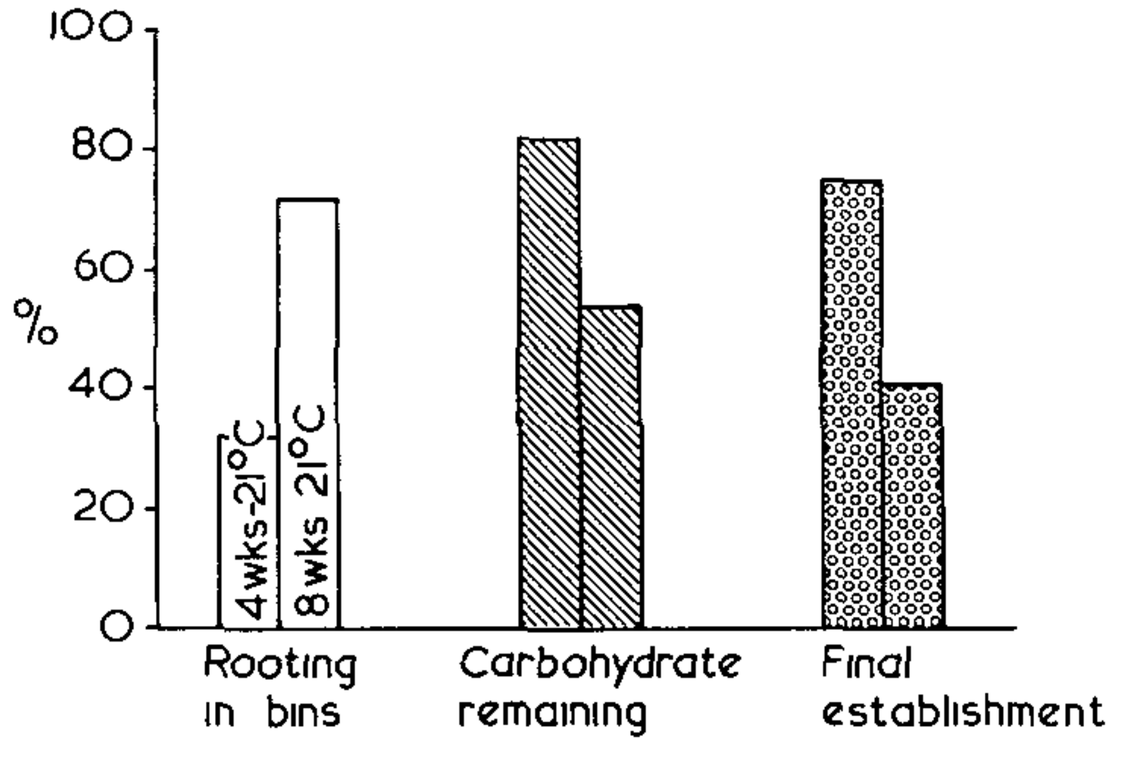

Figure 1. Relationship between rooting, carbohydrate content and establishment of M25 cuttings.

Effect of premature bud activity during root induction upon carbohydrate content and establishment. It has been shown that carbohydrate levels in one-year-old stoolbed shoots decrease during bud break in the spring (7). Prolonged periods in the heated bins can cause buds to resume active growth and this might be expected to further deplete carbohydrate reserves of hardwood cuttings and affect establishment. To investigate this, cuttings of M.25 and M.26 rootstocks were collected in either autumn, mid-winter or early spring, of the 1972-1973 propagation season, treated with auxin and placed in the heated bins at a basal temperature of 21°C. To stimulate shoot growth the air temperature above the compost was raised from 4.5°C to 14.5°C. Cuttings in the mid-winter and early spring samples had experienced sufficient winter chilling for their buds to resume active growth which was associated with large decreases in carbohydrate levels during root induction compared to autumn cuttings. Although the new shoots were removed before planting in the nursery to minimise the dangers of desiccation, the final levels of establishment were exceedingly low where active buds had been present, as shown for M.25 (Fig. 2).

A similar situation was encountered in the 1973-1974 propagation season with hardwood cuttings which had been held in cold storage at 3°C prior to root induction. The cold-stored cuttings were treated with auxin and placed in the heated bins for 8 weeks, again using a basal temperature of 21°C but with the normal air temperature of 4.5°C. Cold storage of cuttings before or after root stimulation has been shown to be a viable technique for apple, plum and quince rootstocks (6), but bud activity occurred in cuttings given 8 weeks cold storage, and more so in cuttings which had been cold-stored for 16 weeks. As before, the occurrence of bud activity was associated with subsequent low levels of establishment (Fig. 3). These results are similar to those reported following the use of pre-rooting cold storage of pear cuttings (1).

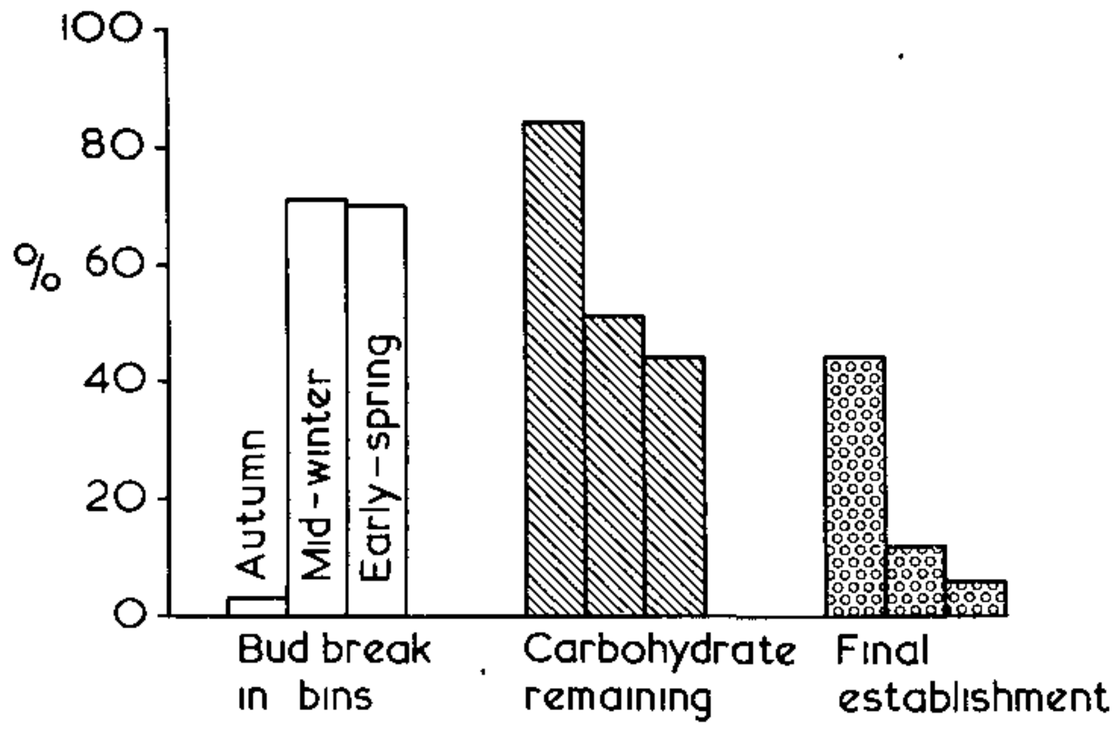

Figure 2. Effect of premature bud break and growth in autumn, winter and spring-collected M25 cuttings.

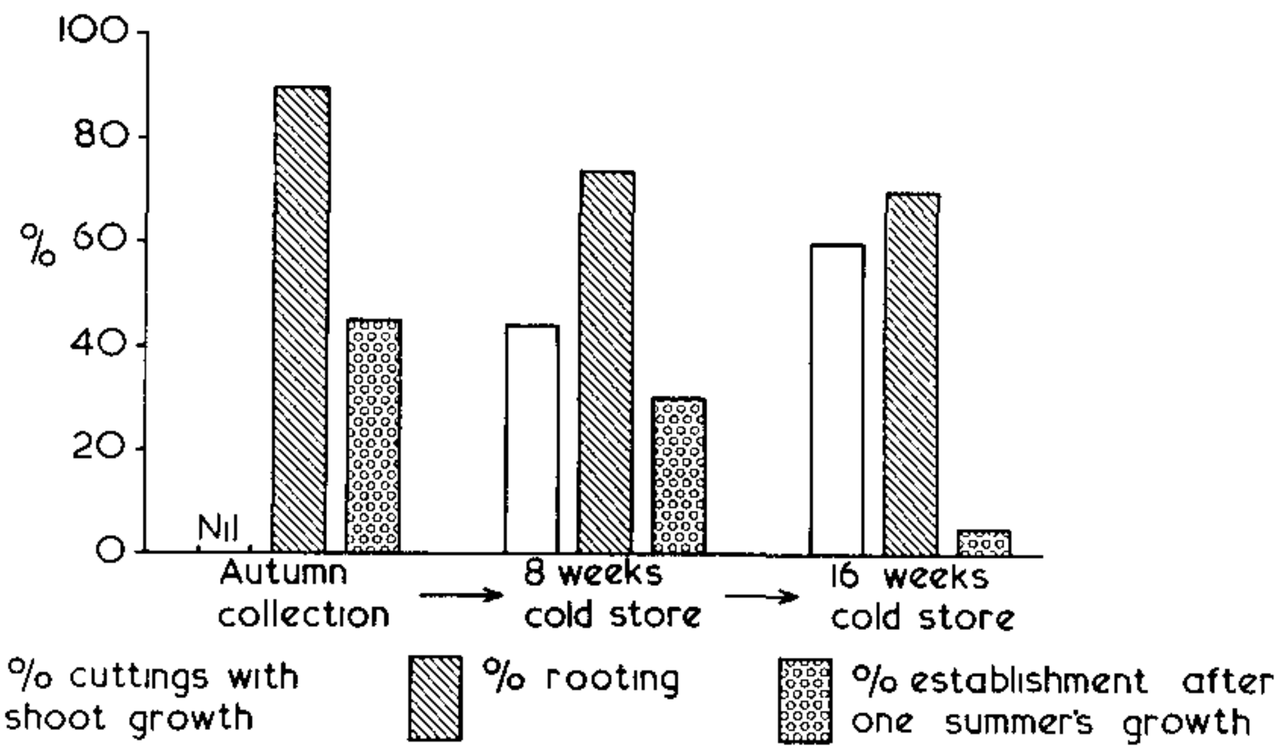

Figure 3. The effect of premature bud break and shoot growth following cold storage of M25 cuttings.

Discussion. Rooting of hardwood cuttings in heated bins clearly causes a depletion of stored carbohydrate reserves. The use of extended periods of basal heat improved the visible level of root production but also increased carbohydrate depletion, which in turn was associated with reduced establishment. It has been demonstrated that high levels of establishment can be obtained after relatively short periods of bottom heat (Howard unpublished) and it would therefore seem preferable to provide only sufficient stimulation to encourage root initiation and *limited* visible root production in the heated bins. When the propagator is satisfied that his conditions are conducive to survival and rooting, two weeks in the heated bins giving a few rooted and many well callused cuttings should prove satisfactory for the handling of subjects which have been shown to respond well to the hardwood cutting technique.

There is a clear need to avoid premature bud activity in the heated bins as shoot growth appeared to create a significant additional drain on carbohydrate reserves. Further, the carbohydrate utilized in shoot growth was totally lost because new shoots were

removed to minimise initial water losses in the nursery, and the low levels of establishment that ensued indicated that insufficient reserves remained to support any renewal of growth.

Recommendations. (1) Cutting collections should be timed to coincide with periods of most rapid rooting, so as to minimise exposure to basal heat and still obtain satisfactory stimulation. For many subjects this is generally towards the end of the winter rest period, i.e. February (3, 8).

(2) To minimise bud activity during rooting, the air temperature around the buds must be kept cool, either by siting the bins in a nursery stock cold store, or in a ventilated north-facing building.

(3) If cuttings must be left for longer than 2 weeks in the heated bins due to pressure upon labor, nursery space, or because of unsuitable soil conditions, the basal temperature should be lowered from 21℃ to 10℃.

(4) There is insufficient experience of cold storage for hardwood cuttings for it to be recommended other than on a trial basis, but nurserymen wishing to use it as an alternative to prolonged periods in heated bins should ensure that buds are restrained from active growth until planting in the nursery (see recommendation No. 2).

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VIRUS DISEASES OF ORNAMENTAL TREES AND SHRUBS

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Using examples drawn from published and my own unpublished data I will describe what viruses do to hardy nursery stock and how their effects may be minimised.

Although gardeners have known for more than 200 years that variegation in *Jasminum* (Fig. 1) probably results from virus infection, Cane showed in 1720 (3) that the condition was graft transmissible, the subject of plant virology is new to many people. I have therefore prefaced my discussion with some background information on the properties of viruses.

Figure 1. Leaves of *Jasminum officinale* naturally infected with arabis mosiac virus and showing yellow blotch patterns.

Viruses multiply only within living cells where they may be "seen" if magnified at 20,000× or more in an electron microscope. These obligatory parasites rarely kill but necessarily debilitate their hosts by, for example, decreasing photosynthetic efficiency through inducing changes in chloroplast morphology which are, in turn, reflected in superficial alterations to leaf color-symptoms. Another organism (a vector) is normally required to carry a plant virus from one host to another although pollen and/or seed are

able to act as vehicles for a few viruses such as those having nematode (eelworm) vectors. Man accidentally and, in some instances, deliberately transmits viruses when using vegetative propagation techniques; diseases attributable to viruses, unlike genetic abnormalities and nutritional or physiological disorders with virus-like symptoms are transmissible by budding, grafting, etc. However, natural graft transmission (mostly root anastomosis) is probably infrequent and insignificant when compared to the virus spreading influences of vectors such as insects, mites, soil-inhabiting fungi or nematodes even though there is a marked virus-vector specificity so that a given vector can transmit one, yet not another virus, with which it shares many other properties.

If studies on viruses were restricted to the naturally susceptible deciduous woody ornamental host, information would be but slowly gathered. Therefore, scientists make isolation from the original host for example, but rubbing expressed foliar sap onto the leaves of glasshouse-grown herbaceous hosts which then serve throughout the year as reservoirs of virus later identified from knowledge of physical, chemical and biological properties. When characterised, viruses are given names which usually indicate the associated symptoms of disease in that host from which the virus was first isolated or most intensively studied, e.g. cherry leaf roll virus (CLRV). However, this name may indicate only one of many possible hosts and it is therefore not surprising to find CLRV naturally infecting, for example, elm, birch, rhubarb and elder in addition to cherry.

INTRODUCTION

Knowledge of viruses which infect food plants is considerable and trees or shrubs grown primarily for fruit have been subjected to close examination over many years. In contrast, with the notable exception of work done in Eastern Europe, (16, 17) few surveys to detect viruses in timber trees or woody ornamentals were made until recently. Despite the comparatively small investment of research time devoted to the study of viruses in these crops, an examination of the scientific literature shows that one or more virus-like diseases has been recognized in some 65 genera from 43 families of trees and ornamental shrubs growing in Europe and North America. A great many of these diseases are reportedly graft-transmissible although their actual causes are unknown. Others are associated with poorly characterised viruses and very few of those viruses having several known physico-chemical properties have been proved to cause the symptoms shown by the woody plants in which they were detected. Perhaps, because they reach high concentrations in hosts they infect and because they have vectors which feed on many different plants, two groups of viruses appear to be particularly prevalent in woody perennials.

One group has aphid vectors and includes viruses such as cucumber mosaic and alfalfa mosaic which have been isolated from one or more individuals of *Buddleia, Caryopteris, Chionanthus, Cornus, Daphne, Euonymus, Hydrangea, Jasminum, Leycestria, Ligustrum, Lonicera, Lycium, Maclura, Magnolia, Nandina, Paulownia, Passiflora, Philadelphus, Romneya, Sambucus* and *Viburnum*, showing symptoms which were usually inapparent or slight. However, information to date suggests that a group of viruses having soil-inhabiting nematode vectors are even more widespread in nursery stock and to illustrate the range of symptoms which these plants may show when virus-infected I will use examples drawn from knowledge of two viruses in particular, arabis mosaic virus (AMV) and cherry leaf roll virus (CLRV).

NEMATODE-BORNE VIRUSES IN TREES AND SHRUBS

Virus-vector nematodes are free-living worms (1-6 mm in length) which typically browse on the outermost cells of roots. Although other nematode genera can ingest virus particles, only four: *Xiphinema, Longidorus, Trichodorus* and *Paratrichodorus* are known to include species able to transmit viruses from infected plants (Table 1). In Europe and North America one or more of the viruses listed in Table 1, or others to which these are closely related, have been detected in each of the following genera: *Acer, Aesculus, Betula, Chamaecyparis, Chionanthus, Cornus, Cupressus, Daphne, Euonymus, Forsythia, Fraxinus, Hedera, Hydrangea, Jasminum, Kerria, Laburnum, Leycestria, Ligustrum, Picea, Populus, Ptelea, Robinia, Rosa, Sambucus, Spiraea, Syringa* and *Ulmus*. Their normal method of spreading necessarily causes infection with these viruses to be initiated via roots where it may go unnoticed.

Table 1. The most important nematode vectors in the United Kingdom and the viruses they carry

Vector	Viruses
Xiphinema diversicaudatum	Arabis mosaic, Strawberry latent ringspot cherry leaf roll
Longidorus attenuatus	Tomato black ring
L. elongatus	raspberry ringspot, tomato black ring
L. macrosoma	raspberry ringspot
Trichodorus and *Paratrichodorus* (more than 10 species)	tobacco rattle, pea early browning

However, it is interesting to note that the only well characterised viruses yet isolated from gymnosperms were nematode-borne and detected in roots of *Chamaecyparis lawsoniana* (9),

Cupressus arizonica (8) and *Picea sitchensis* (9) having apparently normal foliage. Other isolations from tree roots have been reported but leaves are more usually tested because they show symptoms such as those J.B. Sweet of Long Ashton Research Station and I observed in a range of hardy nursery stock and hedgerow plants (Table 2) naturally infected with AMB. Virus-infected foliage is not noticeably abnormal in all instances — symptom expression may be irregular and partial. Thus only about 1% of naturally AMV infected *Fraxinus excelsior* leaflets had line patterns (Fig. 2) yet virus was present in other leaflets. Similarly, when I tested garden stocks of privet, 280 of 287 plants were infected with AMV but in most instances only part of the foliage showed symptoms.

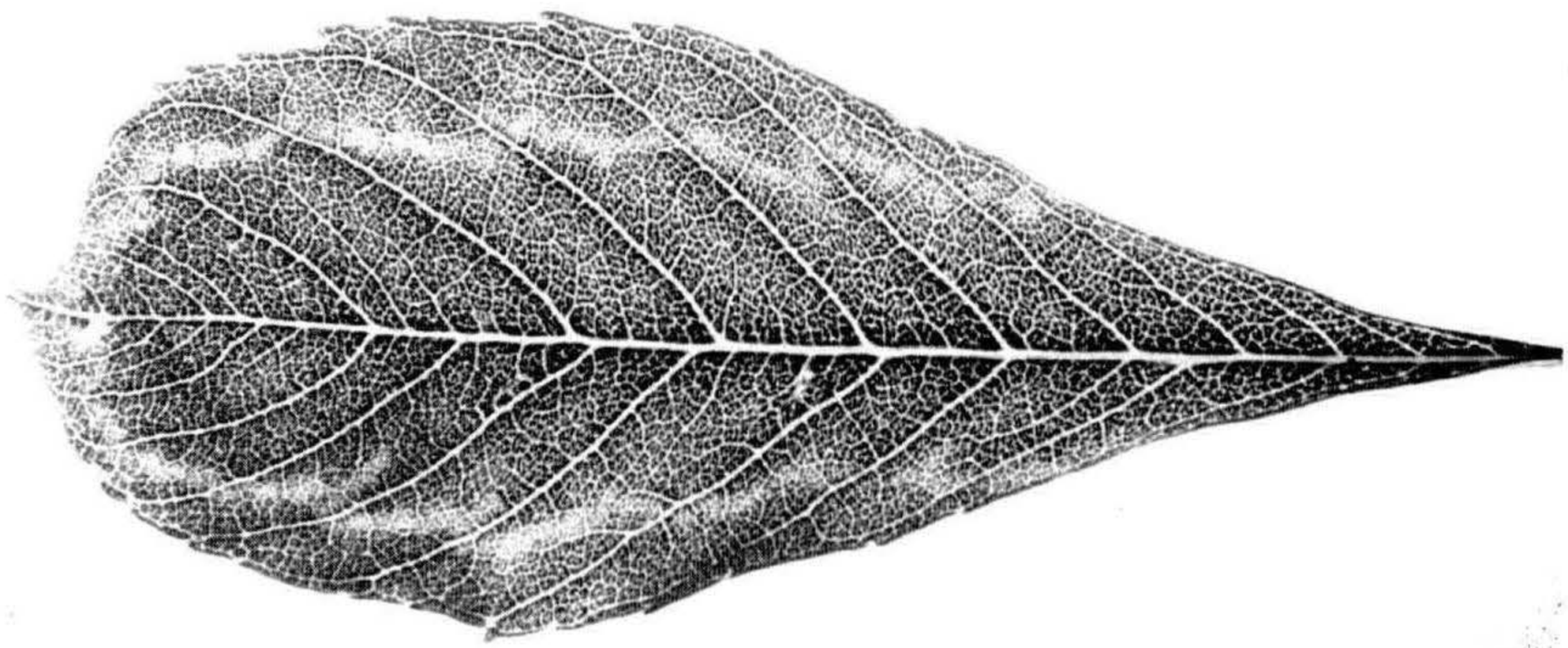

Figure 2. Leaflet of *Fraxinus excelsior* naturally infected with arabis mosiac virus ane showing pale green line patterns.

Table 2. Symptoms in some plants naturally infected with arabis mosaic virus (AMV).

	Host	Leaf Symptom
a) In nurseries and gardens.	*Fraxinus americana**	Yellow-green lines and distortion.
	*Hedera helix**	Yellow blotches and vein banding.
	*Ligustrum ovalifolium**	Pale yellow - green lines or rings.
	*Ligustrum vulgare**	
	Spiraea douglasii	Vein yellowing and outgrowths, enations.
	*Syringa vulgaris**	Yellow ring and line pattern, chevrons.
b) In field and hedgerow	*Fraxinus excelsior**	Yellow green lines.
	*Sambucus nigra**	Vein yellowing.

*virus-carrying nematodes detected in the root region of these plants.

In many instances high temperatures diminish and low temperatures accentuate symptoms. Thus, in autumn, field-grown AMV infected *F. americana* (on *F. excelsior* rootstocks) had distorted leaflets showing chlorotic ring or line patterns (Fig. 3) Yet in spring of the following year the commonest symptoms in these trees were puckering, twisting and chlorotic blotching (Fig. 4).

Symptoms alone cannot be used to identify an infecting virus although related viruses tend to produce similar types of symptoms. Thus leaf vein yellowing in elder (Fig. 5) has been shown to be caused experimentally by arabis mosaic (12) or tomato blackring virus or cherry leaf roll viruses (16).

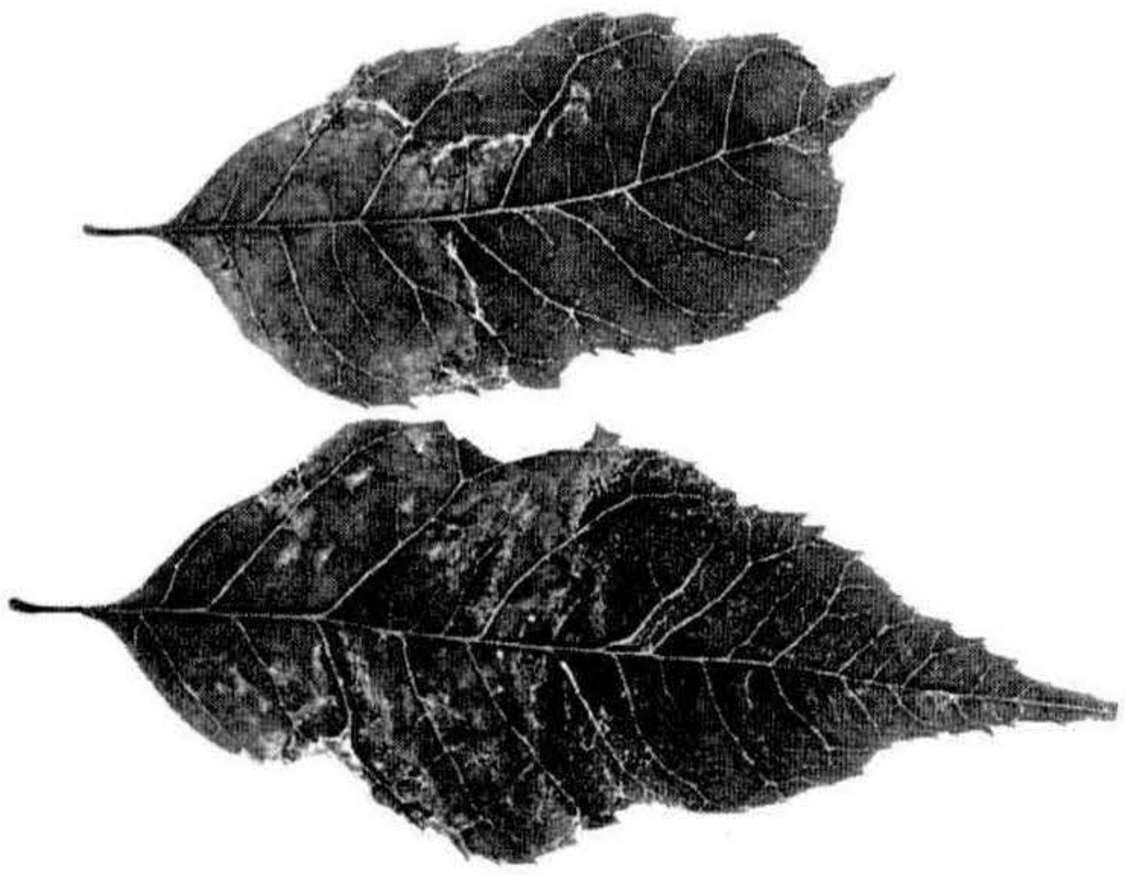

Figure 3. Leaflets of *Fraxinus americana* naturally infected with arabis mosaic virus and showing distortion with pale green line patterns in cool autumn weather.

Figure 4. Leaflets of *Fraxinus americana* naturally infected with arabis mosaic virus and showing puckering with pale green blotches in hot summer weather.

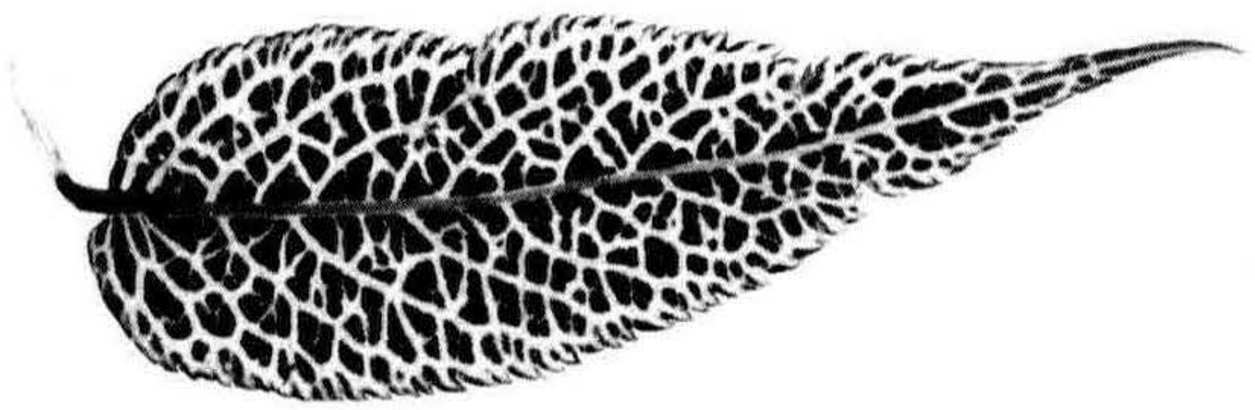

Figure 5. Leaflet of *Sambucus nigra* naturally infected with arabis mosaic virus and showing vein yellowing-yellow net.

Perennial plants are exposed to infection over several years and therefore are particularly liable to contain more than one virus simultaneously, e.g. ivy containing both AMV and SLRV showed symptoms indistinguishable from other ivy plants in which only AMV was found (Fig. 5). Consequently tests to confirm the pathogenicity of an infecting virus are signally appropriate to the study of viruses from trees and shrubs. Such tests are, however, infrequently done because of their long term nature. When confirming that AMV caused chlorotic line patterns in *F. excelsior* leaves, I found that only one of 18 ash seedlings (systemically infected after their cotyledons had been rubbed with purified and concentrated virus propagated in tobacco plants) showed symptoms in the first growing season although three additional plants produced similar, transient symptoms in the following year; 20 months after infection.

Figure 6. Leaf of *Hedera helix* naturally infected with arabis mosaic virus and showing yellow vein-banding patterns.

In addition to producing external symptoms, viruses also induce changes within the cells they infect. Observations made in Oxford on *Betula pendula* (*B. verrucosa*), naturally infected with CLRV, illustrate some of these. Birch leaves naturally infected with CLRV were first observed in Eastern Europe (18) and were more recently seen in Berkshire, Leicestershire, Lincolnshire and Oxfordshire (5). Symptoms tend to be most conspicuous in autumn when CLRV infected leaves typically show yellow ring and line patterns (Fig. 7).

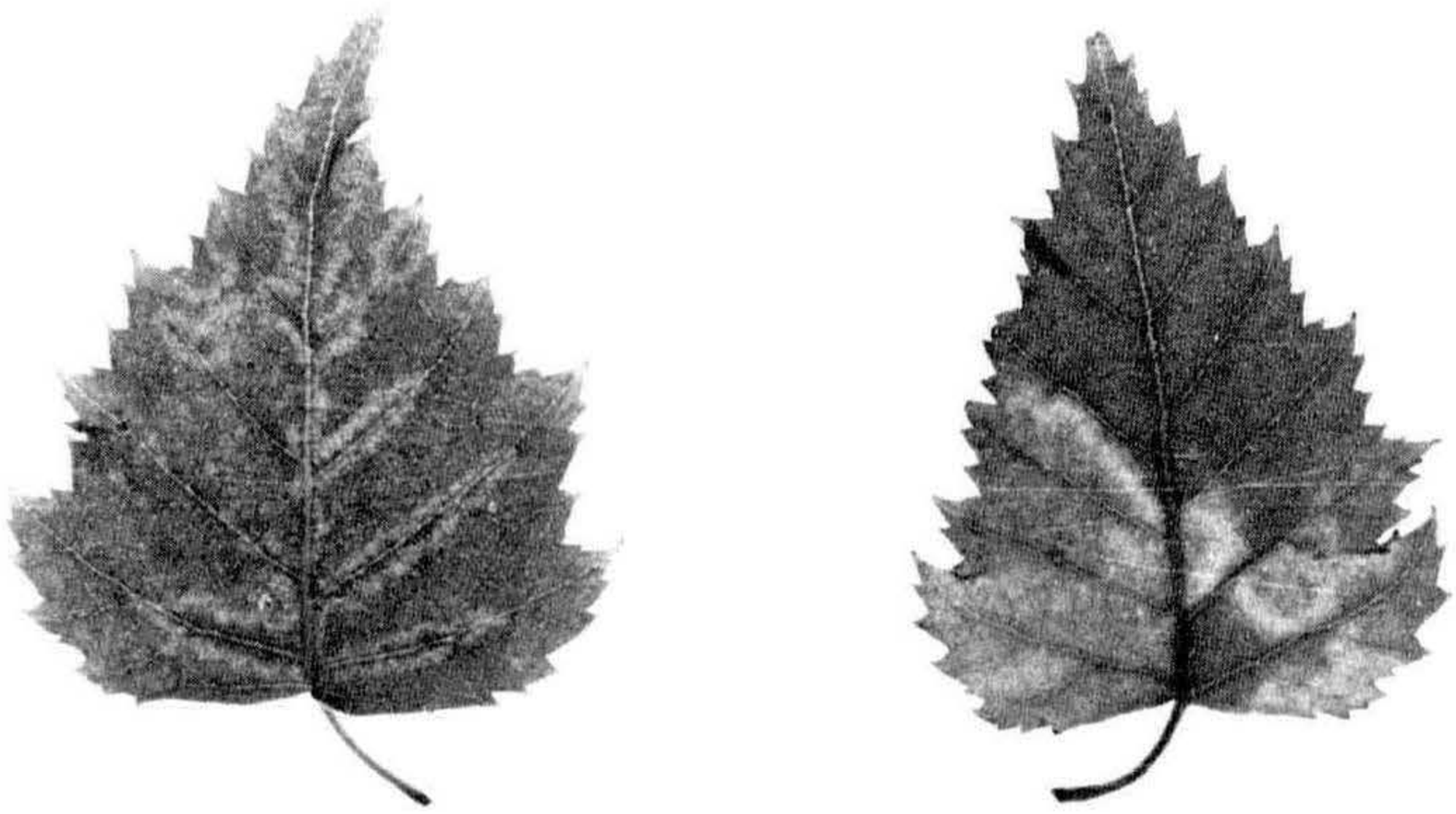

Figure 7. Leaves of *Betula pendula* naturally infected with cherry leaf roll virus and showing yellow vein banding and ring patterns.

Several differences were observed with the electron microscope in sections taken from naturally infected birch leaves in October when compared with tissues taken from symptomless and virus-free leaves collected on the same day from adjacent trees. Virus infected, unlike virus-free tissues, contained chloroplasts having many large black spots (densely stained plastoglobuli) and poorly defined lamellae. Furthermore, the cell well often intruded like fingers into the cytoplasm, the intrusions enclosing strings of virus-like particles. The deviations from normality shown by chloroplasts in virus-infected tissue were very likely to be harmful although it seems possible that cell wall overgrowth represents attempts by the host to prevent virus spreading from one cell to another.

THE SIGNIFICANCE OF VIRUS INFECTION

In woody perennials, a few viruses cause changes which have ornamental value (e.g. that which causes bright yellow mosaic patterns in leaves of *Abutilon*; Fig. 8). But the majority have effects which are only recognisable with difficulty. Despite this, knowledge from food crops indicates that viruses diminish growth rate although their significance may be apparent only when the productivity of virus-free plants having the same genetic constitution are available for comparison. It is difficult to draw general conclusions from the very few published data that describe the economic effects viruses have on the yield of woody plants but the following two examples give a guide. Top fruit and related ornamental rosaceous species have been generally found to grow more rapidly and crop better than virus-infected material (4) thereby justifying the EMLA scheme through which selected (usually fruiting) clones free of known viruses are offered to nurserymen to provide scions for grafting onto virus-free rootstocks. Some studies (1, 13,

14, 22) have also been made on the effects of poplar mosaic virus in poplar (Fig. 9) but different authors used different clones and none seem to have made sequential measurements over a period greater than four years. Collectively the data indicate that this virus causes losses in height and diameter growth which may be greater in some clones (e.g. *Populus* × *canadensis* (*P.* × *euramericana*) 'Eugenei', 15-20% than others (cv Gelrica, no significant effect). Marketable yield may also be affected by poplar mosaic virus which has been said to diminish the specific gravity and the strength of branch wood (1).

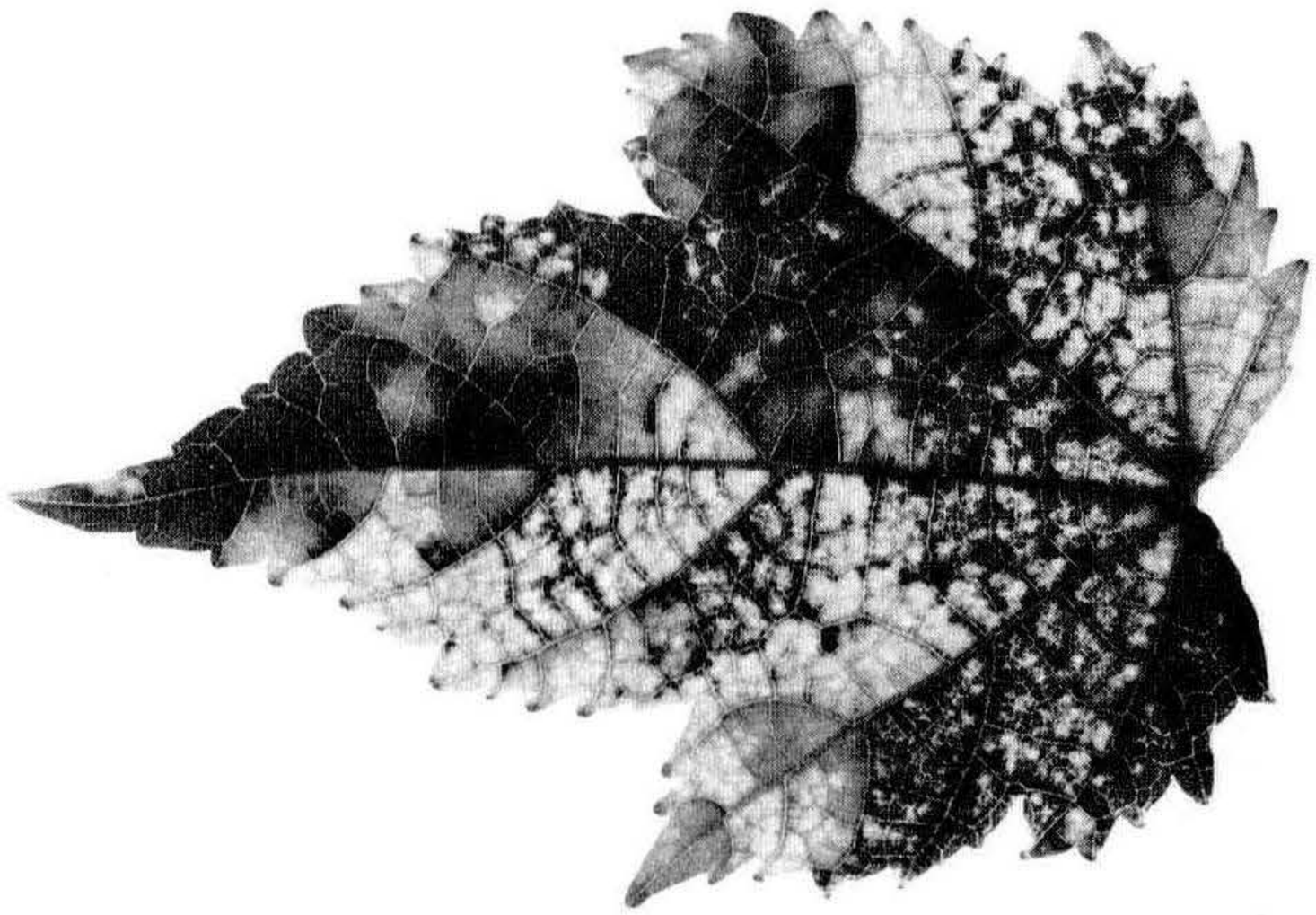

Figure 8. Leaf of *Abuliton* sp. showing the attractive bright yellow and green variegation caused by abutilon mosaic virus.

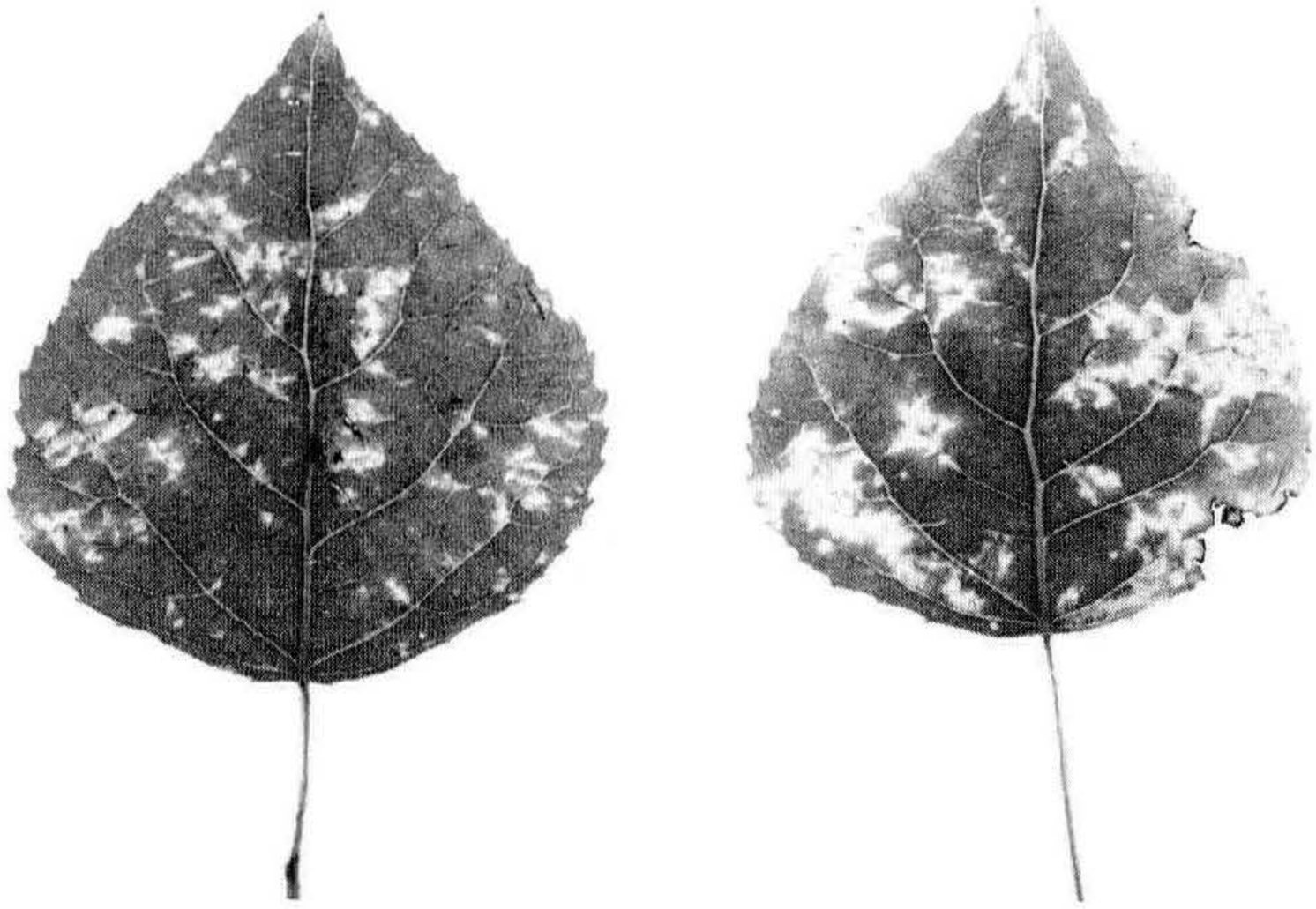

Figure 9. Leaves of *Populus* × *euramericana* naturally infected with poplar mosaic virus and showing yellow spots some of which extend along leaf veins — asteroid spotting.

WAYS TO IMPROVE THE HEALTH OF HARDY NURSERY STOCK

Uniformity of growth rate and extended production life are properties required by fruit growers and, by using existing techniques, it will be possible to obtain clones of virus-free trees and shrubs for timber or amenity planting. These clones would offer the nurserymen more evenness of stand that is now achieved but I doubt whether more uniform growth would by itself be adequate economic justification for the production of virus-free ornamental woody plant clones. The expense and effort may be justified when a virus is responsible for "incompatibility" (e.g. *Rosa rugosa* is a more or less symptomless carrier of strawberry latent ringspot virus until these plants are used as rootstocks for sensitive rose cultivars such as Peace or Superstar) or undesirable horticultural features which affect sales (e.g. virus associated decline of *Daphne mezereum*). The decision to develop virus free material must await more information about the incidence of viruses in hardy nursery stock and about the biology of the viruses themselves.

Alternative methods to prevent the dissemination of viruses are available; nurserymen should intensify their scrutiny of the plants they grow and discriminate against material that is in any way sub-standard or abnormal. Similarly, the risks from viruses will be minimised when healthy plants are isolated from sources of infection and virus-carrying vectors.

THE PROS AND CONS OF SEEDLING ROOTSTOCKS

A great many rootstocks used for hardy ornamentals are produced from seed. This is highly desirable because most viruses are not transmitted to a significant extent through seed, e.g. CLRV in birch about 2%. By contrast, vegetative propagation has a somewhat greater risk. Thus whereas most garden stocks of privet (over 90% in Oxford) are infected with AMV, relatively few (about 10% in Oxford) occur in soils infested with virus-carrying nematodes, thereby suggesting that the virus is likely to have been disseminated by vegetative propagation when seed, having by my estimate, approximately 1% risk of carrying the virus, could have been used.

The use of seedling rootstocks has somewhat broader phytosanitary implications. Most of the seedlings used in UK are imported *with roots attached* from Denmark. The Netherlands, or West Germany. Soil is inevitably introduced with rooted seedlings, thereby offering opportunities for the importation of non-indigenous soil-inhabiting pests and pathogens such as strains of the fungus *Syncytrium endobioticum* which can cause wart disease in potato cultivars immune to strains of the fungus present in UK. As far as is known, virus-vector nematodes occurring in the

exporting countries also occur in UK. However, it is pertinent to point out that studies using nematode-transmitted viruses have shown that the reassortment of genetic material between two viruses present in one host can occur (10) and one cannot exclude the possibility that exotic virus strains may be introduced into UK in this way. Circumstantial evidence suggests that a free living nematode (*Paralongidorus maximus*) not known to be a virus vector but potentially damaging to woody plants on which it feeds, may have been introduced on seedling roots. *P. maximus* is known from Poland, Hungary, West Germany, Austria and France but although UK soils have been intensively examined (e.g. several thousand samples were studied by Dr. B. Boag at the Scottish Horticultural Research Institute) *P. maximus* was recorded three times only: in an ornamental nursery, a tree nursery and a private garden.

PROTECTION OF HARDY NURSERY STOCK FROM VIRUSES

Foliar applications with insecticidal chemicals may prevent the establishment of damaging insect populations but unfortunately viruses like cucumber and alfalfa mosaic are instantaneously transmitted when aphids feed and their spread is not greatly diminished either by systemically translocated or contact aphicides. Experiments with food crops have shown that plants can be protected from infection with viruses like cucumber mosaic. Mineral oil emulsions could be sprayed onto leaves, reflecting (aluminum foil), mulches could be applied around plants and a tall growing barrier crop such as rye could be established around stock to be protected. The prospects for controlling the spread of nematode-borne viruses by changes in management or soil treatment are, however, more encouraging.

Nematode-borne viruses will be avoided by growing plants in containers, but only if the compost is sterilized; all the virus-carrying genera naturally infest a wide range of soils and *Xiphinema diversicaudatum* has been reported from sphagnum peat used for potting compost in The Netherlands (19). Several chemicals when applied to soil have been shown to kill nematodes and to prevent the spread of viruses they carry (6, 11, 15). New techniques may need to be developed to achieve adequate nematicidal effect at great depths in soil permeated by roots of large trees but there is considerable knowledge available concerning the use of nematicides to protect shallow rooted annual and perennial crops and this will be relevant to hardy nursery stock problems. The cost of soil treatment is high but nematodes (including those carrying viruses) cause root damage when feeding and have, in many instances, been detected in tree nursery sites (6, 21) or in the root regions of mature trees (2, 12).

Indeed, one reason why AMV is frequent in hardy nursery stock is that although *X. diversicaudatum* feeds on roots of many plants, the nematodes multiply relatively more on woody perennial rather than weed or herbaceous crop plants (20). Large numbers of virus-carrying nematodes are often associated with hedgerows which may also contain virus-infected trees, therefore areas cleared from hedgerows should be set to arable rotations which tend to discourage *X. diversicaudatum* and wide fallow headlands should be left when practical because nematodes move laterally in soil, albeit slowly.

CONCLUSIONS

The frequency with which viruses have been detected in the few speculative and opportunist tests recently made on ornamental woody shrubs and trees suggests that a programme of virus-testing horticultural clones of the more widely grown plants (to select healthy stocks) might be desirable. Nurserymen should take particular care when selecting material for propagation because man has played an important part in spreading viruses. Graft transmission of a disease is not an adequate proof that a virus is the cause; characterization of a virus and tests to show its pathogenicity are needed. A more intensified research effort also seems justified to assess (a) the effects of viruses on the growth and propagation of hardy nursery stock; (b) the risk that trees and shrubs may pose as sources of viruses transmissible to and perhaps more damaging in neighbouring food crops.

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THE GROWTH REGULATOR "ATRINAL," AN AID TO MANAGEMENT

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Atrinal is a new plant growth regulator manufactured by Dr. R. Maag, A.G. Dielsdorf, Switzerland. Atrinal has demonstrated growth regulatory activity on many ornamentals, shrubs and top fruits. The compound is taken up through both leaves and roots, but foliar applications have provided the best results. Interesting responses include not only growth retardation, but also chemical pinching, induction of side-branching, improved rooting, fruit colouring, ripening and abscission, as well as yield increase depending on plant species involved.

Although Atrinal has demonstrated activity on a wide range of plants, in this paper the discussion is mainly restricted to its use as a plant growth regulator for the chemical pinching of azaleas, particularly the florist's azalea, Indicum hybrid cultivars, cultivars of White Water hybrids and Japanese evergreen azaleas.

The manufacturers claim the following characteristics and uses for Atrinal:

It is a new plant growth regulator with *systemic* activity for chemical pinching of azaleas and other ornamentals, the product being taken up through both leaves and roots.

If applied at adequate dosages, it stops development at the vegetative growing point and consequently induces axillary buds to develop. It can thus be substituted for mechanical pinching.

Atrinal is simple to apply, reliable, and saves labour.

Atrinal produces plants of superior quality, having more shoots and flower buds, and grows to a greater diameter.

Trials at the Horticultural Experimental Station, Guernsey and at F. Le Poidevin and Son, Azalea Specialist, Guernsey, have examined the above statements and results to-date support them. In addition, plants treated with Atrinal have reached a marketable stage in a shorter period of time than where other methods of stopping have been used.

Atrinal can be substituted for mechanical pinching. Apart from the first pinch, where it is desirable to form the basis of uniform, compact plants, by stopping growth mechanically, all subsequent pinching can normally be carried out chemically by the means of Atrinal applied when the new shoots are 5 to 8 cm. in length, and growing actively. It is essential that the chemical is applied before the flower buds have been induced.

The manufacturers recommendations for the timing of the last application is as follows:

late cultivars : end of March to early April
mid-late cultivars : mid-April to early May
early cultivars : mid May to the end of May

Late flowering cultivars, e.g. Road Runner, have been treated considerably later than the above recommendations, i.e. the end of May, and after being given a spray of B-nine in late July, had well advanced flower buds by late August. Further work needs to be carried out on timing which is obviously affected by cultivar; growing conditions and location.

Concerning the first growth stop, if Atrinal is applied to the young plants approximately 48 hours after pinching it increases the number of shoots produced by at least 25 per cent. This is extremely valuable as it forms the basis for a well furnished, high quality plant at an early stage. The cost is negligible.

The manufacturers recommendations for application are as follows:

The concentrations to apply *under glass* are:

from September to May : 2% Atrinal + 1% special wetting agent
from June to August : 3% Atrinal + 1% special wetting agent

Note: The commercial product contains 200 g.a.i. of dikegulac-sodium.

A 2% solution of the proprietary product = 0.4% a.i. = 4000 ppm
A 3% solution of the proprietary product = 0.4% a.i. = 6000 ppm

"Special Wetting Agent". This material is supplied with the Atrinal and contains 37.5 g per litre of alkylphenol oxyethylate. It is important to use only this special wetting agent when mixing Atrinal. The two concentrations above have been satisfactory on all the cultivars tested so far, although generally the 3% strength has given the best results in number of shoots and quality of plants produced, at slightly increased cost. Concentrations greater than 3% have tended to depress shoot yield and plant size.

A spray solution is easily prepared using ordinary water, whether hard or soft. The temperature of the water must not be higher than 30°C. The quantity of spray used will depend on the number, density and type of plants per square metre. Usually 1 litre of the spray solution will cover 4 to 5 sq. metres. The spray must be applied uniformly to run-off, wetting all parts of the plants.

Atrinal is most effective when applied at temperatures between 15^0 and 20^0C. Lower temperatures than this prolong the growing period and higher temperatures encourage flower induction and thereby reduce the effectiveness of the Atrinal. The spray must be used on the day it is prepared. The plants should not be

watered for at least 24 hours after application to avoid washing off the spray. Atrinal should not be mixed with pesticides or foliar fertilizers. After Atrinal treatment, feeding should be discontinued until the lateral shoots develop.

When azaleas are treated with the appropriate dosage of Atrinal, elongation of the shoots is halted. From the second week onwards, the young leaves of the apex turn yellow and, on certain cultivars, also develop brown edges. With a few cultivars the leaves will turn a bronze/red colour and occasionally some minor necrosis of immature leaves occurs. These symptoms are confined to the shoot tips and are a prerequisite for the pinching effect. They do not prejudice subsequent development or appearance of the plants.

The lateral buds start to sprout actively about six weeks after application. Initially these developing shoots may also show slight chlorosis. In the following weeks this soon disappears and the leaves become a dark-green colour. The shoots develop rapidly to reach the next stage, i.e., a further pinching, flower induction treatment, etc.

If flower buds have been induced before Atrinal application or if the conditions are such e.g., high temperatures, that flowering is promoted, then the Atrinal effect is markedly delayed and frequently the flowers buds slowly develop at the expense of axillary shoots. When the shoots and leaves are eventually produced, the leaves are frequently lanceolate and the plants have a "bunched" appearance. This eventually disappears but the plants growth is markedly delayed compared with those plants which have been treated correctly.

Compared with hand-pinched plants, plants treated with Atrinal show somewhat delayed side-shooting, in our experience usually about two weeks. This is important if some plants or shoots of plants are stopped mechanically, to shape the plant, and subsequently sprayed with Atrinal. This can result in uneven shoot development and we have found it wise to delay stopping such plants a week to 10 days after applying Atrinal.

Although Atrinal still stimulates axillary branching and increases the number of shoots on the mechanically stopped plants, the removal of apical dominance by mechanically stopping promotes more rapid development of axillary shoots than on those plants which have received only Atrinal. Later on, however, this two week delay is largely made up, as subsequent applications of Atrinal takes place at an earlier stage of shoot development than is the case for mechanical pinching. More important, plants treated with Atrinal subsequently achieve a greater diameter due to improved side-branching, provided adequate space is given for the plants to develop.

In conclusion, in my opinion, the introduction of Atrinal is a marked development in the field of plant growth regulators. It achieves the claims made for it by its manufacturers. Used as recommended on azaleas it must be a considerable aid to management, not only reducing the labour requirement for pinching plants but also producing a given size marketable plant more quickly than mechanically pinched plants.

Atrinal is, however, still only in its early life of commercial use and because of this it is wise to treat it with the caution with which all new chemicals should be treated. Try it on a limited number of plants first, compare it with mechanically pinched, or with plants which have been pinched with other chemicals, before embarking on full scale application. There are a number of points which still require further clarification on the use of Atrinal on glasshouse azaleas, particularly the timing of applications in relation to different cultivars and the effects of different growing conditions on its performance.

Acknowledgements to: Rhys Phillips, Experiments Officer, Experimental design and statistics; Robert Clark, Management, Work measurement and costing; Judith Falla, Recorder, Recording and analysis; Roland Le Feuvre, Horticultural Technicial, Crop culture.

Note: Atrinal, manufactured by Dr. R. Maag, A.g. Dielsdorf, Zurich, Switzerland has Ministry clearance for ornamentals only, NOT for edible crops.

STAKING IN RELATION TO GROWTH AND FORM

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The provision of support for plants in the nursery is a costly and time-consuming process. An examination of present practices may suggest ways of saving work without a significant reduction in quality. With this in mind a survey of some of the principal features leading to establishment of particular forms of growth has been made.

Botanists and foresters have long been concerned with growth and form and their many publications, particularly in the present century, provide an immense amount of information from which only those findings considered relevant to nursery work will be mentioned here.

TREE RESPONSE TO NATURAL FORCES

Light and spacing. Whilst the hereditary disposition to react in certain ways may pattern growth; light, gravity and other physical forces determine or modify the development and direction of branches. The plant's response is also considerably influenced by the "quality" of the site, this site quality may be assessed by the vigor and erectness of leading shoots; on poor soils trees become crooked.

Close spacing, by increasing the competition for light, soil-water and nutrients results in erect, attenuated plants with few or no side shoots. The mutual wind-protection accompanying close spacing precludes the formation of stem-taper and increases the need for prolonged support at planting.

Close tying to a stake reduces light on one side and the tree grows away from the stake, inviting more frequent tying. Experimentally, "see-through" stakes have not only eliminated this tendency but resulted in stiffer trees.

Wide spacing increases lateral branching relative to height and the main stem becomes tapered and the tree more resistant to wind stress.

Light is rarely a limiting factor in the early life of a nursery but may become so as competition develops. In addition, competition for water and nutrients may be so great between close-spaced trees that lateral buds do not develop into shoots; the apical buds seems to require all available water and nutrients.

Pruning and shoot/root ratio. Pruning effects on growth and form vary with species, season and severity of cutting. In general, growth as a whole will be less impeded by pruning when dormant

than when active in full summer. Light cutting back of leading shoots spreads the resulting laterals but more severe heading results in one or more stiffly erect shoots. This vigorous response follows a disturbance of the shoot/root ratio, clearly seen in well established material; it is also in part due to release and development of hitherto dormant vegetative buds.

Anchorage and soil. Unstable or loose soils such as those containing much broken stone or coarse gravel or, at the other extreme, much peat may provide insufficient anchorage when plants are young, especially when newly transplanted, so that the plants lean away from the vertical. Apical growth is resumed in a vertical direction but the plant is permanently "kinked".

A compact root system is formed in a deep organically rich soil. The primary reason for wind-loosening is inadequate cultivation of soils which are impermeable to roots. Shallow cultivation, with or without surface enrichment, attracts roots to the surface where they are vulnerable to environmental hazards and obtain minimal anchorage.

A small increase in rooting depth can produce a considerable increase in resistance to windblow. Drainage not only increases rooting depth but also increases the mechanical strength of the soil.

Gravity. Plants respond to gravity in very definite but differing ways. A root from a seed goes down, the shoot up, regardless of the influence of moisture or light, but quite soon the genotype patterns the reaction to gravity. In many conifers gravity is seemingly all-powerful. If wind, soil erosion, or mechanical damage displace the vertical axis the upright position is restored. The plumbline accuracy of vertical growth is achieved despite wind pressure, side illumination, or unequal development of lateral branches. Leading shoots of some vertical species may not attain an erect posture initially but only at the end of a growth period during which they may grow in a hemispherical arch towards the ground, indicating secondary growth activity and control some distance from the apical growing point.

The horizontal development of fan shoots from main stems, as in beech, despite their emergence from upward-inclined buds, is initially gravity controlled but the effect of the leaves upon them is largely governed by light.

Sensitivity to gravity often declines with age. Nursery trees are usually more erect than older ones. Whilst due mainly to vigour or speed of growth this equates well with the tendency observed in seedlings, and in adventitious or other fast growths (see pruning and shoot/root ratio). Examples are seen in hollies where shoots from trunk sphaeroblasts grow straight up through the head of the tree regardless of any superior horizontal lighting,

displaying the over-riding directional influence of gravity.

Pendulous growths, as in weeping ash and willow, appear to give way to gravity. By freely dangling there is no need for shoots to thicken to achieve support, they need only to conduct; the thickening and tapering of stems to resist mechanical stress incidentally provides excessive means of conduction (see interplay of forces and trunk motion).

Wind and shelter. Wood formation in a stem or branch is governed by the need for mechanical strength. The requirement increases in a long stem and is accentuated by exposure to wind. Trees require a degree of stiffness; violent shaking restricts extension growth. A stem, especially in a conifer, less clearly in a broadleaved tree, closely satisfies the requirements of a beam of uniform resistance. Exposure to wind pressure, mainly at the top, develops the necessary taper. Overcrowding checks or completely prevents taper. Compare close-grown oaks (*Quercus robur*) in a forest with those isolated in a field. Excessive protection from wind, which prevents movement, also precludes stem taper.

Trunk motion. Experimental separation of environmental stresses reveals the seemingly automatic reaction of the plant. A stiff rod hinged at one end to a fixed support and attached to a non-staked round-stemmed tree at the other ensures a one-way sway. The trunk develops an oval section with the longer axis in the direction of sway. A well-established tree with large heavy branches is structured to resist stress; its main trunk, or principal vertical branches have a round section and a central pith. The pith position of inclined branches varies in strict accordance with stresses principally imposed by gravity. From a series of cross sections near the bases of branches one can, by noting the pith positions, reconstruct the angles of the tree's limbs.

When a young tree is shaken rapidly to and fro by hand or mechanically, if only for less than a minute a day, it produces fewer nodes and these are closer together, consequently the tree is much shorter than one non-shaken and the main stem is much thicker.

NURSERY STAKING

Soil. On a well drained medium loam, deeply cultivated and not too windswept, staking may be beneficially reduced to the demands of "weepers" and "wobblers." Heavy clays eventually provide excellent anchorage but wind-rocking in the year of lining-out may so pug the soil close around that suffocation occurs. This, and wind-rocking in a loose peat or gravelly soil, is prevented by driving a short stake at planting. The stake can be safely withdrawn as the root system develops. If hard soils are well broken up, and have some organic matter incorporated, then

the roots will provide good anchorage, the basis for a proper development of growth and form.

Shelter. It is appreciated that external windscreens are well worthwhile. Adjustment of spacing between and within rows, in relation to plant character, also considerably influences staking needs. Square plants are theoretically acceptable but impractical. At the other extreme very wide row spacings, along with close spacing in the row, may result in flat trees with oval-section stems, hence a compromise is called for. Spacing in the row should not be so close that the individual plant cannot sway a little up and down the row as well as across, neither so close that more advanced plants suppress others by excluding light.

Trimming. Maiden trees intended for bush forms should, wherever possible, be left free. Low-grafted material can usually be held one season by a very short stake. Short-legged material may be kept clean up to the head to save later trimming but plants for standards should be allowed to feather during their nursery life if not beyond. If feathers are tipped or shortened the remaining leaf area should be left undamaged. Defeathering in summer adversely affects the tree's weight and girth, and its stability. Trees allowed to feather gain more in growth the year after transplanting. Defeathering does not materially strengthen leader growth. Active buds and leaves on laterals start downward waves of thickening which increases taper thus reducing the need for staking.

Degree of support. Artificial support controlling growth and form is required for the production of many cultivars, its provision is not only costly but may seriously interfere with the plant's development. Too much support checks stem thickening and prevents normal tapering and may also by rubbing provide entry for disease.

Rigid support by use of thick stakes not only prevents the formation of taper but by unilateral shading causes the tree to grow away from the vertical, involving more frequent tying. A comparatively thin and flexible stake is far better. Such stakes may be held in line by a single string or wire permitting a modicum of flexing between wire and ground. The stakes should first be fixed to the string or wire and then each tree be tied loosely to its stake, away from the string. Tie intervals should be as far apart as practical.

CONCLUSIONS

The hereditary disposition patterns growth.

Light, gravity, wind and other physical forces — soil-anchorage and mechanics — determine development.

Pruning effects vary with species, season and severity of cutting.

Trunk and branch strengthening is in response to environmental stress.

These observations lead to the recommendation that staking should not be rigid so as to completely remove environmental stress but should be flexible and elastic to permit sufficient exercise.

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EXTENSIVE METHODS OF RAISING CONIFER PLANTS

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The Forestry Commission's annual programme of plant production is fifty million plants. To improve on the techniques used research is carried out at the Northern Research Station at Roslin on Bush Estate, near Edinburgh. Facilities for research include a research nursery at Bush, also two others at Gatehouse of Fleet, and Newton near Elgin. A polythene house is used for research on containers, also another at Fort Augustus. The Physiology Section does research on cutting propagation and has glass and polythene house facilities.

Research started first into seedbed technique, pre-war, and later into nutrition and weed control. The basic techniques are described in *Forestry Commission Bulletin* 43, "Nursery Practice" and Bulletin 37, "Nursery Nutrition".

Plant production falls into categories. Bare-rooted stock take up the bulk of the programme. Container plants, such as tubed seedlings, are used for special purposes such as in North Scotland where 500,000 are produced annually. Paperpots are another container of interest and currently used in Thetford forest for Corsican pine where 300,000 are produced annually. Finally, we are currently very interested in developing methods of propagating conifers by cuttings, the objective being to produce stock which has been genetically improved.

Current research is aimed at labour saving methods and production of better plants. Herbicides are screened for their effects on conifers and any promising ones are given trials first in experiments and then later in large scale nursery trials. A recent herbicide of great value is Diphenamid. This can be used as a preemergent spray on Sitka spruce and Lodgepole pine seedbeds. The rates used should be 5kg a.i./ha.; caution is recommended on other species. Weed control is very effective particularly on grasses such as *Poa annua* and control lasts for a whole season.

A fair research effort has been put into improving growth of seedlings in the first year so that a large proportion are ready for lining out after only one year. Recently Dazomet has been used to sterilize seedbeds. Not only has good weed control been achieved but considerable improvements in growth.

Prechilling of seed involving soaking seed and then storing at 3-5℃ in moisture for 3 to 6 weeks improves the rate of germination and subsequently the height of plants after the first year. Cloches have been tried but though the height growth is improved

there is a substantial mortality from excessive heat; labour costs for adding ventilation would be excessive. One could say that cloches are a first step toward intensive plant production.

Tubed seedlings are produced intensively (eight weeks) after sowing in a polythene house at 25℃ day, 15℃ night, gives a plantable seedling. The costs of production are about two-thirds that of transplants. One 15m × 7m polyhouse produces half a million plants per annum. The plants can be planted at twice the rate of conventional stock and out of the normal planting season. However, the plant is small and susceptible to damage and is always a year at least behind in growth of those conventionally produced. On mineral soils tubed seedlings are heaved out of the ground by the first frost. So paperpots have been looked at as the container that can be used on a wide range of sites. They have been tried and tested alongside other containers of similar size and not much difference has been found. the paperpot has been chosen because it has the best cost and handling properties. However, plants in paperpots take up five times the space of tubes so, in fact, are more expensive to produce than transplants. Their main advantage is that useable plants can be produced in the same year as they are demanded.

INTENSIVE PLANT PRODUCTION

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At present the majority of plants produced for use in Forestry Commission forests are produced as bare-rooted planting stock. This is a cheap and relatively efficient system. However, there is wastage and while this is perhaps acceptable when the initial value of the product is low it is not so acceptable when the product being used has a high basic value. Thus when we are considering the use of genetically superior seed we must consider systems which have a higher guarantee of success, i.e. where virtually every seed produces a plantable plant.

In addition, situations arise where it is desirable to have a particular size of plant, e.g. on very weedy sites where the cost of producing a large plant would be less than subsequent weeding costs. Or on sites where, for example, initial survival is a problem and it may be more beneficial to have summer planting. In addition, as nursery costs increase so there is a demand to reduce the time a plant spends in the nursery. Under these circumstances the use of a plant grown under a plastic cover in a container can be justified.

We can, however, consider first an intermediate phase between the seed sown outdoors and subsequently lined out in an open nursery. In this situation the seed can be sown indoors and then pricked out into nursery beds. This produces a high survival rate and allows maximum use of valuable seed. The plants in the beds are still, however, liable to climatic injury particularly during the early growing period. It is perhaps better therefore to consider the use of an indoor programme for producing conifer seedlings. The development of the plastic house has made such a programme possible. In forestry use these plastic houses range from the fairly simple structure producing a few seedlings to the large complex producing millions.

Tube seedlings are now being used as fairly standard practice at least in north Scotland. Likewise paper pots are in use in parts of southern and eastern England although we have not yet reached the state which exists in Scandinavia where, for example, in Sweden 50% of forest plants are raised in paper pots.

A wide range of containers have been developed each with their own advantages and disadvantages. These range from the NISULA roll, which is really an extension of the bare-rooted plant principle in that the plants are grown in an peat base in a plastic roll. They are planted as bare-rooted plants. Others involve filling

with peat or a peat/sand mixture such as Japanese paper pots, senso pots, Kopparfors, Book planters and Finn pots. Some pots are produced in which the seed can be sown direct, i.e. no filling is required, e.g. Vermipeat pots which come in two sizes and Jiffy pots. For the tree breeding work in which I am involved I have found that the paper pots are eminently satisfactory. There are many more types of containers with appearance with differs as much as the names. I have even come across a South African one called the 'BLOB'.

All these can, of course, be used with a simple plastic house. If more rapid growth is required then it is necessary to consider the addition of soil warming cables to aid germination and a form of top heat. A regime of 20℃ soil temperature and a minimum air temperature of 15℃ will produce a seedling Sitka spruce up to three times larger than can be produced in the same time under standard nursery conditions.

If the conifer is particularly valuable, then the seedlings can be grown as individuals and treated like many other plant species which have commercial value. They can be grown in pots with increased soil and air temperature. In addition, supplementary lighting may be used. This will extend the growing season and offers the opportunity to produce a large plant or to have two or three crops in the one year. Various sources of illumination have been tried, but high and low pressure sodium lamps seem very suitable for conifer growth. Using an 18 hour daylength with a minimum air temperature of 15℃, a growth rate twice that without added light can be achieved for a total cost including depreciation of about 0.5p per sq. m. per day. The system to use depends on the end product but there can be no doubt that as labour costs continue to rise more and more intensive techniques will be adopted.

TREE BIOLOGY RESEARCH AND PLANT PROPAGATION

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Several research groups at this station are investigating aspects of tree and forest science from a broad spectrum of interests and approaches, especially in physiology, ecology, genetics and microbiology. The same themes recur: how trees grow and develop, how their responses differ, and how one tree affects another. It is expected that this knowledge will be used to improve and innovate in forestry, and aid the cultivation of ornamental and amenity trees. To a large extent this research is complementary to that of the Forestry Commission Research Division, whose work is particularly related to practical problems associated with commercial forestry species. Fruit tree research in Britain is mainly concentrated at the Long Ashton and East Malling Research Stations.

Compared with herbaceous crop and ornamental plants, much less is known about forest and amenity trees, and new hybrids and cultivars appear infrequently or not at all. Whereas spectacular changes and improvements have occurred for example in the wheat crop during the last 50 years, and countless new forms and colour variants have been developed in the cultivated rose, progress in forest tree improvement has been much slower. However, the importance of the geographical origin or provenance has become widely recognised, and progenies of improved quality have been produced from seed orchards (for example in *Pinus sylvestris*, *P. radiata* and *P. elliottii*). The considerable number of new forms of species of *Populus* and *Chamaecyparis* are exceptions, but it may be useful to ask why tree research in general has lagged behind. Can anything be done to hasten it?

PROBLEMS IN TREE RESEARCH.

In the first place, the *life-cycle* of herbaceous plants allows a man to see many successive generations of crops, whereas trees, except for certain short tropical rotations, generally grow for 20 to 200 years or more. This makes it difficult to retain the continuity of research aims, and also to adjust to changing requirements. Superficially it might seem that research on young seedlings (some of which are able to grow 10 cm/week and even 5m/year) might enable the best types for particular sites to be distinguished. This may be so when establishment and survival are of overriding importance, but in most instances foresters are concerned

with the quality and quantity of the crop at harvest. There is disturbing evidence accumulating which suggests that rapid early growth in trial plots may not necessarily be indicative of later excellence. Thus trees may change their size relative to each other as the crop closes canopy and grows to maturity (3, 5, 24).

Early characteristics may be more reliable indicators of later performance where differences of a qualitative nature are concerned, as for example in stem form, branching habit or foliage colour. However, caution is still needed here for it is well known that a batch of seedlings of *Fagus sylvatica* may sometimes contain a number with bronze coloured leaves, but only a very few of these grow into copper beeches. Similarly, the final height that a tree may attain is unlikely to be predicted from its early patterns of growth unless it has a short life-cycle (for example *Sambucus* spp.). Generally there are too many unknown factors at work, including occasional extremes of climate, for reliable prediction from present knowledge.

Perhaps one of the greatest problems posed by the long life-cycle of forest trees is the scarcity of flowering during the juvenile period, which may extend for the first 10 to 30 years of life (19). Clearly this means that breeding cycles would be very lengthy, and also that it is usually necessary to graft scions of older trees on to seedling rootstocks in order to bring selections together for crossing. Such grafted plants are often described as "mature," because they retain a number of the flowering and vegetative characteristics of older trees, which contrast with the "juvenile" shoots from younger trees. A further complication is that many mature plants do not flower annually.

A second area of difficulty arises from the *large size* which trees attain, with complex shoot and root systems. One cannot hope to study a big tree, still less the entire structure of a forest, from one point on the ground. Thus for example the HORMONAL CONTROL project, one of six at the Bush Station, uses tall ladders and tripods for its flower induction experiments, and has developed a mobile, Landrover-mounted tower of unit scaffolding. A more permanent system of scaffolding and towers is used in a 15 year old plantation of *Picea sitchensis* by the project investigating the EFFECT OF THE PHYSICAL ENVIRONMENT ON TREE GROWTH.

Conditions for growth at the top of a tree are often very different from those at its base, particularly if the forest is tall and dense enough for substantial gradients to exist. Continuous measurement of the micro-environments at various positions in the stand can help to explain how growth is controlled, particularly if aspects of growth are monitored as well as climatic data. In this project many of these measurements are automatically recorded

and, using a computer, it is feasible to unravel the many interactions between the trees and their environment. Root systems pose greater problems still, and are notoriously little understood. Extensive sampling, digging or winching operations are needed even for moderate-sized trees, followed by time-consuming washing and separation of root fragments. On certain soils wind-thrown specimens may illustrate an exposed and relatively intact pattern of roots, but these by their nature may provide a biased sample.

A third problem with trees is their very great *variability*. This is often so large that it obscures the effects of treatments, requires many replicates to be used, and restricts valid prediction from information gained in particular circumstances. Whereas someone buying a packet of tomato seed knows with a degree of certainty the type of crop to be obtained, the same person sowing birch has no assurance of success. Three-quarters of the seeds may never germinate, and those that grow into saplings will probably not closely resemble the carefully selected parent tree. In a sense there is no such thing as The Birch Tree; instead there are trees showing a wide variety of birch-like attributes. In the PHYSIOLOGY OF GENOTYPES project, some factors underlying variability are being investigated in *Pinus contorta* and *Picea sitchensis*, particularly those controlling shoot growth and branching patterns.

Looked at in another way, the existence of all this variation puts growers of trees in a much stronger position as regards the future than tomato growers, having this large potential for selection and as a basis for breeding. But in order to select one must first understand the reasons for variation (Fig. 1). All too often, however, it has been impossible to find out whether a selected tree has grown well because it is inherently vigorous under those conditions, whether it has been specially favored by its local environment, or whether its response is confined to one part of the tree or its life-cycle (i.e. due to internal factors).

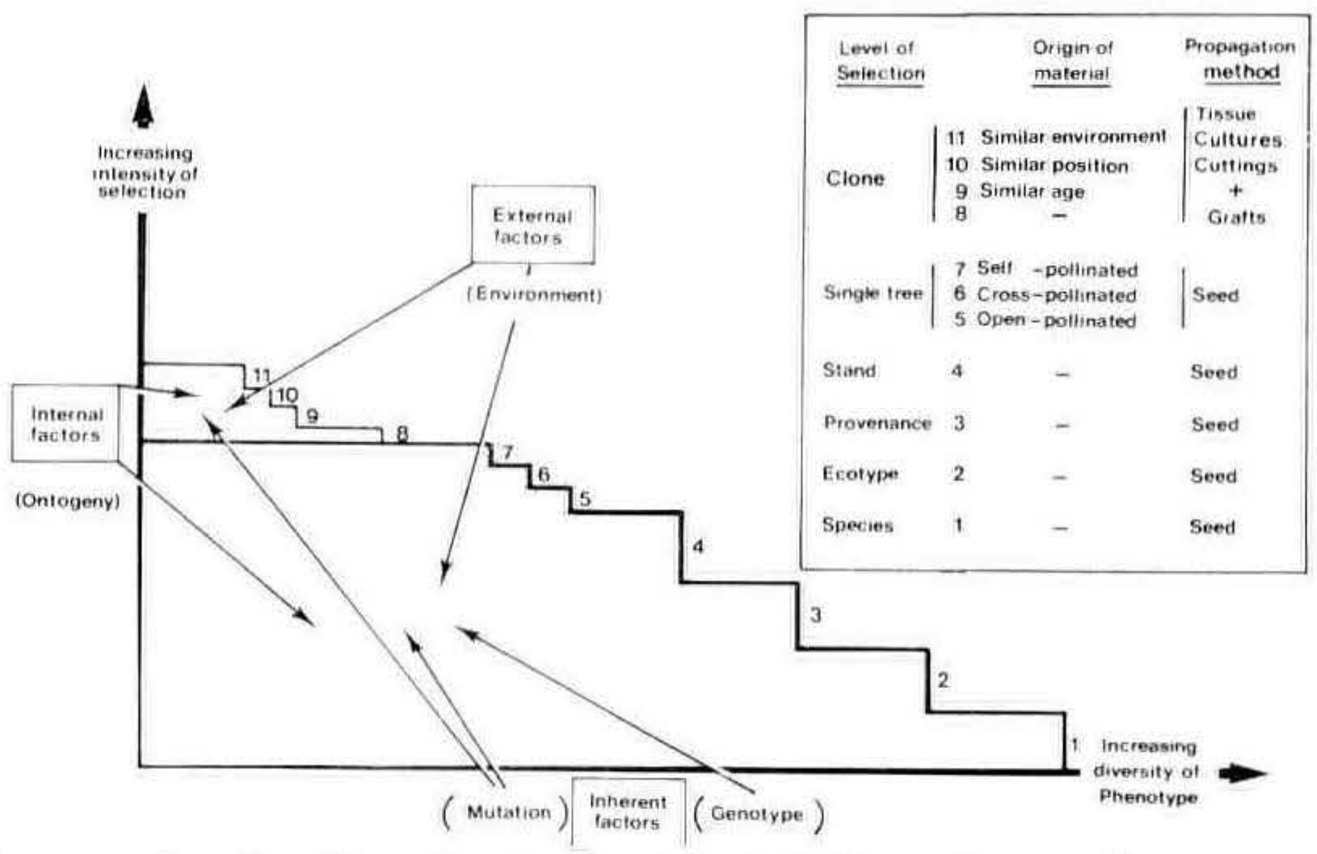

Figure 1. Variation and selection in trees. Variability depends upon an interaction between external, internal and inherent factors. Greater diversity is obtained by selecting near the bottom of the chart; more uniform trees by selection near the top.

Experience with other perennial crops, including apples, citrus, rubber, etc., suggests that a considerable proportion of tree variability is often genetical and distinct forms can, therefore, be established by vegetative means. With forest trees, it is not surprising that the recognition of new types has progressed much faster with *Populus* and *Chamaecyparis,* for they are propagated by cuttings. Grafting selected "plus" trees and ornamental cultivars of many other genera has amply demonstrated the large inherent component of forest tree variation, and indeed it is typically much greater than in other crops. Species of forest trees usually have a wide geographical range; they are generally out-breeding and therefore populations are heterogenous; and there has been a smaller element of selection in their cultivation.

As soon as several replicates of a single genotype are produced, the inherent differences from other clones of the same tree species can be seen, as happened with a collection of four clones of *Pinus sylvestris,* produced by grafting scions from mature "plus" trees. Unintentionally these potted grafts were exposed to gale-force winds, after which it was found that needles on one clone were extensively browned, whereas those of the other three were not affected. The effect was unequivocal, and yet with a single representative of each genotype it would probably not even have been noticed.

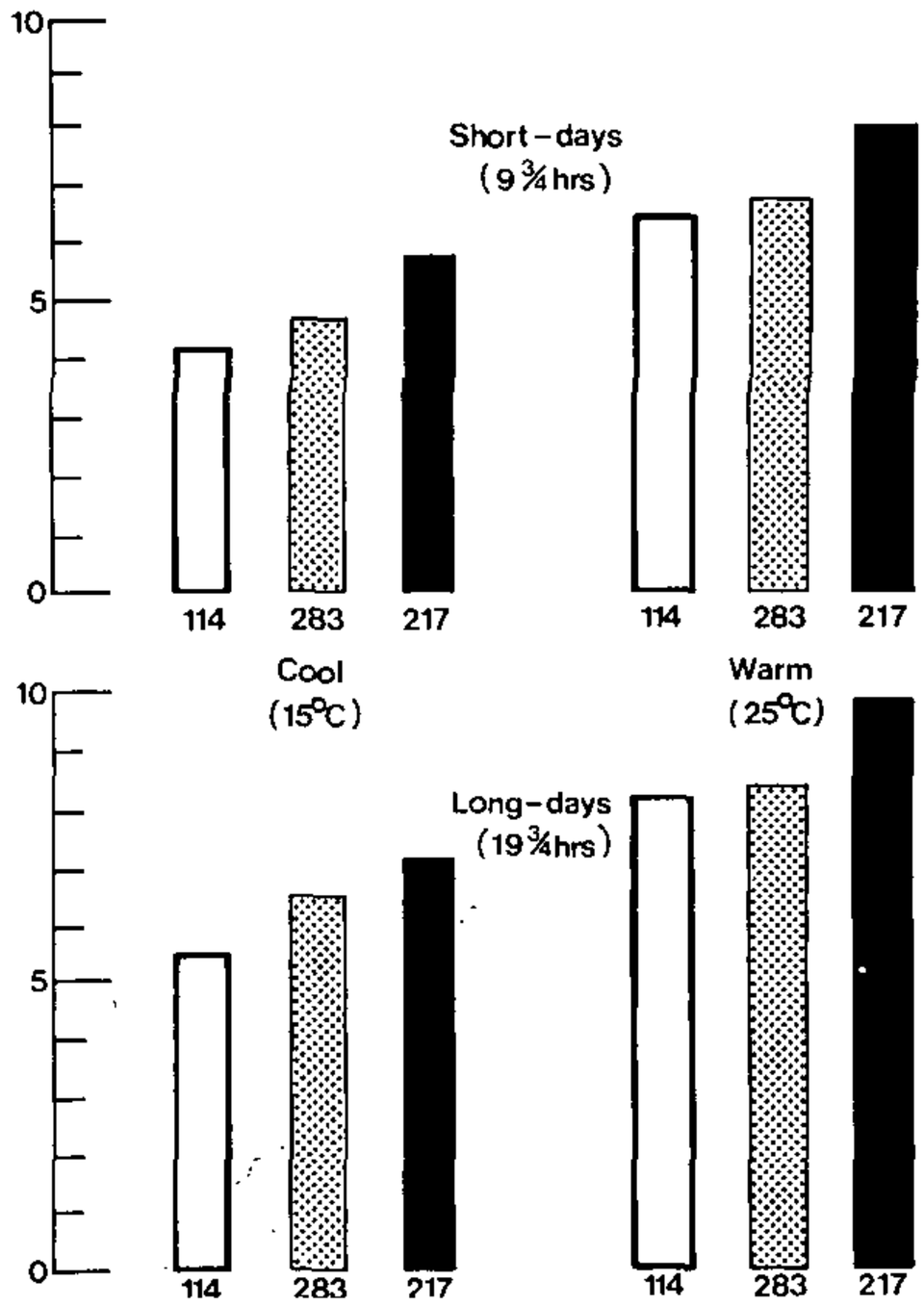

Figure 2. Effects of genotype and environment. Response of 3 clones of Scots pine grafts (scions from mature "plus" trees nos. 114, 283 & 217) to 4 different growth cabinet regimes. ("Needle-display" = average width of shadow cast by current year's needles on a screen, a function of needle length and angle to the main stem.)

When the four clones were grown under four different regimes in growth-rooms (see Fig. 2), the same clone again showed needle-browning, but this was much more pronounced in one of the rooms (long-day; cool). Thus the expression of the genetic character was considerably modified by environment. This is also illustrated in the needle measurements of the other three clones, which were influenced both by temperature and by day-length, besides showing consistent inherent differences (Fig. 2). Indeed, some external and internal effects can be so strong that the genetic component is hard to detect. For example, by selecting the growing conditions and the node position, leaves of a single clone of *Triplochiton scleroxylon* can be produced which differ by as much as 35 times in length, and possess photosynthetic surfaces varying a thousand-fold (Fig. 3). In such circumstances, it will be almost impossible to discover any inherent differences, unless they are qualitative rather than quantitative.

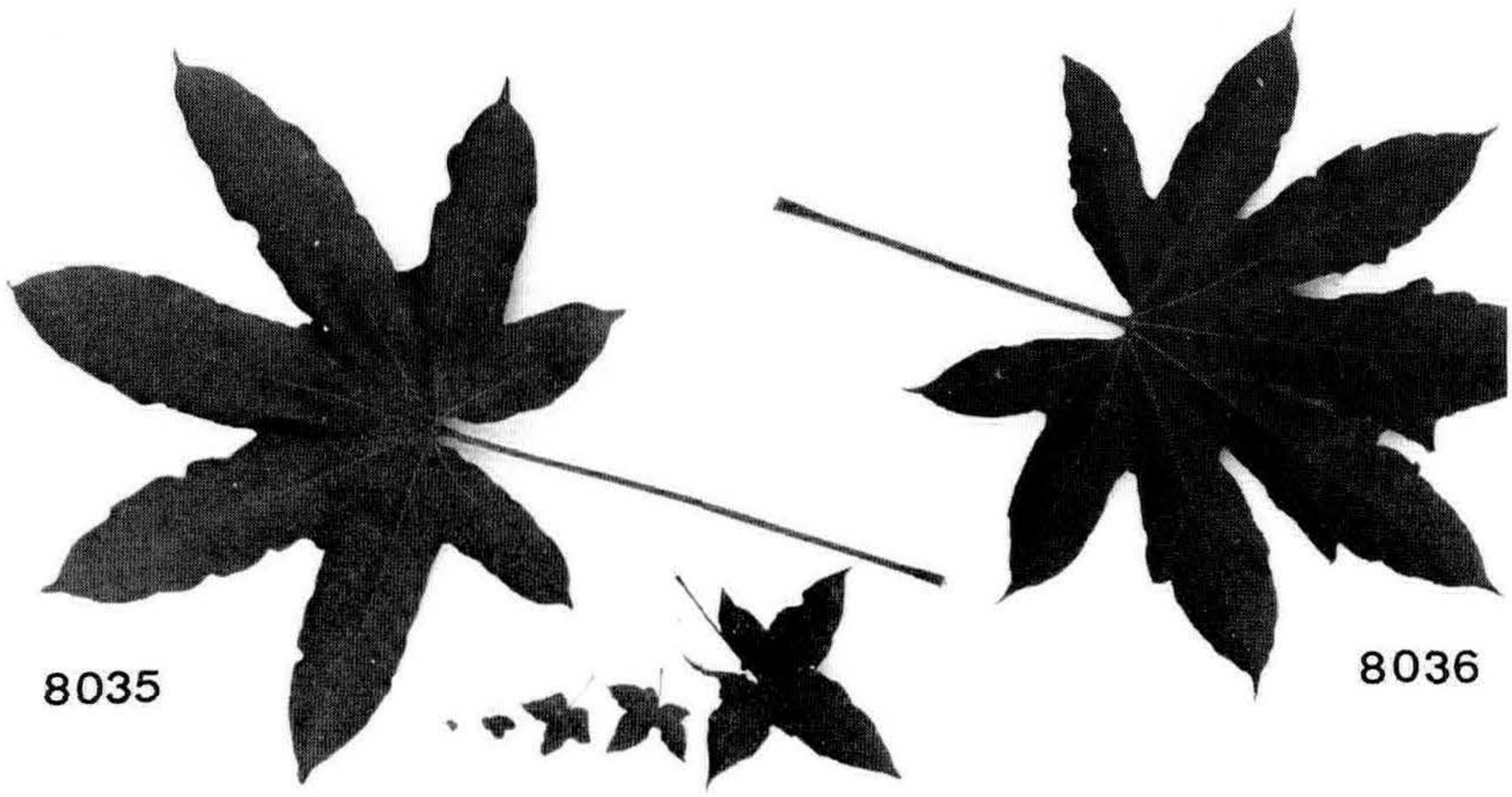

Figure 3. Effects of environment and ontogeny. Fully expanded leaves of Obeche, selected to show variation within a single clone (8035). The smaller leaves were taken from weak shoots on plants in small pots, pruned back and left in a shady place at 15-23°C. The large leaf originated from a vigorous shoot on a plant growing in a large container under supplementary lighting at 25-30°C. Note the differing numbers of lobes, and also the genetical difference shown by the large leaf of clone 8036, with its characteristic secondary lobing. (Scale: 15 cm or 6 in. long.)

During the last few years it has become clear that it is possible to distinguish between genetical and environmental components of variation, now that cuttings can be rooted using material from young forest trees. For instance, over 25 temperate and tropical tree species have been rooted at the Bush during the last two years, using standard hormones and mist propagation with bottom heat (see Table 1). Juvenile cuttings can often provide more elegant

research material than seedlings, and they have far-reaching implications in clonal forestry, a subject which is being actively debated at present (15, 25). The major forest species in use in Britain can now be rooted from young trees, and methods have been developed by the Forestry Commission's Physiology Branch for producing in a few months cuttings which have better structured root systems than standard nursery transplants raised from seed (2). There is a real prospect that before long practical growers may be able to reproduce repeatedly a set of desirable characteristics which they have selected in a forest tree. Each of the following research projects uses cuttings for precisely these reasons.

Table 1. Tree species rooted as cuttings for research at I.T.E., Bush, 1973-75.

Species	Age of Vegetative Stock-Plants	Comments
Temperate conifers:		
Cupressus macrocarpa	old	fairly difficult?
Metasequoia glyptostroboides	old	easy
Picea sitchensis	young	easy
Pinus contorta	young & old	most clones easy
P. sylvestris	young	fairly difficult
Thuja plicata	young & old	easy
Temperate dicotyledons:		
Acer pseudoplatanus	young	difficult
Betula alleghaniensis	young	easy
B. pubescens	young	easy
B. verrucosa (B. pendula)	young	easy
Crataegus monogyna	young	some clones fairly easy
Fagus sylvatica	young	difficult
Fraxinus excelsior	young	difficult
Malus silvestris	young	fairly easy
Prunus avium	young	difficult
Quercus robur	young	some clones fairly easy
Salix capraea	young	easy
Sambucus nigra	young & old	easy
Sorbus aucuparia	young	fairly difficult
Ulmus glabra	young	some clones fairly easy
Tropical dicotyledons:		
Cedrela odorata	young	fairly easy
Chlorophora excelsa	young	easy
Gmelina arborea	very young	easy
Shorea albida	young	easy?
Terminalia ivorensis	very young	easy
T. superba	young	easy
Triplochiton scleroxylon	young	easy

The absence of a tree species from this list does not imply that it cannot be rooted. For further information, see Kommissarov (10); Hinds and Krugman (7); Longman (15).

GENETICS OF TREE NUTRITION

A feature of this project is the growing of "mini-cuttings" of birch on an aseptic medium in small tubes. Seedlings are raised on agar jelly, and are then cut up into a number of single-node fragments, which can be stimulated to form visible roots in as little as three days. After about 2 months propagation is repeated, and when the clonal cuttings are sufficiently numerous they are used to study variability in response to mineral nutrients. It is interesting that it has been found that seedling plants are too variable for these experiments, even when they originate from single trees (see Fig. 1). There is still considerable variation in size within the batches of clonal cuttings, principally due to the node position from which they were derived. However, as the cuttings continue to grow these initial effects appear to become less important (13).

In Table 2 a typical example is given from a series of mineral nutrition experiments. With large amounts of phosphate, both clones tended to make similar amounts of shoot growth, no matter whether stem length, leaf length, leaf area or shoot dry weight were measured. However, with very small amounts of phosphate definite genetical differences could be observed. For example, clone A made less than half the leaf growth, whereas clone B grew nearly as well as with high phosphate. A possible reason for the capacity of clone B to thrive under limited nutrients was that these plants produced almost three times the number of roots.

Table 2. Differences in the responses of two clones of *Betula pendula* to low phosphate. From data of Pelham and Mason (20).

Measurement	Clone	High P (26.0 ppm)	Low P (0.4 ppm)	Change caused by lowering P
Leaf area (cm^2)	A	7.9	3.5	− 55%***
	B	8.8	8.0	− 10%
Root number	A	14.4	18.6	+ 30%
	B	19.5	56.4	+190%***

Means of 16 plants after 10 weeks in sand culture.
*** indicates a highly significant change.

If the low nutrient tolerant clones flourish in long-term field trials on phosphate-deficient soils, this ability could be of great practical importance, considering the poor nutrient status of many planting sites for both forest and amenity trees. In the case of birch it would also be possible to multiply any selected clone very rapidly. Taking the normal 8 cuttings every 8 weeks with over 90% success, it is theoretically possible to obtain a million cuttings in a little over a year, assuming facilities and staff are avail-

able. Alternatively, ordinary mist propagation could be used, as young birch clones root very readily with hormone treatment, as pointed out at an earlier meeting of the Society (6).

In natural conditions tree roots encounter many different micro-organisms, some of which may affect the availability and uptake of mineral nutrients. In particular, many trees form close mycorrhizal associations with specific fungi, and these modified roots are quite different from an uninfected root system. Birch seedlings which had not previously been contaminated with any micro-organisms formed mycorrhizas when inoculated with strains of *Amanita muscaria* (the poisonous fly agaric toadstool). There is considerable variation in both the tree and the fungal strain in their ability to form associations, and some combinations give more vigorous tree growth than others. This is an important discovery, which may prove to be of general relevance to the successful establishment of trees, and perhaps also in their later growth on poor sites.

Ultimately, it is intended that the inheritance of the capacity to utilize mineral nutrients will be studied in the tree, mycorrhizal association and fungus. This should be possible by developing the methods just described, and because birch seedlings can be induced to form flowers in 1 to 3 years from sowing. (See Table 5.)

AMENITY TREES FOR INDUSTRIAL WASTELAND

Choosing the most suitable individuals from the total range available within a species is also the theme of this project, which is concerned with selecting trees for improving the appearance of derelict spoil heaps. It has been clearly established that herbaceous plants colonizing bare ground around abandoned metal mines are often tolerant of the particular metal ions and of the generally very exacting conditions (1). This tolerance has probably arisen as a result of rapid, intense natural selection, and the same may apply to isolated trees which have managed to survive on coal tips, etc., though evolution may not have proceeded to the same extent, in view of the longer interval between generations. Successful establishment of trees would obviously have much to offer in terms of landscape improvement, stabilising the terrain and providing new habitats for wildlife.

For these purposes, clonal stocks are being built up by rooting cuttings of selected trees of many species (see Table 1). These will later be tested on spoil heaps and compared with material originating from unselected seedlings. If the selected plants survive and grow better, they could improve success rates in future reclamation projects, and at the same time reduce costs. Further improvement could then be sought through continued selection and breeding.

Tropical Tree Improvement. The tropical forests of the world are being exploited at an ever-increasing rate, for timber and paper pulp, and for farming and building land (17). Consequently their genetic diversity is diminishing rapidly, and in some instances species may soon become lost from a whole region. In addition to conserving blocks of forest in each area, it is also important to retain examples of the full geographical range of valuable species by planting them in research collections or "banks." So thinly scattered are the representatives of any one species in these mixed forests that it would require an unreasonably large area to conserve all the diversity *in situ*.

In *Triplochiton scleroxylon*, the West African tree producing the important timber "Obeche," a shortage of viable seed restricts attempts at conservation, and indeed limits ordinary reafforestation. Seed cannot be stored for very long, and there is also evidence of inbreeding depression, particularly from small seed lots. Projects at Ibadan, Nigeria, and at the Bush, Edinburgh, have recently shown that large numbers of well-rooted plants can be raised under mist, using leafy cuttings taken from young trees. Vegetative propagation thus offers the triple possibility of increasing the numbers of available plants, preserving some of the many natural combinations of genes, and multiplying those most suitable for forestry. These projects are sponsored by the United Kingdom Overseas Development Ministry and the Nigerian Government to look at the potential and the problems of this approach.

Work of this kind is beset by the basic and most difficult problem of forest genetics: how to identify the outstanding genotypes and then to produce thousands of superior trees from them (15). By the time that one can be reasonably sure that a tree is desirable, its mature shoots are usually very difficult to root. If cuttings can be produced, they may exhibit growth patterns typical of mature trees, and therefore not be suitable as planting stock. Conversely, a young tree is an unknown quantity when it is used as a vegetative stockplant, although this is, of course, also true of seedlings without prior progeny testing.

The group in Nigeria have made the important discovery that cuttings can be rooted easily from coppice shoots growing from stumps of 8 year old trees which had been felled. Moreover, similar shoots can be induced, by such methods as ringing and scoring of the bark, without cutting the tree down. Because coppice shoots have a juvenile growth habit, a single rooted cutting could start a clone of "young" trees from an outstanding older tree. With 25 or 50 such clones, the likelihood of an improved plantation would be high, and it would soon become clear which were those with inherently good stem form and branching habit. It has still to be shown, however, whether old trees lose the ability to form juvenile coppice shoots.

The team in Edinburgh, investigating the physiology of root formation, has shown that bed temperatures around 30°C appear to be optimal for most clones of *Triplochiton* cuttings. A mixture of 0.1% IBA and 0.1% NAA (given as an alcoholic "quick dip") stimulates rooting, again in most though not all clones (11). Further topics under consideration include the role played by the leaf in root initiation, and the possibilities of tissue and organ culture. Meanwhile, other tropical species have been rooted at the Bush (see Table 1), an interesting example being *Shorea albida*, a dipterocarp tree producing seed once every 8 to 10 years, which will remain viable for 14 days. Rooting cuttings from "wildings" may be the only chance of re-afforesting the hundreds of square miles of peat-swamp forest of *S. albida* in S. E. Asia which are due to be felled shortly for paper pulp.

When undertaking a programme of propagation by cuttings, a major consideration is the production of large numbers of uniform shoots from vegetative stockplants. Involved here is the outgrowth of buds which are normally inactive due to dormancy or to apical dominance, for in a number of tropical species, particularly members of the mahogany family (Meliaceae), young trees can grow to a height of 2 to 10 metres with only one active shoot tip. Decapitation may produce a flush of lateral shoots, but in *Cedrela odorata*, for example, one lateral usually re-establishes dominance within a few weeks or months. Such a growth habit obviously tends to lead to non-uniform cuttings.

If *T. scleroxylon* plants about 1½ metres tall are decapitated and planted at about 45° from the vertical, this causes a greater number of laterals to sprout and continue growing (11). Similar gravimorphic effects on apical dominance are known for temperate fruit and forest trees (22, 23, 27). In the "angled" decapitated *T. scleroxylon* plants, the developing laterals rather surprisingly are of two different types: basal sprouts near the roots, which grow vertically and have a spiral leaf arrangement resembling a seedling main stem; and apical shoots near the point of decapitation, which have a distichous or two-ranked arrangement of the leaves and a non-vertical habit of growth more reminiscent of branches (Fig. 4).

Cuttings of the apical type generally root less easily than the basal, and continue to grow (for a time at least) at an oblique angle. Thus cuttings originating from a single plant can show quite wide differences, and it is obviously important to know whether these are temporary "carry-over" effects from the stockplant, or whether they involve permanent phase-change. Planting the main stem horizontally, coppicing or "hedging" (8) may perhaps be found to produce more uniform shoots.

Figure 4. Effects of ontogeny and environment. **Obeche** cutting 2½ yr. old showing the stimulation of many branches by decapitation and growing at an oblique angle. Note that the strong "basal" laterals grow more or less vertically, but the vigorous "apical" laterals tend to grow in the direction that the bud was pointing.

These results pose interesting problems in morphogenesis, and have also suggested a possible way of testing forest trees early in their life for their later characteristics. Some clones respond to treatment by producing one or a few lateral shoots, while in others a large number grow out. Can these differences be used to predict the later branchiness of the tree, or the persistence of its main stem? Clearly there may be many other factors involved, and the hypothesis requires full testing in the field.

Flower Induction. Although some trees flower regularly, and produce ample supplies of viable seed, it is common for flowers or cones to occur so irregularly that breeding is difficult or impossible. Even in a good flowering year, some of the selected parent trees may remain vegetative, or produce too few male flowers to form an effective pollen cloud. In most temperate-zone trees, flowers are initiated in spring or summer of the year before the one in which they open and are pollinated, so any flower-inducing treatments have to be applied sufficiently early.

Considerable progress has been made recently in identifying factors affecting the initiation of flowers, and in some cases techniques are now being developed for the reliable stimulation of heavy flowering in field conditions. One of the most striking of these is the response to gibberellic acid (GA_3), and in this project it has been found that a single dose of a fifth of a gram, injected in June to mature *Thuja plicata* cuttings about 15-20 feet tall, increased the number of cones formed in the same year by around 100,000 female and about half a million male cones. These very large numbers are possible because nearly all the many vegetative shoot tips in this species are capable of becoming reproductive. There were slight differences in response from tree to tree, but all

17 clones used over a four year period of study have shown a pronounced increase in both sexes.

Large numbers of male and female cones can also be induced by GA_3 in *X. Cupressocyparis leylandii* and other members of the *Cupressaceae* and *Taxodiaceae*. In the *Pinaceae*, however, there appears to be no such general response to GA_3, although recent evidence suggests that combinations of other gibberellins may promote flower formation (21). Before long it may perhaps become possible to influence the two sexes differentially, by using different concentrations of gibberellin, or mixing it with other growth substances.

In broadleaved species, on the other hand, it is likely that gibberellins may be found to inhibit rather than promote flowering. In birch (Table 3), both sexes of catkins were decreased by applying GA_3, especially the female.

Table 3. Effects of gibberellic acid[1] on flower initiation in birch.

	Percentage of branches forming catkins			
	Female Injected with		Male Injected with	
	H_2O	GA_3	H_2O	GA_3
Unringed branches	47	6	71	50
Ringed branches	88	43	76	64

[1]100 mg GA_3 in 200 ml H_2O injected on May 15-17 into 17 trees of *Betula pubescens* and *B. pendula (B. verrucosa,)* about 1 m above a fork. The other limb injected with 200 ml H_2O. Assessment of sample branches in autumn of same season (female by dissection, normally of 30-50 buds).

Table 4. Forest tree species flowering in response to complete bark-ringing.

Species	Type of shoot ringed[1]	Year of response[2]	Sexes induced
Betula pubescens	SB, SMS	1	F, M
	LMS*	2	F, M
B. pendula (B. verrucosa)	SB, SMS	1	F, M
	LMS*	2	F, M
X. Cupressocyparis leylandii	SMS	1	M
	SMS	2	F, M
Larix decidua	SB	1	F, M
L. kaempferi	SB	1	F, M
L. x. eurolepis	SMS*	1,2	F, M
Metasequoia glyptostroboides	SMS	1	F, M
Picea abies	SB*	1	M
Pinus sylvestris	SB	1	F, M
Pseudotsuga menziesii	SB	2	F, M
	LMS*	3,4	F, M

Table 4. continued

Species	Type of shoot ringed[2]	Year of response[2]	Sexes induced
Thuja plicata	SB, SMS	1,2	F, M
	LMS	1, 2*, 3	F, M

[1] Type of shoot ringed: SB - small branch; SMS - main stem of small plant; LMS - strong limb or main stem of large plant.

[2] Year of response indicates the year(s) in which substantial enhancement of flower initiation was detected. Year 1 means later in the same season that the shoots were ringed.

* - Observational trial, not yet confirmed by replicated experiment.

Inhibition of flowering also occurs, for example, in apple trees, where it is possible to promote flowering with growth retardants such as Alar, which suppress natural gibberellin production (9). These results should not however be taken to imply that treatments which retard vegetative growth necessarily promote flower initiation (26).

A method of inducing flowering, known even in Roman times, is that of bark-ringing or girdling the stem, and this is effective in a number of unrelated genera (Tables 3 and 4).

Stimulation is greatest when a complete "ring" of bark is removed in spring, well before the time at which the flower initials for the next year are laid down. This varies between May and September in Britain, but, as a general rule, ringing should be done as soon as the new leaves are appearing and the bark will "slip" on the wood. The cut surfaces should be protected with a suitable bitumastic compound, and the ringed shoots may need extra support. They may survive and flower and fruit heavily for a number of years, even though the phloem has been completely severed, provided that the ring is not made in a position which leads to mechanical failure, or to the death of a portion of cambium or of the entire root system (Fig. 5).

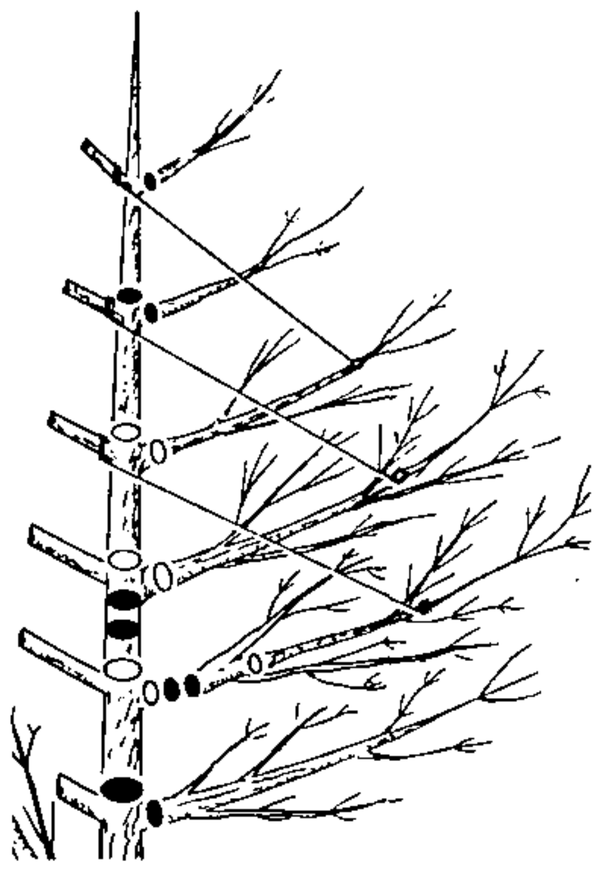

Figure 5. Suitable (○) and unsuitable (●) positions for complete bark-ringing to induce heavy flowering.

In *T. plicata*, which has been used as a test plant for flowering studies, ringing of branches or the main stem of small plants stimulates male and particularly female cone formation in the year of treatment and especially the second year (Fig. 6). Small ringed shoots are liable to break off after a while, but larger trunks and limbs can be treated with less risk, and here the effect occurs less rapidly, reaching a peak in the third year. These methods are also very effective in birch, for example, where small ringed shoots initiate catkins in the current year, whereas flower formation is delayed to the second year when large limbs are ringed.

Figure 6. Prolific female coning induced during the year following treatment in mature cuttings of western red cedar. Left — portion of completely ringed branch; Right — part of control branch.

The stage is now being reached when these discoveries can be developed into practical techniques for tree improvement. Thus gibberellin injection has been used to stimulate approximately 10 million cones on the best selections in a seed orchard which is shortly to be lost through a road widening scheme, and it has also been suggested for other trees which are due to be felled the following year. Where it is desirable to obtain a continuing supply of seed, it may be appropriate to develop "renewal" methods of shaping forest seed-trees. In some species the majority of potential

flowering sites tend to be utilised in a single year of heavy initiation, and so a multi-stemmed tree may be needed (see Fig. 5), one or two limbs of which would be treated each year, and then removed when the seeds were almost ripe.

A further important development is that small mature cuttings have been induced to flower in glasshouses and growth chambers. This allows the research worker greater control, and also enables experiments to be done on the effects of climatic factors on flower initiation. It has been appreciated for many years that there is a correlation between fine summers and heavy flowering the following year (18). It is now possible to test the effects of separate components of climate, keeping the others constant. In one such experiment, a combination of warm temperatures (25°C) and very long days (about 20 hours) stimulated female and male coning in *T. plicata*. This did not happen when cooler temperatures and/or shorter days were given. The Forestry Commission Genetics Branch has recently been successful in stimulating copious flower formation on 5-year-old grafts of selected mature trees of *Picea sitchensis*, kept in a polythene tunnel for the whole of the growing season..

A long growing season in a controlled environment has also stimulated flowering in the Dawn cypress (*Metasequoia glyptostroboides*), which never produces male cones out of doors in our latitudes (14). Pollination of female cones of the same clone has resulted in the first home produced seedlings of this species to be raised in Britain. In addition it also responds to ringing and to gibberellin injection by marked changes in shoot growth as well as by forming cones.

As mentioned at the beginning of this article, one of the greatest barriers to tree breeding is the scarcity of flowers during the juvenile period. Stimulating flower formation is more difficult in seedling material, but is evidently not impossible (16), for several species have now been induced during the first three years of life (Table 5). These developments are being used in Finland for large-scale crossing to produce improved seed of birch (12). It is estimated that by 1985 birch cultivars will be producing 100% more timber than the unimproved species. Selection and breeding for improved yield and form would be particularly relevant in Britain, where many sites are suited to birch, but the natural populations have been subjected to centuries of intense negative selection since they have been regarded as weed species (4).

Hopes for improving tropical trees were increased recently by the occurrence at the Bush of more than 30 flower buds on a cutting originating from a seedling of *Triplochiton scleroxylon*. In the tropical forest, this tree opens its flowers towards dusk, perhaps 50 to 150 feet above the ground, and pollination probably has to occur within the next few hours. By contrast, the flower

buds shown in Fig. 7 were 3 feet from the ground, on a cutting 2 years old. If this can be achieved on a regular basis, controlled pollinations and repeated crossing would become feasible as well as easy seed collection and study of the reproductive biology of this species.

Table 5. Forest tree species induced to form flowers during the first three years from seed germination.

Species	Treatment	Approximate age at first flower initiation (months)	Sexes induced
Betula pubescens	Complete ringing of mainstem	27	F, M
	Rapid growth, then complete ringing of main stem	15	F, M
B. pendula (B. verrucosa)	Complete ringing of mainstem	27	F, M
	Rapid growth, then complete ringing of main stem	15	F, M
	Rapid, continuous growth	8-30	F, M
Larix x. eurolepis	Rapid growth, then complete ringing of main stem plus horizontal orientation	26*	*F, M*
Thuja plicata	Complete ringing of mainstem, grown at 20° - 28°C	24	F, M
Triplochiton scleroxylon	Plant decapitated and grown at oblique orientation	35*	F

* - Observational trial, not yet confirmed by replicated experiment.
See also: Jackson and Sweet (9); Zimmerman (28); Pharis and Kuo (21).

Figure 7. Flowering branch of Obeche, produced in Edinburgh on the plant shown in Fig. 4, at 35 months from germination.

Clearly there is still a great deal of work to be done before all these possibilities have been fully investigated. However, forest and ornamental tree breeding may soon start catching up with other crops, whose rate of improvement must presumably slow down. Spectacular advances can be expected in some tree species, now that the knowledge is being gained and the barriers overcome. One day the grower may get the set of trees for the purpose, instead of plants so variable that there is no way of finding out why some of them are unsuitable.

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HORTICULTURAL DEVELOPMENT OF AUSTRALIAN PLANTS

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The Australian flora consists of some 12,000 to 15,000 species in approximately 850 genera. Of these, probably half have horticultural potential. This vast range of species from which we have opportunity to draw is the envy of horticulturalists the world over. We should pause and consider the success of our endeavors in pursuing the selection, introduction, and improvement of cultivars for ornamental planting.

Cultivars of fruit trees, roses, azaleas, camellias, and a great many other commonly grown exotic plants have been either developed by breeding or gathered as mutations over many centuries and are great improvements over their ancestors. The search for hardier, more floriferous and attractive forms and the development of techniques that allow the propagator to faithfully reproduce these, represents the history of horticulture.

In the case of Australian plants, we have had a comparatively brief time to collect, select and introduce our flora. However, native plant enthusiasts have brought approximately 3,000 species into cultivation with varying degrees of success. Although some improved forms and hybrids have been selected and introduced to gardens, the demand for native plants, both in terms of quantity and range, has increased so rapidly in recent years that the propagators' emphasis has all too frequently been on mass production rather than further selection.

The message I would like to try and convey is that individually, and as a body, we should strive to improve the quality of stock and to reproduce that stock faithfully for distribution to the home gardener and commercial landscaper. Despite inherent adaptability, many natives are unsuited to the diverse conditions across our continent and many others have a disappointingly short life. I would like to draw attention to what I believe we as propagators should be doing to select and develop more reliable and even more attractive species and cultivars.

There are some steps we can take to produce immediate benefits, and others which must only be the beginning of long term development. Among those steps which will yield immediate benefits, I feel the prime one is the substitution of propagation by vegetative means for many species which are customarily grown by seed. Commercial propagators, in particular, are aware of the variation we sometimes get within batches of some seedlings, and

between batches of seedlings where seed has been purchased at different times or from different sources. We often cannot guarantee the size or form of seedling plants, their flower colour, amount or time of flowering, or suitability for a given set of conditions. The genus *Callistemon* is one example where vegetative propagation of selected forms would be preferable.

At present, we are guilty of offering for sale seed-grown plants that are commonly believed to have a standard set of characteristics, as described on plant labels and in popular garden texts, whereas this is often not the case. *Callistemon citrinus* for example, comes in many colour forms from white to pink, red, and burgundy. The size and form of the shrub, the amount nd time of flowering also varies. We can offer *Callistemon* 'Harkness,' 'Reeves Pink,' 'Mauve Mist' and other cutting-grown forms with confidence. For the same reasons, I believe that we must develop methods of producing some cultivars of eucalypts vegetatively, by cuttings or grafting, on a commercial scale.

The gardener is accustomed to buying for example a rose, azalea, or rhododendron of an exact colour specification whereas if the same customer asks for a red flowering gum, all we can honestly say is, "Here is a *Eucalyptus ficifolia*, which might produce red flowers — but on the other hand, might produce orange, pink, maroon or white flowers."

In our nursery, we are beginning to experiment with rooting eucalyptus cuttings. We removed the very young mallee growth from a 1-year-old *Eucalyptus sideroxylon* which had malleed after being damaged. Of 14 cuttings taken, 9 rooted within 3 weeks. These are now growing vigorously and will eventually be planted and their behaviour in the ground examined.

The advantage of hybridizing to combine the aesthetic qualities of one species with the hardiness of another may be of great significance if the resulting plant could then be mass produced vegetatively on a commercial basis. The further incentive for production of eucalypts by vegetative means lies in the shortage of seed of some species. It is disappointing to find that *Eucalyptus scoparia* and *Eucalyptus nicholli* seed are no longer procurable. It is also disappointing to find that some batches of seedlings are more variable than others - for example, *Eucalyptus nicholli*. Thus, the challenge to produce eucalypts vegetatively is, I believe, an urgent one. We have been relying on big stands of given eucalypts to provide sources of true seed. Because of the tendency for eucalypts to hybridize, and because of the continued destructin of natural stands of timber by man and nature, we cannot take for granted continued supply of true seed. This shortage will be compounded if demand for Australian natives continues to increase even at a lesser rate than we have experienced in recent

years. It will be further compounded by the necessary limits imposed on seed collectors by forestry authorities such as has occurred in the case of *Eucalyptus nicholli.*

The next area in which we have responsibility is in taking cuttings from the best and most vigorous plants of parent stocks that have been selected for their good qualities. When there is a shortage of good cutting material we must resist taking cuttings from poorer stock. In the long term, we must be alert to recognize good forms, hybrids and sports that have some improved features. Also, we should be looking for plants which show a higher resistance to various diseases and infestations. I hope that none of us find for example, *Phytophthora cinnamoni,* amongst our nursery stock, but should we find a plant surviving unexpectedly well in soil known to be infected, then we should endeavour to reproduce that plant vegetatively. Similarly, whenever we see plants thriving in conditions which do not usually suit them, then again we should try to reproduce those plants.

Australian native plants in horticulture, with a few exceptions, are first generation plants. By this I mean that seed or cuttings have been taken directly from bush plants and have continued to be faithfully reproduced. However the history of exotic species and cultivars is one of development over a long period of time. In citrus and soft fruit production, quality of fruit and yield have been greatly improved by selection of both rootstock and scion. The same sort of development has occurred with many deciduous ornamentals. One of our goals must be to find rootstocks for those outstanding native plants which will not themselves readily adapt to garden culture. In this group, I would particularly include some *Banksias, Grevilleas, Prostantheras* and *Boronias.* Some work has already been done in this field but further work is necessary before commercial production is possible.

In Europe, the U.S.A. and other places, the history of horticulture has been one of moving away from the propagation of the plant as it grew in the wild. Through various selection and breeding processes, in some cases coupled with budding and grafting, propagators have, over a long period of time, produced what I would call second generation plants: Second generation in that they are at least one step removed from the original native plant, although they may be many generations removed in time. With this knowledge of what has occurred over the centuries of horticulture in other parts of the world, we must be prepared to embark on similar work with our own indigenous flora.

In summary, Australian flora presents us with some 6,000 to 8,000 species worthy of developing horticulturally. This is our inheritance and is the envy of horticulturalists around the world. We are indebted to the enthusiasts who, in the past and present,

have collected and tried new species for horticulture. As propagators, we should move away from indiscriminate production to selection and breeding of improved forms which are hardy over a range of conditions and have characteristics common to each plant of a particular form.

QUESTIONS

NOEL CHOPPING: Were the eucalyptus cuttings derived from the lignotuber? We are able to root cuttings taken from the lignotuber of *Eucalyptus tycocarpa* up to 8 years old, but not from older trees.

NATALIE PEATE: The *E. sideroxylon* cuttings were not all from the lignotubier. Normal tip cuttings and lignotuber cuttings rooted equally well.

MODERATOR CHURCHILL: You mentioned the tremendous variation in *Callistemon citrinus* grown from seed. Do you find the same variation with seed from the one ecotype?

NATALIE PEATE: As we have been propagating from commercial supplies of seed we cannot be sure that they are all from the same ecotype.

PAUL BUCHNALL: In my experience *Callistemons* grown in isolation breed very true-to-type from seed. *C. citrinus* type hybrids grown from cutting do not have the desired plant shape. It is, therefore, preferable to propagate *Callistemon* from isolated seed parents.

RICHARD MARTYR: Whose job is it to carry out selection and, even more importantly, evaluation of the range of variation in particular plants? One wants to encourage growers to do it themselves but they don't have all the yardsticks for this job. Is it a job for a research station in ornamentals which you do not have as yet, or should it be done in universities or colleges or by growers? In The Netherlands, at Boskoop, they collect all clones propagated in their country and evaluate them. The nurseryman can therefore obtain the best stock from them and propagate it. There is vast potential for this sort of thing in Australia. How is it to be done?

NATALIE PEATE: If nurserymen do it themselves, it will be less satisfactory than if done by a research organisation. I would like to see a research station established, but one where nurserymen can go and make suggestions.

LIGHT IN PROPAGATION

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Lighting for specific results in plant propagation is an infant science awaiting our attention. The aim of this paper is to present a summary of available data together with my own thoughts. It is by no means exhaustive, serving only as an introduction to a fascinating aspect of plant propagation.

Consider these thoughts and their impact: Light — the most powerful environmental force; the omnipotent plant growth regulator; light is energy; light is essential for photosynthesis.

Light effectively regulates the rate and type of plant growth by determining the speed of energy assimilation through photosynthesis. Simply — NO light = NO photosynthesis = NO growth.

Visible light consists of a mixture of red, yellow, green and blue lights covering the range of wavelengths from 350 to 780 nanometers (nm). The two zones of most significance to plants are the blue zone (350-550 nm) and the red zone (550-780 nm). Photosynthesis is influenced by both zones but, in addition, the blue zone influences phototropic reactions; e.g. the growth of plants towards light, and the red and far red zones control flower initiation, seed germination and vegetative growth.

As propagators, we find ourselves faced with a dilemma - striking cuttings in as much light as is possible without incurring damage through excessive exposure. We require maximum levels to reach leaf surfaces for maximum photosynthesis and the production of "energized" cuttings.

Misting systems now permit us to propagate in brighter conditions than was formerly possible by obviating high leaf temperatures. Because of the climatic variations, reliance upon the sun to provide light of constant quality and quantity is uncertain. It seems logical then, to turn to artificial sources during the low light periods.

It is important to grasp the essential distinction between "light quality" and "light quantity." Quality refers to the spectral range emitted, or more specifically, the percentage of light that is absorbable (useable) by plant material. The quantity or brightness describes the concentration per unit area in lumens/square metre.

Both factors demand separate consideration for they are not the same, and are not necessarily related. As noted earlier, the spectral range to which plants respond falls between ca. 400-780 nm. In order to coincide with the peaks of photosynthesis, sources

should have highest output in the 600-700 nm band (orange/red), with lesser percentages in the 700-800 nm (far red) and 400-500 nm (blue) ranges. The type of illumination used should give plants with the same characteristics as those grown under natural daylight.

LIGHT SOURCES

(a) *Solar energy*, as we know it, has inherent limitations, not the least of which is the variable daylength. Nonetheless it is free and the wise propagator strives to capture and utilise all that is available.

(b) *Artificial lighting* enables production of better quality material at times of low light, by increasing growth during the brighter period.

Essentially lighting regulates two aspects of plant growth:

(i) photoperiodism
(ii) photosynthesis

In propagation, photoperiodic manipulation is not usually a consideration, except, perhaps, for out-of-season crops, including poinsettia and chrysanthemum.

The main interest lies in the field of photosynthesis. Here we have three choices:

(i) daylight extension - requiring 5-50 watts/sq metre.
(ii) supplementary (dark day) requiring 50-100 watts/sq metre.
(iii) total source - requiring ca. 500 watts/sq metre.

The advantages of each are obvious. However, the criterion must surely be the cost/benefit to the nursery. The levels required for photosynthesis are some 10 to 100 times greater than those for photoperiodic regulation. It follows that lighting must be done efficiently. Plants have saturation levels above which a protective mechanism prevents further assimilation — thus illumination above these levels is wasted.

The aim is to keep saturation levels for as long as possible. Unfortunately little information exists prescribing optimum levels for different crops. Hopefully a handbook will soon emerge for each commercial crop, listing correct level and spectral content required.

HORTICULTURAL LAMPS

Despite extensive experimentation, the ideal horticultural lamp has not yet emerged. No doubt this reflects the sometimes contradictory responses of plants and the limited demand for such a lamp.

However most literature lists the following factors as important in evaluating the suitability of available types:

(i) efficiency between 400 and 700 nm (i.e. percent input converted to visible radiation).

(ii) qualtity of emission.

(iii) economics (capital outlay, cost benefits, power consumption)

(iv) suitability to existing setup.

Inevitably selection is a compromise between desirable and practicable factors. You must choose.

Currently incandescent (tungsten), fluorescent, and gas discharge (sodium and mercury vapour) lamps are used in nurseries. Of these the fluorescent tube finds greatest favour in propagation. It is readily adapted by coating with various fluorescers to emit specific spectral ranges. It has an acceptable form, and because of low heat output, can be placed close to the cuttings for better illumination. Despite high installation costs, power consumption is low and efficiency is good.

The "Grolux" lamp is a response to the needs of the horticultural industry. Interestingly, the "white" fluorescent group, especially the "warm white" tube, produces light with a high percentage of absorbable light and has a cost advantage over more specialised types. The colour coded types viz. C 29, 32, 33 and 34 are good, C 33 being the best (3).

Incandescent globes have a high far-red content and cause excessive stem elongation and high leaf temperatures. Their main application is in night-break lighting of chrysanthemums, particularly where winter stem growth is inadequate. They are occasionally used to supplement fluorescent lamps.

Both mercury and sodium vapour lamps are used for daylight extension. The high energy levels are suitable for the broad lighting of young plants (and cuttings).

To the propagator light is a tool whose manipulation may well revolutionise our thinking. Already we have learnt flowering control of out-of-season crops. Researchers and plant breeders shorten the time to see the results of their work by up to 50%. Growers light their trees and shrubs to extend the growing season and to keep plants vegetative for extra cutting material. Seedlings are produced to predictable schedules. "Energized" cuttings perform better.

In conclusion a quote adapted from A. E. Canham (2) is appropriate. "The most successful grower is the one who learns to use not only his experience, but also that of others, to persuade plants to grow when climatic conditions are least favourable."

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3. Templing, B. C. & M. A. Verbruggen, 1975. Lighting Technology in Horticulture. Phillips Industries, Eindhoven. The Netherlands.

QUESTIONS

In reply to questions Ross explained that as far as light is concerned, glass as a covering for greenhouses permits maximum passage of light, but it filters out the ultra violet rays. Plants taken from here into direct sunlight can be burnt by the UV. Fibreglass gives better growth because it diffuses the light, but its disadvantage is the deterioration of the surface over the years. Polythene is rather similar but it does collect dust.

EXPERIMENTAL TECHNIQUES USED IN BANKSIA GRAFTING

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Abstract Methods that have been successfully used to graft West Australian *Banksia* to East Australian *Banksia* rootstocks are described. Results of trials carried out at different times of the year using different stock/scion species combinations are given. The behaviour of the different stocks and direction in which further work is proceeding is indicated.

MATERIALS AND METHODS

The approach graft technique as described by Pryor & Willing (2) was used in the early stages of this study.

Razor blades are used in preparing all cuttings; 10 mm P.V.C. budding tape is used to bind the grafts. It is split lengthwise to give a 5 mm width for small diameter grafts. No wax is used. Where possible the graft union is made 4-8 cm above the base of the stock plant with firm green stems 2-5 mm in diameter. Grafts are held in a cold frame during their first winter or until new scion growth has commenced. No artificial heating is used.

Four different grafting techniques have been tried:

1. Approach grafting is carried out using the whip and tongue union. Plants are grown near the rim of individual pots to enable plants to be matched according to the diameter and firmness of the stem. Also, being separate, either plant can be raised to enable union at leaf nodes. Cuts 1, 2 and 3 (Figure 6) are made to produce matching tongues which are held together and bound firmly; 6 to 12 weeks after joining, the top is cut off the stock plant (cut 4) and the bottom is cut off the scion plant (cut 5). If the scion still appears healthy after another week, the tape is removed.
2. Wedge grafting is carried out carefully so that the closest possible match of cambium tissue is achieved. A vee section is removed from the stock which is continued down into a vertical cut to a depth of about 2 cm. Shoulders are cut on the scion to match the top segment shaped sections of the stock (Fig. 2). These help to achieve a closer match of cambium around the entire stem.
3. Grafted-cutting. The wedge grafting technique is used as explained above. The bound stock/scion combination, totalling 15-20 cm in length, is treated as a cutting until roots have been formed. The scion used may involve 1-3 leaf nodes.

4 Budding is carried out using the T-budding technique.

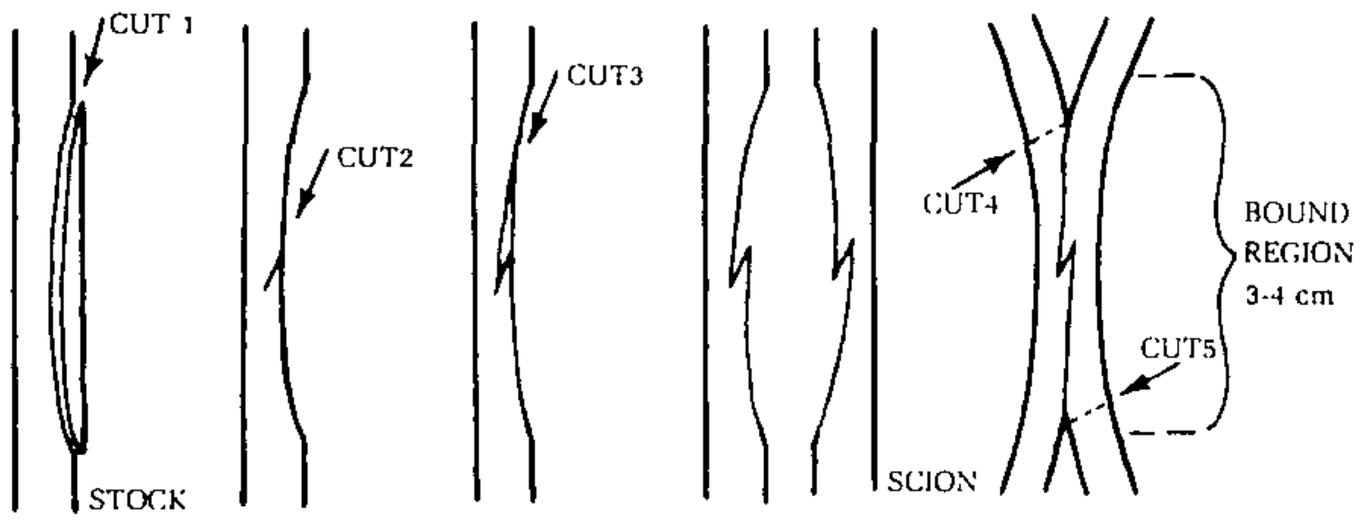

Figure 1. Method of making approach graft.

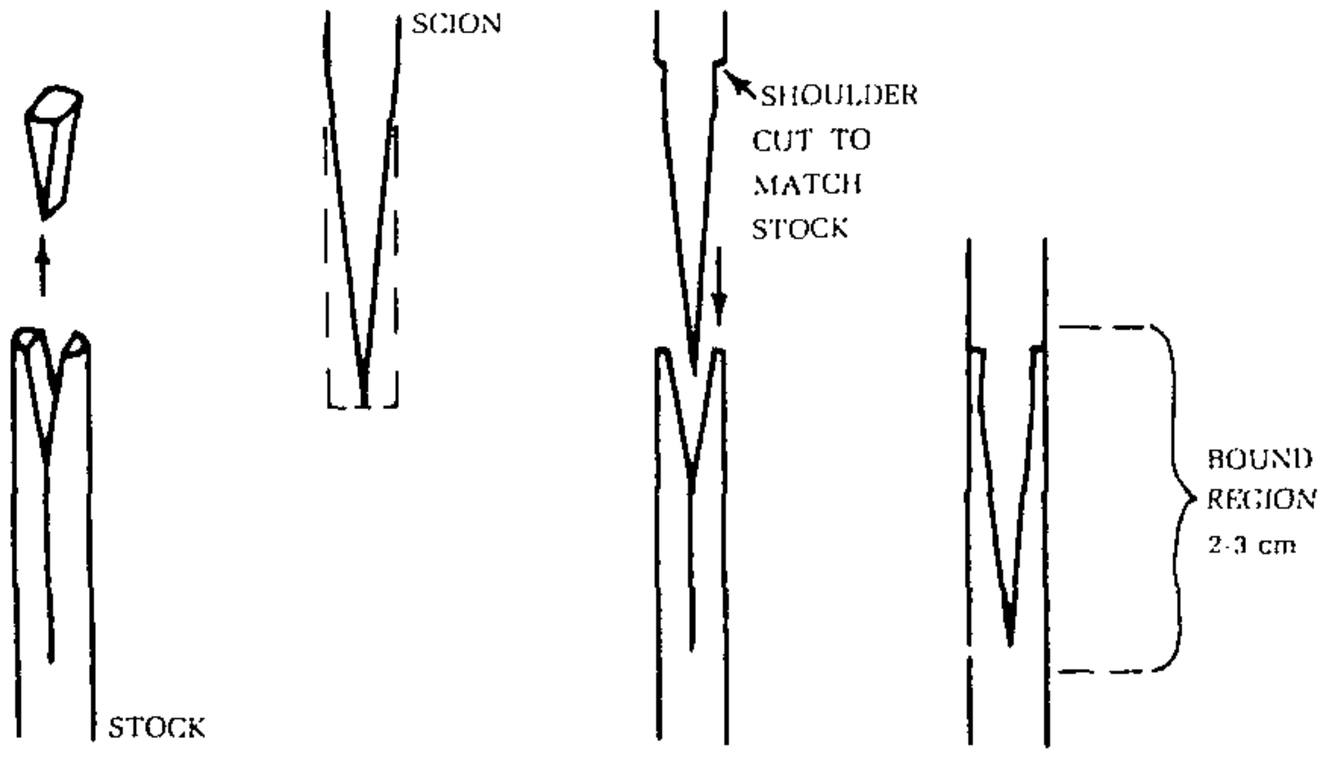

Figure 2. Method of making wedge graft.

RESULTS

Nomenclature follows that of Holliday & Watton (1).

Table 1. Results of approach grafts using as stock: *Banksia ericifolia L.f.*

Scion	Number attempted	Month	Age (Months)	Comments
B. brownii Baxter	1	Nov	2	Scion plant died before cut 5
B. coccinea R. Br.	1	Nov	—	Scion wilted & died within 2 days of cut 5
B. laricina C. A. Gardn.	2	Nov	10	Healthy
		Mar	6	Healthy
B. meisneri Lehm.	1	Mar	2½	Scion died after cut 5
B. nutans R. Br.	1	Oct	23	Healthy
	2	Oct	11	Healthy
B. quercifolia R. Br.	1	Oct	4	Scion died slowly after cut 5
B. sphaerocarpa R. Br.	2	Mar	6	Healthy
		Mar	2½	Scion died slowly after cut 5

Table 1. continued
Results of approach grafts using as stock: *Banksia integrifolia* L.f.

B. ashbyi E. G. Baker	1	Oct	6	Union very good-graft broken by accident
B. coccinea R. Br.	1	Nov	10	Healthy
B. menziesii R. Br.	2	Aug	3	Scion died slowly after cut 5
		Nov	2½	Scion died slowly after cut 5
B. prionotes Lindl.	1	Nov	2	Scion died slowly after cut 5
B. quercifolia R. Br.	1	Oct	4	Died slowly - little callus formed
B. sceptrum Meisn.	1	Oct	1	Scion plant died
B. speciosa R. Br.	1	Oct	23	Healthy - flowered at 18 months

Results of approach grafts using as stock: *Banksia robur* Cav.

B. ashbyi E. G. Baker	1	Feb		Scion died before cut 5
B. brownii Baxter	1	Jan	4	Scion died - new shoots at base of stock
	2	Dec	1	Scion plant died
B. hookerana Meisn.	1	Jan	5	Scion died - new shoots at base of stock
B. lemanniana Meisn.	1	Jan	6	Scion died - new shoots at base of stock
B. menziesii R. Br.	1	Feb		Scion died 1 week after grafting
B. quercifolia R. Br.	1	Mar	3	Scion died after cut 5
B. speciosa R. Br.	1	Jan	2½	Scion died within 3 days of cut 5

Results of approach grafts using as stock: *Banksia serrata* L.f.

Scion	Number attempted	Month	Age (Months)	Comments
B. menziesii R. Br.	2	Mar	—	Scions died within 2 weeks of grafting
	1	Sep	3½	Scion died after cut 5
	1	Jan	—	Scion plant died
B. prionotes Lindl.	2	Mar	2	Scions died after cut 5
	1	Oct	2	Scion died after cut 5 - little callus formed
	1	Nov	10	Healthy
B. sceptrum Meisn.	1	Jan	21	Healthy but stock continues to produce new shoots at base
B. speciosa R. Br.	1	Jan	3	Scion died slowly after cut 5
	1	Feb	2	Scion died slowly after cut 5

Results of approach grafts using as stock: *Banksia spinulosa (cunninghamii)*

B. Ashbyi E. G. Baker	3	Aug	24	Healthy
		Apr	17	Healthy
		Sep	12	Healthy
B. brownii Baxter	1	Dec	33	Healthy, 2m high

Table 1. continued

	6	Jan	—	Scion plant died 3 weeks after grafting
B. burdettii E. G. Baker	1	Aug	14	Whole graft died - soil very dry
B. caleyi R. Br.	1	Sep	12	Healthy
B. coccinea R. Br.	4	Aug, Oct, Nov, Mar	—	All scions began to deteriorate with 3 days of cut 5
B. hookerana Meisn.	1	Jan	1	Scion plant died
B. lemanniana Meisn.	1	Mar	30	Healthy
B. menziesii R. Br.	1	Jan	—	Scion died 2 weeks after grafting
B. nutans R. Br.	1	Mar	8	Died in garden - soil dry
B. occidentalis R. Br.	2	Mar	18	Both healthy
	1	Mar	12	Stock died
B. querifolia R. Br.	1	Apr	5	Stock died
B. sceptrum Meisn.	1	Jan	3	Scion wilted within 1 hour of cut 5 - subsequently died
B. speciosa R. Br.	1	Aug	2½	Scion slowly turned yellow after cut 5 - compatibility doubtful
B. sphaerocarpa R. Br.	1	Sep	3	Scion died after cut 5

Table 2. Results of wedge grafts using as stock: *Banksia asplenifolia* Salisb.

Scion	Number attempted	Month	Age (Months)	Comments
B. brownii Baxter	1	Apr		Tip of scion in graft 1 cm below cotyledon level - stock died in both cases
B. praemorsa Andr.	1	Mar		
Results of wedge grafts using as stock: *Banksia ericifolia* L.f.				
B. brownii Baxter	1	Mar	6	Healthy
B. laricina C. A. Gardn.	1	Mar	6	Healthy
B. nutans R. Br.	1	Mar	6	Healthy
B. occidentalis R. Br.	1	Jan	2	Scion died
B. sphaerocarpa R. Br.	1	Mar	6	Healthy
B. sphaerocarpa var *pinifolia*	1	Mar	6	Healthy
Results of wedge grafts using as stock: *Banksia integrifolia* L.f.				
B. baueri R. Br.	1	Mar	6	Healthy
B. brownii Baxter	1	Mar	6	Healthy
B. laevigata Meisn. ssp *laevigata*	1	Mar	6	Healthy
B. media R. Br.	1	Mar	6	Healthy
B. meisneri Lehm.	1	Aug	2	Scion died
B. pilostylis C. A. Gardn.	1	Mar	6	Healthy
B. praemorsa Andr.	1	Mar	6	Healthy
B. sceptrum Meisn.	1	Mar	6	Healthy
B. speciosa R. Br.	1	Jan	6	Scion died - stock tended to come away from scion - possibly tape removed too soon

Table 2. continued

B. verticillata R. Br.	1	Mar	6	Healthy
Results of wedge grafts using as stock: *Banksia marginata* Cav.				
B. brownii Baxter	1	Jan	9	Healthy
	2	Mar	6	Healthy
B. praemorsa Andr.	1	Mar	6	Healthy
Results of wedge grafts using as stock: *Banksia robur* Cav.				
B. brownii Baxter	1	Apr	1½	Tip of scion 1 cm below cotyledons - stock died
B. lemanniana Meisn.	1	Mar	3	Scion died
Results of wedge grafts using as stock: *Banksia spinulosa (cunninghammii)*				
B. ashbyi E. G. Baker	1	Nov	2	Scion died
	2	Mar	6	Healthy
B. browniiBaxter	11	Dec, Jan	8	5 healthy - scion died on 4 - stock died on 2
B. lemanniana Meisn.	5	Dec, Jan, Mar		Scion died in each case after 3-4 months
B. meisneri Lehm.	1	Aug	1	Scion died

Table 3. Results of grafted-cutting trials using as stock: *Banksia spinulosa (B. cunninghamii)*

Scion	Number Attempted	Month	Age (Months)	Comments
B. brownii Baxter	3	Nov	—	Scions died
	2	Mar	6	Healthy
B. occidentalis R. Br.	1	Mar	6	Healthy
B. lemanniana Meisn.	1	Nov	—	Scion died
	1	Mar	—	Scion died
Results of grafted-cutting trial using as stock: *Banksia ericifolia* L.f.				
B. nutans R. Br.	1	Mar	6	Healthy

Table 4. Results of T-budding trial using as stock: *Banksia spinulosa (B. cunninghamii)*

Bud	Number attempted	Month	Age (Months)	Comments
B. brownii Baxter	4	Mar	6	All healthy

DISCUSSION

Trials to date have been restricted to times of the year when outdoor growth conditions, and therefore cambial activity, are optimal in Melbourne, Victoria. The overall results indicate clearly that West Australian *Banksia* can be grafted to East Australian *Banksia* rootstocks by the techniques used.

The approach graft technique used has not proved completely reliable (Table 1). Failures and successes occurred between the same species combinations, although most of the failures were

possibly due to unfavourable weather (i.e. five consecutive days over 33°C in January, 1974).

No success has been achieved to date in grafting *B. menziesii*. The wedge grafting technique is much more productive and economical, and has proved most successful, particularly with species combinations that were successful in approach grafting. The results of *B. brownii* on *B. spinulosa* grafts (Table 2) may indicate the need for the establishment of compatible clones to achieve more reliable grafting.

Wedge grafts were attempted partly below the cotyledon level on the stock (Table 2) in an endeavour to overcome the problem of shoot formation from the lignotuber. However, this resulted in death of the stock within two weeks. The success of the grafted-cutting trials (Table 3) should, following development of suitable clones, prove to be adaptable to commercial use. Such clones are currently being established.

The success of T-budding (Table 4) may also be of commercial interest.

B. ericifolia promises to be a suitable rootstock for *B. nutans*, *B. laricina* and the *B. sphaerocarpa* group. It may also be suitable for *B. brownii*, although producing a less vigorous product than other stocks. The tendency to form a large callus at the graft union is not as great as that in *B. integrifolia* and *B. spinulosa*.

B. integrifolia, *B. marginata* and *B. spinulosa* all promise to be useful stocks with little tendency to shoot below the union. *B. brownii* has grafted readily to all three, being most vigorous on *B. marginata*.

B. robur appeared suitable as a rootstock for *B. brownii*, *B. hookerana* and *B. lemanniana*. However, shoots were continually produced from the lignotuber, despite regular removal, and the scions slowly dehydrated and died. This problem should not arise if cutting-grown plants, of species that develop lignotubers, are used as stocks instead of seedlings. Further trials are being carried out using cutting-grown plants as stocks.

LITERATURE CITED

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2. Pryor L. D. and R. R. Willing 1963. The red flowering gum. *Australian Plants* 2:35-37.

QUESTIONS

In response to questions Colin stated that he had not specifically tested the practice of chilling scion material as an aid in grafting but that he had collected material from a distance and stored it cold for up to three days before making successful grafts. Ian Tolley pointed out that incompatible lines can become compatible if the height of the union is varied.

RAISING RADIATA PINE AND EUCALYPT SEEDLINGS BY AN INDUSTRIAL FORESTRY COMPANY IN GIPPSLAND, VICTORIA

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Australian Paper Manufacturers Limited requires both pine and eucalypt for pulp production. The eucalypt pulpwood mainly comes from forest residues following sawlog extraction and from sawmill chips obtained from natural stands in State Forests while pine pulpwood is obtained from Company plantations on a continuing basis of thinning, clear cutting and replanting.

We have been actively engaged in the reforestation of abandoned farmland in Gippsland since 1950. During this 25 year period, 41,000 ha. have been established, requiring some 75 million pine seedlings and 7½ million eucalyptus seedlings.

The two main species used for this programme have been *Pinus radiata* (D. Don) on the marginal or low rainfall sites, and *Eucalyptus regnans* (F. Muell.) in the Strzelecki Ranges where rainfall is higher. Planting sites are prepared at considerable cost so it is imperative that the site be fully utilized with high quality seedling stock.

To ensure successful establishment, a high seedling survival in the field is necessary together with a vigorous early growth. Seedlings must have specific qualities to withstand adverse conditions in the field. They must have a woody stem, hardened-off foliage, a fibrous root system in balance with the stock, and have an acceptable level of mycorrhizal infection.

Pine seedlings are raised in a Company nursery, situated at Longford (near Sale) and the eucalyptus seedlings at Traralgon, Victoria.

This paper deals with the basic procedures and material requirements of the nursery programmes from seed origin through to the end seedling product ready for field planting.

RADIATA PINE

Seed Origin. Seedlings for the Company's earliest pine establishment areas were raised from seed purchased mainly from New Zealand and South Australia. This seed source continued until the Company's plantations began producing a cone crop. During this time a tree breeding programme was started and seed orchards established (2).

A.P.M. Forests Proprietary Limited, together with C.S.I.R.O.

Division of Forest Research (formerly Forestry Research Institute) have been involved in a co-operative tree breeding programme since 1958. The aim of the tree breeding programme is to improve wood production per hectare based on form, branch characteristics, and wood quality of all parent trees; their progeny is evaluated for health, vigor and wood properties. Initially the clonal material for grafting onto seedling stock was imported from New Zealand and many areas in Australia after intense selection by Forestry Departments for superior or "plus" trees. More recently, assessment of progeny from locally selected "plus" trees indicates the importance of their adjustment to the Gippsland environment. The scions are grafted onto healthy seedling stock and planted at wide spacing in areas free of outside pollen contamination to form seed orchards. Seed from these orchards is presently used in the pine nursery, and seedlings have been raised from this source since 1968. The seed orchards are being constantly upgraded by the introduction of new genetic material. The Company places extreme importance on seed origin and its potential for improvement.

Cone Collection and Seed Extraction. Cones are harvested from the seed orchards during the early summer period each year. Seed is extracted from cones by thermostatically controlled hot air from an oil-fired unit passing through a mesh drum. The drum is rotated intermittently to free the seed which drops through the mesh onto a conveyor belt. This seed is de-winged, cleaned and graded into three size classes. It is checked for moisture content (maximum allowable 8 percent), packed in plastic drums and stored at 4^0 C for until required.

Seed preparation - Stratification. Seed is soaked in water in the plastic storage containers for 12 hours. All surplus water is then drained off and the drums are returned to 4^0 C for 28 days before sowing. Stratified seed gives a more rapid and even emergence and a higher germination percentage than does unstratified seed.

Soil preparation. The Longford nursery soil is a relatively fine sand with a pH of about 5.5. Clay content and humus are both low. Humus is increased by cultivating in a 5 cm layer of pulverised pine bark (to which nitrogen has been added to give the correct carbon-nitrogen ratio). This is not a routine operation having only been done twice in six years. The maximum benefit to seedlings was evident two years after application. Soil preparation for the new crop begins immediately after the previous seedling crop has been lifted (usually in mid-winter). The total nursery area is rake harrowed to level the site and to harvest any surface weeds.

Fertilizer. Fertilizer requirements are determined from chemical analysis of seedlings from the previous crop. If the previous crop was healthy and showed no major deficiencies, then the same fertilizer regime is applied for the new crop. Initial fertilizer application to the current nursery was 560 kg per ha of superphosphate with copper and zinc added at 1% each.

Sowing. In mid-September (early spring) the nursery area is rotary hoed and beds 1.8 m wide and 15 cm high are formed. The seed is removed from the refrigerator on the day of sowing and surface dried on hessian sheets to facilitate sowing. It is essential that the period of time between drying and sowing be kept to a minimum. Stratified seed is planted into 10 evenly spaced rows 15 cm apart with a Connor Shea combination seed sower, fitted with an adjustable roller at the front for bed compaction should the beds be too fluffy. Loose trailing "crowders" cover the seed, which is sown to a depth of 1.3 c.m.

The crop of 6 to 8 million seedlings usually takes a four-man crew two days to form beds and sow. The sowing rate is based on cabinet germination figures and the aim is 38 germinates per m for a potential recovery of 22 plantable seedlings per m.

Weed Control. Pre-emergent weedicides are applied by boom spray immediately after sowing is complete. Common summer grass (*Digitara sanguinalis*) has recently become a major problem and Tok E (Nitrofen) is being used to combat this. A rate of 4.5 kg ai per ha was applied immediately after sowing and will be repeated at regular intervals of six weeks. Tok E can be applied over developing seedlings without damage.

Propazine is applied at 0.8 kg per ha to control all other annual weeds but a second application may be necessary three months later. Persistent weeds can be controlled by spraying White Spirit (a petroleum distillate) through jets set close to the soil between seedling rows. Some hand weeding is necessary to check sorrel *(Rumex acetosella).*

Maintenance. An application of Pivot 400 fertilizer at 168 kg per hectare is applied through the Connor Shea combine six weeks after sowing or earlier should seedling development indicate. Later any slower developing areas will receive a further application. Added growth is induced when necessary by the application of "Aquasol" foliar fertilizer through a liquid fertilizer spreader.

The pine seedlings which should be plantable size by late summer (February), are then subject to regular root pruning to encourage a fibrous root system and to check further top growth. A secondary benefit is an increase in the mycorrhizal infection of the roots. Root pruning is initiated by undercutting 10 cm below the surface with a reciprocating blade. This is repeated four times

before lifting but each undercut is fractionally lower than the previous one.

Roots are vertically pruned along the rows by a set of coulter wheels fixed in front of a wheel tractor with the cutting wheels running in the centre of the row spacing. This lateral pruning is done twice during the nursery season. If seedlings become too tall, they can be topped with battery powered cutters, but this practice is avoided where possible. Wind is a constant problem at the Longford nursery as it lifts sand from the surface and virtually "sand blasts" the seedlings on the windward side. This can be overcome by applying clay slurry through the fertilizer spreader to seal the soil surface. Normal watering reduces the effect of the seal so the clay slurry may have to be applied several times whilst seedlings are small.

Lifting. Lifting of the seedlings begins after the first substantial rains (usually May). An angled blade equal to the width of the bed is passed under the seedlings at a depth of 15 cm. This action loosens the soil without altering the vertical position of the seedlings which suffer minimal root damage when lifted from the bed. Seedlings are lifted by hand, the roots are puddled in thick clay slurry, and are then heeled back into the soil until required for planting. The rate per man day is 25,000 which includes bypassing or culling out reject stock. As seed is graded and sown separately, the occurrence of suppressed individuals is reduced to a minimum. Culled seedlings are mainly double leaders, malformed or diseased.

The majority of seedlings are carried to planting sites in open tip trucks covered with tarpaulins to avoid wind dessication. Randomly selected despatches are followed to the field by nursery staff to assist in determining whether any future losses were the result of incorrect field handling or could be traced to any one nursery practice.

EUCALYPTUS REGNANS

From 1953 to 1960, we experimented with various species of Eucalypts for establishment both in the foothill forests and in the Strzelecki Ranges with mountain ash *(E. regnans F. Muell.)*. In 1960 it was decided to concentrate on planting mountain ash on abandoned and derelict farms on deep mountain soil as this species showed high volume production (1).

The annual seedling requirements can vary but the number raised is usually between 800,000 and 1,200,000. Approximately 80 percent of the crop is *Eucalyptus regnans;* the remainder consists of *E. globulus, E. viminalis* and *E. robusta* some of which are reserved for amenity and environmental planting and outside sales.

All seedling stock in the Traralgon nursery is raised in peat pots (Jiffy pot No. 517) (3).

Seed Origin. It is believed that seed of *Eucalyptus regnans* harvested locally and planted back on the same site performs better than seed from non-local provenances. Local seed harvested from dominant trees is now used whenever possible.

In 1969, a tree improvement programme was started with *E. regnans* based on seed from local open-pollinated mother trees (4). These dominant mother trees were selected from even-aged, naturally regenerated stands arising from the 1939 and 1945 bush fires in the Strzeleckis. Seed was obtained from selected trees by shooting down limbs bearing capsules with a high-powered 0.222 sports rifle.

Seedlings from this seed were planted in family groups at 6 m centres to form seed orchards. Seedlings were also planted back on site in progeny trials so that differences between families could be assessed. Families which perform poorly will be culled from the seed orchards and progeny from the "better" families will later form the basis of improved seed orchards. It is anticipated that eventually all *Eucalyptus regnans* nurseries will be sown with improved seed.

Preparation and Sowing. Peat pots are placed into black plastic trays and set out on 2 m wide beds of metal aggregate. Paths between beds are 60 cm wide and alternate paths carry a water line for the sprinkler system.

Fine granulated MagAmp is broadcast into empty pots at the rate of 170 gm per 1000 pots. Pots are then filled en masse by hand with a fine grained sand which does not require sifting or sterilizing. The sand is then levelled to the top of the pot and lightly watered. This consolidates the sand slightly and the pots are retopped and levelled ready for sowing.

Seed Treatment. *Eucalyptus regnans* requires stratification to break seed dormancy. Dry seed is placed in fine muslin bags and soaked in water for 12 hours. Excess water is drained off and seed is stored in closed plastic containers at 4^{0}C for 28 days.

Sowing. The sand-filled pots are watered lightly once more and the stratified seed (mixed 100 parts sand to 1 of seed) is broadcast over the pots. Nursery germination is usually about 80 percent of cabinet germination and the sowing rate is adjusted to achieve 3.0 to 3.4 germinates per pot. The seeded area is watered immediately then lightly covered with fine peat moss which is, in turn, watered lightly to complete the sowing programme. The nursery is sown in mid-summer over a two day period. Germination begins approximately 14 days after sowing and should be completed within a further 7 days. Germination, vigour and stems

per pot are determined by assessing small plots located in the nursery prior to sowing.

Maintenance. To lessen the dangers of losses through fungal development, the beds receive a weekly application of Difolitan until germinated seedlings reach the developed cotyledon stage, then Benlate (benomyl) is applied at regular intervals. The MagAmp applied in the base of the pots supplies the seedlings' basic nutrient requirements but "Aquasol" is applied fortnightly through the watering system after the second set of primary leaves are formed. Any small areas of retarded seedlings receive a light application of urea chips to bring them forward. One seedling per pot is desirable for field planting and all pots are thinned back to one seedling by removing surplus germinates and leaving one good seedling near the centre of the pot. This operation is done in the early post cotyledon stage.

Weed Control. The sand medium used is relatively free of weed seed but some weeds do result from wind-blown seed.

Watering. The pots require frequent light waterings because of the large surface area, shallow depth and the sand medium used. Water is delivered through butterfly sprinklers set 6 m apart on a 5 cm aluminium pipe.

Transportation. At planting time in May to June, the seedlings have reached and maintained a height of 20 to 25 cm and have become hardened off due to the colder autumn temperature and reduced nursery feeding.

Seedlings are transported to the planting site in a truck fitted with multiple decks to carry a total of 12,000 pots. The black plastic trays are used in the field as seedling carriers then returned empty to the nursery. The nursery staff endeavours to follow seedlings to the field to ensure that they receive correct handling and finally to assess seedling performance.

Acknowledgments. The material presented in this paper has been made possible by the unified effort over many years within A.P.M. Forests Proprietary Limited. Special appreciation is offered to Mr. M. J. Hall and Mr. R. N. Cromer for their guidance and assistance in technical matters. Permission to publish this paper by the General Manager of A.P.M. Forests Proprietary Limited is acknowledged.

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ADVANCES IN PLANT HORMONES

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Research and development activities involving plant hormones contribute significantly to the information explosion. This seems to be especially true of horticultural crops where even minor manipulations of the natural sequence of growth and development produce substantial benefits either aesthetically or commercially.

Sifting through the rubble of this explosion of information, one can observe some pattern emerging to indicate that mans' knowledge (i.e. organized information) and mans' wisdom (i.e. his use of that knowledge) are making slow but steady progress. Plant physiologists classify the active agents into: (a) auxins, (b) gibberellins, (c) cytokinins, (d) inhibitors, and (e) ethylene.

In terms of their application to agricultural production, Weaver devotes separate chapters to: (a) rooting and propagation, (b) dormancy, (c) flowering, (d) fruit set and development, (e) senescence (f) abscission, (g) size control and related phenomena, and (h) weed control. Clearly the matrix of the five chemical agents, alone or in combination, on the eight plant growth phenomena, provide a complex system even within the one plant species, not to mention the multitude of species with which we are concerned in commercial crop production. The first lesson we learn is that what works admirably in one situation may not work at all or may even give the opposite response in another plant or crop situation.

In the face of increasing demands for accountability in the use of resources, including the resource of scientific manpower, it is well to consider attitudes that may develop in regard to the end-uses to which plant hormones are directed.

Herbicides, once universally acclaimed as the saviour in man's fight to produce more food, have lost some respectability in the hands of military strategists or with amateur enthusiasts in urban and fringe-urban environments.

In plant propagation, simple compounds in small doses have been a boon to nurserymen, but the volume of trade in these products suggests that the cost of continued research and development must be borne by the user of the product, not the manufacturer or supplier.

Chemicals used to regulate flowering, fruit set, growth, de-

velopment and form must continue to be regarded as short term answers to problems that must be resolved, ultimately, by genetic means. Plant breeders need time to develop crops of the stature, timeliness, productiveness and with the product quality that the market demands. In perennial crops, where this time span is long, we can expect growth substances to be used extensively to remedy deficiencies in the existing genotypes. In these crops, control of vegetative growth, initiation of flowering, control of fruit size and fruit development are still the areas offering most potential for the use of growth regulating sprays. In some cases, the end results are blatantly cosmetic; degreening of citrus, colour promotion in tomatoes, shape of apples. In other cases these chemicals are being used as corrective therapeutants, to induce tolerance to aerial pollutants, salt and other contaminants of water and the soil. In the public eye, these uses are the least easy to justify.

Controlling the time of ripening or the time of abscission of leaf, fruit or buds, would seem to be of lasting significance to agriculture, and especially horticulture. It seems unlikely that these phenomena can be controlled genetically with the degree of precision required by nurserymen, orchardists or farmers having to programme crops for machine processing. The recent phenomenal interest in the use of ethylene-releasing sprays attests to this need.

Control of senescence by chemicals appeals to the producer of non-edible (ornamental) crops, but because of the hitherto association between senescence inhibitors and cell-division factors, it has remained largely of academic interest in food crops. Control of the thermal and gaseous environments (controlled atmospheres and cool storage) proves to be a more acceptable alternative.

When the dust settles, what can we expect to see as the permanent gain from the explosion of published information on plant hormones? I think they will be these:

(1) An appreciation of herbicides as no more than a strategic weapon in the fight for crop protection.

(2) The small, but continuing use of chemicals for the propagation of tissues, cells and cuttings; also for the induction of and the release from dormancy of storage bulbs, buds, etc.

(3) The production by plant breeders of cultivars having attributes already proven to be advantageous. In this respect, growth regulating substances permit the manipulation of existing cultivars in a way that allows their evaluation by the market in advance of their permanent introduction.

(4) Chemical control of ripening and abscission in those industries where precision in programming is an essential element of production.

(5) Increased use of environmental control rather than chemical treatment to inhibit senescence of crop produce.

(6) Some use of plant hormones as plant cosmetics and as remedial therapeutants in adverse or polluted environments. Not all communities will be able or agreeable to afford this luxury.

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TISSUE CULTURE IN PLANT RESEARCH AND THE ORNAMENTALS INDUSTRY

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In recent years plant tissue culture has experienced a boom period both in research and commerce. Research workers around the world continue to find new applications of the technique with the result that some areas of research have progressed rapidly. Industry in turn has been quick to adopt tissue culture techniques where improved production can be realised.

In this paper some of the more recent advances will be discussed. Also, because enquiries have been received from growers interested in using tissue culture in their own operation, some basic requirements for starting such work will be outlined.

When we talk of plant tissue culture we are usually referring to any kind of plant tissue growing on a sterile nutrient solution under aseptic conditions.

Depending on the aim of the exercise, the growing tissue may subsequently differentiate into recognisable plant organs such as roots, shoots, petioles and leaves, or it may continue to produce a mass of undifferentiated callus tissue.

Usually the type of growth can be determined by changing the balance of hormones in the nutrient solution as shown by Earle and Langhans (2) in their work on the propagation of chrysanthemums *in vitro*.

A wide range of plant material has now been grown in culture. Ornamental plants include carnations, chrysanthemums, gerberas, geraniums, freesias, irises and lilies. However, each plant species has particular nutrient requirements and much time is often spent trying different nutrient combinations to achieve good growth of the cultures.

One aspect of this work which may have important implications for the future concerns the use of tissue cultures as a food source (3). Given the right conditions the growth in culture of plant cells of food crops may be extremely rapid and weight gains have surpassed those of field or container-grown plants.

With such a system operating, nutrients could be fed in at one end, and vitamin rich plant material harvested at the other.

Such studies are in their infancy. However, already good growth has been achieved with tissue cultures of bean, cucumber, endive, parsley, lettuce, spinach and potato tuber.

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Several important medical applications of plant tissue culture were recently outlined by Kehr (4) of the US Department of Agriculture. He referred to the production of insulin which has proven difficult to manufacture artificially. Up to the present it has been obtained from animal sources. However, recent work indicates that it can be conveniently obtained from tissue cultives of *Momortica charantia* and as a result this source may be of considerable future importance. Other substances which can be produced in this way include cardiac glycosides, the reported anticancer drug "camptothecin" and a wide range of alkaloids. Medical industries are quick to adopt and develop such methods of producing drugs.

It is interesting to note that tissue cultures to date have been mostly of herbaceous plants. By contrast few successful tissue cultures from woody plants have been made. Their requirements seem to be more complex and it has proven more difficult for healthy callus growth to be initiated and sustained. Widely divergent parts of many plants can be grown in culture. Healthy callus growth has been obtained from leaves, stems, shoots and roots as well as various storage organs such as carrot and potato tubers (1).

This phenomenon may be an extension of wound tissue formation. In response to localised damage, some differentiated cells may recommence dividing to form wound tissue.

Furthermore, each new cell thus formed seems to have genetic coding and physiological flexibility necessary to recreate a plant similar to the parent. This has been shown by Vasil and Hildebrandt (9) who produced tobacco plants from a single tobacco cell in microculture in fresh nutrient solution. In studies such as these single living cells are suspended in a drop of nutrient solution in a special glass slide.

In this way they can be examined with the aid of a good microscope and changes which occur in the cell can be noted.

TISSUE CULTURE IN PLANT DISEASE STUDIES

Techniques of this kind have proven particularly valuable in studying the interaction of some disease organisms with plant cells. Where the invading organism exists within living plant cells and a delicate balance exists between the two; this interaction is difficult to study using other methods. Typical diseases which may conveniently be studied this way are those caused by viruses, mycoplasmas and obligate fungal pathogens such as *Plasmodiophora brassicae*. This organism causes the "club root" disease in a range of cruciferous plants (10). These diseases represent the situation where the invaded plant cells sustain the growth of the pathogen as well as carrying out their normal function.

Often, particularly where cells are infected with viruses, crystal-like inclusion bodies can be seen within the cells. Using single cell techniques these can be closely observed (7).

In studies using sugar cane, plants were grown from single cells. From one cultivar, plants were produced with characteristics differing from those of the parent. This could indicate the presence of different cell clones within the parent and hence the possibility of selecting superior strains. However, an alternative possibility which must not be discounted is that genetic aberrations may have occurred early in the growth of some cultures, giving rise to the non-uniform types.

TISSUE CULTURE FOR THE RAPID MULTIPLICATION OF PLANTS

The use of tissue culture for the rapid propagation of some ornamental plants is already being used widely by some sections of the horticultural industry. In recent years much progress has been made, particularly with some plants notoriously slow to multiply vegetatively.

It should be emphasised that the tissue culture process is relatively complex and specialised facilities are required, some of which will be referred to later. Therefore, the technique is generally considered only when simpler methods of propagation have proven unsatisfactory.

The propagation of orchids is a noteworthy example where alternatives were not available. Using the conventional back bulb division it could take 10 years to get a dozen or so good sized divisions. Morel (5) in France found that orchids could be multiplied indefinitely by growing corm pieces in nutrient tubes and continually sectioning them. Each new piece became what he called a "protocorm" which could be sectioned further.

When sufficient plantlets were obtained they were allowed to develop without further sectioning until they could be transferred to a suitable orchid potting medium where growth continued to maturity.

In 1968 a similar technique was described for the rapid vegetative propagation of asparagus (8). Asparagus, which is generally propagated through seeds, shows extreme variability in the yielding ability of individual plants.

To avoid this variability, attempts were made to propagate by segmenting established and selected crowns. However the practice is very slow and commercially not feasible. It was found that actively growing spears could be cut into sections, surface sterilised, and grown on a nutrient medium. In the dark, such sections produced a mass of callus tissue at the base. The callus tissue was then divided and placed into separate flasks containing a modified nut-

rient medium. These cultures were grown under fluorescent lights. After about one month shoots and roots had developed to the stage where planting out was possible.

The process, therefore, consisted of three main stages:

1. The induction of callus from freshly excised spear sections
2. The initiation of plantlets from the callus
3. The further development of plantlets into plants of transplantable size.

For the three steps, the basic nutrient was the same. However, the growth factor supplement and light intensity was varied. Before transplanting it was found very important to "harden" plants off with an acclimatisation process, otherwise serious losses occurred. Hardening was achieved by opening the culture in the greenhouse. It was also necessary to flush with a dilute Hoagland's solution to avoid contamination. Using this technique, numerous plants similar to the parent in vigour and productivity, were obtained. In later work with asparagus up to 62% of cultures developed roots and shoots within three months.

Tissue culture has also been used for the rapid propagation of the gerbera. This is a flower of increasing economic importance. However, as with asparagus, propagation by seed results in seedlings which are not uniform due to the heterozygous nature of the plant. Vegetative propagation by division is too slow to be commercially practical.

In some recent work (6), a method appropriate for commercial application was described for the rapid propagation of gerberas. It was found that, on suitable nutrients, gerbera shoot tips produced numerous miniature divisions which could be separated and recultured. Gerbera shoot tips seem difficult to decontaminate. However, about 20% of the cultures were not contaminated and this was sufficient to start the propagation process.

The examples just given of rapid propagation of orchids, asparagus and gerberas, serve to illustrate typical situations where tissue culture has had or will have a major impact. It should be noted that, as well as avoiding problems of seedling variability and slow propagation rates, the technique has incidental advantages in that fungal and bacterial pathogens are generally absent. For these reasons, use of plant tissue culture for plant propagation in the coming years is likely to be extensive.

MERISTEM (SHOOT-TIP) CULTURE FOR THE PRODUCTION OF PATHOGEN-TESTED PLANTS

To obtain plants free of detectable diseases, several methods are available. Usually meristem culture is only used when simple methods do not work well.

Plants propagated by seed are usually virus-free, even though the parent plant may be infected with several viruses. However, the method is often unsatisfactory because of seedling variability previously mentioned.

A second alternative exists where crops are not wholly infected. Local tulip crops represent such a case where plants free of tulip-breaking virus can be found in many crops.

By careful selection and testing, healthy plants can be isolated and used as a source of clean propagation material. It is important that selected plants are maintained in an environment where deterioration will not occur. Since many plant viruses are spread by aphids, insect proof cages are an important aspect of this approach. Unfortunately plants free of diseases cannot always be obtained using methods such as these. For this reason, the discovery, some years ago, that meristem culture could be used to produce plants apparently free of diseases, was received with great interest.

Since that time much progress has been made with the result that crops such as carnations, chrysanthemums, potatoes and several others, can now be obtained free of diseases.

Meristem culture is a particular type of tissue culture. It involves dissecting out the growing tip or meristem from a bud. Because meristems are small (about 0.2-0.4 mm) this work must be done with the aid of a good dissecting microscope. After removal from the bud the growing tip is transferred to a tube containing sterilised nutrient solution. Provided the correct nutrient solution is used and that light and other factors are in proper balance, the meristem continues to grow and differentiate until a small plant is formed. The work is done under aseptic conditions to prevent contamination from bacteria and fungi.

The reasons are not well understood why, using this technique, plants can be produced free of diseases. It seems that virus multiplication is inhibited where plant cells divide rapidly such as the meristematic regions of buds. Furthermore, the cut which removes the meristem causes wounding at its base, thus stimulating more cell division to occur.

It is important to realise that only a proportion of plants produced in this way are free of virus diseases. Therefore, testing meristemmed plants for residual diseases is a vital part of the technique.

Our work with carnations indicated that viruses are eliminated more efficiently if, before meristems are cut, the plants are heat treated. Heat treatment at 37.5^{0}C (100^{0}F) for periods in excess of 4 weeks seemed to result in more vigorous growth of meristems, less contamination and a higher proportion of virus free plants.

REQUIREMENTS FOR TISSUE CULTURE WORK

A number of commercial organisations, in particular those concerned with the propagation of orchids, have been quick to utilise tissue culture to increase production.

Some of the facilities and equipment needed for such an operation are included in the following:

1. A clean, draught-free room or laboratory for contamination-free work.
2. Chemicals and an accurate balance for the preparation of nutrient solutions.
3. Facilities for sterilizing nutrient solutions. Steam-operated autoclaves are suitable for this purpose. A pressure cooker can be used for small amounts.
4. Glassware for use in preparing and storing nutrient solutions and for holding tissue cultures. Suitable caps are necessary to preevent contamination and drying out of the cultures.
5. A variety of dissection instruments.
6. Both light and dark areas with temperature control, where cultures can be held during growth.

Using facilities and equipment such as those referred to, and with an appreciation of aseptic handling of cultures, most commercial propagators could use tissue culture for the rapid propagation of some plants.

However, to extend the technique to the commercial production of virus-free plants by meristem culture is not so easy. Firstly, a good binocular microscope is essential so that meristems can be excised from buds with minimal damage. Secondly, a hot box may be necessary to heat-treat parent plants before taking meristems. Finally, because testing of plants following meristem cultures, is essential, methods to identify infected plants must be available.

Virus tests can often be done using "indicator plants." In these tests, sap from plants to be tested, is wiped onto the leaves of sensitive indicator plants in the presence of an abrasive.

If viruses are present in the sap, the indicator plants may react with characteristic leaf symptoms after 6-10 days.

Access to an electron microscope may be a great advantage, enabling tests for some viruses to be completed in minutes. Unfortunately, most propagators do not have access to equipment such as this. For these reasons, it seems likely that the production of virus-tested stock will continue to be done at suitably equipped research institutes such as the Victorian Plant Research Institute, at least for the foreseeable future.

CONCLUSIONS

In conclusion I foresee that interest in plant tissue culture will continue to grow. As a tool, aiding research, its role is already well established. In the future, application of the techniques will widen, enabling progress to be made in many areas of research previously neglected.

As a production method for elite planting stock, it will mean improved yields and more reliable and consistent production for some crops.

As a means of obtaining disease-free plants, the technique has already had major successes and for many crops seriously affected by virus diseases the technique represents a light at the end of the tunnel.

The story of plant tissue culture even at this early stage is one where great progress has been made largely through the cooperative efforts of industry and research organisations around the world.

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QUESTIONS

In reply to questions it was stated that they believe they now have two virus-free clones of daphne. These are from selection, not tissue culture. They have been tested for 10 known daphne viruses and are now being multiplied. Seedling

daphne have not been tested for virus but they are probably free of it. It was emphasised that freedom from virus does not guarantee that they will not become infected. The aim is to inform growers of the ways that virus is spread so that they can then reduce this spread.

PROPAGATION AND CULTURE OF AFRICAN VIOLETS

HENRY C. JACKSON

East Malvern "Idaho" Nurseries
East Malvern, Victoria

African violets are fast becoming a favourite house plant in Australia. I have been growing them at "Idaho" Nurseries since 1957. The only cultivars that were available at that time were a single blue named "Blue Boy," a single pink (unnamed) and a double pink called "Bud's Pink Waltz." I grew these cultivars until 1961. Then the late Dr. Sydney Crawcour went to America and contacted several growers. On his return I started to import named cultivars and over the next few years I imported some 300 cultivars.

Propagation. African violets can be propagated by three methods, i.e. seed, division, and leaf cuttings. The quickest and most successful way to reproduce named cultivars is by leaf cutting. If you are growing named cultivars much time can be saved when making up orders by arranging them in alphabetical order, starting with propagation and following on into potting. By this method several dozen plants can be picked out in a short time.

Leaf cuttings are taken all year round from stock plants that are healthy and flowering true-to-type. I strip the plant of all mature leaves. All petioles are cut at a 45^0 angle about 1" to 1¼" from the leaf. The end of the petiole is split for about ½"; this gives a greater rooting and shoot initiation area. All cuttings are then dipped in Mancozeb for protection against decay of the leaves; cuttings are planted in a mixture of 50% peat moss and 50% Styrene foam (or perlite); enough lime is added to bring the pH to 7. Trays are placed on the top bench of the glasshouse using natural light and a temperature of 65F^0 to 70^{0}F. As soon as the cuttings are rooted, feeding is started with ¼ strength liquid fertiliser every watering.

Depending on the time of year, plantlets usually appear by 1 to 2 months and are usually ready to pot off singly into 2" pots in about 3 months. Never be in too much of a hurry to break up the clumps; let them grow to about 2" high before splitting into single plants. You should get between 4 and 8 plantlets from each leaf. I pot up all plantlets into 2" pots, irrespective of whether they have roots or not. It makes no difference for all young plantlets grow evenly.

Let the plantlets in the 2" pots grow to a good size, about 3" to 4" leaf span before potting on into 3¼" pots. This will save a lot of

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Let the plantlets in the 2" pots grow to a good size, about 3" to 4" leaf span before potting on into 3¼" pots. This will save a lot of

bench space and time and, as these plants have a fine root system; they do best if slightly potbound.

Watering. Never water African violets by a time routine as too much water will cause decay of the tiny roots and also cause crown rot. Water only when the top soil feels dry to the touch. Always water with tepid water which is 10°fi. above glasshouse temperature. I water overhead but in doing it this way one must not have the plants exposed to sunlight; otherwise sun and wet foliage will result in a yellow mottling of the foliage and this will ruin the crop for market.

Fertilizing. Regular feeding in small amounts is far better than say once a month. I fertilize every watering with ¼ strength liquid feed.

Light. For successful growth and flowering, African violets require plenty of light. Avoid direct sunlight in the spring and summer months, either by whitewashing the glasshouse or by shading with curtains. A general guide is that the optimum natural daylight is such that one's hand just throws a shadow on the plants.

Humidity. African violets require high humidity. This is one of the essential conditions for successful blooming. Glasshouse humidity at approximately 75% is ideal.

Diseases and insect pests. African violets are not more susceptible to disease than any other plants, but like all plant life, they are subject to attack by insects and fungi. There are two cardinal rules in prevention of disease. Firstly, isolate all new stock brought into the nursery for 6 to 8 weeks to check for disease. Secondly, use preventive treatment by spraying regularly with the appropriate chemical.

Cyclamen mites. In the early stage of infestation, the new small leaves lose their green colour and become grey and stunted; the central leaves become bunched up and new leaves become brittle and hairy. Mites cannot be seen easily by the naked eye — a X20 magnifying glass is useful for detecting them. Mites are easily controlled by spraying weekly with one of the many miticides available.

Nematodes. These are deadly enemies to African violets, but don't be unduly worried for sterilization of the soil kills nematodes. Unless introduced by infected plants one never need see a case of nematode infection. An effective treatment is to water with a "Nemagon" preparation.

Aphis and Thrips. These can be seen with the naked eye as clusters of green or black slow-moving insects, the thrips being just visible. They attack the young leaves but can be eliminated by spraying with Meta-systox, pyrethrum, or with Malathion.

Mealy bugs. If you notice patches of "cotton wool"-like clusters, these are mealy bugs. They are sucking insects but are easily killed by spraying with Matacil.

Botrytis. This is a fungus disease resulting in a greyish mould developing in the centre of the plant; this will destroy the centre of the plant and ultimately kill it. Botrytis thrives under conditions of high humidity and temperature with inadequate ventilation. A fan running continually is a great help in preventing botrytis, but should it appear, a spray with Brassicol or Zineb will soon clear it up.

Crown rot. This is a fungus and is basically promoted by over-watering. If a previously healthy plant suddenly collapses, this is often caused by over-watering, or by fungus infection from pathogens in the soil.

Powdery mildew. This is also a fungus disease and is recognised by a powdery white growth on buds, flower stems and blossoms. Lack of ventilation and excessive humidity favours the development of this. As a precaution, remove all dead blossoms and leaves, avoid overcrowding of plants and provide fresh air in the glasshouse. This condition may be controlled by opening vents in the glasshouse or by the use of fans. A spray of Benlate will soon clear up powdery mildew.

Yellow spots and blotches on leaves. This is not a disease. It is usually caused by damage from cold water, or by leaving plants exposed to sunlight after overhead watering. Make sure that your glasshouses are whitewashed or protected by curtains.

Soil. Essentially, a good soil mixture for African violet culture must be light, porous, and easily-drained.

Soil has two functions:

(a) to support the roots and consequently the plant, and
(b) to absorb and translocate nutrients and water for the growth of the plant.

The soil must be sufficiently porous to provide aeration for the roots. Let it be emphasized that, in my opinion, it is essential to always sterilize your soil by steam or by methyl bromide. The pH of soil for African violets should be between 6.5 and 7. The most successful fertiliser I have used in soil mixing is John Innes base fertiliser. It has everything in it for good growth and flowering of African violets.

DISCUSSION

Items of interest from the discussion were that if the petioles are cut off at the leaf many sports develop. To retain the parent character cut the petiole 1 to 1¼ inches below the leaf. It is preferable to only grow those African violets which have flexible leaves to reduce damage in packaging and marketing. Plants with white at the base of the leaf tend to have very brittle leaves. Sideshoots must be removed or the plants become very straggly and few flowers are produced.

SAWDUST AS A CONTAINER GROWING MEDIUM

PETER E. ALBERY

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Interest in using sawdust and other timber residues such as shavings and bark as a potting medium has recently come to the fore in Australia. This interest, no doubt, has been fostered by the expense of imported peat moss and shortages of Australian sedge peats. Growers have also noted that overseas nurserymen have used these wood materials with success. For several years wood materials hae been used in a limited way by a few Australian nurseries. I first saw terrestrial plants growing in a mixture of partly decomposed sawdust and spent tan-bark in the early 1950's. Nevertheless, fresh Eucalyptus sawdust has only recently become very popular as an organic constituent for container growing.

Physical Properties. Baker (1) explained that sawdust is one of the best organic constituents that may be used in a growing medium. Its outstanding properties are as follows:

1. Readily available in a uniform grade.
2. Chemically uniform.
3. Stable to fumigation.
4. Easily made into a uniform mix.
5. Resistant to loss of nutrients by leaching.
6. Fertility low (initially).
7. Relatively inexpensive.
8. Moisture retention good.
9. Light *in weight.*
10. Shrinkage negligible.

It would appear that few materials obtainable at present could match sawdust as a growing medium.

Nitrogen Nutrition. Baker (1) points out the effect of adding low nitrogen and high carbon materials to your growing medium, as follows:

100 lbs. of shavings = 35 lbs of carbon and 0.2 lbs of nitrogen.
35 lbs of carbon, 40% assimilated by soil fungi = 14 lbs of carbon assimilated.
Ratio of carbon to nitrogen in soil fungi = 10 to 1 = 1.4 lbs of nitrogen assimilated.

The shavings supplied 0.2 lbs of nitrogen, but the fungi required 1.4 lbs. So that 1.2 lbs of nitrogen had to be added for the decomposition of the shavings. In this way you can calculate the approximate amount of nitrogen needed when shavings are added.

Our Eucalyptus sawdusts contain resin which actually retards the microflora's ability to decompose it. So, even when supplied with extra nitrogen and conditions that would favour decomposition, our hardwood sawdusts decay rather slowly. This is one of its good points; it is not going to shrink much. If complete decomposition cannot be achieved, less than the calculated amount of nitrogen may be needed.

Mixes and Nitrogen Materials Used.

Mix 1. A sawdust and sandy loam 1:1, was used for a wide range of trees and shrubs for several years. This was for outdoor growing of ½ gallon, 1½ gallon and larger sized containers. A very coarse and lumpy form of dried blood was added at the rate of 6 lbs per cubic yard of mix. Calcium, phosphorus, potash, etc. were also added.

Problems: Decomposing lumps of dried blood on the surface attracted hoards of small flies and it was also foul smelling. Even small lumps close to the plant seemed to encourage stem decay. The containers were heavy when wet and, if some of the sandy loam was too finely textured, it tended to water-log.

Ammonium sulphate was used experimentally as an alternative to dried blood. It was soon discarded, however, as the mix was too high in soluble salts, the pH dropped to a level very rapidly, and it was extremely corrosive to metal containers.

Mix 2. This consisted of fresh sawdust and coarse sand, 3:1, with 5 lbs of chip form U.F. 38 (urea formaldehyde) added per cubic yard of sawdust, plus other essential elements. Most hardy plants grew in this mix beautifully.

Problems: Heating of the mix up to 140^{0}F in one and two gallon black plastic containers due to decomposition and high summer temperatures seemed excessive. Tall growing plants tended to blow over during windy weather as it is light in weight. A saprophytic fungus appeared in many containers. Though apparently not interfering with the plant root growth, it did tend to clog up the air spaces causing the sawdust to cake and reduce water penetration. Nitrogen deficiency symptoms appeared about 12 weeks after using the mix, even though liquid feed with each irrigation had been used, so the nitrogen needed to be increased. Osmocote, at the manufacturer's suggested rates, was also used but extra nitrogen was again needed as the mix aged. The worst thing that occurred was two micronutrient toxicities, zinc and manganese. These toxicities appeared in only a few species. Liquidambar trees seemed badly affected showing stunting, leaf distortion, and necrosis of the leaf blade. Of course, this isn't going to happen every time you use sawdust, but it did happen with a particular lot.

Good point. Early spring and autumn use did not show so high a temperature rise; in fact, the warmth of the mix during the cool nights stimulated root growth on most plants.

Other Mixes. Various mixes of sawdust and Australian sedge peat or imported German peat have been more successful than either the sawdust or peat moss used alone. U.F. 38 was used to stabilise the sawdust.

Other Considerations. If you haven't used sawdust in your mixes before and you intend doing so, try it on a small scale first. Whatever physical components and proportions you wish to use, test the pH of the mixed materials and adjust the pH to your requirements before you add any nitrogen materials. All the sawdusts I have ever used have been very acid, needing about the same amount of lime as German peat. You will notice that a rise in pH will occur after the addition of the U.F. 38, but will drop to a more satisfactory level after about 3 weeks. If you add nitrogen before adjusting the pH, you may find very little lime is needed. But in a few weeks time the pH will have dropped markedly.

I do not use mixes containing appreciable amounts of sawdust for potting rooted cuttings of shrub and tree seedlings, or for germinating shrub and tree seed as many seem sensitive to the higher salinity or ammonium release of these fresh sawdust mixes.

The Advantages. The advantages that I have found of sawdust and sawdust/peat mixes over loam soil mixes are as follows:

1. Roots grow right to the bottom of the container and there are dense fibrous roots throughout the mix.
2. The sawdust is still in excellent physical condition even after 1½ years in a container.
3. More uniform moisture throughout the pot than any other mix I have used.
4. Easier to use and less soggy after prolonged heavy rain.
5. Light and easy on the machinery used for mixing.
6. Lighter for staff to handle and for trucking.
7. Hand removal of weeds easier because of its loose, friable nature.

I think most of the problems, such as overheating etc., could be overcome by composting, but I would like to point out that to be even at least 6 weeks ahead enormous stockpiles would be required. Unfortunately, space required and the sawdust availability would not allow composting to be feasible.

ACKNOWLEDGEMENTS

I would like to thank the following nursery companies that have allowed me to experiment with the use of sawdust over the years:

Tomkins Enfield Nurseries Pty. Ltd.,
Fivedock Nurseries Pty. Ltd.k
A. J. Newport and Sons Pty. Ltd.,
Colour Spot Nurseries Pty. Ltd.,

also, O. A. Matkin of Soil and Plant Laboratories, Santa Ana, California, U.S.A. for his advice.

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BUDDING AND GRAFTING TECHNIQUES IN THE PRODUCTION OF STREET TREES

NELSON R. WILSON

Melbourne City Council - Wandin Nursery
Wandin, Victoria

The production of street trees from seed or cuttings in the past has been a slow and haphazard process with very indifferent results being obtained.

Seed from trees such as *Ulmus procera* (*U campestris*) gives such a wide variation in type that as many as 50% of seedlings need to be discarded. The other major problem is to grow the seedlings to an acceptable street tree height, i.e., 12 to 15 feet with a nice smooth trunk of 4 to 5 inches caliper. Usually *Ulmus procera* seedlings require 8 to 10 years or longer to reach this size and, even after initial culling, the finished products generally require further culling.

One method that we use to great advantage to overcome these problems and obtain 100% straight trunked trees of 12 to 15 feet in 3 to 5 years is by budding or grafting.

Selected cuttings of *Ulmus procera* are planted in the open ground, lifted after one year, trimmed and replanted out in nursery rows 9 inches apart with 3½ feet between rows.

Budwood from selected parent stock is then used to bud the stocks, using a normal T-bud during February. These stocks are then cut back to the bud during July - August. Those having buds that did not take are grafted using a simple whip and tongue graft, although, generally, 95 % bud take is achieved.

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As the bud grows during the spring and the summer, it is trained to a single leader by breaking off any side shoots before they reach two inches in length. Staking may be necessary when the young tree reaches 4 to 5 feet. In a normal growing season a tree of 6 to 7 feet can be produced with a straight and smooth trunk.

The yearling trees are lifted the following winter and re-planted into rows 7 feet apart and 4 feet between trees. There they grow for a further 3 years and, with yearly shaping, reach a height of 12 feet with a trunk caliper of 3 to 5 inches.

Instead of budding, stocks can be grafted using a whip and tongue graft during the late winter or early spring using scion wood with 3 to 4 buds. When the buds shoot and reach 4 to 5 inches the scion is cut back to the strongest shoot, the rest being removed. The tree is then treated the same as a budded one. When grafting, a take of 100% can be expected.

Half-inch P.V.C. tape is used to tie all buds and grafts, the tape being removed from buds after 21 days. The tapes on grafts are removed after the shoots are 4 to 5 inches long. The P.V.C. tape must be removed before the tape cuts into the wood as growth takes place.

This method of producing straight-trunked trees is also used to produce standards for weeping trees such as *Acer palmatum*, *Ilex*, *Pyrus*, *Malus* and any other stocks that are slow growing.

REGENERATION OF STRAWBERRY PLANTS FROM TISSUE CULTURES

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Abstract. Aseptic strawberry plants were obtained by culturing axillary buds from stolon scale leaves on medium-MLLM (3). When the basal stem region of these aseptic plants was cultured on medium-MMMM (3) in the light, numerous buds developed, each of which formed into a complete plant; repeated culture of the basal region of each plant thus formed constitutes a rapid method of clonal propagation, with a potential in one year of millions of plants from each original plant.

When the basal region of aseptic plants was cultured on medium-MMMM in the dark, callus was formed along with several etiolated shoots. Apical meristems from these etiolated shoots were much easier to excise than from field-grown plants. A programme for using a combination of meristem culture and heat treatment of buds and plants in culture tubes, is described for the production of virus-free material from virus-infected strains of strawberry.

Other methods for obtaining aseptic strawberry plants using tissue culture techniques are also described, including the regeneration of plants from callus derived from anthers. This is thought to be the first report of organogenesis from unorganized strawberry callus.

REVIEW OF LITERATURE

Our research with strawberries is aimed at ridding virus-infected strains of strawberries of their virus content by a combination of tissue culture, meristem culture and heat treatment. And, having done this and having obtained virus-free certification, to use rapid clonal propagation of this certified material through tissue culture techniques; our calculations indicate a potential of millions of clonal strawberry plants in one year from each certified virus-free plant.

One method of eliminating viruses from infected cultivars is by heat treatment of the mother plant but, at East Malling, some cultivars treated in this way remained infected (6). The use of single-bud cuttings following heat treatment removed crinkle virus from some clones but not from others, and few cuttings of some cultivars survived (7). Meristem culture holds more promise than stem tip culture for ridding virus-infected strains of their viruses. In general, the smaller the stem tip excised and cultured the greater the likelihood of obtaining virus-free cultures; the apical meristem, about 0.1 mm in length, is the ultimate in smallness in this respect and thus has the greatest potential for achieving the stated objective. Unfortunately, the smaller the stem tip the greater the difficulty of inducing it to grow in culture; meristems are thus the most difficult to grow in culture. Parenthetically, much that is described as meristem cuture, e.g. for *Cymbidium*, is in reality stem tip culture, often 5 or even 10 mm in length; such techniques are aimed at clonal propaga-

tion - not at virus elimination. The culture of strawberry apical meristems has been described by Belkengren and Miller (1) as a method of freeing *Fragaria vesca* strawberries of latent A virus. These authors (5) later reported freeing *F. vesca* from vein-banding and crinkle, and the cultivars Northwest and Rockhill from yellow virus complex. McGrew (4) eliminated latent C virus from plants of the Suwannee variety. Vine (9) reported freeing five cultivars from crinkle and vein chlorosis, and the elimination of yellow edge virus from 90 percent of cultured apical meristems of another cultivar. A generalized account of meristem culture for elimination of strawberry viruses has been given by Smith, Hilton and Frazier (8). Boxus (2) has reported a stem tip culture method for the rapid multiplication of strawberry clones.

MATERIALS AND METHODS

Strawberry cultivars: 'Kendall,' 'Red Gauntlet' and 'Torrey' (*Fragaria chiloensis* Duchesne var. *ananassa* Bailey) have been used at various stages of this research but most work has been done with the first two.

Sites of explants: Sites of explants are illustrated in Figure 1. Site A is the bud in the axil of the stolon scale leaf. Site B is the young plant at the end of the stolon prior to the development of roots. Site C is the immature flower.

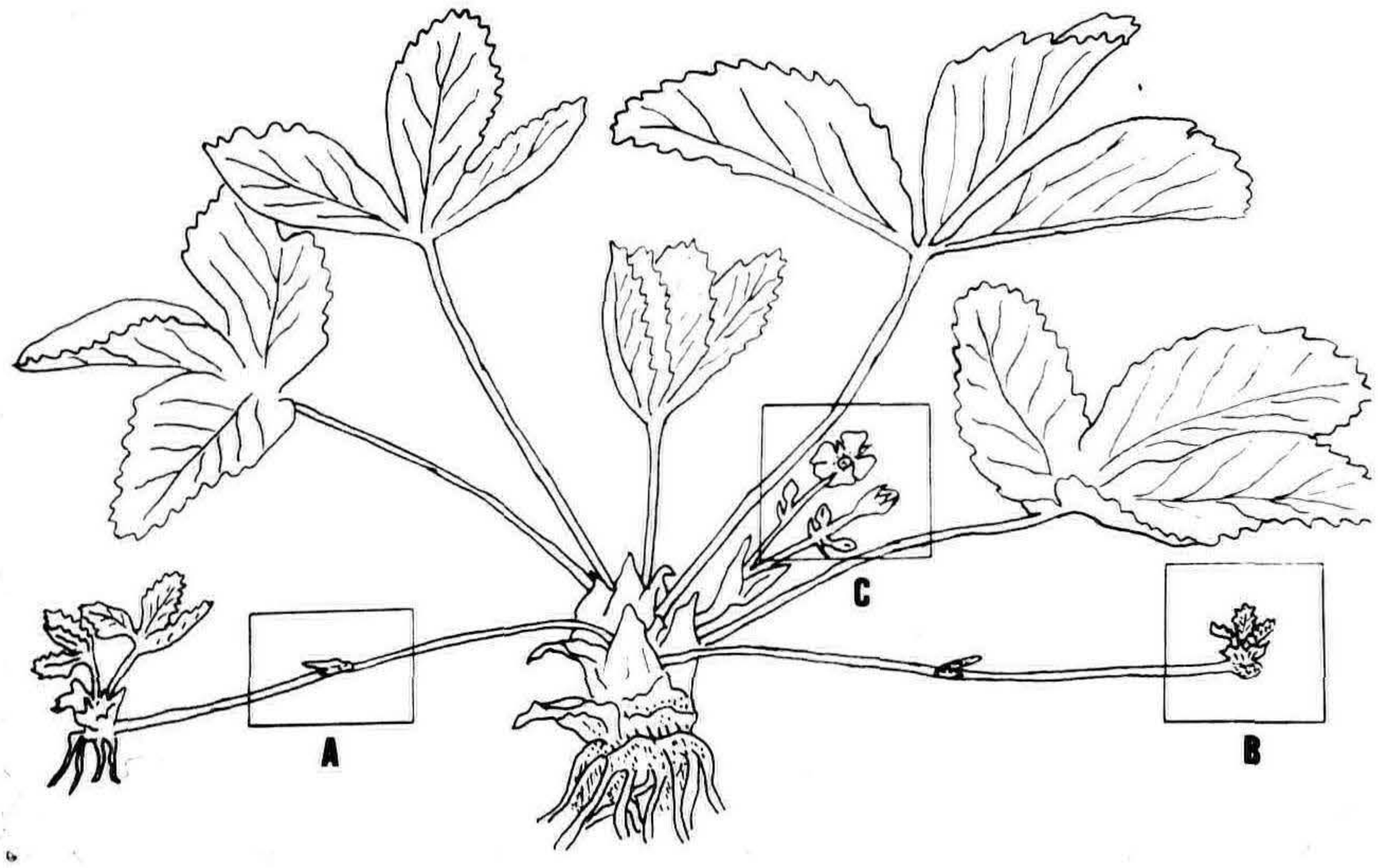

Figure 1. Diagrammatic representation of a strawberry plant with runners showing explant sites A, B and C, which are, respectively, the bud from the axil of a stolon scale leaf, the young plant without roots at the tip of the stolon, and the anthers and receptacle of immature flowers.

Disinfestation of explant sites: Site A: stolons with tightly closed scale leaves were selected. The scale leaf part of the stolon

was cut off, washed in detergent (in lots of ten nodes at a time), disinfested with chlorinated lime (saturated solution, freshly prepared and filtered before use) for 20 min., and then rinsed in two changes of sterile water. The axillary buds were then excised aseptically and individually disinfested with chlorinated lime (10 min.), rinsed twice in sterile water, and placed on the surface of autoclaved culture medium. *Site B:* the young plants were cut off from the stolon and the apex, leaves and basal region removed, followed by paring off the surface layers of the remaining piece; these pieces were then dipped in alcohol and flamed briefly, disinfested in chlorinated lime (20 min.), followed by a second paring off of the surface layers, and further disinfestation in chlorinated lime (20 min.) and three washes in sterile water; the explants were then placed on culture medium. *Site C:* Immature flower buds were dipped in alcohol and flamed briefly and disinfested in chlorinated lime (20 min.) followed by three washes in sterile water; anthers and receptacles were then aseptically excised from the flower buds and placed on the surface of culture medium.

Culture media: A broad spectrum experiment (3) was used to find media suitable for the culture of explanted materials (sites A, B, C), for the initiation of callus, for callus growth and for the regeneration of plants from the callus. The broad spectrum experiment consisted of combinations of four broad categories of constituents, namely: (1) minerals, (2) auxins, (3) cytokinins and (4) sucrose plus growth factors plus amino acids, each at three concentrations, low, medium and high. This gives an experiment with 81 treatments (media). When necessary, other substances such as coconut milk, yeast extract and casein hydrolysate, are also included in the experiment. These experiments resulted in the selection of two broad spectrum media, codes MLLM and MMMM, for bud culture, callus induction and regeneration of plants from calluses. These two media are defined in Table 1. It may later be found that several of the listed constituents are not essential, and that others are not at their optimal concentrations. (A booklet describing the logistical aspects of preparation of these broad spectrum media will be sent on request). The main differences between medium-MMMM and -MLLM are that the former has ten times more auxins and cytokinins than the latter.

Incubation conditions: Site A cultures were incubated in 12/12 (h light/dark regimen) at 25°C, and illuminated during the photoperiod with Gro-Lux fluorescent lights (2,000-16,000 lux). Sites B and C and callus cultures were incubated in the dark at 25°C. Only limited experimentation with incubation treatments has been done so far; other regimens might be as good or better than those described.

Table 1. Constituents and their concentrations of two broad spectrum media (MLLM and MMMM) selected for strawberry tissue culture.

Macronutrient elements (mmol.1^{-1})
NH_4NO_3 (10), KNO_3 (10), NaH_2PO_4 (1), $CaCl_2$ (2), $MgSO_4$ (1.5)

Micronutrient elements (μmol.1^{-1})
H_3BO_3 (50), $MnSO_4$ (50), $ZnSO_4$ (20), $CuSO_4$ (0.1), Na_2MoO_4 (0.1), $CoCl_2$ (0.5), KI (2.5), $FeSO_4$ (50), Na_2EDTA (50), Na_2SO_4 (450)

Main carbon source (mmol.1^{-1})
Sucrose (60)

Growth factors (μmol.1^{-1})
Inositol (300), Nicotinic Acid (20), Pyridoxine. HCl (3), Thiamine. HCl (2), Biotin (0.2), Folic Acid (1), D-Ca-Pantothenate (1), Riboflavin (1), Ascorbic Acid (1), Choline Chloride (1).

Amino acids (μmol.1^{-1})
L-Cysteine. HCl (60), Glycine (5)

Auxins (μmol.1^{-1})
MLLM-medium 1 μmol.1^{-1} of each of the following auxins, in contrast to MMMM-medium with 10 μmol.1^{-1} of each auxin: IAA (indole acetic acid), IBA (indole butyric acid), NAA (α-naphthalene acetic acid), NOA (2-naphthoxy acetic acid), 2,4-D (2,4-dichlorophenoxy acetic acid), pCPA (*para* chlorophenoxy acetic acid).

Cytokinins (μmol.1^{-1})
MLLM-medium 1 μmol. 1^{-1} of each of the following cytokinins, in contrast to MMMM-medium with 10 μmol. 1^{-1}: Kinetin, BAP (benzyl amino purine).

RESULTS

Bud Culture: The first experiment was with axillary buds from site A. There were 2^5 (=32) treatments (media) using low and medium concentrations of the four broad spectrum categories of constituents; half of the experimental media included 150 ml coconut milk per litre. There were five replicates and a total of 160 cultures. The experiment was examined after two weeks incubation in 8/16 (*h light/dark*) at 25°C. *More cultures on coconut* milk media had grown and were healthy looking than on plain media, and particularly good cultures were associated with the medium concentrations of minerals and auxins. On plain media, the best treatment was MLLM, that is, the medium concentrations of minerals and sucrose plus growth factors plus amino acids, and the low concentrations of auxins and cytokinins. The experiment was prematurely terminated due to a fault in an incubator.

A second experiment using coconut milk media only was planned but, because of the non-availability of coconuts at that time, an experiment was done with the plain medium-MLLM using various additives which were possible substitutes for *coconut milk. The additives were: glutamine (1 mmol.*1^{-1}), *yeast* extract (1 g.1^{-1}), casein hydrolysate (1 g.1^{-1}) and a fourth treatment included all three additives. One half of this experiment was done with agar (8 g.1^{-1}) and the other half was made up as liquid media using a filter-paper "thimble" to support the cultures. There were

10 treatments and 20 replicates, and the cultures were incubated at 12/12 (h light/dark) at 25°C. The experiment was examined after 3 weeks incubation and medium-MLLM without additives supported the best and healthiest looking cultures; none of the additives improved the growth of the cultures. The cultures on agar media suffered an average 63% loss due to microbial contamination, whereas cultures on liquid media had a 35% loss. This was a reflection of the greater growth of contaminating organisms on agar media and, in consequence, their earlier detection. Non-contaminated cultures on agar medium-MLLM were as healthy as those on liquid medium-MLLM. So, for two reasons, namely ease of detection of contaminated cultures and ease of preparation and handling, it was decided to standardize bud culture on agar medium-MLLM. A later planting with nearly 100 buds resulted in only 15 percent contaminated cultures using the disinfestation methods described above.

Induction of callus from anthers and receptacles: Anthers were excised from immature flower buds (4-5 mm in length), and from buds with petals exposed but only slightly opened. Ten anthers per culture tube were used in the case of the smaller buds, whereas 4 to 8 anthers per tube were planted from the more mature buds; one receptacle per tube was also planted from each mature bud. There were 81 broad spectrum treatments.

Callus formation on anthers from the smaller buds was associated mainly with the low concentration of sucrose plus growth factors plus amino acids and, in the case of anthers from older buds, it was also associated with the high concentration of cytokinins. These calluses were subcultured on medium-MMMM (judged on qualitative criteria as supporting the best callus growth of both 'Kendall' and 'Red Gauntlet') and, after two passages (sub-cultures) some calluses produced roots and one (derived from anthers from the more mature buds cultured initially on medium-MMHM) produced shoots. These examples of organogenesis are evidence of the totipotency of anther tissues. In addition, some calluses from receptacle explants produced roots when subcultured on medium-MMMM.

The culture which produced shoots continued to produce several buds when subcultured again on medium-MMMM in the dark (Fig. 2). When pieces of these calluses plus shoots were subcultured on the same medium but incubated in 12/12 (h light/dark) at 25°C, the shoots developed into whole plants, with healthy fibrous root systems and green leaves; numerous buds developed from the basal part of each plant (Fig. 3). Buds and plants from this source have, at the time of writing, been subcultured six times on medium-MMMM always with the same result: whole plants with 12/12 incubation and callus plus shoots (but no roots) on dark incubation. However regeneration of shoots from calluses

in the dark were less vigorous on each of the later subcultures.

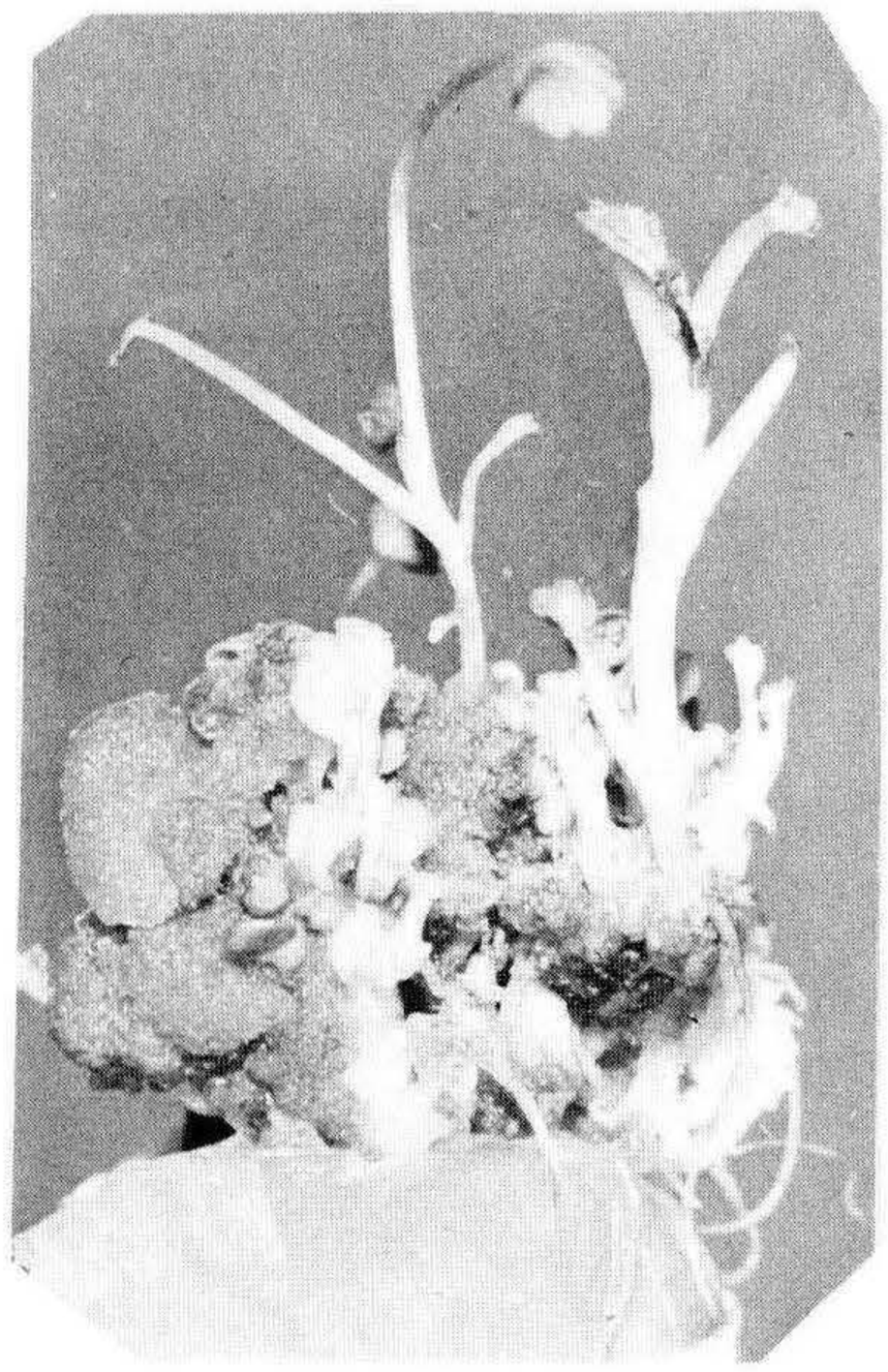

Figure 2. Etiolated shoots from callus of anthers cultured on medium-MMMM in the dark at 25°C (magnification x 7).

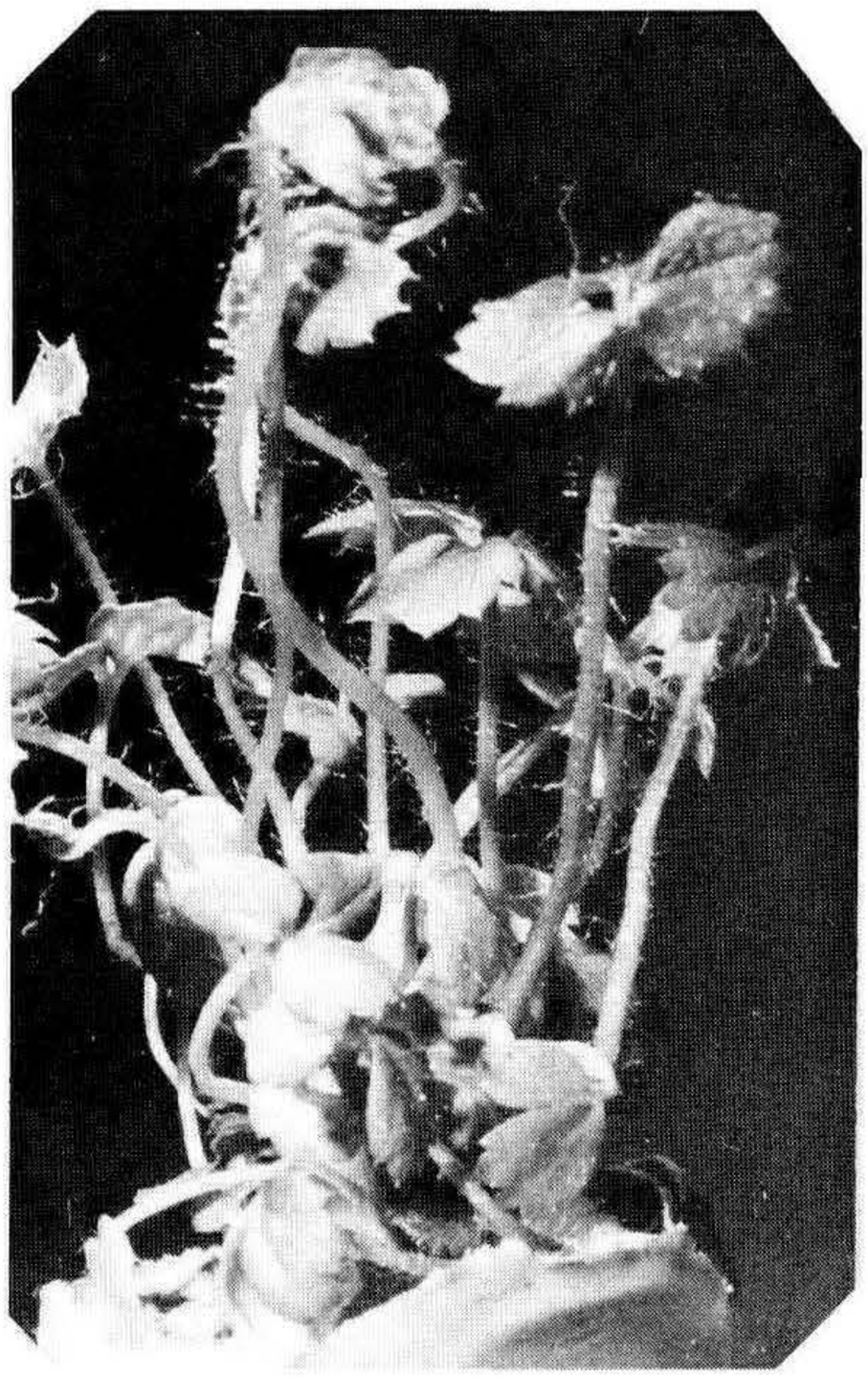

Figure 3. Complete plants with numerous buds at the base; cultured on medium-MMMM in 12/12 (h light/dark regimen) at 25°C (magnification x 7).

Callus and shoot induction from aseptic plants: Site A buds were cultured on medium-MLLM and then transplanted on medium-MMMM (both with 12/12 incubation). Pieces of stems containing buds, excised from vigorous plants, were then cultured in the dark. These developed callus and a few etiolated shoots and, when transplanted to fresh medium-MMMM and incubated in 12/12, these etiolated shoots developed roots and formed complete, healthy plants. Again, numerous buds developed from the basal part of each plant. Each of these buds formed a complete plant when subcultured on fresh medium-MMMM and exposed to 12/12 incubation, yet again with the formation of numerous buds at their base.

Site B explants planted directly on medium-MMMM, avoiding the initial medium-MLLM step, developed callus and buds on dark incubation in the first passage, and later transfer to fresh medium and 12/12 incubation again led to the formation of complete plants with numerous buds at the base of each plant.

DISCUSSION

The results described above have led to the following strategy for our forthcoming research with virus-infected strains of strawberry:

1. Culture the buds from the axils of stolon scale leaves of virus-infected strains on medium-MLLM and incubate in 12/12 (h light/dark regimen) at 25°C. If stolons are not produced, culture buds from the axils of leaves on the plant. Transfer of young plants to medium-MMMM accelerates the development of these plants.
2. Pieces of stem-containing buds are then cultured on medium-MMMM in the dark for induction of etiolated shoots.
3. Excise apical meristems from the etiolated shoots of the cultures prepared in (2); apical meristems are very much easier to dissect from aseptic etiolated shoots than from field-grown plants; culture the meristems on experimentally-determined suitable media.
4. Transfer shoots that develop from (3) to medium-MMMM and incubate in 12/12 (h light/dark) at 25°C.
5. Excise the numerous buds that develop on the complete plants produced in (4) and culture on fresh medium; repeat this process to obtain a stock of putative virus-free material.
6. Rear some of these plants under normal conditions for virus-indexation and virus-free certification by appropriate authorities.
7. Virus-free certified material can then be rapidly multiplied

by repeated subculture on medium-MMMM in 12/12 incubation, prior to release to specialist runner-producers and growers; virus-free material would be maintained in culture tubes rather than in insect-proof houses, the present practice.

Meristem culture alone may be sufficient to rid virus-infected strains of their viruses. This assumption will be tested as an integral part of the above programme concurrent with the testing of a new way of heat-treatment in combination with meristem culture. The usual practice is to heat-treat whole plants, and this is followed by application of disinfestation treatments, excision and culture of either stem tips or meristems. However the disinfestation is rarely complete and more often substantial loss of cultures is incurred due to microbial contaminants. Moreover, poor growth of excised meristems in culture could be, at least partially, attributable to tissue injury caused by either the heat treatment, the disinfestation treatment, or to both. We plan to reduce, and in the case of disinfestation treatment to avoid, tissue injury by heat-treatment of *aseptic* buds, plants, calluses and/or meristems in culture tubes. Heat treatment of plant tissue in culture tubes would avoid dessication injury to the tissue because the tissue is in contact with an aqueous-based medium. This way of heat-treatment, if successful in the elimination of viruses, would have the additional advantage of being more controllable than heat treatment of whole plants.

Finally, we wish to emphasize two results: one is the induction of organogenesis, both roots and shoots, in calluses derived from tissues (anthers, receptacles) which normally would not develop either of these organs. The second result relates to the culture of twice-pared explants of young stolon-plants (site B explants) in which callus was initiated and which simultaneously initiated buds. Theoretically, the paring off of superficial layers should have removed all buds since these have a superficial (exogenous) origin. We are currently investigating whether such explants (site B explants) have deeper-seated buds or whether *de novo* organogenesis, as with anthers and receptacles, has occurred.

Acknowledgments. A Commonwealth Post-Graduate Scholarship to E.C.M. Lee is gratefully acknowledged. We thank Mr. R. A. Bourne for his excellent technical assistance, and Dr. R. C. Smith (Department of Agronomy, University of New England) for his comments on this paper.

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QUESTIONS

In reply to questions it was stated that neither the cutting of such small meristems nor the heat treatment had induced observable mutants but that the progeny must be watched closely for any such development.

TOWARDS A POLICY FOR A CAREER STRUCTURE IN ORNAMENTAL HORTICULTURE

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After less than one month's residence in a new continent, I am very conscious of being at the stage when one should keep one's eyes and ears open but one's mouth shut. My invitation to spend 6 months at the Queensland Agricultural College came through the initiative and with the assistance of the Queensland Nurserymen's Association. It was brought about by the concern of professional horticulturists who felt the absence of educational and training opportunities in ornamental and amenity horticulture; that neither the industry nor the profession were getting enough people of the calibre they needed which, in turn, was affecting the whole status of the horticulturist. In other words, they were missing out on the excellent facilities which exist in technical and technological education which appeared to be available to every other section of the environmental disciplines except ornamental horticuture.

When Professor Oliver Batcheller from California Polytechnic University came to Australia on sabbatical leave in 1970/71 he "was shocked to learn there is not a single Chair of Horticulture or a department of horticulture in any 4-year degree granting institution in the entire country of Australia." That state of affairs has, at least, improved with the establishment of the Chair at Sydney University in 1971. The situation as expressed by Batcheller's further comment, "the field of ornamental horticulture is practically unheard of as are college or university programs in park administration," is just beginning to change.

An interesting and, probably very relevant question to ask is why Australia, alone of all the highly developed countries, has missed out in this way and why it holds horticulture in such low academic esteem. Why, for example, New Zealand should be able to sustain degrees in Horticulture in two universities and have approximately 600 horticultural students throughout the country. It is worth noting that even countries like Norway or Switzerland, which hardly conjure up a picture of horticulture in one's mind, can each offer greater educational facilities for the young horticulturist than can Australia.

There is not, however, time here to surmise on history. With so little time available I must assume that the position is accepted and that there is a genuine desire to put the matter right. If this is the case then the problem becomes one of designing, in close association with the professional and trade organisations, the type of

course which will command the respect of the academic, interest and motivate the student, and satisfy the needs of the industries and professions who will employ the end product.

I must make it clear at this juncture that my remarks do not refer specifically to any recommendations for the Queensland Agricultural College. I am expressing a general philosophy backed up by experience and observations in several countries and I cannot see why they should not be applicable here.

Academics, by themselves, are really only qualified to propagate their own species. The more fundamental scientist and research worker will normally seek their training by an Hons. Degree route in the basic sciences; some of these will, we hope, eventually be attracted into horticultural research at the post-graduate stage. To produce the graduate for industry, the technologist, the professional parks and recreational manager, the landscapist — all such training requires a close fertilisation with the industry or profession, and an exposure to each during the course. Obviously the lower down the academic scale one goes, from graduate to craftsman training, the more sustained the need for this exposure becomes; but it is essential at the technological degree level, too. Industry has a right to expect that the graduates have been trained realistically and prepared for the responsibility of managing people as well as having been filled with technological data. Students have a right to see ahead where they are going and must feel that all their course is relevant to their chosen subject.

Have you ever really thought why the International Plant Propagators' Society has been such a success and has spread so rapidly when introduced into new areas - and why its meetings are so stimulating and rewarding? There are many contributory reasons no doubt but, fundamentally, I am convinced it is a question of status. It is an organisation in which the academic and the researcher on the one hand, and the grower and the skilled craftsman on the other, meet on equal terms; each respect each other's knowledge and skill. They meet on the common ground of horticulture, albeit on a relatively small section of it.

That is what horticulture is all about - and that is what makes the conventionally minded academics suspicious of us. "It is not," they claim, "a subject in its own right." "It can be taught effectively," they claim, "as a specialist elective in an agricultural course." "What is the difference," they ask, "in one crop from another — cereals or fruit or vegetable or flowers?"

It is certainly more economical — and more prestigious for the agricultural sciences — to have them all lumped together. There is only one snag — it does not succeed. Let them look around and see that it does not work. Look at the United Kingdom where 3 univer-

sities have struggled to maintain a handful of horticultural courses, two now petering out into insignificance with their elective courses. A fourth University (Bath) came along with a technological degree in horticulture and within the first few years outstripped the other three combined in its student intake. A new degree course in Horticulture has just made a successful start in Scotland at the University of Strathclyde, devoid of agricultural dominance but using the horticultural facilities at the West of Scotland Agricultural College.

At the technological layer of the Higher National Diploma (which is now a sub-graduate course but designed to equate roughly with pass degree standard) no attempt is made to combine any aspect of agriculture and horticulture in the U.K.

Look at any institution in the English speaking world where horticultural education is really successful — both in numbers of students they attract and the quality of the product they turn out — and you will find a strong Department of Horticulture or a separate horticultural entity within a School of Biological Sciences. You will not find horticulture as an agricultural elective.

Why not? Basically because horticulturists, especially those in the ornamental field, are a different kind of people and their motivation is different. Dr. John Carew of Michigan State University defines horticulture as "plant science with a human goal." Courses are for people, about people. You have to attract them as students in the first place — and fit them for employment at the end. In particular, there is a higher degree of "plantsmanship" required than in basic agriculture, a deeper understanding of the plant — usually as individuals rather than as crops. If you wait for the nursery-oriented student to develop as a "spin off" from the general agricultural approach you will miss the majority of potential recruits.

May I now concentrate on a few general points.

(1) Improve the public image of the horticulturist, particularly of the nurseryman. *You* know the developments which have transformed the industry in the last decade, but the public does not, neither do parents or school leavers. Begin with the schools — invite them to the nursery; show them that there is a career in the subject. Let your fascination for propagating plants rub off on them. In this matter of the public image I must commend the whole concept of the Australian Institute of Horticulture. They are fighting a battle for status and they merit the wholehearted support of every horticulturist.

(2) Take steps to train any young person you have in your employment — irrespective of whether he is attending classes. Don't expect them to pick up the skills as they go along. For example, there is no more skilled job than the effective watering of plants — it is not an innate skill. Even the graduate with all his knowledge of soil moisture relationships still has to acquire the skills of application.

Nor is the skill or importance any less because the method of application is mechanised. It still remains basically a question of human judgment. In this, as in all other basic operations, time spent in showing a novice how to acquire such judgment is well repaid not only by getting a better worker but also by helping to find out more quickly his true potential.

(3) There must be courses of education and training for all intellectual capacities. Horticulture needs research workers, teachers, graduate managers, technologists and technicians. The "craftsman" of today is a technician. Propagators now know that the environment into which they place their cuttings is normally much more important than the actual craft of making them. The skill is still there and demands a much wider understanding. The industry needs effective "*Indians*" *as well as good "Chiefs." Thankfully one does not see* here the idea, somewhat prevalent in the U.S.A., that all subgraduate course are for the educational "throw outs," with the inevitable trend that the standard of college courses are continually lowered to pass more and to reduce the number of psychiatric cases which apparently develop from the "failures."

(4) The industry must be involved *in* the educational and training process. Not only in the planning and formative stages but, throughout, in membership of advisory committees and by maintaining a close and meaningful link with the staff. They can more readily gain confidence in teaching their subject through personal contact and observation than they can from theory.

The most developed form of co-operation between college and industry is the fully fledged *sandwich course* in which periods of industrial employment are integrated into periods of college attendance[1]. This provides the best preparation for the entry of a young person into a technological or highly technical job. It undoubtedly provides the best product for industry to employ. It also provides the College with a much more mature student and the final semester is usually a stimulating and challenging one for staff and student.

(5) *Finally I would* stress that horticulture must be taught on the basis that it is a business as well as a science, a technology and, indeed, an art. Appropriate levels of business study and management should be in all courses — including amenity courses. The word "management" is used too loosely these days in the educational context and the needs at each level must be more precisely defined. The need to handle people and to get the best out of them

[1]This system of training in horticulture is described in "The Sandwich Program" by the author in Vol. 24 *I.P.P.S.* Combined Proceedings (1974).

is a factor shared by the executive and the nursery leading hand. Basic man management training has proved a most successful introduction by the Agricultural Training Board for the mature worker in the U.K. This subject, which is about human relations and communications, is a "must" in all our basic courses.

DISCUSSION

A MEMBER: It is time for I.P.P.S. and the nursery industry to update the image of the horticulture industries by a concerted public relations effort. We should recommend to the I.P.P.S. Executive Committee that it embark on a public relations effort through newspapers, radio, TV, etc.

RICHARD MARTYR: I agree. Increasing the membership of I.P.P.S. is also an important way of improving public awareness of horticulture and more effort should be put into attracting young members.

ROB DAVIDSON: The Horticultural Advisory Committee of the Queensland Agricultural College has circulated the horticultural and related industries throughout Australia for a Horticulture Promotion Fund. Subscriptions have been received from all States and a 12-page, illustrated brochure entitled, "Horticulture — a New Approach" has been prepared for distribution, particularly to schools and careers officers. Copies are available from the College or from Box 19, Brisbane Market P.O., Qld. 4106. It is hoped that this will help to attract students into horticulture but, above all, it is designed to tell the rest of society what horticulture is all about.

A METHOD FOR BREAKING SEED DORMANCY IN *BORONIA spp.*, *ERIOSTEMON spp.* AND OTHER NATIVE AUSTRALIAN SPECIES

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It is probably necessary to outline a few basic concepts about seed germination and seed dormancy before discussing in more detail the breaking of seed dormancy.

Germination of viable non-dormant seed usually occurs when certain conditions are fulfilled. These include the imbibition of water, suitable temperature and an adequate oxygen supply.

When seeds do not respond, i.e. do not germinate when subjected to these favourable environmental conditions they are commonly called dormant.

Seed dormancy can be divided into two basic categories.

1. Physical dormancy
2. Chemical dormancy

Physical dormancy. These seeds have coats which are physically impermeable to water. When this seed coat is abraded, nicked, cracked or removed, the embryo imbibes water and germination occurs quickly; e.g. *Acacia* spp. and members of *Papilionaceae* (Pea family).

Chemical dormancy. When the normal criteria of moisture, temperature and oxygen have been fulfilled, and any physical barrier to water imbibition has been removed, and germination still does not occur there is a chemical dormancy operating.

It has been known for a long time that there are inhibitory substances present in seeds which prevent germination. These may be present in:

a. The surrounding fruit, e.g. *Fraxinus chinensis* var. *rhynchophylla* (3)
b. Seed coats
c. Endosperm
d. Embryo

These inhibitory substances prevent various physiological processes from beginning.

Growth promoting substances are also present. The role of these substances appears to be to stimulate the synthesis of enzymes which are necessary for growth of the embryo, particularly in phosphorus metabolism. Gibberellic acid (GA_3) appears to be the most prominent of these promoting substances.

Amen (1) states that all forms of seed dormancy (chemical)

are basically concerned with the inhibitor/promotor mechanism and apparent differences in dormancy are merely in the mode of changing the balance to one more favourable for growth rather than one favourable to rest.

The interaction of the levels of these hormones with environmental stimuli such as light and temperature controls germination. (4).

Some environmental factors which may break chemical dormancy are:

a. Light; e.g. certain weed seeds.
b. Cold treatment; e.g. many temporate zone species require a cold treatment to stimulate germination. This usually leads to an increase in GA, and in many cases can be substituted for by applying GA.
c. Leaching of inhibitors.
d. Heat, e.g. fire.

The last two categories are the ones on which this present study has been based.

Many Australian species have evolved through a history of fire, and for many of these, in nature, fire is necessary before germination occurs.

Seeds of species of the Eastern Rutaceae, which include *Boronia* spp., *Eriostemon* spp., *Zierie* spp., *Phebalium* spp., etc., will not germinate by normal means. They will not germinate if their seed coats are nicked or abraded to allow water to reach the embryo so a physical dormancy can be ruled out. In nature they germinate in profusion after a fire has been through an area.

The original work with *Eriostemon australasius* (2), showed that by chipping the seed coat of the radicle end of the seed and putting the seeds in running water for about 3 weeks germination would occur. There appears to have been a water soluble inhibitor leached from the endosperm, thus changing the inhibitor/promotor balance and allowing germination to occur.

Seeds of other species from the same family have also responded to this treatment, and these include *Boronia ledifolia, B. denticulata, Zieria smithii, Crowea saligna, C. exalata* and *Geijera parvifolia*. In most cases the percentage germination has been low, around 10%. With some of the larger seed it has been possible to extract embryos and do tetrazolium chloride viability tests on them. In all cases the apparent viability has been much higher than 10%. This indicated that only some of the viable seeds have responded. This could be explained by the fact that there may be varying amounts of inhibitors present as a mechanism to ensure that not all seeds germinate at any one time.

The role of fire in their natural germination still remains a puzzle in relation to the above results.

Persoonia pinifolia (Proteaceae) which has a very stony layer (endocarp) surrounding the seed has been germinated using the washing technique. The fruits were cracked in a vise and then placed in running water for 3 weeks. These fruits were sown and some of the seeds germinated.

Seeds were also germinated by carefully extracting them from their fruits and placing them on filter paper soaked in a 250 ppm gibberellic acid (GA_3) solution.It would appear that this also fits the promotor/inhibitor hypothesis. In the first case the inhibitor was reduced by leaching and in the second the promotor level was increased by adding GA. Another species to respond to chipping and washing was *Ricinocarpos bowmannii (Euphorbiaceae).*

Some of the species mentioned have great horticultural potential and are extremely difficult to grow from cuttings.

At the moment this technique is not a really reliable method of seed propagation, but rather as a beginning in the understanding of how the various dormancy mechanisms work. If evidence such as this can be collected on the physiological systems operating, then simple reliable systems for breaking dormancy and growing these species from seed may be devised. In the meantime the patient, dedicated grower can be assured of some success by using the chipping and washing technique.

There are literally hundreds of species of Australian plants which cannot yet be grown from seed. Some of these may respond to the technique outlined above.

A simple line of attack has been outlined in the following table to help in deciding what treatment to use.

Table 1. Possible treatments to use in overcoming seed dormancy.

Treatment 1	
Temperature 20°-30°C Adequate water Oxygen	*Non-dormant seeds* Germination should occur within 1 to 3 months.
When no germination has occurred using Treatment 1:	
Treatment 2	
Scarify Boiling water Nicking seedcoat Acid treatment	*Seeds with Physical dormancy* Seeds will imbibe water, swell and germinate when given Treatment 1.
When both Treatments 1 and 2 have failed:	
Treatment 3	
Light Scarification and washing Chipping and washing	*Seeds which have a chemical* *dormancy* Following one or more of

Table 1. continued

Removal of seed coat and washing	these treatments seeds may germinate when subsequently given Treatment 1.
GA_3	
Kinetin	
KNO_3	
Ethylene	

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A TECHNIQUE FOR THE ACCELERATED PRODUCTION OF COMMERCIALLY ACCEPTABLE CITRUS CLONES FROM SEED

IAN S. TOLLEY

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I am often asked, "Couldn't we plant the seeds from that nice fruit we have just eaten and grow a tree in our garden just like that."

Two of the important aspects making this impracticable are time and thorniness. In the first place, seedling trees take considerably longer to produce fruit than budded trees do. Secondly almost all citrus cultivars grown from seed show a high degree of juvenile vigour which is accompanied by a high degree of thorniness.

Twenty years ago I got "hooked" on the technicalities of citrus production and particularly in citrus nursery propagation. It didn't take long to discover a vast amount of fascinating information in word and picture in "The Citrus Industry," by Reuther, Batchelor and Webber (1). One of the interesting snippets I remembered was, "the physiological change which causes the decrease of seedling thorniness, therefore, can not depend solely on the age of the tree or clone from seed: it seems to be favoured rather by repeated cell division, and perhaps by erectness or exposed position of the shoot."

Table 1. continued

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As I collected over the years for my citrus arboretum, one of the problems I found in introducing new cultivars from overseas was the need to be ultra-cautious to avoid the introduction of serious virus diseases not present in Australia. I decided to introduce seed rather than budwood, as a precaution against future trouble with virus. Citrus seeds do not carry virus. This is where the propagation problems started. Fine strong, thorny, fruitless, time-consuming seedlings, year after year, growing bigger. Faced with this problem, it was then that I remembered the comment equating distance with time.

Utilising this fact has, and will continue to make it practicable for me to produce within my own life-time new cultivars which can be early fruiting, thornless, and acceptable in the commercial sense.

Using seed intended for development as a commercial clone, strong vigorous clones are grown as single pole trees for literally as long in distance or length as is possible on a seasonal basis. As time progresses apical buds and peripheral buds will tend to be less thorny. Once thornless buds are available, Stage 2 can be attempted.

To assess fruit quality early it is necessary to overcome the juvenility of the seedling material and to induce fruiting. This is done by budding into *Poncirus trifoliata* rootstock. Trifoliata is one of the most precocious rootstocks known, and it is common to have fruit produced from buds placed in this stock in the second year instead of in 5 to 6 years as with most other stocks. Sufficient Trifoliata seedling trees are required for continuous testing. Since the growing of these Trifoliata seedlings takes some years in itself it took me some years to establish this prerequisite before I could start the programme.

The second stage consists of selecting two thornless buds close together at the apex of the seedling. One is put into the Trifoliata stock, and the other into the base of a vigorous seedling rootstock of a different cultivar. The rootstock of a different cultivar is used to avoid any error in identifying the test bud if other buds in the stock shoot at the same time. Whilst the two buds taken are not identical (in view of the tendency of citrus to mutate) it is nevertheless reasonable to assume that they are, providing that continuous checks are made throughout the programme.

The first bud in the seedling rootstock is grown on using the lopping technique (1), the aim being to grow the bud for as long in length and time as possible. For practical purposes let us assume that six feet is a reasonable obtainable length in the one season. When the bud placed in the Trifoliata stock has developed nicely the tip of that shoot is pinched out to produce a bush of shorter shoots which will be more fruitful. If the check fruit pro-

duced on the Trifoliata is not commercially acceptable then that seedling combination is eliminated from the testing program before more time consuming development is done with it.

The same process is repeated for the next four or five years. One thornless bud is placed back into a Trifoliata seedling, and the other thornless bud back into the base of the previous year's growth. As time progresses, the decreasing thorniness of the seedling becomes more and more obvious. This continuous reproduction must be accompanied by a reliable and legible identification number system.

Hopefully by the end of the 5th year the original bud from the first seed has progressed at the rate of 6 ft. per year to achieve a total of 30 feet of growth. Relating this back to the original comment in Reuther, Batchelor and Webber — in the shortened time of 5 years, 30 years of effective growth has been obtained. In summary 5 years of continual reproduction plus the introduction of the 5th test bud into the Triofoliata stock, followed two years later by fruit for testing, gets us to a situation of 7 years development in lieu of a 30 year wait. We are still dealing with seedlings which started off virus-free and, providing that care has been taken not to cross innoculate the test material, a further stage can be undertaken.

The new material is put onto a range of rootstocks considered commercially useful and these are planted out in a commercial orchard for observations, including:

— bud union compatability
— earliness or lateness of fruit maturity
— adaptability of the rootstock/scion combination to various soil types
— and many other criteria which go hand-in-hand towards development of a new commercial variety.

The program is limited by the practical considerations of the number of seeds that can be handled on an individual basis. The more you can handle the greater the chances that some of the selections will turn out to be commercially useful.

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PROPAGATION OF TREE FERNS FROM SPORES

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The beauty of tree ferns and the ease with which they will grow make them very desirable garden plants.

At present, most commercial plants are being collected from the wild but it would be better if tree ferns could be grown from spores.

Several species are sold commercially. They are all attractive, but vary in their ability to withstand exposure. The black tree fern or mamaku *(Cyathea medullaris* Swartz) is usually considered to be the best species for cultivation, and so most of my studies have been with theis species. Other species that I have used are *Dicksonia squarrosa* Swartz and *D. fibrosa* Col. By using sterile culture techniques, I have been able to find out some of the requirements for "normal" growth of tree fern spores into new fern plants.

Collecting spores. The spores of tree ferns are found in sporangia grouped together in sori found on the back of older fronds. The sori open when mature, shedding sporangia which, in turn, split and release the spores.

To collect spores, I choose fronds with abundant mature but unopened sori. Then, I place the fronds over clean thick paper in a draft free place so that sporangia and spores fall onto the paper as they dry. Spores can be separated from sporangia by sloping the paper and tapping it gently whereupon the heavier sporangia slide down the paper leaving the powder-like spores behind. A single frond of *C. medullaris* can yield about 20 g of spores.

The colour of the spores is a useful indication of their maturity in the case of *C. medullaris* and *D. squarrosa*. Their immature spores are grey or yellow. Mature spores of *C. medullaris* are dark brown and of *D. squarrosa* are light brown (tan). On the other hand, mature spores of *D. fibrosa* are bright yellow. Mature spores have high germination rates (80-100%) and remain viable for over 12 months if stored in tightly stoppered tubes in a refrigerator. Immature spores do not have high germination rates and do not retain their viability.

Conditions for spore germination. Germination of spores requires moisture and light (4).

My tests showed that the optimal temperature range for spore germination is 20-29°C for *C. medullaris,* 18-28°C for *D. squarrosa* and 16-22°C for *D. fibrosa*. It is interesting that *D. fibrosa* does not

germinate as well as the other species at the higher temperatures. This species does not occur naturally north of latitude 37° 30'.

Structure and development of the gametophyte. In ferns, the spore does not grow directly into a typical fern plant but forms first a small, delicate, green, heart-shaped structure rarely more than 2-3 cm in diameter. This separate little plant is called the gametophyte because it produces the male and female gametes. In fertilization the gametes fuse to form an embryo which grows into the new fern plant or sporophyte. The structure and development of tree fern gametophytes have been described previously (1, 5, 6).

In order to understand the factors limiting the production of young tree ferns, it is necessary to delve into this life cycle in more detail. When the spore germinates, the young gametophyte grows as a short filament 6-10 cells in length. This one-dimensional phase is followed by a two-dimensional phase when the cells further divide to form a plate-like structure one cell thick and about 0.5 cm in diameter.

The male sex organs or antheridia are usually formed by the gametophyte at this stage. If unfavourable conditions limit the growth of the gametophyte, it may not proceed beyond these early stages so that filamentous, sterile or male gametophytes are formed. With favourable conditions, on the other hand, the gametophyte continues to grow to about 2-3 cm in diameter and becomes more or less heart-shaped with a thickened centre. The female sex organs or archegonia are formed on the thickened centre, on the under surface behind the apical growing point. In many ferns, these larger "female" gametophytes are known to secrete chemicals or hormones which induce antheridia formation in adjoining smaller gametophytes.

In *C. medullaris* I found that antheridia were formed in cultures about 6-8 weeks after germination and archegonia in about 12-16 weeks after germination. Both "male," "female" and "bisexual" gametophytes were observed.

It is well known that the development of the gametophytes of some ferns can be altered readily by cultural conditions (2, 3). I found that *C. medullaris* gametophytes are very sensitive to external growth conditions being more plastic than those of *D. squarrosa* and *D. fibrosa*. Factors which influence their development are as follows.

1. *Density of spores.* If pores are sown too thickly the developing gametophytes become crowded, and under these conditions most of them remain sterile or male. If spores are sown more sparsely some larger "female" gametophytes bearing archegonia are formed intermingled with the smaller male gametophytes. The mature "female" gametophyte of *C. medullaris* is 2-3 cm in width and to attain this size it needs ample space.

2. *Temperature.* In experiments where cultures were grown under a light intensity of 120-220 foot- candles at 25°C or 20°C, gametophytes grew very slowly at 25°C and many did not develop past the filamentous stage. Growth was more "normal" at 20°C, where "typical" expanded gametophytes were formed. After three months, 80% of the gametophytes grown at 25°C were male and 20% were female, while at 20°C, 20% were male and 80% were female.
3. *Light intensity.* In experiments where cultures were grown at 20°C under varying light intensities, it was found that both high light intensities (800-1400 foot-candles) and very low light intensities (60 foot-candles) reduced growth and produced gametophytes which were predominantly filamentous and thus sterile or male. The optimal light intensities for producing gametophytes with archegonia are 120-220 foot-candles. (This is about 2-5% of full daylight).
4. *Moisture.* Free water is needed to insure the release of the male gametes and to provide an adequate film of moisture for the motile male gametes to swim to the immobile eggs. Fertilization only occurred in cultures which were regularly flooded with sterile tap water or nutrient solution.

Production of sporophytes. In theory the gametophytes of *Cyathea* and *Dicksonia* are bisexual, but in practice they tend to be unisexual as the conditions which favour the production of male sex organs do not favour the production of female sex organs. This ovbiously limits the formation of sporophytes.

I was able to induce sporophyte formation in several different ways, as long as the steps taken resulted in both male and female gametophytes being present in the same culture at the same time.

Thus, when large female gametophytes were taken from three month old cultures grown at 20°C under 120 foot-candles of light intensity, and mixed with smaller male gametophytes taken from similar but younger cultures (two months old) sporophytes appeared in another 4-6 weeks. Sporophytes were also produced by sowing a second lot of spores into two month old cultures. In a third experiment, cultures were grown first at 20°C for three months and then transferrred to 23°C in order to encourage male gametophyte formation in the slower growing gametophytes intermingled with the larger female gametophytes. Again sporophytes were formed.

In conclusion, my studies suggest that tree ferns could be grown from spores if the following procedure was followed:

Choose mature spores and sow them thinly on a loose potting mix similar to that used for orchids. Grow the gametophytes under low light intensities in a cool place not above 20°C and water them frequently to ensure free water for fertilization.

The minimum time for sporophytes to appear is 3 to 4 months and for plants 10-30 cm high, one to 2 years.

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Question — Is the use of distilled water beneficial when working with fern spores?

Answer — If available, use is recommended.

THE APPLICATION AND USES OF TERRAZOLE SOIL FUNGICIDE

GLENN A. DYE

Olin Corporation of New Zealand, Limited
Napier

Although Terrazole soil fungicide is a relatively new chemical to us here in New Zealand, having only been registered since November 1974, development and research work has been going on in the United States and other overseas countries since the early 1960's.

The early registrations of Terrazole in New Zealand were for use on turf and ornamentals but recently registration has been granted, extending the area for use into vegetable seedlings.

Chemical and Physical Properties: Terrazole is a soil fungicide used for prevention and control of diseases caused by pythium and phytophthora, commonly called water moulds. It is both fungicidal and fungistatic. That is, it kills the organism as well as prevents reinfection.

Terrazole's chemical name is 5 ethoxy-3-trichloromethyl1-1, 2, 4-thiadiazole, but don't let that put you off as "chloroethidiazole" has been proposed as the common name and this is much more pronounceable.

The technical material is a pale yellow-brown liquid of 95% purity. We receive it in New Zealand in this form and formulate our own emulsifiable concentrate. The wettable powder is received in New Zealand in its manufactured form.

Formulating can have its problems as one of the physical characteristics of the technical material is that it freezes, or solidifies, at 19.9^{0}C (68^{0}F), so on a day that is very pleasant for you and me to be out in, Terrazole technical material will remain quite firmly in its drum. This characteristic could also be the reason for some growers having had difficulty in mixing the wettable powder form with water. If this problem does occur, try adding a small quantity of warm water to bring the temperature above the freezing point for Terrazole technical.

Toxicology:

Animal Studies:

Acute L. D.$_{50}$ (single oral dose)
Mice : 2,000 mg/kg
Rats: 1,077 mg/kg
Dogs: 5,000 mg/kg (premedicated with morphine)
Rabbits: 799 mg/kg

No major pathological effects developed in dogs receiving

1,600 ppm of Terrazole in the diet for 90 days, or in rats receiving 1,250 ppm in the diet for the same period.

Fish Studies:
Bluegill: More than 7.5 mg/l at 18°C (water)
Rainbow trout: More than 4 mg/l at 13°C (water)

Terrazole is toxic to fish. Do not contaminate lakes, streams, ponds or any other body of water by application, run-off, or the cleaning of equipment.

Dermal Toxicity:
Acute L. D.$_{50}$ Rabbits: 1,366 mg/kg
(200 mg/kg caused only slight irritation which subsided after 72 hours. The injured area recovered normally and growth and survival were not affected).

Acute Inhalation: Rats exposed to aerosolized technical Terrazole at 200 mg per litre of air for one hour showed no mortality or toxic effects over a 14 day observation period.

From this data it can be seen that Terrazole is a reasonably safe chemical to use, although the usual precautions for handling chemicals should be observed.

Applications: Present day practice is for most commercial propagators and nurseries to raise seedlings in a pathogen-free environment by growing seedlings in a steam or chemically treated soil. However, the effects of such treatments are often not long term and can create an environment ideally suited to fungi multiplying rapidly in a competition-free medium if reinfection does take place. In spite of these treatments, outbreaks of damping-off diseases can, and do, occur. This is because the fungi can be reintroduced by way of dirty soil, unclean implements, unsterilized seedboxes and via water supplies. I am sure you have all experienced this type of disaster.

The current trend, both here in New Zealand and overseas, is to use soil-incorporated fungicides in the soil mix and to follow up with fungicidal drenches. The aim of this practise is not only to prevent expensive losses while the seedlings are in their very early stage of growth, but to produce plants that will continue to grow at their potential rates.

It is a mistake to consider losses from damping-off fungi as being restricted only to juvenile plants, as the same fungi that cause losses in seedlings can also cause major losses at a later stage of the plant's growth. Propagators have given considerable attention to controlling plant diseases, but in many instances have neglected to control the soil pathogens that can be just as serious. The aim should be to produce plants free of pathogenic organisms, not merely free from disease. Hence the importance of using a sterilized soil medium and further supporting this sterili-

sation process by the incorporation of fungicidal and fungistatic chemicals as routine practice.

Here I should give a word of warning. Terrazole is particularly effective and very efficient in the control of pythium and phytophthora but is not a broad spectrum fungicide. The control of other fungi must also be attained to produce strong, healthy and well-grown plants.

Formulations: Terrazole is available in two formulations — a 35% wettable powder which mixes well with water but does require agitation to maintain a consistent suspension, and a 25% emulsifiable concentrate which is readily dispersible in water. Both formulations have a long shelf life and are very stable in sunlight. This, of course, gives it the advantage of being able to be used irrespective of weather conditions and, if your weather forecasting has been "off course," the effectiveness of the chemical, and its control, will not be affected.

It would be worthy of mention here that Terraclor, which has proven outstandingly effective against rhizoctonia, has been withdrawn from the New Zealand market as have all other P.C.N.B.-based chemicals.

Phytotoxicity: The dangers of phytotoxicity are something that propagators must always be aware of and Terrazole has proved to be very safe in this area, providing it is used at the rates recommended on the label. Work done at Massey University by Murray Richards, has indicated that rates up to 4 times the recommended rate are considered unlikely to cause any serious phytotoxicity hazard when incorporated into the growing medium. However, we do suggest that growers carry out limited trials on their own account before putting a previously untried cultivar to hazard. Further experimental data is available from Olin Corporation regarding the rates of Terrazole on a wide range of crops.

Methods of use:

Seed Treatment: Seed treatment has an important place in prevention of pre-emergence damping-off and is, therefore, particularly important when seed is sown in the field. The dusting of seed with a fungicide before planting creates a small zone of protection about the seed, giving protection for a short time to the seed and emerging seedling from attack by pathogenic soil fungi.

Seed treatment is of little value in controlling pathogens which have completely penetrated the seed. Likewise it is of little value against post-emergent damping-off but, nevertheless, does have its uses in particular areas.

The first area of use is obviously in the growing medium. Control of, and protection from, pythium and phytophthora at-

tacks can be obtained here by incorporating 50g to 100g of Terrazole 35% wettable powder per cubic metre of mix. As this is a very low ratio of fungicide to mix, blending will be improved by first pre-mixing the fungicide with 5 or 6 parts of mix and then incorporating into the larger volume. This will give control for 5 to 10 weeks, depending on conditions, at a cost of approximately $1.60 per cubic metre or, if potting into 15 cm pots, just under ½ cent per pot.

Drenching: To maintain an adequate concentration of Terrazole in the mix, we recommend that the initial application be followed by drenching at 5 to 10 weekly intervals.

The wettable powder or the emulsifiable concentrate can be used for this treatment but in either case it is advisable to follow up the drench with an equal quantity of water to ensure that the fungicide penetrates into the mix.

Irrigation: Terrazole is also being applied through overhead sprinkler systems, and trickle irrigation systems on a regular schedule as a means of preventing reinfection by fungi. Through overhead sprinkler systems a concentration of 1 litre (0.45 gallon) of Terrazole 25% E.C. to 2,000 litres (445 gallons) of water applied to an area of 0.4 hectare (1 acre) has proven effective in giving control.

Terrazole can also be introduced into trickle irrigation by first mixing 9 litres (2 gallons) of 25% E.C. in the 160 litre (36 gallon) container of a Cameron diluter. This solution is then incorporated into the irrigation system at the rate of 4.5l (1 gallon) per 450 litres (100 gallons).

The Future: Research and experimental work is continuing both in New Zealand and overseas into new areas of application and registration. Crops at present being investigated include sugarcane, pineapples, avocadoes, macadamia nuts, pears, citrus, passionfruit, peaches, potatoes, kiwifruit, boysenberries, hops, tobacco, coffee and taro.

There are also reports that Terrazole has certain algacidal properties and where used in sprinkler and misting systems assists in reducing algae growth. This has not yet been fully investigated but future research will be directed into this area of application.

Summary: In summary, I would suggest that Terrazole has a place in every soil, or soil-less mix, where losses from pythium and phytophthora occur or are likely to occur. By incorporating the wettable powder into the growing medium, and by drenching at 5 to 10 weekly intervals, losses caused by these fungi can, and should be eliminated completely.

Question — What is the effect of Terrazole on useful micro-organisms?

Answer — At this stage no damage has been established, but trials are still under way.

THE PURPOSE AND OPERATION OF A NUCLEAR STOCK UNIT

K. L. DAVEY

Horticultural Research Centre
Ministry of Agriculture and Fisheries
Levin, New Zealand

1. (a) **Purpose.** A Nuclear Stock Unit is based on the concept of an enclosed insect-proof area where plant material can be maintained in a "virus-free" or "high-health" status, and kept true to type. "Virus-free" — usually means free of known viruses. "High-health" — free of viruses of known economic importance.

Although insect-proofing is of prime importance to the maintenance of the high level of plant health required, strict observation of plant-hygiene is of equal importance and includes regular application of plant therapeutants for the control of pests and diseases with a special emphasis on the control of the main virus vectors, i.e. aphids, leaf hoppers and nematodes. The Unit becomes the source of nuclear plant material for research and for distribution of "Clean Stock" to growers.

(b) **Establishment and Layout.** The present Nuclear Stock Unit at the Horticultural Research Centre in Levin was built in 1967 and replaced a smaller temporary unit that had been in existence since 1961. It consists of a central service shed 13.70 x 3.95 m with two 15.20 x 3.55 m glasshouses on one side and three 30.45 x 6.10 m screenhouses on the other.

The unit is proofed against all insects as large or larger than winged aphids by screening glasshouse vents and service shed windows with a 24 x 24 mesh woven plastic gauze. The gauze completely covers the screenhouses. Entrance to the Unit is by a double door airlock in which an aerosol insecticide is released manually immediately after the outside door is closed.

(c) **Operation: Glasshouses.** The glasshouses are lined with clear plastic sheeting for increased heat retention in the winter and at night, and a shading compound is applied to the outside of the glass for the duration of the hotter months (September to May), to reduce overheating.

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The glasshouses are heated by underbench electric fan heaters, the heat being distributed by a perforated plastic tube, and are maintained at a minimum of 16-17°C. The cooling of the glasshouses is by fan and vent with the aim of keeping the houses at 18-20°C. If the temperature rises above 24°C a misting system comes into operation to prevent overheating. When required, (from March to October) the plants are provided with supplementary lighting to extend day length. Banks of 150 watt incandescent light globes provide the supplementary light and are controlled by time switches and some additional heat is also provided by the lamps. There is a mist propagation unit in one house. All watering in the glasshouses is done manually.

Screenhouses. The screenhouses contain the "banks" of berryfruit cultivars in the form of Nuclear or basic stock. Usually 2 or 4 plants of each are kept and maintained in 2-4 litre containers.

Any strawberry cultivars wanted for bulking up are grown in soil bins 2.40 x 1.20 x 0.30 m and will yield up to 400 plants per bin, depending on cultivar, from two mother plants. *Rubus, Ribes* or *Vaccinium* cultivars that require bulking up are planted in 100 litre steel drums and grown on for cutting production.

All watering in the screenhouses is by mist line and trickle and is controlled by time switches.

(d) **Importance to the Berryfruit Industry in N.Z.** This Unit is a part of the Berryfruit Section of the Research Centre and is important to the berryfruit industry as it serves several purposes.

1. Provides a source of "high-health" nuclear plants for release to the nursery side of the industry.
2. Serves as a quarantine unit for the introduction of new strawberry cultivars from overseas — other berryfruit cultivars are held by Plant Diseases Division of DSIR at Mt. Albert for their Post-Entry Quarantine period of 1 to 2 years before release to the Levin Horticultural Research Centre.
3. Introduced strawberry plants are indexed soon after they arrive.
4. Provides plants for trials to evaluate cultivars.

2. The main cultivar collection consists of:

Fragaria (strawberry) — 135 cultivars (including 17 virus indicator clones).

Rubus — red raspberry — 43 cultivars
purple raspberry — 3 cultivars
black-cap raspberry — 1 cultivar
brambles — 26 cultivars

Ribes — blackcurrant — 26 cultivars
whitecurrant — 2 cultivars
redcurrant — 7 cultivars
gooseberry — 12 cultivars
Vaccinium — blueberry — 17 cultivars

3. **Propagation.** As the glasshouses are maintained at a minimum of 16 to 17°C and daylength is controlled by supplementary lighting to give 16 to 18 hours of light in every 24 hours, plants of most berryfruit cultivars can be induced to provide propagation material at almost any time of the year, at the same time the standard methods of propagation are still used: that is,

Stolon plants — strawberry
Winter dormant cuttings — currants, gooseberry, blueberry
Tip layers — bramble
Stool division — raspberry

Other methods of propagation used are:

1. Strawberry —
   (a) Seed — *Fragaria vesca* 'Alpine' is grown from seed as it does not produce stolons.
   (b) Crown discs — Used in heat therapy and if a cultivar becomes infected with red core (red stele) disease. The crown is stripped of all leaves and roots and then is cut into 4 to 6 mm discs; the discs are put into fine pumice and placed in a mist unit. Dormant lateral buds usually break and can soon be carefully removed and grown on.
   (c) Unrooted stolon tips removed before leaves and root initials appear root readily under mist.
2. *Ribes* –
   (a) Softwood cuttings (gooseberries need more research into propagation technique as they are more difficult to root from soft cuttings than currants).
   (b) Single node cuttings are treated like single node grape cuttings; any dormancy is broken by bottom heat and extended day length.
   (c) Seed. Seedlings of several cultivars are useful as virus indicators.

Rubus —
(a) Softwood cuttings. These root readily but there is a fairly rapid decrease in rooting ability as the wood matures. Winter cuttings made from dormant canes will root but there is a tremendous amount of cultivar difference in the ability to root and in the ability of the developing buds to differentiate into growth shoots and not fruiting spurs.

(b) Root cuttings. All raspberries and most brambles will produce plants from adventitious buds on cut up sections of root, the exceptions being some of the thornless brambles that arose as bud chimeras and must be propagated from the shoots and not the roots to maintain the thornless state.

4. **Virus indexing.** For strawberry virus indexing, selections of several *Fragaria* species are used: *Fragaria vesca, F. v.* 'Alpine', *F. virgininia,* and *F. chiloensis.*

Until recently an excised leaf-petiole method of virus transmission was used, but this has been replaced by a modified stolon graft using a double-tongue bottle graft with the donor stolon kept in a test tube of water. The graft is bound by using a piece of self-adhesive crepe rubber bandage (usually one graft is sufficient). After grafting, the indicator plant is defoliated. Three to four weeks after grafting, the grafted stolon is removed and any virus-like symptoms are recorded — some viruses produce symptoms in less than 3 weeks.

Symptoms produced can be found in the following general groups: chlorosis, necrosis, distortion, stunting.

Any part of the indicator plant can be affected and mild to severe symptoms can be found.

It is possible for a virus to be symptomless on the donor plant yet cause severe symptoms or death to the indicator. Some viruses are harder to transmit than others and may require several attempts before transmission is achieved.

PLANT TISSUE CULTURE — POSSIBLE APPLICATIONS IN THE NEW ZEALAND NURSERY INDUSTRY

DANIEL COHEN

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Over the past 10 years or so there has been considerable interest in the prospect of using tissue culture methods in modern plant propagation practice (1, 2, 3, 4, 5, 6, 7, 8, 9, 10). Progress in the tissue culture field has indeed been exciting and it is now possible, with some cultivars of some species, to grow complete plants from single cells and even from protoplasts (i.e. cells from which the cell wall has been removed). Such areas are still only research tools which allow us to investigate in more detail the processes of cell growth and differentiation.

There are, however, two applications of tissue culture which have already found a place in plant propagation. Firstly, in the production of virus-free (disease-free or high-health) propagating material and, secondly, in the rapid clonal multiplication of selected plants. It is about these applications that I will speak today. I will describe some of the principles and problems involved, the work we are doing at Plant Physiology Division, D.S.I.R. and, finally, some prospects for the future.

Virus-free Propagating Material. Selected desirable plant types are usually propagated vegetatively using cuttings, grafting, budding or simple plant division. Using any of these methods there is a very real risk of propagating virus-infected material since symptoms are often masked or show only seasonal expression. It has been found that many horticultural cultivars are almost, if not entirely, infected with one or more viruses; typical examples are daphne, lily, and some cultivars of chrysanthemum, carnation and rose. In order to obtain virus-free material we must, first of all, have adequate facilities for virus indexing using an electron microscope, inoculation, or grafting to indicator plants and other specialised techniques. These methods will sometimes indicate specimens apparently free of known virus diseases and these specimens can be used for subsequent propagation.

High temperatures (usually around 37-40°C) will inactivate many viruses and new shoot material on heat-treated plants will often be free of virus. The preceding paper presented by Mr. Ken Davey illustrated the use of thermotherapy in berry fruit propagation. The general principle involved appears to be to raise the temperature as high as the plant can tolerate and yet still continue growth and to maintain this temperature until virus inactivation

has occurred. Any treatment which can enhance plant survival at high temperatures is likely to increase the effectiveness of thermotherapy. Work in Australia has shown that elevated carbon dioxide concentrations enhance plant survival at high temperatures and there are good indications that reduced root temperature may also be beneficial. To determine optimum conditions for thermotherapy controlled environment facilities such as the Climate Laboratory of the Plant Physiology Division D.S.I.R. should prove invaluable.

An alternative approach to obtain virus-free plants has been shoot tip culture. In the vicinity of the apical or axillary bud meristems, virus is either absent or much reduced in concentration. If the shoot tip consisting of the meristematic dome and one or two leaf primordia is carefully dissected under a microscope and cultured under suitable conditions the resulting plant has often been found to be free of virus.

A combination of thermotherapy and meristem tip culture have been shown to be more effective than either method alone. This combination is now applied routinely in many centres in Europe and the U.S.A., for flower crops such as carnations and chrysanthemums and also for strawberries, potatoes and hops. The potential for these techniques is very promising and progress is limited principally by the time and facilities required to investigate the specific requirements for each crop. It is essential to emphasise that the virus-free status of plants produced by these methods must still be thoroughly checked by virus indexing. As mentioned above virus indexing involves the use of expensive and sophisticated instrumentation and techniques. To be certain that a virus is eliminated may take months or even years in cases where the virus expression is seasonal or where the virus has been attenuated (i.e. rendered less virulent). Often only one plant is grown from each shoot tip. Subsequent propagation may be either by traditional means or by tissue culture methods as discussed later.

To date these techniques have been used mainly in research stations and universities. Overseas some large commercial firms are establishing their own laboratories and specialist tissue culture services are also being established. In Great Britain the Nuclear Stock Association (Ornamentals) Ltd. works in close association with the Glasshouse Crops Research Institute at Littlehampton. In Australia the Victorian Plant Research Institute has a section working on ornamental plants which produces virus-indexed stock for sale to both commercial and amateur growers.

Providing that both interest and support from the industry is forthcoming we hope that arrangements can be made whereby the Plant Physiology Division, in conjunction with the Nursery Re-

search Centre at Massey University, will be able to perform a similar function. Virus-free stocks of commercially important plants could be produced and maintained for distribution to the industry.

Rapid Clonal Propagation. The term micropropagation has been proposed to cover tissue culture methods of plant propagation. When a shoot tip is cultured, changes in the hormonal balance can produce either a single rooted plantlet, a proliferation of shoots or development of undifferentiated callus. The precise conditions required for each species (and sometimes for each cultivar) must be determined by trial and error. Generally the class of hormones known as *auxins* promote root initiation at low concentrations and enhanced callus formation at higher concentrations. A second class of hormones, the *cytokinins*, tend to inhibit root formation except at very low concentrations and often induce multiple shoot formation at higher concentrations.

Alteration of development can also result from agitation of cultures. If a culture is placed in a liquid medium and rotated so that the tissue is gently tumbled root and shoot development is retarded. In orchid cultures protocorms proliferate and in chrysanthemum cultures "leafy" callus develops. If rotation is stopped or if cultures are transferred to a medium solidified with agar, shoot development proceeds rapidly.

So far these methods have only been applied to a limited number of species but in these cases the multiplication rates are impressive. For instance Earle and Langhans (4) compared conventional propagation of chrysanthemums by cuttings which can produce 30,000 plants from a single plant in one year with two methods of micropropagation. Multiple shoot formation from shoot tips could produce at least 9 million plants and a "leafy" callus system over 90 billion plants in a single year. Murashige, *et al.* (9) compared the 50 to 100-fold increase per year by division of a gerbera plant with the 1 million-fold increase attainable by tissue culture.

None of the published calculations of multiplication rate have so far included an analysis of labour and costs. Application of micropropagation methods in the nursery will depend on the value placed on the plants produced. In the orchid industry, tissue culture was readily adopted because of the extremely slow rate of traditional propagation methods and the high value of selected clones. But when plants can be readily grown from cuttings, as for example with chrysanthemums, can tissue culture grown plants compete in price with traditional cuttings? I don't know the answer, but obviously the total number of plants required would greatly influence the costings. The growing space for stock plants is saved in micropropagation but the plantlets produced are initially smaller and more fragile than traditional cuttings.

Where stocks of new cultivars are being increased for release, the time for stock buildup may be reduced from 2 years to less than a year for chrysanthemums (4). In the case of gerbera or bulb crops, such as gladioli or lilies, natural rates of increase are very slow and the rapid rates of increase that can be achieved with tissue culture (2, 9, 10) then become more attractive.

It is possible to carry out small scale tissue culture work with relatively simple facilities and equipment. Numerous orchid hobbyists have successfully mericloned their favorite orchids with only minimal capital outlay but, of course, they have no indication of the virus status of the plants they are propagating. Progressing from a backyard propagator to a full-time commercial undertaking requires considerable financial commitment, and economies of scale quickly become evident. If you look at any orchid magazine you will find advertisements for mericloning services with minimum fees and charges which become less as numbers increase. The difficult steps are the initial culture establishment and reliable virus indexing, not the subsequent subculturing steps required for large scale production.

Research at Plant Physiology Division. I am one of a group of workers concerned with aspects of plant tissue culture and genetic engineering. I began my micropropagation work by looking at methods of clonal propagation of asparagus.. Here was a process crop with considerable export potential, which showed great variability among plants grown from seed and was badly damaged by root rot infections. When I commenced this work I envisaged large scale production of elite plants. Over the past few years, however, higher density planting and direct seeding has raised plant populations from about 20,000 to more than 100,000 plants per hectare. I now see the use of tissue culture in the propagation of parent plants, selected on the basis of desirable progeny, which would be used to establish a bed for seed production.

Shoot tips approximately 1 mm long from primary or secondary laterals of asparagus spears can be rooted readily but survival of these rooted plantlets on transfer to soil is variable. Survival appears to depend on the development of crown buds and thick storage roots and the factors controlling their formation on the tissue culture plantlets are not understood at present.

In New Zealand several lily breeders have produced many fine hybrids of *Lilium auratum* x *L. speciosum* and there appears to be a good export market for these hybrids if they can be produced cheaply enough free from virus. However it appears that at least one virus known as Lily Symptomless Virus (LSV) is widespread in these hybrids. As the name implies this virus causes no visible symptoms in most cultivars, but in conjunction with either Tulip Breaking Virus or Cucumber Mosaic Virus, serious and damaging effects can be clearly seen. Work from the U.S.A., in

particular, has indicated lily buds developed on lily scale pieces in tissue culture may be free of virus. Although cultivars differed in the percentage of virus-free bulbs obtained, the results from the mid-century hybrid, 'Enchantment' were promising and this cultivar showed a rapid rate of multiplication in culture (2). With Dr. Ken Milne of Massey University, I have been checking whether bulbs grown on scale pieces are free of virus and also investigating the use of tissue culture for rapid propagation.

When bulb scales are cut up and placed in a modified Murashige and Skoog medium, many small bulblets form and later develop leaves. Based upon electron microscope examination many of these plantlets appeared to be free of rod viruses but following transfer to potting medium in the glasshouse, virus levels appear to build up rapidly in some plants. Much work remains to be done to survey the lilies in order to determine which viruses are present in New Zealand and the economic importance of these viruses. When virus-free bulbs have been produced, methods to maintain these bulbs in a virus-free condition have yet to be tested.

In the Climate Laboratory at the Plant Physiology Division we have 24 growth rooms in which temperature, humidity, light level, photoperiod, nutrient application, and carbon dioxide level can be controlled automatically. Dr. Roger Slack, Dr. Ken Milne, and myself are investigating factors which will enhance plant growth during thermotherapy. We are testing the effects of root cooling and carbon dioxide enrichment to 900 ppm, the normal level being 300 ppm. The present experiment is being carried out with chrysanthemums but subsequent experiments will include other plant types such as roses and daphne.The results of these experiments will be assessed on the basis of plant growth at temperatures near 40°C, on our ability to grow shoot tips from heat-treated plants, and the presence or absence of virus after treatment.

We have already checked out micropropagation methods for chrysanthemums and carnations and are presently attempting to culture shoot tips of roses and daphne.

The Future. In this paper I have dealt with developments in two areas of the tissue culture field which I feel should have an impact on the nursery industry in the near future. There are other, perhaps more exciting, areas involving genetic engineering which may eventually lead to new plant types but to predict results from these developments requires a crystal ball.

Of the two areas I have discussed, I believe that the production of virus-free stock to be the one of most immediate concern. The plants I mentioned were mainly herbaceous because these are the plants that have been studied most widely in tissue culture.

Obviously there is need for work to be done on more woody species such as roses and daphne and, no doubt, you can think of a dozen or more plants that you would like to obtain in a virus-free condition. However, the amount of work involved for each plant is large and best prospects can perhaps be expected by exchange of both information and plant material with other workers overseas.

In New Zealand most nurseries handle a wide range of plant material and are relatively small by international standards. With the exception of orchid specialists, there are probably very few growers who could justify establishing facilities for tissue culture on economic grounds at this time. Possibly orchid specialists who are mericloning for other growers might expand their services to handle other types of plants. Other growers who are contemplating specialisation of production might well consider the potential of tissue culture for rapid clonal propagation. At the Plant Physiology Division we hope to be able to advise on techniques and problems associated with individual crops. If required, specific problems could be investigated and workshops on tissue culture methods could be organised.

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NEW ZEALAND PEAT-SAND MIXES, INCLUDING THE USE OF ZINC

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Though our nursery business is small compared to many others in New Zealand, I feel that we have gained a great deal from joining the New Zealand Chapter of I.P.P.S. and it is now my endeavour to make a contribution to the Society. The following thoughts and observations are personal opinions and conclusions reached from practical experience.

The "container-grown" nursery business in New Zealand is not so many years old. I well remember when the most widely used container was the clay pot. Potting composts contained soil, along with other components ranging from turf, straw, animal manure, charcoal, scoria, leaf mould etc., as well as fertilisers such as were commonly used in the field. Often a different "recipe" was produced for each crop.

Today we require large volumes of a consistent "mix" which must be acceptable to a wide range of plant species and cultivars. I do not subscribe to the concept that a nursery should use only one mix. I fail to see any possibility of one mix being acceptable to the wide range of plants produced in most New Zealand nurseries.

My requirements for a suitable container mix are:

1. Controlled growth, minimising the need of supplementary fertilizers.
2. The mix should not become waterlogged in wet weather, nor dry out quickly.
3. The cost must be reasonable.
4. The mix must provide anchorage and sufficient aeration for healthy roots and be heavy enough to provide stability in average weather conditions.
5. Our mix must suit machine potting and bagging of our plants. (A more recent requirement)

The U.C. peat-sand mix comes nearer to these criteria than others we have used. We started using soil mixes as recently as 1971. Our reason for being slow to adapt to the U. C. mix was the availability of good volcanic soil at very low cost.

We were, however, becoming more concerned with cultivars that we considered unsuitable for container growing. Some nurserymen using the U.C. Mix were successfully growing some of the plants which we could not. We decided to experiment using

"Osmocote" fertiliser which had recently arrived in New Zealand. Pumice sand, with particle sizes of 1 mm to 6 mm, and peat in equal parts by volume formed the ingredients of our first mixes. Two objections were noted; firstly, it was very expensive for large scale operations in our area. Secondly, the mix was light and loose and caused problems with plants blowing over and requiring much more watering.

We discussed our problems with another nurseryman who had used a U.C.Mix for some time. He asked us why we had chosen to use expensive pumice sand whereas the University of California Manual 23 (page 12) states "fine sand, particle size 0.5 mm to 0.05 mm." We found a suitable source of beach sand as used in the building trades.

The combination of 50% fine sand and 50% peat became our first U.C. Mix used in quantity. Results were reasonably good over a wide range of cultivars but we felt that the mix retained moisture rather too well, and it was undesirably heavy when wet. Four cubic feet of perlite was added to each cubic yard of mix with some desirable lightening of texture and weight. Subsequently this portion was replaced with the pumice sand as used previously. We now had a stable mix which did not waterlog easily nor dry out too quickly. It was and still is rather expensive but we have not been able to overcome this aspect any further as yet.

We now had our "Javo" potting machine and found that the mix suited the machine very well. Holes bored with the machine do not collapse as would a coarse light mix.

Our attention now turned to deficiency symptoms with several species. Species of *Acacia, Banksia, Boronia, Eriostemon* and *Proteaceae* were among those noted. "Sporumix" trace element fertiliser was added to the mix but deficiency symptoms were unaffected in most cases.

About this time we were becoming involved with the growing of *Pinus radiata* and exchanged visits with N.Z. Forest Service Nursery Officers at the Sweetwater Nursery north of Kaitaia. This nursery is established on a large area which was previously a peat swamp. A Senior Officer asked if we had had any experience with zinc deficiency. The Sweetwater nursery initially had a major problem due to copper and zinc deficiencies. Areas where thick fibrous moss peat was encountered did not respond to copper alone but only when zinc was added.

We set up tests and found that the one containing zinc sulphate was outstanding among the others. A base fertiliser was made up consisting of:

Dolomite lime	**super-phosphate**	**Uramite**	**potassium nitrate**	**iron sulphate**	**zinc sulphate**	**Sporomix**
60kg	30kg	9kg	3kg	1kg	1kg	1kg

Five kgs of the above was added to each cubic meter, plus 2.5 kgs of Osmocote 18-26-10.

A wide variety of nursery stock has been successfully grown using the above fertiliser, but we did not find it suitable for "fertiliser tender" plants, particularly those in the *Proteaceae*. I believe that these plants must have a different fertiliser mix. We have obtained some interesting results since omitting the superphosphate from the above mix, and reducing the dolomite by half. We then used 1.5 kg of this special base fertiliser together with 1.5 kg of Osmocote 18-26-10 per cubic meter. When "Sporomix" was not immediately obtainable we continued without it, and have not noted any deficiency symptoms in the plants concerned.

Fritted Trace Elements (F. T. E. 36) have now taken our attention, but we feel that their adequacy as a total source of zinc may still be doubtful. The composition of F. T. E. 36 is:

Cu	Mn	Fe	Zn	B	Mo	K_2O
2.3	2.4	9.0	2.2	0.4	0.5	31.2

Zinc is an essential element for plant growth. Deficiencies were first observed in Florida in 1927 on crops growing in peat soils. Sandy soils are also recorded as usually having a very low zinc content. The application of lime is known to reduce the availability of zinc. It therefore follows that when we use a mixture of peat and sand to which we have added a liberal quantity of dolomite lime we are likely to create a deficiency of zinc.

Zinc deficiency is usually more obvious in summer and on the sunny side of the plant. Zinc is not easily translocated in established plant tissue. For this reason application of dry zinc sulphate may be ineffective or very slow. Zinc sulphate as a foliar spray is quickly effective. We used 50 gms in 10 litres of water in our experiments.

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SOME ASPECTS OF PROPAGATION INFLUENCING THE LANDSCAPE GARDENER

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The landscape gardener has to present to his client a complete garden capable of a continuing and lasting process. Present plant production techniques do not always provide his requirements and I am suggesting that this is because as often as not he is not concerned with individual plants but plants in number and the design reactions between those plants. The propagator is frequently very aware of the individual specialized merits of a single species or cultivar, and becomes concerned with the plant's propagation needs and subsequent sales requirements in isolation from its potential garden usage.

Such a narrow view taken to many individual plants results in a collection of specialised plants which the landscape gardener has to draw together within a scheme embodying the design elements of unity, scale, light and shade, texture and colour to create a process involving time and space division resulting in a particular style.

Style in New Zealand at present has been largely influenced by a national preoccupation with the quest for a maintenance-free garden. The nurseryman's answer has been to convince the public that a garden need consist of only trouble-free conifers and a few hardy shrubs — mostly plants easily propagated and presented for sale. Only the specialist provides the crafted plant and then at considerable cost.

This style or lack of style has resulted in a standardised garden framework throughout the country which has destroyed any regional differentiation. If one takes the view that the low maintenance garden should be largely made up of plants that thrive in the broadest sense then it will follow that any propagator will have a core of production that the landscape gardener not only endeavors to identify but also to purchase when he is to create a garden for a client. Because he is concerned with the above design elements rather than horticultural cosmetics he requires trees, shrubs, herbaceous perennials and annuals.

The obvious difficulty is that he cannot get all of these plant types at any one time. Probably the biggest single gap in supply is with herbaceous perennials — at present they are offered over a limited season. Yet the perennials the landscape gardener mostly requires are those that could be offered over the greatest period. At present a delphinium cultivar with a potentially magnificent bloom and a high maintenance requirement and a limited range is

offered for a few weeks, whereas a low maintenance wide range plant such as agapanthus could be offered all year round.

Frequently it is difficult to achieve the unity of design desirable through the use of herbaceous material even when it is available because of the presentation techniques centred on self-service garden centre sales. The landscape gardener is not interested in pots and highly descriptive labels. He would be delighted to receive a bundle of rooted *Hedera* cuttings as he does his kumaras if it resulted in better economics.

The selection of material for propagation is important as not only does the landscape gardener rely on the propagator for correct identification but also for reliability of material. Obviously the propagator is responsible for such things as freedom from disease and graft compatibility but he also frequently determines the choice of cultivar to be put onto the market. For instance, a tall Michaelmas daisy with large flowers may be easy to advertise but a smaller flower on a short sturdy stem does not require staking.

The popularity of groundcover is indisputable and yet the most common material used is pebbles — surely an indictment on the plant propagator I feel this is definitely a case where traditional plant production and sales presentation have prevented optimum use of a plant form. Perhaps to lower costs, woody plants such as *Coprosma kirkii* could be grown and sold in the "Nisula Roll" with herbaceous plants, such as Ajuga, being grown by the square metre on polythene or in flats. I am not tendering these suggestions as positive ways to reduce costs but as illustrations of the possibilities. New planting scheme styles can only be sustained by suitable production and presentation of plant material.

After unity perhaps the most significant design element missing in our garden is scale and it is increasingly difficult to provide within the limitations of recent subdivision. There is a dearth of small trees, which has resulted in widespread dependence on only a few species, e.g. *Betula pendula (B. alba)* which further adds to the lack of regional character. Not only is there a need for trees to be used within these limitations but their presentation is important. It is almost impossible to get tailored trees for set purposes — so called advanced specimens are frequently only bigger plants in bigger containers. The landscape gardener requires tailored character trees, specimen trees, multitrunk trees, etc. to satisfy his client. Basic formative culture has to be purchased, not left to the client.

Annuals are an example of where economics has resulted in the declining use of a plant type. The specialised seed and cost of production has resulted in a short term crop which is contrary to the low maintenance and permanence philosophy. Yet the landscape gardener loses a basic opportunity to provide not only a

sense of time but also style if he does not use annuals. The annuals I look for are not polyploids or F_1 hybrids but those which can continue to remain as a contributing element in a continuing process. Examples are *Myosotis*, *Cerinthe* and granny bonnets.

Perhaps I have not dwelt sufficiently on propagation techniques affecting the quality of plants but the purpose of my paper has been to point out the type of plant the contemporary landscape gardener is looking for. It may be that it is for the landscape gardener to identify the core group of material required for the basic unity and scale within each area and then for the propagator to produce the material in a way as to allow us to maximise the potential usage. Clients are no longer requiring collections of plants offering the challenge answered by the hobbyist but are now requiring a garden designed to support their life style at an input level monitored by that life style.

HEAT THERAPY: METHOD AND APPLICATION TO CONTROL PLANT VIRUSES

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Viruses multiply within the cells of plants and may be found in all the vegetative tissues. Seed transmission, which occurs with some viruses, is the exception rather than the rule, but all vegetative parts of plants used for propagation may contain virus and give rise to infected progeny. Many cultivars of plants such as fruit trees, berry fruit, grapes, carnations, chrysanthemums, and bulbs, have become extensively infected with one or more viruses because infected parent plants have been used as a source of propagating material. Further infection has occurred by the working of healthy cultivars on to diseased rootstocks or by top-working of orchard trees.

Intensive investigations into virus diseases of pip and stone fruit trees in New Zealand commenced about 20 years ago. In early investigations, work centred around diseases which were readily apparent in the orchard such as mosaic, green crinkle and ring spot of apple, stony pit of pear, and line pattern (formally mosaic) of plum. In later years, reports from other countries suggested that pip and stone fruit trees could be carrying a number of virus diseases in a latent form. These diseases were detectable by the use of special indicator species and cultivars, or by the mechanical inoculation to herbaceous hosts in the glasshouse. An extensive indexing programme made by Plant Diseases Division showed that there was a high incidence of these diseases in New Zealand trees, particularly in apples and sweet cherries. It seems likely that almost all apples and sweet cherry trees grown in New Zealand are infected with a number of virus diseases. Pears, plums and apricots are infected to a slightly lesser extent, and only a small incidence of infection has been found in peaches and nectarines. Clonal rootstocks, particularly those which have been used in New Zealand for many years, are extensively infected.

Because of the extent of infection found in New Zealand trees, control measures for the virus diseases were required. Pioneer work in North America by Kunkel in 1935 showed that some virus diseases could be eliminated from peach trees by growing the trees for a period of time in a high temperature environment.

These methods were therefore adopted to try to eliminate the virus diseases present in pip and stone fruit trees in New Zealand. Several methods were used in early work such as dipping scion-wood in hot water for short periods or by the longer term process

of growing plants in a high temperature cabinet for periods of approximately 28 days. Some success was achieved with these methods in eliminating diseases such as apple mosaic, *Prunus* necrotic ringspot and plum line pattern. However, these methods were not successful with most other diseases. Accordingly, a method first developed in England in 1962 by Campbell was adopted and this has proved to be the most successful procedure for virus elimination from both pip and stone fruit.

The present heat treatment of pip and stone fruit at Plant Diseases Division is carried out in a heat treatment room, which has been converted from an existing glasshouse unit. Internal dimensions of this room are 4 m long, 2.5 m wide and 2 m high. Walls of the room are insulated and painted white for light reflection. Triple layers of glass in the roof provide further insulation but allow natural daylight penetration. Mercury vapour lights boost natural light on dull days and continue through most of the night. Humidity of the room is kept at about 60%, and the CO_2 content of the room is slightly increased during daylight hours. Potted plants for heat treatment are placed in metal trays on slotted wooden benches 75 cm above floor level.

Clay pots have been found to be more successful than plastic pots for heat treatment. A potting mixture composed of equal quantities of peat and fine sand with added lime and nutrients is used. Plants with a well established root system have been found to withstand the heat treatment temperatures best. Potted seedlings are therefore budded with the cultivar to be treated in the season prior to heat treatment, and the root system of the potted plant left undisturbed in the intervening winter.

When growth commences in spring, the potted plants are brought into a cool glasshouse for a short period before being transferred to the heat treatment room where they are maintained at a temperature of 32°C for 7 to 15 days. Extension growth during this 32°C period is rapid and carries through into the final heat treatment period at 38°C. The treatment temperature of 38°C has been selected as it is close to the temperature limit at which pip and stone fruit will survive without heat damage. Even so, heat damage usually occurs after about 21 days and tip grafts are usually taken prior to this. Plants near to collapse at the termination of the 38° period recover quickly once the temperature is returned to 32°C and rapid extension growth is again made. Thus it is possible to give selected plants several alternating 32°C and 38°C heat treatment periods during the season and this has proved to be an effective method of eliminating some of the more difficult viruses.

Tips 1 to 2 cm long cut from extension growth at the termination of the 38°C period are grafted without delay to potted seedlings of their respective species. A simple wedge graft is made,

where possible at a node on the seedling, as this appears to provide more stimulus for union. Best results are obtained when both the tip and the seedling stem are of just sufficient maturity for the tip to be held firmly in place without falling out. Medical adhesive plaster has been found the most effective material for holding the graft in place till union is achieved. A strip 1.3 cm wide and 4 cm long is folded partially back on itself, slid around the graft union and gently firmed in place, care being taken that the union is not forced apart.

After grafting, the shoots are covered by a plastic bag supported in such a way that the plastic does not touch the grafted tip. The bag is left partially open at the base for aeration and to avoid the high humidity which favours fungal infection, particularly *Botrytis*. The bag is removed when new growth develops from the tip, indicating that the graft union has been successful.

Tip-grafted plants are kept in a cool glasshouse for 4 to 6 weeks and then placed outdoors. At this point there is no way of determining if the tip-grafted plant is completely free from virus infection and it is necessary to test the plant with both herbaceous indicators in the glasshouse and woody indicators in the nursery. The nursery indicators are normally grown and observed for 3 years before it can be certain virus elimination has been successful. Heat treatment is thus a 6 year process. When the cultivars are considered to be free from known viruses, propagation material is released to the commercial trade.

This method of heat treatment plus tip grafting has proved successful in the elimination of most virus diseases found in pip and stone fruit trees in New Zealand. Similar methods are used to heat treat grape vines, although the heat treatment period is longer and the tips taken from treated vines are established on their own roots, rather than being tip-grafted to other vines. As all vegetatively-propagated plants may be carriers of virus diseases it is probable that these heat treatment methods could be successfully used with a number of other species.

The advantages of using pip and stone fruit propagation material free from virus diseases include improved growth and fruit yield, the elimination of some stock-scion incompatibilities and a possible improvement in fruit quality. Fruit from grapevines propagated from free-from-known-virus material are earlier ripening than those from diseased vines; the fruit has a higher sugar content and the colour of red wines is improved.

THE ROLE OF THE TECHNICAL CORRESPONDENCE INSTITUTE IN THE HORTICULTURAL INDUSTRY IN NEW ZEALAND

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The original concept of education by correspondence was to offer tuition to students who, for defined acceptable reasons such as distance, poor health, disability, occupation, were unable to attend an educational establishment that offered the tuition they wanted, or who were living in areas where such tuition was not available. In some countries tuition by correspondence is regarded as simply a back-up, or support function, of a college or technical institute involved with students who are taught in the classroom situation. I wish to emphasise that in the case of the New Zealand Technical Correspondence Institute, Lower Hutt, this does *NOT* apply.

The TCI has expanded rapidly from a four tutor team in 1946 to become the foremost correspondence organisation in the Southern Hemisphere with a current student roll of over 20,000 and nearly 400 tutors.

Emergence, nearly 30 years ago, from a modest school, to the largest single teaching organisation in New Zealand has brought its share of the difficulties associated with rapid growth. That we have dealt with these difficulties is reflected in our expansion and examination successes.

One can reasonably ask why does the TCI continue to expand in these days of increased availability of study centres and when more and more institutes are being established? The reasons are many and varied but we think these three are worth highlighting:

1. The wide variety and depth of courses and subjects available — far wider in scope than in any other technical institute in New Zealand.
2. The consistently high examination pass rate of TCI students when compared with students from other New Zealand technical institutes or schools.
3. The fact that TCI students can set their own study pace.

Students living and working in remote locations pose no problems for TCI. We reach out to assist any student no matter how far away he or she may be — we have over 1500 overseas students, most of them being in Australia and the other Pacific countries. Some are New Zealanders temporarily domiciled over-

[1] Tutor in Horticulture

seas, others are nationals in their own country. We can, therefore, easily reach any horticulture student within New Zealand.

The Written Word. We at the TCI specialise in the written or, as the students see it, the printed word. We take great care in technical accuracy and while realising that no two nurseries grow the same range of plants, have similar layouts, equipment or facilities, or the same soil and climatic conditions, we adhere to principles that can be applied anywhere.

Nevertheless our teaching material — we call them assignments — maintains the broad theory of horticultural practice in New Zealand whilst including many useful, practical descriptions of techniques and equipment that our horticultural tutors have known from practical experience.

The written word — as read by our students in their assignments is our teaching strength and gives us our reputation; we have to stand or fall by what we have written. The written word is much more lasting — and usually more efffective from a teaching and learning viewpoint — than the spoken word of many lecturers.

The classroom tutor, because he or she is in front of a class of students, seems available for a personal, face-to-face, discussion. In practice, however, this is not always the case because the lecturer is not only obliged to keep fairly closely to the syllabus but usually his loading is a fairly heavy one.

Those students "up-with-the-play" usually get the most attention while the slower ones are constantly reminded that their studies and comprehension are falling further behind and that as individuals they are likely to adversely affect the lecturer's record of student efficiency — especially as reflected in examination results.

On the other hand, TCI tutors have the unique opportunity of encouraging students to ventilate their difficulties and problems by letter and by so doing, tutors are more helpful and tolerant of student problems; the relationship between tutor and student is an enviable one-to-one.

Don't overlook that — such is human nature — a student will often write to his TCI tutor about his difficulties that he'd be reluctant to discuss with a classroom tutor — especially in the presence of other students. We see many examples substantiating this.

Team Effort. Before I discuss some of the advantages of studying by correspondence, I'd like you to know that our assignments are produced by a co-operative team effort.

Even before the author begins to prepare his draft, many hours have been spent preparing a writing plan of initially subject, then assignment, content. Not only does the depth of treat-

ment to be allotted to a topic receive careful consideration by at least four tutors, but the whole content of each assignment is carefully assessed and the sources of background material determined.

Throughout his draft preparation, the author is conscious of availing himself of the latest advice and material, and relating this to the time that will be ultimately demanded of the student in his home-study situation.

Technical editing — usually by a tutor colleague — is a continuation of the writing process and aims to ensure that the information in the author's draft is accurate and expressly fulfills the requirements of the course. Being free of the complex thought-train that encompasses the author, the technical editor views each statement independently and is thus well able to envisage how the student will understand it.

Presentation editing follows. Again this editor's priority is to see that the author's meaning is conveyed with the utmost clarity, that there is no ambiguity and that it is in a "language" suited to the age, knowledge and experience of the student level. The presentation editor ensures the ease of reading and contributes to the "eye-appeal" of the final, printed material.

Before the draft begins its progress through the Production unit — typing, illustration preparation, and preparation for printing — the Course Supervisor and Head of the Department concerned must approve and signify that they, too, consider that the material constitutes a fair contribution to the concept of the course, and upholds the high standard so carefully preserved over the years.

You'll gather from this, that — including the author — at least five members of the tutorial staff have been involved in the preparation of the draft to ensure that it promotes the interests of vocational education by providing the best study material possible.

All activities that contribute to the production of the study assignment are conducted on the site in Lower Hutt.

ADVANTAGES OF CORRESPONDENCE TUITION

Correspondence tuition has a number of advantages over classroom teaching and they apply to a much greater degree than most people think.

Some of these advantages to the students are that:

1. They receive personal and individual attention from their tutor.
2. They have equal opportunities for study no matter where they are living.

3. Their completed work is assessed fairly and accurately — there is no personal presence, or personality trait, to bias their tutor — and their tutor adds constructive comments for their guidance.
4. They receive study material in a simple form that their tutors will have specially arranged. Complex topics are "broken down" for their benefit.
5. They prepare themselves for future examinations by completing each set of Practice Exercises — accompanied by answers for immediate self-checking — and Test Papers, in a written form.
6. They do not miss a lesson or assignment. If they are ill the assignment is there when they are well enough to study it.
7. Their correspondence with their tutor is confidential — fellow students are never informed of results other than their own.
8. They do not have to travel to and from classes. Time, expense, energy and frustration of travel can be avoided.
9. They can study while continuing their employment.
10. They develop self-discipline — the most important point of all. Most people who aspire to promotion have to work diligently and methodically for long periods on their own.
11. They acquire desirable personal qualities such as initiative, tenacity of purpose and enterprise by studying on their own.

DISADVANTAGES OF CORRESPONDENCE TUITION

There are a few disadvantages, some of which are largely overcome during the block courses that accompany correspondence courses we offer to apprentices.

These disadvantages as we see them are:

1. Little opportunity for student and tutor to meet — only a written rapport can result.
2. No competitive spirit among students.
3. Some students find it a real problem to budget their own time so as to give sufficient attention to their studies.

CORRESPONDENCE TUITION IN HORTICULTURE

So far I have given a general outline of the TCI and its work. I

would like now to talk in more specific terms about the role of the TCI in the horticultural industry. In doing so I will have to mention some other topics such as the apprenticeship system and the attitude of employers towards students because these have a very profound influence on the efficiency of our teaching.

A question that is often asked is, "How can the TCI teach by correspondence a practical subject like horticulture?" We obviously cannot teach a student how to bud, sow seeds, select suitable wood for cuttings and so on. We can describe how these operations are done but it is up to the employer to give practical instruction and to ensure that the student is given the opportunity to practice them.

The function of the TCI is to complement the instruction given by the employer and the practical work done in the nursery. We give the technical background information about horticultural techniques, botany, soils, plant protection and so on that will give the student a better understanding of the work he has to do and will give the more advanced student who may be working on his own, the confidence to tackle new work.

Of the 20,000 students enrolled with the TCI, just over 650 are studying horticulture. These are made up of 170 horticultural apprentices, 150 studying for the National Diploma in Horticulture, 50 greenkeeping apprentices, and 100 studying farm forestry. The remainder are pre-entry university students and other non-examination students.

It is with the first two groups that I wish to deal in more detail.

Apprentices

All apprentices are required to study with the TCI under the terms of their apprenticeship contracts and to complete two of the three stages of the apprenticeship course written to the prescription of the trade examinations. They can, if they wish, continue with Stage III work subsequently.

The New Zealand Trades Certification Board sets the examinations; these are the First and Second Qualifying and Trade Certificate examinations. The TCI gives tuition in all subjects required for these.

The TCI is sometimes criticised for teaching horticulture, botany, soil science and plant protection to apprentices at too high a level. I would like to point out that we teach to a syllabus set by the Prescriptions Revision Committee of the Trades Certification Board on which are representatives from the trade and from parks and reserves departments of local bodies and we must teach to a level that will enable apprentices to pass the examinations set by the Trades Certification Board.

Apprentices are not required to sit any examinations. This seems to me to be one of the weaknesses of the apprenticeship system and is the cause of considerable discontent among those who have studied conscientiously and passed their Trade examinations. When they come out of their time they are on practically the same footing as those who have done the minimum amount of study with the TCI.

One of the complaints I hear most frequently from both commercial nurseries and parks and reserves departments is the shortage of good propagators and adequately trained staff in general. It seems to me that the blame for this situation lies fairly and squarely with the employers themselves. This brings me back to the apprenticeship contract. I'm afraid that some employers look upon this as a rather one-sided document; that is, the apprentice is kept to his obligations towards the employer but the employer tends to overlook his obligations towards the apprentice. It is laid down in the contract that the employer is to teach certain specified basic skills — but how many do? I hasten to add that this is not always the fault of the employer, as I will mention in a moment.

I know of apprentices who have completed their time without having sown any seeds, taken cuttings, potted plants or done other simple operations. They have spent most of their time on jobs that could well have been done by labourers. These apprentices get very discouraged. They start off full of enthusiasm and do first class work with the TCI but gradually the quality and quantity of the work falls off and by the second year they do just enough work to avoid default notices being sent to their employers. They rarely sit their second qualifying examination or carry on with third year study. Most of these apprentices are lost to the industry.

Perhaps I could mention here a point that is not often realised. Tutors frequently strike up a very close relationship with their students and can usually tell when they are not happy or are going through some sort of crisis.

I want to go back now to a point I mentioned a little earlier — the lack of adequate training. Should employers be allowed to take on apprentices if they cannot train them in all the basic skills? I am thinking of nurseries that grow a very limited range of plants or carry out a very limited range of operations. These are frequently first class nurseries in their own field but simply do not have the facilities to give an all-round training.

In cases such as these I would like to see it made obligatory for apprentices to move around to different nurseries so that they could get a training in all the basic skills. We find it extremely difficult and very disheartening to try to teach the theoretical side

of operations of which the student has no practical knowledge. The student then gets discouraged because he doesn't understand the assignments.

The employer's argument against this is that he would have to train three and perhaps four apprentices during the course of three years or so. This is correct but I think it is taking a very short-sighted view. An apprentice coming out of his time with a good all-round knowledge is going to be a far better nurseryman than one who has trained in a very narrow field. He will be less likely to leave on the day his contract is up as is the case so often now.

A suggestion of considerable merit was made at a recent block course. It was that employers in an area should group together so that there could be a free exchange of apprentices within the group. They would move round the different nurseries and at busy periods say, at rose budding, all could move to that property.

The failure of some apprentices to cope with the assignments because of their low educational standard causes tutors considerable concern. With horticulture becoming more and more technical we find that, in general, only apprentices with School Certificate have no trouble with their examinations. I think employers could be far more selective and perhaps I could add here that there is still a tendency among career advisors in schools and vocational guidance officers to turn the brighter students away from horticulture.

During the course of their study with the TCI, apprentices are required to attend three block courses, each lasting a fortnight. The purpose is to reinforce the correspondence studies with lectures and demonstrations in classrooms, laboratories and in the field. We try, where possible, to give students the opportunity to do a little practical work but with the time available this is very limited. The TCI is mainly responsible for organising these courses and many of the lectures and demonstrations are given by TCI tutors.

The courses are held at diffferent venues so that apprentices can get some idea of horticulture in various parts of the country. We visit as many different kinds of commercial nurseries as we can, parks and reserves nurseries, conservatories, sports grounds, orchards, market gardens and research areas. We find that very few apprentices, especially those in their first year, have any appreciation of the scope of horticulture; their horizons are limited to the boundaries of their own particular place of work. Those in commercial nurseries have little idea of what goes on in other commercial nurseries and less of the activities and scope of parks nurseries. Apprentices in parks nurseries are hardly aware that commercial nurseries exist. Lack of general background informa-

tion such as this makes it more difficult for students to fully understand our teaching material. I think this is another example of where employers could do a great deal to stimulate the interest of apprentices by arranging visits to other nurseries and places of horticultural interest.

Perhaps I could mention here that only two of the 45 apprentices attending recent block courses for second year apprentices, knew anything about the International Plant Propagators' Society.

One of the greatest benefits of block courses is that they bring together people of similar interests from a diverse range of commercial and parks nurseries scattered throughout the country. In the formal and informal discussion periods much valuable information is exchanged and many useful contacts are made — and many lasting friendships.

NATIONAL DIPLOMA IN HORTICULTURE

I would like to mention briefly those students studying for the National Diploma in Horticulture. The NDH is the highest attainment that the practical horticulturist can receive — and I must stress the word practical. To attain an NDH, students must have at least 5 years practical experience, pass oral and practical examinations and about 20 written papers, including a thesis. Apprentices who pass their Trade Certificate examination are credited with 5 subjects towards an NDH and holders of Massey and Lincoln diplomas receive some cross credits as well.

The TCI can now offer tuition in most subjects for the options open to commercial nurserymen and parks employees. The prescriptions for the National Diplomas are expressed in very general terms so that our assignments, especially for the more advanced subjects, concentrate mainly on technical background information and general principles. In the test papers students are required to interpret this information and apply it to practical situations and so develop their initiative and ability to think clearly.

THE EMPLOYER

In this paper I have made frequent reference to employers (and I include all supervisory staff in this term). Employers tend to regard study by correspondence as a two-way thing between student and tutor. Where apprentices and NDH students are involved, correspondence teaching concerns three parties, the employer being the third.

The employer should:

1. Have a moral responsibility to take a continuing interest in his apprentices and NDH students. Most students, especially the younger ones, need reassurance from time to time to help maintain their confidence.

2. Try to ensure that students are not so over-loaded and over-committed with their daily work that their home studies prove difficult due to sheer fatigue.
3. Not expect "too much, too soon" or the "best possible" results from everyone.
4. Ask to see student's work — this not only gives him an insight into the student's studies but ensures that the student becomes aware of employer interest — always a sound policy from the human relationship angle.
5. Be genuinely interested in the student's study activity and in the progress he is making.

CONCLUSION

We at the TCI feel that we are making a very real contribution in the field of horticultural education. We have faith in our system and this faith is backed up by comments we receive from our students and by examination results. We realise that any system has its imperfections and ours is no exception. I consider that a number of the shortcomings of the correspondence method can be remedied by a series of complementary block courses and, as I have already indicated, we have expanded our activities considerably in this direction over recent years. But I would like to leave you with the belief in the importance of the employers of our students. These people play a most important part in encouraging the student to keep on with his study and they should endeavour to make this as easy as possible.

AN EMPLOYEE'S VIEW OF CURRENT HORTICULTURAL PRACTICES IN EUROPE

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I spent from August, 1973, to January, 1975, in Europe. My arrival was timed to coincide with the sixth annual meeting of the Region of Great Britain and Ireland, I. P. P. S., and the associated two week's tour of British and Dutch horticultural establishments (nurseries, parks, research stations and universities) by a visiting party of fellow American members. With the I. P. P. S. I toured West England and Boskoop in Holland and attended the G. B. & I. Conference. But, my horticultural experience overseas was not limited to a whirlwind camera-clicking tour. I worked in a commercial nursery in Wiltshire and then at Kew Gardens. Hence,the view, as an employee, not only seeing new ideas and methods — but using them first hand.

I would like to share with you the ideas seen on the I. P. P. S. tour and later used when employed, which I feel we can use to practical advantage in New Zealand. Some of you may already be familiar with some or all of these practices.

Sun Frames. At Hilliers & Sons, Winchester and at Waterer, Sons & Crisp Ltd., Bagshot, I was impressed by their outdoor propagation structures — miniature polythene tunnel houses and portable mist units. The Sun Frames medium is sterilized soil topped with a two-inch layer of sand. After the cuttings are rooted, holes are cut in the polythene and gradually increased in size, to harden off the cuttings. From insertion to lifting takes 18 months. One frame held 10,000 cuttings. I think that we, in New Zealand, could use these structures for the propagation of hardier material that does not fit into the hardwood bracket, but can do without glasshouse care and is needed in quantity. For example, *Photinia* for hedging, with the cheaper cost and need of less care and attention.

Cold Frames. At Everton Nursery, Lymington and at Barter's Farm Nursery, Wiltshire, I noted an old fashioned method of propagation using cold frames (made of railway sleepers). Everton's put *Erica* cuttings straight into a sand and peat medium within the frame, and kept them covered with wooden laths until rooted. After one year they were lined out without potting, and sold as two-year-olds.

Barter's used their frames for conifer cuttings taken in midsummer. The cuttings were inserted in the sand and peat medium, watered in well and covered with .015 gauge polythene, glass

lights, another layer of polythene (to keep rainwater out) then topped with shade cloth. After one year these were lined out, without a potting stage.

We in New Zealand tend to disregard old methods and have come to rely very much on mist and bottom heat. When we, at Martins, ran out of room in our glasshouse propagation pit we adapted Barter's method making our conifer cuttings in early winter, 1975, for autumn lining out in polythene beds in 1976. Although as yet unrooted, the cuttings remain healthy, receiving a fortnightly check and a Captan or Benlate spray.

Transportable frames. At Grootendorst Nursery, Boskoop I saw easily constructed and dismantled frames — simply 12-inch by one-inch timber cleated into place with pegs. These are used for temporary cold frames, for cuttings; seedling beds; or temporary frost protection. Cheap and easily moved as and where needed.

Chip budding. I first saw this type of budding at Hilliers on *Tilea* (lime tree) and later used it at Barter's Farm Nursery. Barter's maintain that it is a quicker method then the conventional "T" bud, makes a cleaner union, gives a higher percentage take, and is able to be used when other methods can not. For example, when the bark does not lift easily. This summer, for the latter reason and on a trial basis we have chip budded *Acer negundo, 'Elegans' ('Elegantissimum'), Fraxinus excelsior* 'Aurea,' and *Ulmus Procera* 'Van Houttei.' The percentage take was higher and I am sure that it is much faster for us than T-budding.

Grafting. Barter's Farm Nursery carry out an extensive grafting programme. Not seeing any serious attempts at grafting on a large scale in New Zealand, I was particularly interested in their set up. The benches are raised two feet off the glasshouse floor allowing an oil furnace air duct to travel beneath. The benches are made of heavy duty Netlon, a polythene liner, with six inch wooden sides. Peat fills the benches. Before the grafts are plunged, covering the union, the peat is dampened, turned and dampened. All stocks were established in pots and dried before grafting, or bareroot. Grafts were sprayed with Benlate then covered with polythene sheeting. The glasshouse was partitioned off with polythene "drapes" and the temperature kept at 58°F. A wide range of plants were treated in this way; for example *Cupressus, Picea, Cedrus, Rosa, Wisteria, Gleditsia, Acer negundo, Acer palmatum, Betula, Hamamelis, Fagus sylvatica,* and *Hibiscus.*

This year we are trying out adaptions of Mr. Weguelin's grafting set-up. It is still very much in the experimental stage, but well worth pursuing, as I am sure you will agree; successful grafting is certainly a paying proposition.

Polythene film versus mist. In Boskoop I saw 0.015 mm thick polythene used instead of mist. The film is laid directly on the cuttings, tucked in and made airtight. Shade is important and here 250 gauge dense white film was used. After 10 days the cuttings were aired for an hour and if necessary sprayed with Captan. The cutting bed was then opened weekly until the cuttings rooted and then they were hardened off by gradually removing the polythene. Nowadays we tend to think only in terms of our sophisticated mist units to maintain a high humidity for cutting propagation. But this is an alternative method and could be used here when the mist areas are filled, if the mist unit fails and the repairman is slow, or in cold frames or on heated glasshouse benches.

Synthetic propagation media. At the Boskoop Research Station I was intrigued by the experiments with cubes of fibreglass-looking material for propagation. With problems of obtaining peat — and the price — all experiments for an alternative medium must be worthwhile. This one would have the added advantage of individual rootballs and thus no transplanting problems.

The Box Blox System. I first saw this system of boxing cuttings and seedlings at Barter's Farm Nursery, Wiltshire. The Bloxer is an apparatus made of an aluminium alloy that inserts a continuous strip of polythene film into a seed tray, so as to divide the tray into individual compartments. Cuttings are then inserted into the cells or compartments. When rooted plants are established the polythene strip very easily pulls out, leaving each plant with its individual root ball. Superior I feel to the New Zealand equivalent, the Plix tray, and ideal for subjects with transplanting difficulties such as *Cupressus sempervirens* 'Gracilis.' The Bloxer could also be used for pricking out ornamental seedlings, for houseplants, and for bedding plant production. The Bloxer is easy to operate (30 to 40 trays can be prepared in one hour). Different sizes giving from 24 to 60 cells per tray can be obtained.

Nisula Roll. The experiment that impressed most at Merrist Wood College, Worplesdon was an adaption of a Finnish idea for the cheap production of forestry seedlings. Instead of seedlings they used easily-rooted cuttings of plants suitable for ground cover — produced in a roll of polythene, peat and fertilizer. Twelve-inch wide polythene 100 gauge is laid on a bench, fertilized peat is spread, cuttings are placed on the medium on each side of the film; that is, basal end to the centre. The polythene is then rolled up, secured with tape and cut in half making two rolls six inches in depth. The rolls are then stood up and left until ready for planting. This idea I feel has great potential for producing ground cover plants in quantity and cheaply — for the landscaper, with convenient handling both in the nursery and on the landscape job.

Erica production en-masse. Windlesham Court Nurseries, Windlesham, produce 360,000 ericas per year. This figure alone is staggering; 1000 cuttings off each stock plant per year is normal and each propagator makes 400 per hour. The stems are snapped by hand, rather than cut with a knife, into one-inch lengths. As each cutting is made it is inserted into a box of pure sand using a 6-inch nail as a dibble. No hormone or fungicidal dip is used. Usually boxes of cuttings are put into a glasshouse and under mist but when that is full they go into a polythene tunnel house with scrim shading and a central mist unit. Rooting takes 10 days. The plants are sold as two-year-olds in P. B. 1½-size pots. Seeing this method made me wonder if we in New Zealand are too fastidious in our methods of making erica and, perhaps, some other types of cuttings.

Cane Supports. Everton Nurseries conquered the battle of staked plants falling over in the wind by making string squares — one per plant. A less finicky operation I saw at Scotts Nurseries. They used Netlon strips with the canes poked through and maintain that even P. B. 2-sized plants resist the wind; a good idea, especially with plants such as *Clematis* grown in P. B. 5-sized pots.

Capillary watering. Three nurseries I visited used this method of irrigation; namely, Waterer, Sons and Crisp Ltd. (Bagshot), Evertons, (Lymington), and Scotts (Somerset). Waterers have had their unit successfully operating under glass for 5 years and, in this period, found raised beds prevented the water flow being altered with ground movement. Their unit consisted of perforated pipes 5 feet apart, covered with 2-inch strips of fibreglass, then 2 inches of sand; the pipes were one-inch wide and the holes 3/16-inch. Evertons had their capillary watering operating in outdoor sand-based beds. The pipes were exposed and had drip nozzles 18 inches apart. I believe some New Zealand nurseries do use this method of watering instead of overhead sprinklers and find it helpful against Phytophthora problems with conifers and ericas. The idea of using pumice sand (or sawdust) as a bed base could be useful by holding water and conserving it, with our summer droughts and water shortages in mind.

ASPECTS OF KAURI PROPAGATION BY SEED

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Kauri (*Agathis australis*) is a characteristic tree of forests in the northern part of the North Island (New Zealand) from near North Cape to latitude 38°. The genus *Agathis* contains about 15 species in the Pacific basin from the Philippines to Polynesia and Australia. The single New Zealand species is endemic. Much has been written about the N. Z. Kauri — of its botanical features and large dimensions, of its timber quality, and of the exploitation by man for lumber, kauri gum, and clearing of kauri forests for pastoral purposes. This has led to a serious depletion of the original virgin forest (from 1.2 million hectares to 5,200 ha.) but has left behind a legacy of natural regeneration much of which is retained in reserves and state forests. Kauri is one of the few native trees which exhibit potential for management; it associates gregariously, forming almost pure stands, (under certain conditions) and is a natural colonizer of shrublands, having good seed production and seed dispersal.

Silvicultural management of Kauri stands, (that is by tending regeneration or artificial establishment) has been of limited extent, although compared to management of other native tree species, Kauri has received somewhat more attention. Management research has been done in Northland — Auckland by the N. Z. Forest Service and other agencies seeking answers to fundamental questions about Kauri ecology, regeneration, thinning and artificial establishment, including nursery practice. Unfortunately many of these research projects have not had the continuity necessary to provide sufficient information on which to base firm management systems. The reasons for this "stop-go" research can be found in past Government attitudes towards indigenous forest management (1). Research has, however, provided sound guidelines for nursery production of Kauri, and this is largely due to work by F. T. Morrison at Waipoua Forest (5, 7).

Early work at Waipoua developed basic techniques of Kauri propagation in open ground beds, and provided valuable information on seed trees, seed collection and extraction, methods of sowing, and general nursery handling of seedlings. During later years research commenced on growing plants in containers and the survival and growth of such plants in the field gave encouraging results. Our nursery system at Hunua, is a continuation of this latter development — growing in containers but with emphasis on propagation under more controlled conditions, i. e. germination of seed under glass and growing on in a shadehouse.

Seed collection and extraction. Kauri seed crops are borne annually on trees after the age of about 35-50 years and, although seed quality varies by years and between trees, there is usually a plentiful supply.

The cones break up on the tree as they mature and it is thus necessary to collect whole cones before the period of final ripening. Trees are climbed with the aid of aluminium ladders ascending to the upper part of the crown where most cones are found. Trees selected for climbing are usually poles in the 60 to 100 year age range and about 10 to 20 metres in height. It was found[1] from studies at Waipoua that about 20 cones weigh 1 kilogramme, with sound seed per cone ranging from 42 to 94 (average 70). (5). We know from our own experience that seed quantity and viability varies between individual cones, even quite considerably within the same tree. A recent count of seed in 40 cones from the same tree yielded a range of 18 to 86 sound seed (average 60) and total seed per cone averaged 93 (ra. 72 to 109). Cones break up at room temperatures in about 5 to 10 days and seed is extracted by sieving to remove scales.

Separation of sound seed. The variation in seed viability in any one year makes it necessary to have some method to separate sound from blind seed. Trials at Waipoua (6, 7) indicated that separation could be achieved by immersion of seed in cold water for between 24 and 48 hours, the sound seed sinking and empty seed remaining on the surface.

Our own experience using this method has been poor, and in glasshouse trials over 3 years (with various seed lots) there was a marked difference in length of time taken for all sound seed to settle out. In a recent experiment with freshly gathered seed (early March), 29 to 67% of sound seed sank in 48 hours, and 78 to 100% after 70 hours soaking — average temperature of the water baths at 7:30 a.m. was 21.1°C. In none of these "flotation" trials

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[1] Samples taken from a recent collection of cones at Hunua (March, 1976) gave an average of 11 cones per kilogramme. (range 9-14/kg.) Cones were collected from about 15 trees, then all mixed together, and stored at room temperature for two days before sampling. From this total collection 34 samples (with ten cones per sample) were selected at random and weighed. One seed tree yielded above-average cones; these were weighed separately and gave an average figure of 8 cones per kilogramme. (125 grammes/cone.)

On the basis of these figures it seems that the information given in Morrison 1955[(5)] (i.e. 20 cones/kg.) is incorrect. Morrison's data appears to have been based on an earlier observation by McKinnon 1937 (N.Z. Jour. For. IV.) who stated that "between 9 and 10 cones weigh one pound."

Some variation in average cone weights is to be expected from year to year, due to differences in moisture content, cone size, and stage of ripening. However, on the evidence to date, a selection of Kauri cones (from a number of seed trees) should average in the range 90-110 grammes each. (9-11 cones/kg.)

did any sound seed ever settle out in 24 hours. In previous trials (where seed had been stored for about a month) it has taken 7 to 8 days for 90% of sound seed to sink in water.

There is a great variation in the rate of sinking of seed, both between lots from different trees, and between individual seeds. The method then is not very precise and can result in sound seed being discarded when "floaters" are removed, if insufficient time has been allowed in the water bath.

We have found the best means of separation to be by eye, and this method has also been used with accurate results in research (2). After a little practice, seed with well formed embryos can be recognised visually (Fig. 1) or by lightly pressing seed against the sorting table if doubt exists (2). A skilled person can sort through about 2,000 seeds per hour, — the rate of separation depending upon the number of sound seed present. This method of separating sound and empty seeds has consistently given 90 to 95% accuracy in germination tests.

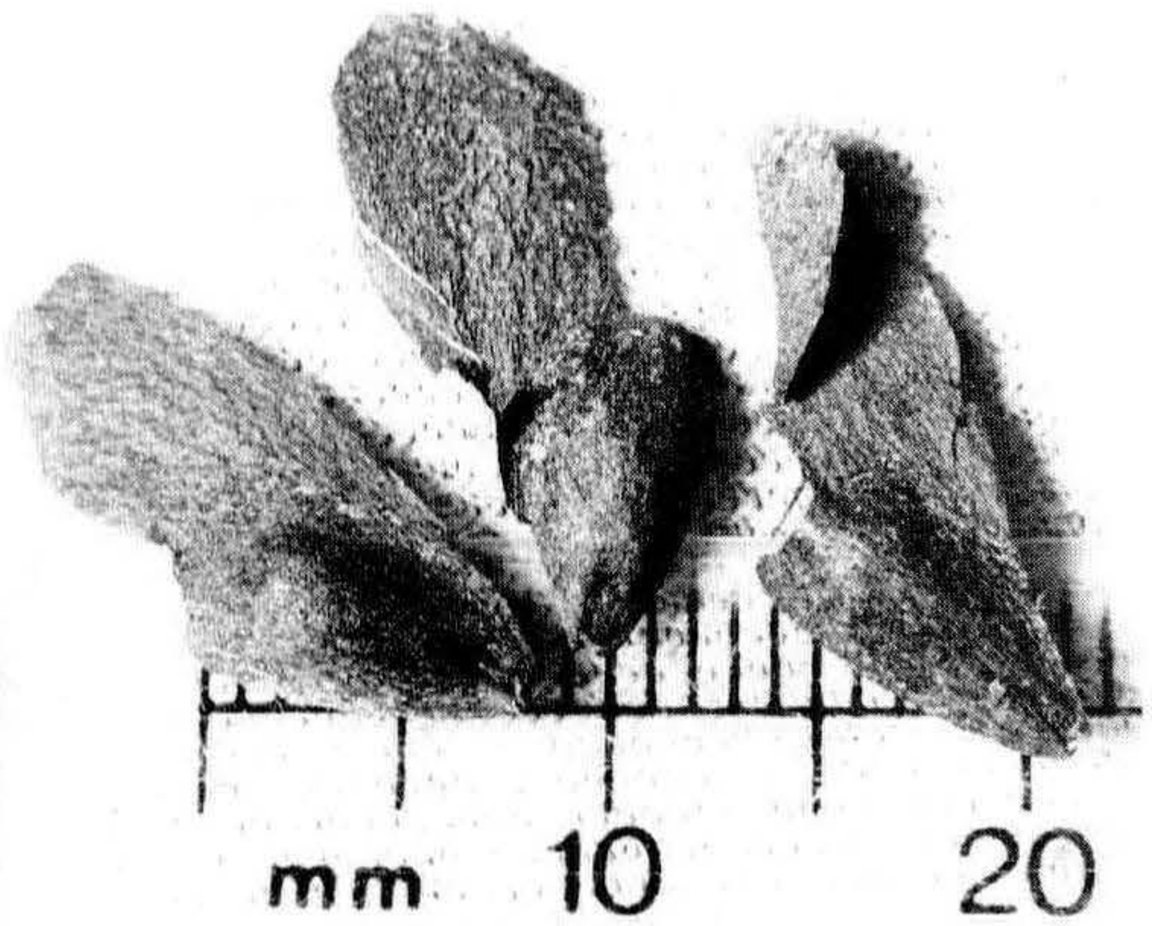

Figure 1. Viable Kauri seeds.

Seed storage. It has been known for many years that Kauri seed loses viability rapidly if stored under normal atmospheric conditions. Mirams (4) showed that there is a steady decline in germination from 100% at time of collection to only 5% by mid-winter; the rate of decline varied between the two seed sources used in the experiment.

Standard nursery practice is to sow seed immediately after extraction (5, 7) and a good germination percentage is usually achieved.

Storage for a longer term may be of importance where a good quantity of special seed is collected, and not all is used in one year. It has been shown by Preest (see ref. 7) that if Kauri seed is

stored at 5° to 10°C with a moisture content of 6% then germination can still be 80% after four years storage. Drying the seed to a low moisture content seems to be the most important factor. We have found that storage of seed in plastic bags or tins, placed in an ordinary refrigerator (temperature 2° to 5°C) is satisfactory for a few months. However, it is difficult to maintain a controlled environment and the seed gradually deteriorates.

Sowing and germination. A seedbox compost is used for sowing, composed of 2 parts soil (loam), 1 part scoria (or sand) and 1 part peat (parts by volume) and screened through a 1 cm sieve. To each cubic metre of this mix is added 2.1 kg superphosphate and 1.5 kg calcium carbonate. The compost is steam pasteurised before use.

Seeds are lightly dusted with Thiram fungicide and sown in wooden trays at 2.5 x 2.5 cm spacing, which gives about 120 per box. Seeds are covered lightly with a fine compost to 1 to 3 mm depth, watered thoroughly, and placed in a cool glasshouse for germination. (Mean monthly temperature 18° to 20°C).

Probably the most important point at sowing is not to cover seeds too deeply; this is a common cause of failure in Kauri seed germination. Bieleski (2) in a small trial sowed seeds at: (a) soil surface, (b) 1 cm depth, and (c) 2 cm below soil surface. The germination percentage was: (a) 86% (b) 1.6% (c) 1.6%; the weak hypocotyl is unable to push the shoot tip through the soil from any great depth.

Kauri seed has a thin testa and imbibes available water very rapidly, hence the need for heavy watering at sowing. In an experiment (4) seeds were given varying amounts of water, and it was found that "those seeds which received a large proportion of their available water supply at the commencement (at sowing) had best germination."

The glasshouse is shaded, but additional shade cloth cover over boxes during germination aids in reducing evaporation.

First germination commences in 4 to 8 days, and is completed in a short time if conditions are favourable. Usually 90 to 95% of the selected sound seed germinates; most seed coats are shed and the cotyledons expanded in 30 to 40 days from sowing.. Buds break before winter, and two or four sets of "true" leaves are formed before the following spring.

At first potting, survival from sowing is 75 to 90%, with losses due to "damping-off" and the death of weak seedlings. Plants are culled fairly heavily, and only 60 to 70% are potted on.

CONCLUSION

The nursery method described produces good quality seedlings for artificial establishment at Hunua and has some advan-

tages over production in open ground; i. e. seed sowing, germination, and early growth is less affected by climate, and disease and insect problems are reduced. The number of seedlings produced per unit area is increased, and growth in containers is less variable than in outside beds. In addition, staff generally have better working conditions.

There are still some areas in which improvements can be made (both in nursery technique and in plant growth) and we feel that investigation into the following should yield valuable results:

1) Direct sowing to individual propagation pots. (Seedlings are potted on in the small container thereby avoiding root damage).
2) Direct sowing and growth in a final container, in which the plant will be set out (acceptance of a smaller seedling at planting appears necessary to achieve this).
3) Better systems for hardening off and preparing plants for field conditions.
4) Improving seed selection. (Heavier seeds have been found to produce more vigorous seedlings — at least in early stages of growth) (5).
5) Development of a tree improvement programme for reproduction of superior trees. (This involves asexual propagation and some initial work has commenced on propagating from cuttings) (3).
6) Use of heated structures to improve the early growth of seedlings over winter.

If some (or all) of the foregoing can be developed and applied successfully, then prospects for reducing the length of time taken to grow a plantable seedling are very good.

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We wish to thank E. A. Scanlen for providing the photograph (Figure 1), and I. L. Barton for his constructive criticism of the manuscript.

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PRACTICAL ASPECTS OF ROOTING AND GROWTH OF RIMU CUTTINGS

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The Rimu *(Dacrydium cupressinum)* is one member of a predominantly South Pacific genus in the family Podocarpaceae. There appear to be about 20 species in the genus (1), occurring in Malaysia, Borneo, New Caledonia, New Guinea, Philippines, Tasmania, Chile and New Zealand. In N. Z. there are 7 endemic species, (1) ranging from the Rimu which attains heights up to 35 metres and rarely to 60 m, down to the Pigmy pine, *D. laxifolium*, often only 0.5 to 1 metre high. In terms of size the Rimu would rank as the largest tree in the genus with its closest rival the Huon pine of Tasmania, *D. franklinii*, which attains a height of 30 metres.

Rimu has always been an important timber species in N. Z. and the volume cut annually at present amounts to 15 to 20% of the total timber production. For over 70 years the country has enjoyed almost unlimited supplies of this versatile wood, but the trend over recent years has been towards decreasing the cut, to conserve a dwindling resource. Rimu is the most widely distributed of all our native tree species and is prominent in many forest types from North Cape to Stewart Island. It occurs naturally over a wide range of climatic conditions, on widely differing soils, and has an altitudinal range from sea level to 950 m. (3). Because of this wide adaptation to differing sites the species would appear eminently suited to artificial establishment on a forestry scale. As yet there are no artificially established stands in existence (4), although small scale plantings have been done to supplement natural regeneration.

At Hunua nursery, production of Rimu is for this latter purpose and enrichment plantings are undertaken in areas where the natural stocking of seedlings is at a low level. Our annual programme calls for ca. 5000 to be set out and the usual methods of propagation in the past have been to collect small "wildling" plants from the forest floor, and to sow seed directly, when this is available. Nursery production depends then upon a good source of seed, but unfortunately Rimu is a shy seeder, and a good seed year may occur only once or twice in ten years (4). This variation in seed; and (consequently) seedling availability has led to our recent trials with cuttings, as an alternative means of propagation.

Rimu is one of the most graceful and beautiful of N. Z. native trees and apart from its place in forestry establishment it has un-

questioned horticultural merit. Young trees especially, have pale green drooping foliage, this taking on bronzy hues in winter; indeed, a splendid specimen tree.

The species is mainly dioecious, and there is a noticeable difference in appearance of male and female trees. Franklin (3) describes the differing characteristics: "in female trees the ends of fertile branches are upturned, giving the foliage a tufted appearance when viewed from the side, while in male and juvenile trees, the branchlets remain pendulous." It does not appear possible to separate young nursery plants by these characters although some individuals do exhibit a very pronounced "weeping" habit at early stages of development.

Such variation in the foliage and form of individuals should lead to cultivars being produced asexually for garden planting. Likewise in forestry, selection of individuals can be made to improve the performance of planting stock.

PROPAGATION METHODS

Past Work. Early trials at Hunua (2) and at Massey University (6) have shown that Rimu can be propagated successfully by cuttings from juvenile stock plants. At Hunua, terminal cuttings were used, set in a scoria/peat mixture and rooted under mist with no bottom heat. At Massey, cuttings were set in a pumice/peat mixture and rooted with bottom heat in a glasshouse with light watering.

In both these trials the application of indolebutyric acid in talc improved speed of rooting and number of roots formed. In Hunua trials 0.8% IBA (Seradix 3) gave best results, while at Massey 2.0% IBA was reported to give an even better result than the 0.8% level.

Wounding of the cutting base gave somewhat varied results in our Hunua trials, but proved to be beneficial at Massey. In both these trials, cuttings made good height growth after potting. Little information is available on cutting performance from older trees. Richards (6) set cuttings from an "adult" tree and observed that rooting and growth after potting was slower than for juvenile plants.

A current trial at Hunua with cuttings from an 18-year-old tree (garden planted) indicates that cuttings root more slowly, produce fewer roots, and grow at much slower rates than juveniles; this is the case (at least) in the initial development stage.

At this stage cuttings from young stock plants offer the best potential in propagation, they root easily, have 80-100% take, and grow well after potting.

Time of Year for Setting. In a series of trials we have set cuttings every month of the year except February and May, and even though percentage rooted varies, cuttings have always formed adequate root systems despite the month of setting. However, cuttings set in late autumn (April) and through the winter do not usually form roots until the following spring (September).

A current trial in which terminal and lateral cuttings were set monthly from June to December indicates that September-set cuttings gave good overall results in terms of speed of rooting, percent rooted, and height increment after potting.

In an earlier trial March-set cuttings also gave extremely good results, and this offers a choice of setting time dependent upon what size plant is required for planting to the field. At this stage we favour March for setting terminal cuttings as (in trials) they grow faster, enabling us to put out a 30 to 40 cm plant in May/June, 15 to 16 months from setting. With lateral cuttings these grow more slowly and a September setting would give us a 30 to 50 cm plant in 20 to 21 months.

We have not been able to demonstrate conclusively in our trials (to date) that any one month is optimum for setting; rather, the time to set will depend upon end use, size of plant required, the nursery production system, and facilities available.

Stock Plants and Cutting Material. Stock plants are 2 to 4 years of age grown under about 60% shade; they are not specially selected (at present) and are drawn from ordinary nursery stock.

Terminal cuttings are made by severing just above a strong growing semi-upright lateral; cuttings are made 10 to 15 cm long, with basal leaves removed (this is a form of wounding) and 0.8% IBA (Seradix 3) applied.

Lateral cuttings are taken by selecting semi-upright material from near the apex of the stock plant; 4 to 6 cuttings can usually be gathered from this source. Recent trials (not yet concluded) indicate that lateral cuttings from the apex of the stock plant (if tending upright) form a normal orthotropic shoot. It was suggested (2) that cuttings taken from lateral branches would continue to grow horizontally, and this may still occur if material is selected from pendulous branchlets, but does not appear to be the case with upright laterals.

The effect on the stock plant when a terminal shoot is removed is for the lateral to assume the terminal role (in most cases) Figure 1.

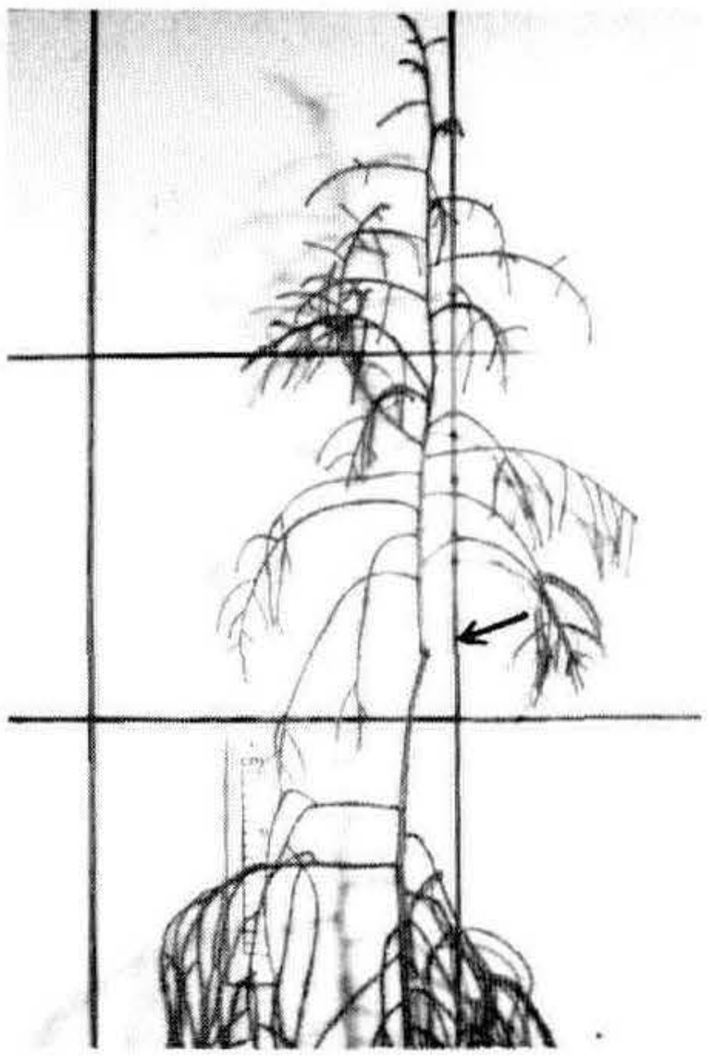

Figure 1. This shows the point where the terminal cutting was taken and shows regrowth of lateral. (Note increasing weeping habit from apex to base.)

The time taken for the lateral to come upright seems to depend upon the length of season left for growth; i.e. in our trials 85% of laterals on stock plants used in Sept-Oct came upright by April, some 7½ months after cuttings were taken, whereas with December stock plants only 26% of laterals were upright by the same date (5 months later).

We attempted to shorten the time taken for laterals to come upright by tying them to a stub left on the main stem; results revealed that this had little effect when compared with control plants. There is a marked variation in the ability of laterals to form a vertical shoot; those with semi-fastigiate branchlets coming upright sooner, and with less stem deformity.

Growing Conditions. The setting mixture consists of scoria, sand and peat (2), but we have reduced the size range of scoria used previously to 0.25 - 4.00 mm particle range and cut down on sand content by 50%. The mixture is scoria, sand, peat — 3:½:½ parts by volume and has enabled the cutting to be held more firmly in the container. Cuttings are placed in individual plastic tubes (4 cm diam.); these are more satisfactory for later handling than trays and have given good results in rooting.

Cuttings are struck under intermittent mist and first roots are formed (with September settings) in 7 to 8 weeks. In a previous experiment (2), November and January set cuttings formed first roots in 6 to 7 weeks, while June settings (2, 6) produced first roots in about 12 weeks. The effect of temperature is evident here and as conditions become warmer the time taken for cuttings to form roots was shortened.

It was speculated that bottom heat might be of benefit in start-

ing cuttings earlier in the season (2) and a recent experiment has shown this to be the case. A batch of cuttings taken in late April were placed in a cold frame. During mid-August 100 were relocated on a bench with bottom heat maintained at 20 to 23°C and a control lot was placed alongside as comparison on an unheated bench. After 5 weeks cuttings were examined and those with basal heat had 90% rooted compared with no heat, 20% rooting.

Growing on. Cuttings are removed from the mist when roots are about 20 mm long, and potted into plastic pots (5½ x 9½ cm). The potting medium is fine sand and peat (50/50), with base fertilizer added. Variation in length of time to form roots is experienced between individuals and it is not considered worthwhile retaining late rooting cuttings after 70 to 80% of a batch have rooted (2). Plants are grown on under shade before final potting in a small planter bag. After a further period in the shadehouse they are moved outside to harden off before winter planting.

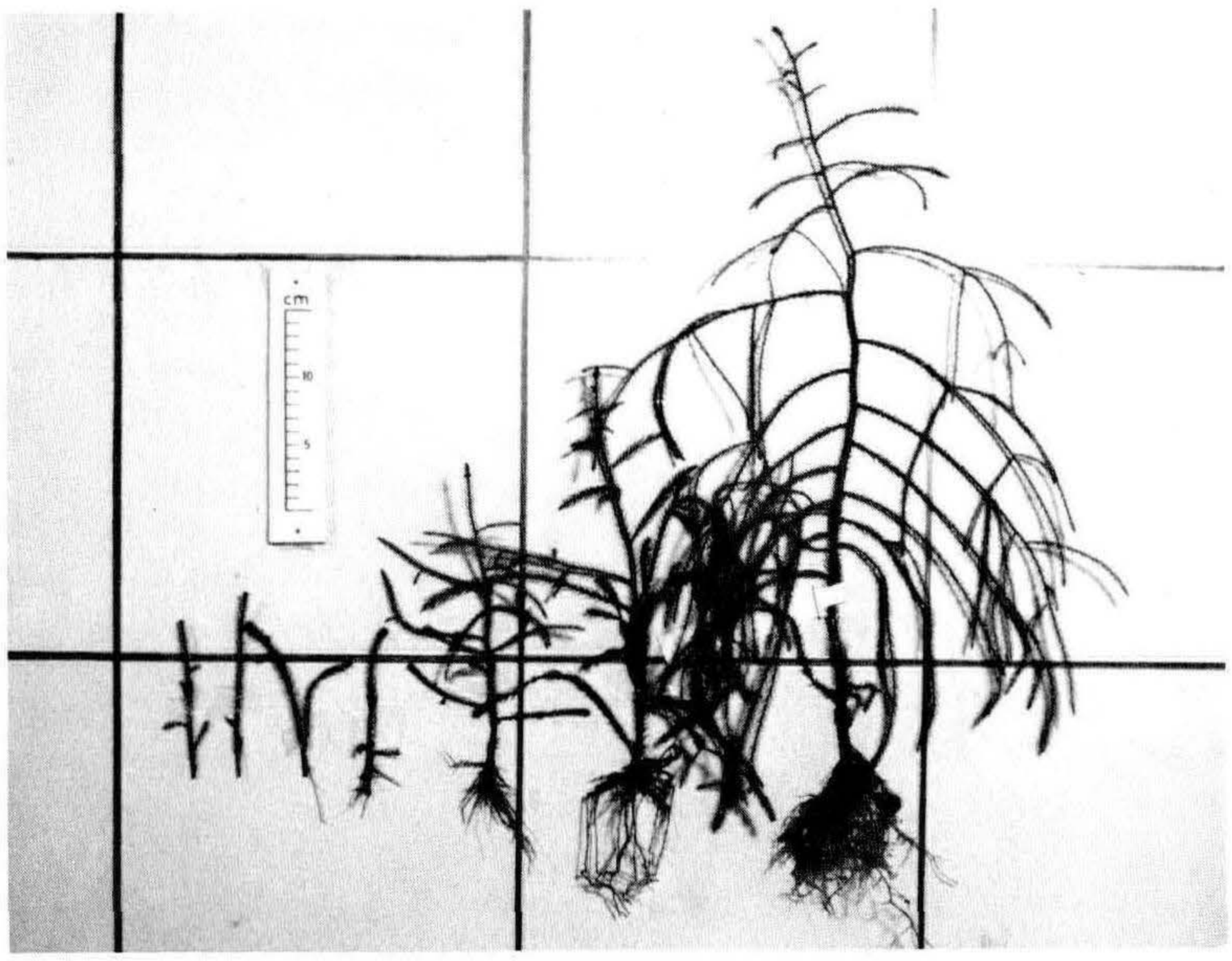

Figure 2. Development of cuttings from setting to plantable size.

CONCLUSION

Rimu *(Dacrydium cupressinum)* is an easy species to propagate with cuttings from juvenile nursery plants. Cuttings do not necessarily require elaborate facilities and, although aids such as misting are of practical benefit, will root quite successfully in a simple cold frame. (unpub. notes)

The species responds well to applications of a root promoting

chemical (IBA) which hastens root initiation and increases number of roots formed. Recent trials have also shown that heat at the cutting base is beneficial in starting root formation earlier in the season (in early spring).

The effects of tree age on the rooting and growth of cuttings is an area in which further research is needed and, in common with many other tree species, Rimu cuttings appear to respond and grow more slowly as trees become older. This is of some importance because if plants are to be chosen for some "superior" characteristic, i.e. vigour, special foliage form, or colour, etc., then this will often not be identifiable until an adult stage of growth is reached. To ascertain the phase of growth (or age) at which Rimu cuttings lose vigour (past an acceptable limit for propagation), will require setting a series of cuttings from trees of various ages.

Some of these maturation effects may be arrested by repeatedly pruning back all new growth above a certain height as has been done in trials with *Pinus radiata* (5). "Over the 7 to 8 years of the studies, the training of trees as hedges arrested the normal decline in rooting percentage, quality of roots, and growth potential of cuttings taken from ageing tree-form plants" (5).

Such "hedging" may also provide a partial solution to building up nursery stocks. Training plants as hedges should yield a good quantity of upright cuttings. Radiata pine (5) hedges yield over 100 cuttings per square metre of hedge top per year. A particularly bushy Rimu at Hunua (9 years old), although not trained as a hedge, yielded 150 upright cuttings from sides and apex.

However, it is unlikely that plants will be specially set out and trained as hedges until quality clones have been identified. In the interim, most cuttings will come from young plants in the nursery bed; these should be carefully evaluated for form and vigour before using to provide cutting material.

ACKNOWLEDGEMENTS

We are particularly grateful to Mr. E. A. Scanlen for taking the photographs reproduced in Figures 1 & 2.

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QUESTIONS

Q. What is the fertilizer composition when the plants are moved from the liner stage to containers?

A. 2.4 kg Osmocote, 0.3 kg Uramite, 1.0 kg superphosphate, 2.4 kg dolomite lime, 1.0 kg calcium carbonate, per cubic meter.

Q. Does the bronzing colour of Rimu have any effect on the rooting of cuttings?

A. At this stage there are no obvious indications that colour of wood selected gives better rooting results.

THE CARE AND PREPARATION OF PLANTS FOR EXPORT

R. T. BURTON

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New Lynn
Auckland, New Zealand

Exporting of plant material can be a difficult and frustrating business if not carried out carefully. There are several factors making this so; for instance, exporters of plant material must meet the following requirements depending on what country the consignment is to be sent. These are:

Arrangement of International Health Certificates
Custom Clearance
Delivery Schedules
Insurance
Correct point of entry into country
Growing media
Correct packaging
Preparation of plants for inspection prior to despatch

From my experience in exporting plant material a high standard of plant health is essential and standardization of product is well observed. Selection of suitable stock should be arranged well in advance of despatch. Plants should be assembled and isolated from further saleable stock and marked clearly for export only. Regular examination of plants to ensure that they are free of pests and disease is essential.

Plants must be free from pests such as aphids, scale, mealy bugs, caterpillars and mites. It is always wise to inspect some of the plant's roots for such things as canker, root rot and galls while they are at this pre-export stage.

Most countries will require the plants to be free of soils or peat from their roots. However, some countries will accept sterile media such as peat or sphagnum moss. If these are used I suggest that a dressing of Osmocote N/18 P/6 K/12 and Uramite fertiliser be applied three months prior to despatching.

For countries that need their plant material bare-rooted, I suggest that all excess growing medium is removed and all roots washed thoroughly in water to make sure the roots are vested of all growing media. Make sure, at all times, that these freshly exposed delicate plant roots are not exposed for any duration of time, as this will be extremely detrimental to most plants. I personally prefer to cover the roots with sphagnum moss whilst awaiting for all of the consignment to be executed.

Once you have completed this procedure it is necessary to

treat the plant material with a fungicide and insecticide or it may require fumigation. When a fungicide and insecticide is required I suggest the dipping method, using a vat allowing total immersion of the plants for a period of 20 minutes, using Captan at a rate of 1½ oz to 4 gallons of water, and Malathion at a rate of 1½ oz to 4 gallons of water.

After this procedure has been completed all plant foliage must be allowed to dry thoroughly and be labelled. I prefer to label each item individually to avoid any confusion at the place of destination. It is at this stage you will require the presence of an Officer of the Ministry of Agriculture & Fisheries to personally inspect the plant material for export and issue you an International Plant Health Certificate, which must accompany your consignment to its destination.

The next procedure, after clearance by the Agriculture Officer, is to commence assembling the items into their correct genera and the bundling of the plants into convenient sizes for packaging. The packaging is done by placing damp sphagnum moss on appropriate sized sheets of polythene film. Sphagnum moss is spread on half the polythene film, next step is laying the plant's roots on top of the moss followed by another layer of moss. Then by folding the plastic over, commence to roll into a bundle and tie. These bundles are then placed into waxed cardboard cartons using a filler of woodwool.

I find it essential to allow maximum ventilation in containers as this eliminates the possibility of the plants "sweating" and being totally useless on arrival. Cartons and containers must be securely tied and clearly marked, *"URGENT LIVE PLANT MATERIAL, PERISHABLE, THIS SIDE UP."* Prior arrangements should have been made with your custom agent to handle your consignment ensuring that the flight connections are not missed in other countries as well as New Zealand.

If you are exporting plant material that needs fumigation treatment with "48 c/m^3 methyl bromide" the procedure is the same as above excepting that the necessity to dip the plants in a fungicide and insecticide is not required; but there still is inspection by an Officer of the Agriculture & Fisheries Department. Once this has been executed you proceed to pack the material, this time leaving the cartons untied. Then you make contact with your fumigation station and make necessary arrangements for the fumigation of the stock. This usually takes a period of approximately two hours. When plants have been released you are required to seal down the cartons within the fumigation station and address and label same as in the former.

Once again I must stress the importance of good packaging, care of flight connections, and ensuring that consignments do not

arrive at place of destination on weekends and public holidays. Also make sure of correct documentation.

If these rules are followed carefully, exporting plant material can be rewarding and profitable.

THE "SWISS ROLL" METHOD OF RAISING CUTTINGS AND SEEDLINGS

SID DESBOROUGH

S. & J. Desborough, Ltd.
Summerland Nurseries
Box 161, Levin, New Zealand

Every nurseryman and plant propagator is looking for propagation methods which will be: cheaper, easier, more efficient, can utilize unskilled labour.

Potting young seedlings or rooted cuttings requires skill and dexterity which takes a long time to master. This new method fulfills all the above criteria and gives a consistently good result.

Pautti Nissula of the Forest Research in Finland used this idea for growing conifer seedlings and took out a patent. This system was further developed by the Merrist Wood Institute in the U. K. and it was from their system our nursery developed a technique for New Zealand conditions. We saw a big potential for rooting cuttings this way and this was the idea we developed.

The Method. A strip of polythene 4 metres long, 300 millimetres wide with a thickness of 50 microns is laid out on a bench 3.5 metres long and 12 mm thick with side strips of wood 300 mm apart. A 12 mm layer of rooting medium or potting compost is placed over the polythene and firmed by hand. It should come level with the top of the board. The roots of the seedlings or the cuttings are laid along the compost on each edge the roots facing inwards and the tops to the outside. The plants are spaced so as to give the correct distance apart when rolled up. The polythene is then carefully rolled up, keeping the bundle tight and firm. The end is fastened with polythene tape. An ordinary wood saw is used to cut the bundle of plants in two down the middle. Normally we have rolled up 30 plants each side giving 60 plants per roll. We count on each ½ roll to produce 25 saleable plants.

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The advantages:

Costs — To raise 1,000 plants: plastic $8.00 — pots $40.00, assuming soil of propagating medium is the same in each case.

Time — To roll 50 plants: 5 min., a rate of 600 per hour.

Time — For potting, 200 per hour.

It is far less tedious, with less handling of small pots; a roll is equal to 25 pots in a box. Standing out ground is much less; high densities can be maintained even when well-spaced pots do not blow over.

Tightly rolled plants do not dry out as quickly, and need less watering; nutrients are not leached out so quickly and the plants do not become rootbound. When unrolled, plants have a fan-shaped root system and are easy to plant in a cleft made with a spade.

Cuttings, rooted cuttings, and seedlings of 34 different species and cultivars are currently under test using this method.

USE OF HARDWOOD BARK AS A ROOTING MEDIUM

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Abstract. Hardwood bark and hardwood bark-sand mixes were evaluated as rooting media for both herbaceous and woody plants. There was no difference in rooting with 3 or 4 of the herbaceous plants with respect to medium. Chrysanthemum rooted best in the all bark and the peat-perlite mix. Of the 7 woody plants tested only *Cornus florida* and *Ilex cornuta* 'Burfordii' rooted better in non--hardwood bark media. There was no difference due to medium with the other 5 species.

REVIEW OF LITERATURE

Increasing cost of propagation media components has led many propagators to look for substitutes. Hardwood bark has been gaining increasing favor as an amendment or a growing medium for container-grown nursery stock. The advantages of hardwood bark may be summed up as follows (1): 1) excellent water holding capacity and the ability to release water for easy uptake; 2) well-drained and aerated; 3) economical in both initial cost and handling cost (lightweight); and 4) a fairly high CEC. Hardwood bark and hardwood bark-sand mixes also contain most of the other qualities which have been considered necessary for a good propagation medium (2).

There are certain aspects of hardwood bark culture which have to be taken into consideration. Lunt and Clark (3) have determined that hardwood bark is not as stable as sphagnum peat moss and when it decomposes it ties up nitrogen. Hardwood bark may have toxic quantities of other materials which may impede plant growth (4). Finally hardwood bark has been shown to increase in pH with time.

N deficiency and toxicity symptoms may be avoided by the addition of sufficient N and composting for a period of time (4). The pH problem may be avoided by the addition of elemental sulfur and iron sulfate (1).

There has been little evidence to support the use of hardwood bark as a propagation media. It has most of the characteristics of a good propagation medium and the bad characteristics can be avoided.

MATERIALS AND METHODS

Two separate experiments were conducted. One tested the effect of hardwood bark on the rooting of four herbaceous cultivars and the second used seven woody species as greenwood cuttings.

Herbaceous plants[1]. The plant material included *Chrysanthemum morifolium* 'Nob Hill'; *Dianthus caryophyllus* 'Scania'; *Pelargonium hortorum* 'Quest'; and *Euphorbia pulcherrima* 'Annette Hegg Diva.' The cuttings were placed in flats under intermittent mist.

The five rooting media on a volume basis were: 1) all sand; 2) 1 peat moss: 1 perlite; 3) all hardwood bark[2]; 4) 1 hardwood bark: 1 sand; and 5) 2 hardwood bark: 1 sand. All hardwood bark media were supplemented with the following chemical amendments per cubic meter: 597 g elemental sulfur (1 lb./yd^3); 597 g iron sulfate; 2.96 kg 20% superphosphate (5 lb./yd^3); 297 g potassium nitrate (½ lb. /yd^3); 5.37 kg ammonium nitrate (9 lb./yd^3). All hardwood bark media were stockpiled for 1 month, then steam treated at 180°F for ½ hr.

A randomized complete block design with five replications was used. Each replication consisted of ten cuttings. The rooting period for the poinsettias and geraniums was from June 28 to July 18, 1974. The rooting period for the chrysanthemums was July 22 to August 8, 1974 and the carnations from July 22 to August 27, 1974. At harvest each cutting was evaluated on a rooting index from 1 to 7 with 1 being *no roots and 7 having a root ball diameter of greater than 4 cm.*

Table 1. Influence of medium on rooting of *Chrysanthemum morifolium* 'Nob Hill'.

	Rooting index means[y]	
	Exp.1	Exp. 2
Medium	7/22 - 8/9/74	9/4 - 10/1/74
1 Bark - 1 Sand	5.46a[z]	5.30a
2 Bark - 1 Sand	5.64b	5.33a
1 Peat - 1 Perlite	5.68b	6.23d
Sand	5.76b	5.66b
Bark	6.58c	6.06c

[y]Rooting index, 1-dead, 7-excellent rooting.

[z]Treatment means followed by a different letter in one column are significantly different at the 5% level.

Woody plants[3]. The plant materials used for this part of the study included *Cornus florida, Spiraea vanhouttei, Juniperus chinensis* 'Hetzii', *Ilex cornuta* 'Burfordii', *Forsythia x intermedia, Magnolia x soulangeana,* and *Ilex decidua.* The rooting media on a volume basis were 1 bark: 1 sand, 2 bark : 1 sand, 1 peat : 1 sand, 1

[1]Sample, Anne B. 1975. The evaluation of hardwood bark as a propagation media for some selected herbaceous ornamental plants. Unpublished Master's Thesis. Southern Illinois University, Carbondale, Illinois 62901. 29 p.

[2]Weston Paper Co. Terre Haute, Indiana. Fine grade of hardwood bark.

[3]Zaeske, Alan D. 1975. The use of hardwood bark in the propagation of woody ornamental plants from cuttings. Unpublished Master's Thesis, Southern Illinois University, Carbondale, Illinois, 62901 30 p.

peat : 1 perlite and all sand. The bark media were chemically amended, composted and steamed as described for herbaceous plants. The cuttings were inserted into flats after the appropriate hormone treatments on July 3 and 4, 1974. Intermittent mist was used and the plants were harvested July 29 and September 13, 1974.

A randomized complete block design was used. There were four replications of ten cuttings of each cultivar. At the end of the experiment each cutting was given a rating of one (dead) to five (well) rooted.

RESULTS

Geraniums. There was no difference in the rooting index among any of the media. The rooting percentage was above 90 in all media.

Poinsettias. There was no difference in any of the media in rooting index. The rooting percentage was above 90 in all except the all-bark medium which was only 86%.

Carnations. There was no difference in rooting index for any media, except the rooting percentage was 86% and 84%, respectively for the all bark, and all sand media.

Chrysanthemum. The chrysanthemum rooted significantly better in the all-bark medium. The worst medium was equal parts of sand and bark. The other media were intermediate (Table 1).

This portion of the experiment was rerun in September, 1974. Peat-perlite proved to be the best medium followed by the all-bark medium; the two bark-sand mixes were poorest (Table 1).

Only the chrysanthemum showed any significant differences in rooting index due to medium. Root quality was not quantitized; however, root quality appeared to be better in media containing bark.

Only the dogwood and the Burford holly showed any significant differences due to medium (Table 2). Both of these plants rooted better in the sand-peat and perlite-peat media. The tendency of the others was generally to have a lower rooting index and percentage rooting in the bark media.

Table 2. The effect of medium on the rooting index and percentage rooting of cuttings of seven woody plants.

Medium	*Spiraea vanhouttei* index[y]	%	*Forsythia x intermedia* index	%	*Ilex cornuta* 'Burfordii' index	%	*Juniperus chinensis* 'Hetzii' index	%	*Cornus florida* index	%	*Magnolia x soulangeana* index	%	*Ilex decidua* index	%
Bark/Sand (1:1)	3.30	80	3.63	80	1.98a[z]	20	2.15	25	2.25a	35	1.38	28	1.73	5
Bark/Sand (2:1)	3.35	70	4.23	90	1.93a	13	2.25	15	2.10a	18	1.05	20	1.98	8
Sand	3.00	70	4.38	95	1.95a	8	2.53	40	2.65b	38	1.95	45	2.23	20
Peat/ Perlite (1:1)	3.33	73	4.50	100	3.23b	65	3.60	73	3.98b	83	1.38	25	2.15	38
Peat/Sand (1:1)	3.13	68	4.73	100	3.55b	58	2.95	58	3.35b	68	2.18	50	2.10	15

[y]Root indices are 0 for dead plant, 5 for well-rooted plants.

[z]Treatment means followed by a different letter in one column are significantly different at the 5% level.

CONCLUSIONS

Hardwood bark and hardwood bark-sand mixes are worthy of a trial as propagation media, and have in some cases proved to be as good as other mixes. Bark mixes may be excellent for propagation in situations where plants are propagated directly in containers.

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VEGETATIVE PROPAGATION OF HEMEROCALLIS — INCLUDING TISSUE CULTURE[1]

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Mass production with improved colors, and better flower forms of *Hemerocallis* cultivars has been limited because of slow natural increase. Many of the newer cultivars produce only 1 or 2 new fans yearly under natural conditions in temperate zone climates. Using Traub's (12) improved propagation technique, only 20 to 30 plants can be obtained per year in greenhouse environments. Because of slow increase most of the best new cultivars remain in breeder and collector gardens and are unknown to the general gardening public. A better propagation method will increase both garden and commercial potential of this plant.

This paper discusses 1) current propagation techniques practiced by a limited number of commercial growers and breeders; 2) a new propagation method involving the application of kinetin compounds to freshly cut crowns; and 3) propagation by tissue culture.

CURRENT PROPAGATION METHODS

Until the late 19th century, *Hemerocallis* consisted of unimproved species types. In the 1890's, George Yeld (6) made the first interspecies crosses and selected improved cultivars. Many of these new cultivars contained genes from rhizomatous types (those that multiply by underground stems) which propagate freely.

Further improvements within the genus resulted from research work conducted by Stout (6) at the New York Botanical Garden between the years 1920-1940. Stout obtained many species and cultivars directly from China and in a well documented research program was able to produce the forerunners of today's true pinks, reds and purples. However, with the improvement in colors and garden quality, the rhizomatous genes were largely eliminated, further reducing the natural vegetative propagation potential.

In early work, Morrison (7), Bailey and Bailey (1), and Stout (10) described dividing compound rhizomes and multiple stems. Since the crown division method produces only a few new plants each year more rapid propagation techniques have been sought. Traub (11) reported two successful propagation methods that are still used today. One method involved making 4 vertical cuts through leaves and crowns such that four sections were formed. Both the roots and

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leaves were trimmed to 2 to 3 inches and the sections rooted in a sand medium. Eventually each newly rooted section formed a new shoot. If crowns were divided into more than four sections new plantlet formation was greatly reduced. Traub also reported a method whereby crown tip cuttings were cut from a plant such that a small portion of the stem was included with adhering leaves of each shoot. The crown tip cuttings were rooted and the mutilated plant remaining in the ground subsequently produced another shoot.

Various other authors have reported similar methods (2, 3, 5). Norman (9) mentions the feasibility of producing 12 to 30 plantlets from cuttage, the method Traub used. He also suggested the possibility of 20 to 40 plantlets from an undescribed method he labeled "spooning."

PROPAGATION WITH KINETIN COMPOUNDS APPLIED TO FRESH CUT CROWNS

In February of 1974, a clump of *Hemerocallis* 'Sea Gold' was brought into the greenhouse. The fans were divided and potted in 15 cm clay pots such that the crowns were above soil level. Greenhouse temperatures were maintained at 21°C nights. Plants were lighted to provide a long day (14 hrs) for this otherwise dormant cultivar. In 2 weeks, after active growth had started, the tops were cut off with a sharp knife. The cut was made directly through the crown perpendicular to the shoot growth. The fresh cut crowns were treated with various concentrations of kinetin once daily for 3 days in succession (approximately 2 ml/plant). The kinetin treatments were applied with an eye dropper using the tip to spread the liquid to cover the entire crown without running off.

Approximately 7 days after the cuts were made new shoot formation was visible at the sides of the crown and sparingly in leaf axils across the top of kinetin and SD 8339[1] treatments. Crowns treated with distilled water produced new shoots but usually either at the side of the crown or the center terminal shoot. Four weeks after the treatments began, shoots 10 cm in length (Figure 1), were torn from the mother crowns and treated with Hormodin No. 2 and rooted under mist. New shoots were taken from each crown as they reached the 10 cm size every 2 weeks for a total of four times. At the eighth week one shoot was allowed to remain on each plant. Later the old crown and roots were removed and the new shoot repotted and grown on. All of the plantlets from these treatments were rooted and grown to flowering size during the summer and fall of 1974. With ample plant material obtained from a single cultivar a future experiment was planned.

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[1]SD 8339 is a synthetic cytokinin produced by Shell Development Company, Biological Science Research Center, Modesto, California 95352.

Figure 1. Daylily plantlets approximately 10 cm in length formed on the crown of *Hemerocallis* 'Sea Gold'.

Materials and Methods

'Sea Gold' plants obtained from the preliminary study were treated with distilled water (control), 25 ppm kinetin plus 4% DMSO, 50 ppm kinetin plus 4% DMSO, 400 ppm SD 8339 or 800 ppm SD 8339. The experiment was initiated January 16 and terminated April 16, 1975. Nine plants were used for each treatment (each treatment contained three replications with three plants each which were randomized throughout the block). Each plant was removed from the soil, the top severed, and the plant repotted such that the crown was again above the soil level. Treatment application technique was similar to the preliminary study. Since it was difficult to keep SD 8339 in solution new formulations were prepared each day.

Results and Discussion

All of the treated crowns produced a greater mean number of new shoots than the control (Table 1). The site of new shoot development varied from the control plants and that of the kinetin and SD 8339 treatments. New shoots always occurred at the extreme outside of the crown or at the center of control plant crowns. Kinetin and SD 8339-treated plants often had shoots arising from the axil of leaves midway between the terminal and lateral buds. Some crowns produced as many as 23 new shoots in the 3 month period of time. Although the mean number of shoots was greatest for the kinetin or SD 8339 treatments, the data were not significant at the 0.05 probability level. We attribute this to difficulty in cutting each crown at the most desirable level — a problem which could be overcome with further refinement of the technique.

Table 1. The effect of kinetin and SD 8339 on shoot production in *Hemerocallis 'Sea Gold'*.

Treatments	Total number of new shoots from 9 ramets	Mean number of new shoots per ramet
Control	78	8.6
Kinetin 25 ppm plus DMSO	105	11.6
Kinetin 50 ppm plus DMSO	96	10.6
SD 8339 400 ppm	105	11.6
SD 8339 800 ppm	113	12.5

Our results indicate that the method of severing the top shoot through the crown appears to have considerable merit in vegetative propagation of *Hemerocallis* cultivars. Further, this method appears to be enhanced with cytokinins.

TISSUE CULTURE PLANTLET FORMATION

Materials and Methods

A complex inter-species hybrid 'Chipper Cherry' which divides slowly in gardens was the source of flower petal explants. Immature flower buds (5-7mm) were removed from the flower stalk and surface sterilized by immersing in 95% ethyl alcohol for 5 sec, soaked for 15 min in 10% sodium hypochlorite, and washed three times with autoclaved double distilled water. Petals and sepals were aseptically removed from the sterilized buds and placed on the culture medium.

The culture medium was essentially that of Murashige and Skoog (8) with 0.5% casein hydrolyzate added; 2,4-D (1 mg/l), and kinetin (1 mg/l) were added in combination or individually depending on the treatment. The pH was adjusted to 5.7 before autoclaving. For culture induction, 25 ml of a medium containing 2,4-D and kinetin were placed in 60 ml bottles with loosely fitting plastic caps. Plantlet formation was induced by transferring the callus to an agar medium minus 2, 4-D but containing kinetin at 1.0 mg/l and IAA at 0.5 ml/l.

Callus initiation occurred in a controlled environment room at 29±1°C without lights. Plantlet development was carried out at 26±1°C with a 16 hr photoperiod.

Results and Discussion

Callus was induced on flower petals and sepals. It was compact, yellowish-green in color, and had what appeared to be organized cell masses. Development of numerous rooted plantlets was accomplished by transferring the callus to a medium without 2.4-D but containing kinetin and IAA (Figure 2).

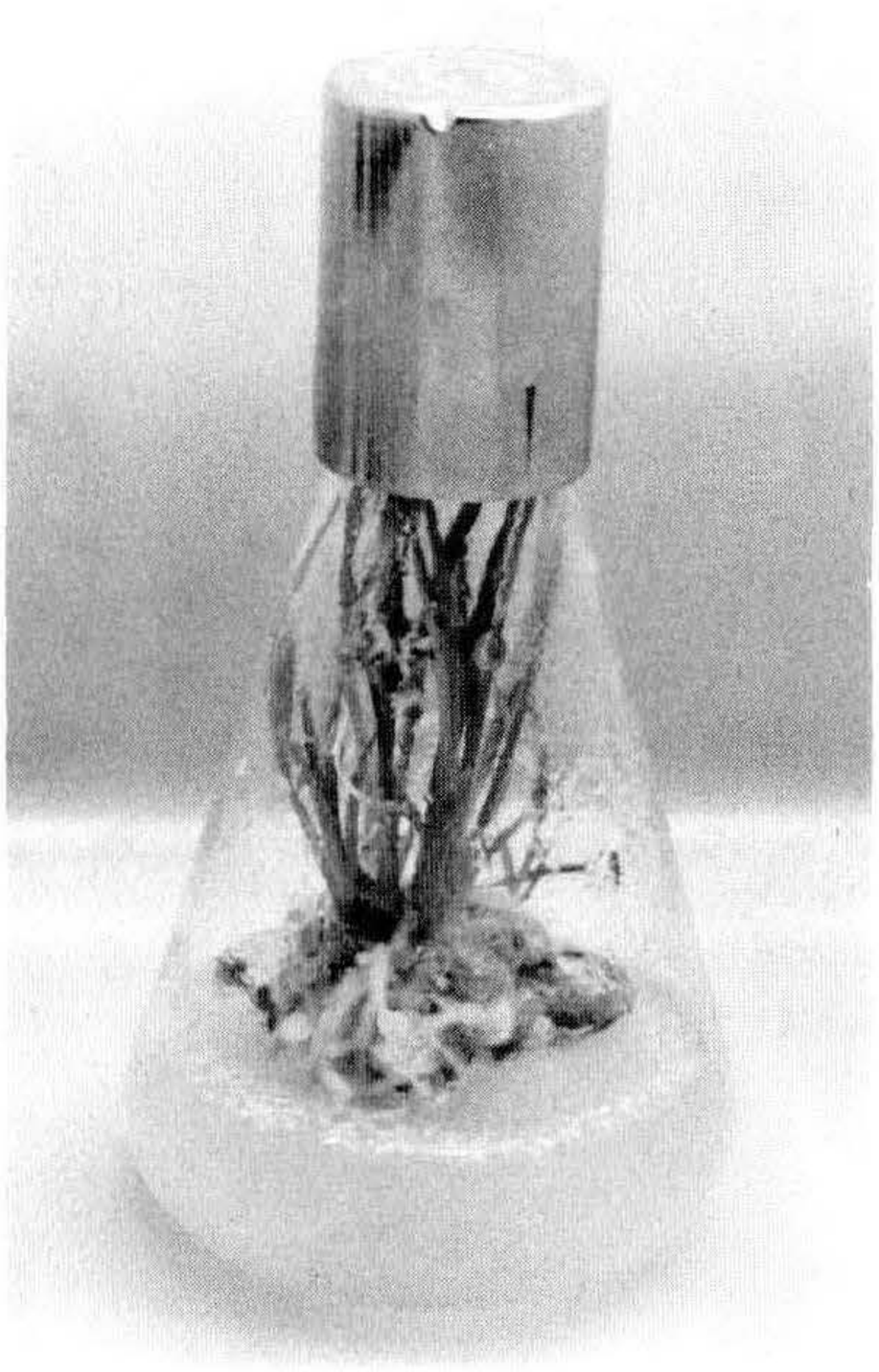

Figure 2. Daylily plantlets formed in tissue culture.

In this experiment, we observed the development of callus directly from petal and sepal explants. Chen and Holden (4) previously have initiated plantlets from callus of *H. flava (H. liliosaphodelus)*. However, they first developed adventitious roots on petal explants and then initiated callus from the root sections.

The plantlets were then removed from the 60 ml bottles, separated into individual plantlets and planted directly into 6 cm clay pots. When they had grown to sufficient size (3 months), they were transplanted to 15 cm plastic pots.

At this writing, the tissue-culture plants have not flowered, however the foliage appears identical to the parent plant. If the procedure is to be of value for rapid propagation the resulting plants must have the same genotype and phenotype as the parent. This portion of the study will be documented as flowering occurs.

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VOICE: How long does it take from putting the tissue on the medium until you get plants formed?

DARREL APPS: It is about 3 to 5 months but this varies considerably depending upon the cultivar.

VOICE: Have you been able to get the callus to proliferate?

DARREL APPS: Yes we have and we have lots of callus and therefore lots of potential for plant production.

VOICE: What type of medium do you plant the young plantlets into from the flasks?

DARREL APPS: We use the Penn State mix which is 2:1:1 soil, perlite, peat. We had to be very careful with the plants at this stage and we kept them in the growth chamber until they could be satisfactorily established to be moved out of there onto the greenhouse bench.

PRODUCTION OF SELECTED ORNAMENTAL SPECIES IN SOUTH FLORIDA

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INTRODUCTION

According to the U.S. census of agriculture, the 8 southeastern states in the U.S. (Ala., Ark., Fla., Ga., Ky., Miss., Tenn., and Va.) sold nearly $47 million worth of nursery products in 1969. The value of these sales for the 8 states rose some 458% between 1949 and 1969 (5). These data, as reported, are considerably less than the actual values for the whole ornamentals industry because the census did not cover all the firms engaged in the nursery business, such as turf, foliage, plants and flowers. A more recent report (4) indicates that the value of woody ornamentals sold in Florida during 1974 amounted to about $38 million. During the same year, the Florida flower industry sold some $66 million worth of products, the Florida foliage industry some $65 million, and the turf industry some $30 million, for a combined total of $199 million for the total ornamentals industry in Florida in 1974.

The ornamentals industry has been one of the fastest expanding segments of agriculture in Florida. It has enormous potential for future expansion as people from all over the nation rediscover the value of plants in making our environments more livable. The tropical foliage industry of Florida has increased more than 100% in the past 3 years and today accounts for over 50% of the national sales (4).

Because of the importance of ornamental plants in Florida, the University of Florida's Institute of Food and Agricultural Sciences has established on-going research projects in ornamentals at Gainesville, Monticello, Apopka, Bradenton, and Ft. Lauderdale. Because of its location on campus, the Gainesville station has active teaching and research programs in all areas of ornamental horticulture, whereas the branch Research Centers are research-oriented and tend to focus on facets of the industry which are more localized. Thus, the Monticello staff works on hardy woody ornamentals, Apopka on foliage, Bradenton on flowers, and Ft. Lauderdale on turf and semi-tropical woody ornamentals.

Research information generated from the Research Centers is disseminated through publications of the faculty members doing the research, through the extension service in its publications, and from the county extension agents.

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Because of the importance of the tropical foliage industry, and because many people from more northern areas are not as familiar with foliage plants as with temperate zone woody ornamentals, the main emphasis of this report is on the foliage plant industry as it exists in southern Florida.

SOUTH FLORIDA PLANT PRODUCTION

Between 80 and 90% of the total nursery production in Florida is in containers ranging in size from 2-in plastic pots costing a few pennies to fiberglass or plastic containers 4 to 6 ft across (so called 90 gal size) costing over $40 each. Field growing operations typically sell a good proportion of their production to landscapers for local consumption as balled and burlapped stock or, after planting the stock in a container, to allow it to adjust to the shock of being dug. After a period of time in a conditioning house, some field production is also sold in the foliage market as containerized material.

A number of landscape plants in south Florida are also used as foliage plants for "interiorscaping" in the north. Table 1 lists 30 of the plants most commonly grown for landscape purposes in south Florida and indicates whether or not the plants are also utilized for foliage purposes indoors.

Most of the larger tropical foliage plants produced in south Florida are monocotyledons and fall into several families: Agavaceae, which includes *Yucca, Dracaena, Cordyline,* and *Sansevieria;* Araceae, which includes *Dieffenbachia, Philodendron,* and *Spathiphyllum;* and Palmae, including *Chrysalidocarpus, Howea (Kentia),* and *Chamaedorea.* The main dicotyledons include various *Ficus* species, members of the aralia family *(Dizygotheca, Brassaia, Polyscias),* and several cultivars of crotons *(Codiaeum).* Two members of the gymnosperms grown in the south are *Podocarpus* and *Araucaria.*

Table 1. Some of the most commonly grown landscape ornamentals in south Florida.

Scientific Name	Common Name	Also Used for Indoor Foliage Plants
Araucaria excelsa R. Br.	Norfolk Island pine	Yes
Acalypha wilkesiana Muell. Arg.	Copperleaf	No
Asparagus sprengeri Regel.	Sprengeri Asparagus fern	Yes
Bauhinia blakeana Dunn	Hong Kong orchid tree	No
Brassaia actinophylla Endl.	Schefflera	Yes
Bucida bucerus L.	Black olive	Occasionally
Callistemon rigidus R. Br.	Bottle Brush	No
Carissa grandiflora A. DC.	Natal palm	Some cultivars
Caryota mitis Lour.	Clumping fishtail palm	Yes
Chrysalidocarpus lutescens Wendl.	Madagascar palm; Areca palm	Yes

Table 1. (continued)

Coccoloba uvifera L.	Sea grape	Occasionally
Codiaeum variegatum Blume	Croton	Yes
Dizygotheca elegantissima Vig. & Guill	False aralia	Yes
Dracaena marginata Lam.	Red edge dracaena	Yes
Ficus benjamina L.	Benjamin fig	Yes
Ficus elastica Roxb.	Rubber tree	Yes
Ficus retusa L.	Cuban laurel, Nitida	Yes
Hibiscus calycinus Willd.	Yellow hibiscus	No
Hibiscus rosa-sinensis L.	Red or Chinese hibiscus	No
Ixora coccinea L.	Red ixora	No
Jasminum volubile Jacq.	Wax jasmine, (J. simplicifolium)	No
Ligustrum japonicum Thumb.	Waxleaf privet; 'Recurvifolia'	No
Murraya paniculata Jack	Chalcas, Orange jessamine	No
Philodendron selloum C. Koch	Self-heading philodendron	Yes
Phoenix roebelenii O'Brien	Pygmy date palm	Occasionally
Pittosporum tobira Ait.	Japanese pittosporum	Occasionally
Podocarpus macrophylla D. Don.	Podocarpus	Yes
Roystonea regia H.F.K. Cook	Cuban royal palm	No
Swietenia mahagoni (L.) Jacq.	West Indian mahogany	No
Viburnum suspensum Lindl.	Sandankwa viburnum	No

PROPAGATION METHODS OF SELECTED SPECIES

Yucca, *Dracaena*, and *Cordyline* are propagated by rooting leafless cane cuttings or leafy cane tips commonly called "heads." Seeds of these plants are rare and are not normally used for propagation material. Rooting hormones are not generally needed because the canes and heads root easily in 3 to 5 weeks without any such treatment. If canes are used, mist is not necessary; it is not essential with heads, but if not used, considerable leaf fall or desiccation can occur during dry weather. Satisfactory rooting media range from peat moss to sawdust to sand; mixtures of these and other materials are also used. Bacterial cane rots which sometimes develop in *Dracaena* can usually be controlled with foliar sprays and/or drenches of streptomycin.

Sansevieria is grown out-of-doors in extreme south Florida. It is propagated by rhizome divisions or through leaf cuttings. *Sansevieria* leaves are severely damaged by temperatures near, but above freezing; however, the rhizomes produce new foliage fairly quickly when warmer weather returns.

Dieffenbachia is grown in a few areas in the extreme south part of the state under shade and requires winter protection, as temperatures below 45 to 50° F. (7 to 10°C) will cause severe damage to the foliage. Reproduction is primarily by cane tip cuttings, although air layering may be done on a limited scale.

The selloum type philodendrons are grown from seed or bought as seedlings from liner nursery outlets. Bacterial soft rots which occasionally develop in young plants may usually be controlled with streptomycin sprays.

Spathiphyllum is a very hardy indoor-type plant and will even flower indoors. Acreage devoted to it is limited, although the demand is high. It is reproduced by divisions of the crown, by seed, or by root cuttings. It takes about 2 years to grow a quality plant, hence the turnover rate is considerably slower than for many other foliage plants.

Palms are collectively propagated from seed. Seeds of certain palm species lose their viability within a matter of days after harvest, others in a few weeks to months, while others may not germinate for several years after planting. A portion of the seeds of *Chamaedorea* will germinate in the first 9 months to a year after planting, with another increase in germination noted about a year later, and a small portion a year after that. Bottom heat of 80 to 90° F. (26 to 32°C) can often be used to increase the rate of germination of palm seeds. Depending on species, palm seeds may be imported or grown and harvested locally. Seeds of the Howea palm are imported from New Zealand, where they take 7 years to mature on the plant. Planting beds for palms may be outdoors, under shade, in a greenhouse on a raised bench, or seeds may be sown directly into small pots. A highly organic but well-drained medium is usually used. Seedling diseases are not often a problem, although red spider mites are occasionally.

Plants of most *Ficus* species have the potential of growing quite large, very rapidly. Two of the most popular species, *F. benjamina* and *F. retusa*, are propagated by leafy cuttings under mist. The larger-leaved species such as *F. lyrata* and *F. elastica* are more often air-layered, because the large leaf area causes quick desiccation of cuttings, and because once an air layer is removed from the mother plant it can be established and sold within 60 days. Ficus plants are well adapted to growth in containers and can tolerate root binding which might severely set back more sensitive plants. *F. retusa* is very susceptible to thrips damage, otherwise most are relatively resistant to disease and pest infestations.

False aralia *(Dizygotheca)* and schefflera *(Brassaia)* are grown primarily from seed, some of which is gathered locally. Seed may be broadcast on raised bench beds in shade covered areas or sown into individual containers. False aralia may also be grown from cuttings, but the leaves undergo a change in morphology as the age of the shoot increases, which results in a coarser looking plant than one produced from a seed. Spider mites can be a critical problem on schefflera at times.

The so-called aralias (actually members of the genus *Polyscias*)

are propagated by cuttings and root readily in 3 to 6 weeks. These plants are also sensitive to cold, being defoliated by temperatures below 45 to 50° F. (7 to 10°C). Near freezing temperatures kill fairly large plants if they continue for more than a few hours.

Crotons *(Codiaeum)* are grown for their spectacularly colored leaves, and there are many cultivars available. Seeds are produced by mature plants but do not come true-to-type, hence tip cuttings are commonly used. These are rooted under mist in from 3 to 5 weeks. A small amount of production is also obtained from air-layering. Diseases are not much of a problem with crotons, but spider mites can be severe.

Podocarpus is used in south Florida primarily as a landscape plant. Nevertheless, considerable quantities of seed are gathered and sold locally for seedling production for use in terrariums and dish gardens. Tip cuttings may also be used to produce a more compact, heavy plant in a shorter period than can be obtained from a seed. Some podocarpus plantings are sheared to obtain greens for the floricultural trade. An aphid and an eriophyid mite can be limiting factors in production.

In south Florida, *Araucaria* is grown almost exclusively from seed although numbers of them are grown from terminal cuttings in Europe. The seed set locally does not germinate; thus seed or liners are imported from Hawaii, Puerto Rico, or other warmer areas. Seed must be freshly harvested and sown immediately, as it has a relatively short life of several weeks. Germination occurs rapidly. About 5 to 10% of the seedlings that emerge are albinos and these, of course, die in the seedling stage. Young plants grow fairly slowly, taking about a year to reach an overall height of 15 inches (38 cm) in a 6 inch (15 cm) pot, but thereafter, in a 10 inch (25 cm) diameter pot, they grow to 4 to 6 feet (120 to 181 cm) during the next 12 to 18 months. Plants may be grown in full sun or under light shade; a more compact plant results under full sun, but a richer, darker green plant is obtained under partial shade.

Many other types of foliage plants and landscape plants are, of course, grown in south Florida nurseries, but due to space limitations these cannot be discussed here. The reader is referred to 3 general publications about foliage plants listed at the conclusion of this paper (1, 2, 3). Unfortunately, there is no one textbook or reference which contains all of this information.

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CONTROLLING QUACKGRASS IN THE NURSERY

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Abstract. The results of three separate studies indicate that pronamide (Kerb) and glyphosate (Roundup) will control quackgrass. Pronamide can be used as an over-spray on existing quackgrass in established nursery stock. Glyphosate, when labelled, will have a role in controlling quackgrass prior to planting and as a directed spray under trees and large nursery stock.

Quackgrass, the major weed problem in Ohio nurseries, has been controlled by producers through tillage or with a limited number of herbicides. Cultivation and hoeing yield, at best, temporary control. The use of herbicides has been limited to spot treatment of post-emergence herbicides such as dalapon and aminotriazole or fall or winter applications of the pre-emergence herbicide dichlobenil.

Two new herbicides have recently been labelled for the control of quackgrass. Pronamide, marketed as Kerb, a pre-emergence compound, has been registered for use in nursery stock for the control of quackgrass and winter weeds. Glyphosate, sold as Roundup, a post-emergence material, is registered for weed control in industrial areas and prior to planting field crops but not in nursery plantings.

Three field studies in commercial nurseries have recently been completed in which pronamide and glyphosate have been evaluated for pre-plant and post-emergent quackgrass control.

Study Number 1 — Pre-plant Quackgrass Control.

If quackgrass can be controlled prior to planting nursery stock, subsequent need for control will be significantly reduced. With this in mind, a study was initiated to evaluate several herbicides for pre-plant control of quackgrass. The data as shown in Table 1 indicates that glyphosate at 2.0 lbs. ai/A (active ingredient per acre) and dichlobenil were the most effective herbicides 11 months following treatment if coupled with disking. All herbicide rates are in active ingredient per acre.

In most instances disking every 6 weeks resulted in greater quackgrass control as had been noted in earlier studies (4). The results of this study coincide with the findings of Hall and Parochetti (3) who noted that glyphosate was superior to pronamide in control of quackgrass after 10 months in sod. Ahrens (2) reported that glyphosate at 1.5 and 3.0 lbs. resulted in excellent control of quackgrass without injury to ornamentals when applied to quackgrass 8-10" tall 8 days prior to planting.

Table 1. The effect of 5 pre-plant applied herbicides in the control of quackgrass.

Treatment*	Pounds ai/A	Percent Quackgrass Control Disked**	Non-disked
Glyphosate EC	2.0	85	40
Dichlobenil 4G	6.0	85	45
Pronamide 50W	2.0	60	60
Pronamide 50W	4.0	75	70
Pronamide 50W + Simazine 80W	2.0 + 2.0	70	55
Simazine 80W	4.0	75	50
EPTC 10G	15.0	50	35
Control	—	30	25

*Herbicides applied November 6, 1973 and evaluated October 8, 1974.
**Plots were harrowed with a tractor-drawn disk every 6 weeks from May-August.

Study Number 2 — Evaluation of Pronamide and Glyphosate in Taxus and Spruce

Herbicides were applied November 11, 1974 to a planting of 3-4' *Taxus cuspidata* (syn. T. c. 'Capitata') and 4-5' *Picea pungens* 'Moerheimi' heavily infested with quackgrass (5).

Quackgrass was essentially eliminated as shown in Table 2 with glyphosate alone and in combination with pronamide. Pronamide at 4.0 lbs. was more effective in controlling quackgrass than the recommended rate of 2.0 lbs. The addition of dichlobenil and simazine did not enhance the effectiveness of pronamide in quackgrass control.

Table 2. Effects of pronamide and its combinations in the control of quackgrass in *Taxus* and *Picea*.*

Herbicide	ai/A	Percent Quackgrass Control
Control	—	10
Pronamide 50W	2.0	70
Pronamide 50W	4.0	85
Pronamide 50W + Dichlobenil 50W	2.0 + 4.0	70
Pronamide 50W + Dichlobenil 50W	2.0 + 6.0	70
Pronamide 50W + Simazine 80W	2.0 + 2.0	60
Pronamide 50W + Simazine 80W	2.0 + 3.0	70
Pronamide 50W + Glyphosate	2.0 + 1.5	100
Glyphosate	1.5	100

*Herbicides applied November 7, 1974 and data recorded May 20, 1975.

Pronamide which should be applied in autumn or winter will not control late spring or summer weeds thus increasing the need for combining with another herbicide. No injury occurred to the *Taxus* or *Picea*; however, the glyphosate was applied as a directed spray and contact with the foliage was avoided. The results agree with the

findings of Ahrens (1) in which pronamide at 2.0 and 4.0 lbs. controlled quackgrass without appreciable injury to Taxus.

Study Number 3 — Evaluation of Pronamide in Established Evergreens.

Several herbicides were applied on November 6, 1973 to *Taxus media* 'Hicksii', *Juniperus chinensis* 'Hetzii', and *Buxus* microphylla var. *koreana* to control quackgrass and dock (6). The results as expressed in Table 3 indicated that pronamide satisfactorily controls both quackgrass and dock.

No injury to the ornamentals was observed; however, subsequent unreported studies have indicated that pronamide will injure boxwood.

Table 3. Control of quackgrass and dock in Hicks yew, Hetz juniper and Korean boxwood.

Treatment*	Pounds ai/A	Percent Weed Control	
		Quackgrass	Dock
Control	—	20	20
Pronamide 50W	2.0	75	75
Pronamide 50W	3.0	80	80
Pronamide 50W + Simazine 80W	2.0 + 1.0	80	70
Simazine 80W	3.0	70	20
Dichlobenil 4G	6.0	45	60

*Herbicides applied November 6, 1973 and data recorded June 4, 1974.

SUMMARY

Two promising new new herbicides, pronamide (Kerb) and glyphosate (Roundup) will control quackgrass. Pronamide can be used to effectively control existing quackgrass in established nursery plantings. Glyphosate, although not labelled for use in nursery crops, is highly effective in the control of quackgrass. When labelled, glyphosate will have a role as a pre-plant treatment and as a directed spray in tree or large nursery plantings.

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Tuesday Afternoon. December 2, 1975

The afternoon session convened at 1:30 pm with Mr. Ed Bunker serving as moderator for a special presentation by the group of visiting Australian members. The second portion of the afternoon program was moderated by Mrs. Judith L. Shirley.

GERMINATING PALM SEEDS

EDWARD J. BUNKER

Redlands Greenhouses
Redland Bay, Queensland, Australia

Linnaeus said "Man dwells naturally within the tropics and lives on the fruit of the palm tree. He exists in other parts of the world and there makes shift to feed on corn and flesh." I am sure in everyone's mind a picture of the tropics conjures up palm trees swaying in the balmy breeze.

In the realm of economically important plants, palms stand second to grain-yielding grasses. The world's first sealed milk bottle — the coconut palm; it also gives us copra and coir for mats and roofing of homes. Dates — the staff of life; we have palm cabbage; arrack — a potent alcoholic drink; leaves for thatch and brooms, cabinet wood and veneers. Fruit, such as bactris, the peach palm, are very nutritious; sago palm; betel nuts chewed by over 400,000,000 people; palm oils — and the list goes on and on. In Southeast Asia, *Borassus flabellifer* has over 800 uses to the native people there.

In our western civilization the palm has become important for its decorative and durable capabilities. It is with these so called decorative palms that we are involved. In propagation some palms can be increased by division and a few can be air-layered, but seed propagation is by far the most important means of increasing stocks.

The special issue of The American Horticultural Magazine, Jan., 1961 lists palms as to their viability and length of time they hold this trait. Germination times are also listed in this fine book and I would recommend it to you.

This report is about some tests we are carrying out with planting palm seed, either cleaned or with the fruit pulp attached. I believe in many cases the fruit acids are beneficial to germination, hasten it and also give much higher germination results. The palms we have tested and the results are shown in Table 1. Germination was recorded as having occurred when the first seedling appeared. All seed were collected from the same plant within each species and planted in peat-perlite, 1:1, over variable heat between 75 and 82° F.

6. Smith, Elton M. 1975. Quackgrass, chickweed and dock control in nursery plantings. Nursery Notes Vol. VIII, No. 1.

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We have had our best success in most cases by planting the seed enclosed in the ripe pulp. A lot of work still needs to be done on some varieties and we are continuing our trials. With *Arecastrum romanzoffianum* and *Livistonia chinensis* we have better results in open ground beds using ripe seed with the fruit attached.

McCurrack lists many species and gives cultural information which is very helpful. Palms have been cultivated for at least 5,500 years and I am sure in 5,500 years more we will still be learning about this marvelous family of plants, without which the world would be an infinitely poorer place.

Table 1. Germination of palm seed sown as mature-green or ripe seed with fruit attached, or as cleaned seed planted immediately, or after being stored one month.

Palm species	Fruit attached to seed						Cleaned seed					
	Mature-green			Ripe			Not stored			Stored 1 mon.		
Archontophoenix cunninghamiana	100[a],	63[b],	71[c]	100[a],	98[b],	24[c]	100[a],	82[b],	43[c]	100[a],	61[b],	59[c]
Archontophoenix alexandrae	100,	41,	62	100,	97,	29	100,	71,	43	100,	49,	63
Areca cathecu	10,	—,	—	10,	7,	71	10,	8,	69	10,	5,	67
Arecastrum romanzoffianum	100,	6,	56	100,	4,	61	100,	46,	59	100,	42,	63
Bactris monostachya	5,	—,	—	5,	5,	123	5,	3,	140	5,	—,	—
Borassus flabellifer	10,	—,	—	10,	10,	148	10,	6,	142	10,	—,	—
Calamus spp.	70,	—,	—	70,	46,	34	70,	—,	—	70,	—,	—
Caryota urens	10,	—,	—	10,	—,	—	10,	—,	—	10,	2,	82
Caryota mitis	10,	—,	—	10,	—,	—	10,	6,	80	10,	1,	97
Chamaedorea erumpens	100,	74,	48	100,	98,	35	100,	82,	164	100,	41,	178
Chamaedorea elegans	10,	2,	56	10,	10,	29	10,	8,	34	10,	6,	44
Chamaerops humilis	—,	—,	—	100,	92,	53	100,	74,	43	100,	31,	49
Chrysalidocarpus (Areca) lutescens	100,	2,	42	100,	83,	30	100,	74,	38	100,	57,	36
Dictyosperma album	10,	2,	81	10,	10,	63	10,	7,	54	10,	2,	78
Hedyscepe canterburyana	—,	—,	—	10,	7,	198	10,	7,	181	10,	6,	193
Howea belmoreana	100,	42,	223	100,	61,	212	100,	65,	197	100,	62,	202
Howea fosteriana	100,	20,	242	100,	53,	202	100,	41,	200	100,	34,	197
Livistonia australis	100,	76,	28	100,	99,	21	100,	72,	34	100,	21,	41
Livistonia chinensis	100,	—,	—	100,	—,	—	100,	6,	34	100,	18,	37
Phoenix roebelenii	100,	37,	45	100,	92,	31	100,	81,	42	100,	53,	49
Phoenix rupicola	10,	3,	31	10,	10,	27	10,	6,	29	10,	7,	41
Phoenix sylvestris	10,	—,	—	10,	9,	31	10,	7,	34	10,	6,	36
Roystonea regia	100,	71,	27	100,	94,	26	100,	78,	23	100,	21,	43
Syagrus weddelliana	4,	4,	56	4,	3,	47	4,	1,	49	4,	—,	—
Washingtonia robusta	100,	62,	21	100,	100,	16	100,	92,	22	100,	81,	34

[a] Number of seed planted.
[b] Number germinated.
[c] Number of days until first germination.

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SOME ASPECTS OF BEDDING PLANT PRODUCTION IN QUEENSLAND, AUSTRALIA

MARCUS A. PETERSEN

Dannebrog Nurseries PTY. LTD.
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Our nursery is 11 miles from the heart of Brisbane in a suburban area, which has a population of just under a million people. The Tropic of Capricorn passes through our state about 400 miles to the north of us, so that puts us in the sub-tropics.

The nursery industry in Australia services a population of 14,000,000 people spread over 3,000,000 square miles, while in the U.S. there is over 200,000,000 people in approximately the same area. Consequently, nurseries in our part of the world tend to be smaller in size. However, size isn't a criteria of efficiency and quality of production; we have some very efficient nurseries producing excellent quality plants. Modern up-to-date methods are used and many of our growers keep up with the latest developments from overseas which can be incorporated into their programme.

In my nursery we grow a variety of different things including bedding plants, ornamentals and house plants. I will endeavour to explain a little of how we produce and market bedding plants in our area.

Some 15 years ago we had a visitor to our country named Dr. Ken Baker, Prof. of Plant Pathology, University of California, a man who I'm sure most of you know. Ken had a marked influence on the nursery industry in Australia and I was one who became interested in his proposals and of the U.C. System of growing containerized plants. Prior to this time our bedding plants were produced in field beds using a large area of land. Now our annuals are produced and marketed in plastic punnets on a smaller area of land and much more economically.

We use 50% German sphagnum peatmoss and 50% fine river sand as our growing medium, adding the required amounts of lime, phosphate, nitrate, potash and trace elements for our conditions. This is thoroughly mixed in a paddle type mixer and transferred to sterilizing bins where we steam pasteurize the mixture with aerated steam at 140°F to kill the bulk of the pathogens and retain the saprophytic organisms to combat reinfestation.

The punnets are packed in trays of eight and the seed is sown by vacuum. The seed we use comes from various parts of the world, including the U.S.A. We find it necessary to heat-treat a great deal of the seed to control seed-borne diseases. Some, we hot-water-treat and others we treat with aerated steam. One particular problem we

have is alternaria leaf spot of zinnias. Excellent control is obtained by treating this seed at 130°F for 30 min. To make some seed easier to sow on the vacuum plate,. we pelletize it ourselves. This is quite easily done using methyl cellulose and very finely ground calcium carbonate. Seed is first coated with methyl cellulose which makes the seed quite sticky, then the very fine lime is mixed with it and all of a sudden we have beautifully separated seed, much larger than the original and much easier to handle. Small quantities can be done with a shallow dish, a spatula, and a fine sieve to remove excess lime.

During cold weather (perhaps 2 months a year) it is sometimes necessary for us to germinate some seed under glass with bottom heat. Most lines that we grow are germinated in the containers in which they are to be sold. These are placed on sterilized concrete surfaces in shade houses of from 46 to 62% shade throughout the year.

In our area we experience heavy summer rains and very high humidity from December to March. Summer daytime temperatures are usually 80-85°F with 50-60°F nights; however, in a bad winter we can experience some light frosts. We are able to grow a fairly wide range of bedding plants throughout the year.

METHOD USED TO PELLETIZE SEED

Dissolve 1½ oz. methyl cellulose powder in ½ pt. of hot water. Stir continually until dissolved. Add 1½ pints of cold water and stir vigorously until properly gelled. It will have the consistency of honey. This can be stored in sealed jars for quite a long time without deteriorating. Put seed in flat dish — spoon the methyl cellulose gell onto the seed — sufficient to coat seed evenly — mix with spatula until seed is well coated and just sticky. Add calcium carbonate to seed — a liberal sprinkling (approximately ½ weight of lime to seed). Again mix with spatula till evenly coated and seed separates. Allow to dry for a couple of hours, then gently sieve off excess lime. Place pelletised seed into airtight containers to await sowing. Larger quantities of seed can be processed in a tumble-drum type motorized mixer.

SOME EUCALYPTS OF THE AUSTRALIAN HIGH COUNTRY

MARIANNE MACMILLAN

Commonwealth Gardens
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The alpine eucalypts consist of less than 10 species in all, there being many variations of the main species *Eucalyptus pauciflora* (white sallee or cabbage gum). The variations or sub-species are recognized under their own names as with *Eucalyptus niphophila* (snow gum), *E. de beuzvillei* (giant snow gum) and *E. gregsoniana* (Wolgan snow gum). These small mallee-like trees or shrubs are excellent as ornamental specimens. They have creamy flowers but their most attractive features are their irregular stems with white and red bark and glaucous leaves. As the light intensifies in higher altitudes the eucalypts have adapted by producing a waxy glaucous leaf surface to give them the advantage of the maximum photosynthesis required yet protection from light reflectance in exposed alpine environment.

SELECTION

Collection of viable seed is very important for the production of good plants; these are dependent upon a number of factors. Seed is collected from a plant having the most favourable characteristics of that particular species; this for the alpine eucalypts means the ability to survive under extreme climatic conditions.

Dr. K. G. Eldridge found in tests on *E. regnans* that the trees from higher altitudes produced seedlings that were more frost resistant, grew straighter stems and, although they grew more slowly than seedlings from lower altitude parents, were better quality trees. The seed source range varied from 37' to 41' on an altitudinal transect of Mt. Erica in Victoria. Note was taken of each original parent and these were then used for subsequent collections.

GERMINATION

There appears to be a chemical inhibitor in the seed coat, thus explaining why germination of some eucalypts can be erratic and germination percentage low from apparently viable seed. In nature the seed undergoes cold, moist conditions with warm days and cool nights. This can be sufficient to break dormancy allowing continuation of the species, and for immature viable seed to gain maturity.

The Seed Sub-section of the Forestry and Timber Bureau in Canberra has conducted tests on the optimum temperature, moisture and light requirements of the majority of eucalypt species. The following results were obtained on replicates of approximately 50 seed prechilled for 2, 4 or 6 weeks at 5°C.

Table 1. Germination percentages of seeds of some eucalyptus species.

Species	Weight of Replicate (mg)	Temp. °C	First Count	Final Count
E. alpina	500	15	10	42
E. coccifera	250	15	10	28
E. de beuzvillei	500	20	7	14
E. delegatensis	500	20	5	14
E. gunnii	250	20, 25, 30	7	28
E. mitchelliana	250	20	5	14
E. niphophila	500	20	5	10
E. pauciflora	500	15	7	21
E. perriniana	50	20	5	10
E. regnans	250	15	10	21
E. rubida	250	(25)	5	21
E. stellulata	100	15	10	21

Simulation of natural conditions appears to give more even and higher percentage germination, by subjecting the seed to various temperatures over 24-hr periods.

INFORMATION ON SOME OF THE EUCALYPTS

E. niphophilla Maiden et Blakely (snow gum)

A true alpine found on Mt. Kosciusko, N.S.W., at the highest tree line, 6500 ft. Height varies with altitudinal climes from 3-20 ft, and prefers north-facing slopes (warmest).

E. pauciflora Sieb. ex Spreng. (white sallee or cabbage gum)

A very useful species for altitudes between 2000-5000 ft. Valuable for fuel and shelter. A small to large tree that can withstand severe cold, wind and snow. Yields a golden coloured honey without high density.

E. gregsoniana L. Johnson et D. Blaxell

Limited occurance at Wolgan, N.S.W., restricted to the tops of board spurs on tablelands of sandstone or other silious rock.

E. stellulata Sieb. ex D.C. (black sallee)

A multistemmed small tree with bushy habit, located on poorly drained soils in frost hollows. Typical habitat is one of the most severe in Australia.

E. rubida Deane et Maiden (candlebark)

A sub-alpine species widely distributed in the Australian Alps, found up to 4500 ft. Located on a wide range of soils and very useful for shade, shelter and second-class timber.

E. delegatensis R. T. Bak. (gum-topped stringybark ash)

Second most important timber tree from sub-alpine areas, prefers southern and eastern exposures on moist well drained loams, especially granite or dolomote.

E. regnans F. Muell. (mountain ash)

The most important hardwood, average height 175-250 ft, mostly found in deep sheltered gullies on deep, good quality loams over clay.

E. perriniana F. Muell. ex Rodway (roundleafed snow gum)

Occurs in small stands in high country on southest N.S.W., Victoria and Tasmania. Preferes plateau-like ridge tops, also sub-alpine slopes from 4000-6000 ft. The glaucous foliage contrasting with the greener foliage of *E. pauciflora*.

E. mitchelliana Cambage (weeping or Mt. Buffalo sallee)

A rare species from Mt. Buffalo in Victoia, found in slight depressions and exposed edges at the top of steep slopes on prevailing granite outcrops, with good surface drainage.

Definition: MALLEE — the native name for a Eucalyptus thicket: shrubby species with a bulbous rootstock from which ascend several slender stems.

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SOME ORNAMENTAL EUCALYPTS FOR DRY AREAS

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In Australia, the genus *Eucalyptus* covers some 500 species many of which are suitable for ornamental planting. Some features considered in selecting ornamental species are suitability for conditions in the area of planting, habit, foliage, bark, flowers and sometimes fruit.

Eucalypts fall into two main groups; shrubs and trees. The shrubby species, ranging from about 4 to 20 ft in height, frequently have enlarged rootstocks, called lignotubers, from which several stems usually grow. These eucalypts are known as mallees and comprise the highest proportion of the most floriferous and beautiful species in the genus. Other shrubs and trees have either poorly developed or no lignotubers and are generally single trunked. Many of these are also highly ornamental.

A high proportion of ornamental eucalypts come from a small area in western Australia known as the "Goldfields Area." A brief description of ten of these species has been tabulated below with information taken from "Eucalypts of the Western Australian Goldfields (and the adjacent wheatbelt)" by G. M. Chippendale.

Propagation is by seed as vegetative means have proved difficult. In our nursery we are setting up a programme to investigate propagation from cuttings. This is being done in an attempt to reproduce hybrids which combine the aesthetic qualities of one species with the hardiness of another, species for which seed does not germinate readily, species for which seed does not reproduce uniformly, and species for which seed is not readily available.

We have carried out an initial crude experiment on *E. sideroxylon*. Cuttings were taken from around the lignotuber of an 18 mon. old plant dipped in medium strength IBA powder and placed in a peat/polystyrene (ratio 1:3) medium, under intermittent mist with no bottom heat. Within 3 weeks 70% of the cuttings had rooted, and all of these have developed well.

Further information on sources of Australian plant seed or available information can be obtained from the author.

Table 1. Characteristics of ten eucalypts.

Species	Habit	Ht.,ft.	Habitat rain inches	Flower colour[x]	Flower time	Resistance to:[y] drought	Resistance to:[y] frost	Special sites suited
E. eremophila	tree/ mallee	8-20	8-20	cr, yel pk, crim	winter spring	yes	yes	coast, dry
E. erythrocorys	tree/ mallee	9-25	19	yel	autumn	yes	mod.	coast
E. ficifolia	tree	30	35+	red, pk or, cr	summer	mod.	tender when young	coast
E. forrestiana	tree/ mallee	15	13-16	yel	summer	yes	yes	salty, coast, dry
E. macrandra	tree/ mallee	9-20	15-30	yel, green	summer	yes	mod.	salty, dry
E. macrocarpa	mallee	4-8	15-20	crim, pk	spring early summer	yes	mod.	sandy
E. platypus	tree/ mallee	9-25	15-37	yel-green	mid-summer	yes	mod.	salty, coast, dry
E. rhodantha	mallee	7-10	15-20	red	summer	yes	mod.	
E. salubris	tree	45	8-15	cr	summer	yes	yes	dry
E. sepulcralis	tree/ mallee	25	17-20	yel	summer	mod.	yes	coast

[x]Flower Colour: Cr=cream, crim=crimson, yel=yellow, or=orange, pk=pink.
[y]Resistance: Mod.=moderately.

PROPAGATION OF CODIAEUMS (CROTONS) BY TIP CUTTINGS

IAN D. RAWARD

Raward's Nursery Supplies
Southport, Qld., Australia

Because of our climatic conditions in southeast Queensland, we find that glasshouse grown container stock is superior to open ground cultivation. Our average summer temperature range from 65° to 85°F and winter 45° to 70°F. We can maintain a minimum of 65°F night temperature during the winter months, which permits year-round propagation, and we can have closer control of pests and diseases. The main pests are mealy bug and red spider. We root tip cuttings from 12 mon old well-coloured stock. At peak propagation times we also use younger stock. Tip cuttings are used in preference to node cuttings as these provide a good quality plant quickly.

The removal of the tip of 3-4 leaves causes the next 3 or 4 nodes to break out on the stock plant. These then provide us with our next tip cuttings, yielding not 1, but 3 or 4 tip cuttings in approximately 6 weeks. On an average we can produce 60-80 tip cuttings per plant in a 12 mon period depending on growth habit of the cultivar.

Our propagation medium consists of river sand, peatmoss and perlite (1:1:1 v/v) sterilized at 145°F for 30 min. This mix is used in preference to 1:1 perlite, peat, not because it is superior, but because of economics. Each cutting is struck in 2'' propagating tubes in trays of 100, each having been dipped in hormone powder. Trays are initially watered by hand and placed on heated misting benches, which have a dressing of river sand. Both heating cables and mist are electronically controlled. Bottom heat at 85°F and mist ensure growth and moisture retention. The light requirements are about 70% shade. After 14-16 days of these conditions they have callused and have roots ½ to ¾ inch long. These are taken from the mist controlled area and are given slightly harder conditions for a period of 2 weeks at least, depending on availability of space. These are then ready for tube sales or potting on to larger containers in 6 to 7 weeks from propagation time. In summing up we find that we can produce a saleable item in a 5-inch container in 14 weeks from propagation.

A SUCCESSFUL TECHNIQUE FOR GRAFTING HIBISCUS

ALEX SCOTT

Birkdale Nursery
Birkdale, Qld., Australia

Birkdale is a small country township about 16 miles southeast of Brisbane. It is nestled in the heart of a farming area commonly called the "Salad Bowl." We have 3½ acres of production nursery and 1½ acres of landscaped display gardens, rainforest, etc. Our main lines are shrubs and trees of an exotic and indigenous nature. Within this range we specialize in azaleas, native shrubs, trees and hibiscus.

Hibiscus is a line that we grow particularly well and have built up a trade supplying something like 50,000 a year in smaller container from a 2" tube to a 4" liner. We consign to all states in Australia. There is a particularly strong demand for the Hawaiian strain of hibiscus. For those who do not know hibiscus, this particular strain has been produced by using a species in the development program which produce extremely large flowers in some very unusual shades and colours. An example would be one called 'Surf Rider' and another called 'Golden Belle' which I believe would be grown in any area where hibiscus can be grown.

When we first started to produce the Hawaiian cultivars our stock plants were young and vigorous and our production results were very high; however as the years went by the stocks became woody and the strike became less and less. I was faced with the decision of having to bed out new stock plants every few years, or to look into the possibility of grafting. I feel sure that the economics of grafting far outweigh a re-planting program; in addition, the grafted plant commands a much better price than own-root stock.

We first had to establish a technique that would produce high percentage "takes." We set down a series of trials to sort out the most suitable rootstocks (the three most satisfactory were found to be 'White La France', 'Ruth Wilcox' and 'Apple Blossom') the most suitable grafting method (whip, bud, or cleft) and the best post-grafting environment.

In our first trial we covered the grafts with plastic bags, enclosing pot and all. The grafts were packed in trays of 40 and placed in a well-shaded house. We tried two colours, clear and blue bags. The results in the blue bag far outstripped the results in the clear bag. Although the results were good, the losses were too heavy.

We next put the completed grafts under mist and over bottom heat in a rather close environment and the results were much more promising. In most cases, union of scion and stock took place in 3 weeks; they were left in the house for an extra week, then put into a

shadehouse for hardening off. Within 7 days the plants were standing quite rigid and at the end of the second week they were ready for potting-on or for sale. The grafting tape is left on at this stage to give strength to the graft, but the tapes are cut after potting.

Of the three rootstocks, I feel 'Apple Blossom' is the best because it produces big long canes with well spaced internodes and strong resistance to root diseases. The wood selected is usually pencil thickness and about 5" long; all productive eyes are cut out except the upper two which are left to produce new growth. We strike the cuttings in 9" plastic containers in pure sand, about 50 cuttings to a container. The three rootstocks selected are noted for their quick strike and I feel that the co-factors that facilitate easy striking also assist in a quicker callus and union in grafting.

When struck, the cuttings are potted into 3" dia 4" deep growing tubes and placed in the open sun for rapid root development and top growth. Once adequate root growth has taken place, they are ready for grafting. We use the cleft graft and usually graft about 4" from the top of the soil level in the pot. The scion that we use is of firm new growth with about 3 leaves. Usually the scion diameter relates to the diameter of the stock, so that cambial contact is assured. We then paint the completed graft with a solution of Benlate and derris dust. The graft is then bound with ½" clear budding tape and the upper part of the tie covered with grafting mastic. The grafts are then put into a propagation house covered with UV-inhibited polythene with bottom heat and mist. The grafts are held in the house for 4 weeks, after which they are hardened off in a 50% shadehouse.

The plants are ready for sale 7 weeks after grafting. An advantage of this technique is that if scion and root-stock diameters are the same, it is hard to notice that the plants are grafted once the tape is removed.

CREATION OF A RAINFOREST IN THE CANBERRA BOTANIC GARDENS

D. K. McINTYRE

Botanic Gardens
Canberra, Australia

The Canberra Botanic Gardens occupy about 100 acres on the northeastern slopes of Black Mountain, less than 1 mile from the centre of Canberra. Canberra has an annual rainfall of 25" distributed fairly evenly through the year, although during some summers as little as 2" of rain has fallen in 3 months. The temperature range in the past 10 years has been from 109° maximum to 4.5°F minimum. Frosts occur regularly from May to September but snow rarely falls. Relative humidity is low, often as low as 15%. It is easy to see that these conditions are not those conducive to the growth of rainforest species, particularly as it is the extremes of climate which usually determines whether a plant can be grown in an area.

Only Australian plants are grown and we hope to have a complete living collection of the Australian flora, which has some 20,000 species. At the moment there are more than 5,000 species in cultivation and about 100,000 plants in the gardens. There are a large number of tropical and frost-sensitive sub-tropical species in the Australian flora, and in an attempt to grow some of these outside a glasshouse in Canberra an artificial rainforest environment has been created.

A deep gully runs through the gardens formed in times when the rainfall was obviously much greater than at present. It rarely has more than 6" of water in the bottom of the gully even after heavy rain. It is up to 40 ft deep and averages about 120 ft wide.

An extensive misting system has been installed in part of this gully about 700 ft long. The system is in four sections, each serving both sides of the gully for a length of 170 ft. Along the laterals which are spaced at equal intervals down the slope, there are mist nozzles (Buchner Fogger nozzles) spaced about 3 ft apart on ⅜" dia copper pipe risers. There are about 3,000 nozzles in the whole system. The mist is only turned on during the day. In the summer it is a 2 min on, 2 min off cycle, and in the winter the cycle may be as low as 2 min on, 15 min off. The decision to turn the mist on, and the frequency setting, is made on a daily basis, based on experience.

The top of each side of the gully has been densely planted with *Acacia* spp. which grow on the fringe of rainforests. These have grown rapidly and are providing a protective canopy. The sides of the gully have been extensively planted with ferns and rainforest species. Staghorns, elkhorns and orchids have been tied to trees and are thriving. The acacia canopy, together with the mist has increased

the humidity, which has allowed moisture loving plants to grow well and the canopy has prevented frost from settling in the gully.

Many rainforest species are well established after only 5 years; however the natural dry sclerophyll vegetation is dying because of the increased water regime. The use of a mist spray in this situation has allowed species which would normally not grow in Canberra's low humidity and cold winters to be successfully grown. It also provides an unique and aesthetically beautiful collection of rainforest plants where one would least expect to find them.

HAND POLLINATING SOME PHILODENDRON CULTIVARS

LEONARD DELLOW

General Nurseries Pty. Ltd.
Queensland, Australia

The inflorescense of these species is made up of the spathe and the spadix. Most cultivars are bisexual or dioecious and hence the spadix contains both pollen-producing and ovular sections. The male, pollen producing part of the spadix, is at the top end usually about 1/3 of the total, and the female or ovular section is partially protected in a cup at the base of the spadix. A third part, the function of which I am not sure, but appears to be to keep the male and female sections apart, is in the centre of the spadix and occupies a little more than a third of the total length.

In most cultivars, the flower opens fully in late evening, but does not release pollen or become receptive until later, (this time difference varies considerably). The female section next becomes receptive and this is indicated by the emission of a strong perfume and a pronounced rise in the temperature of the sapdix. Within a very short period the spathe then begins to close around the ovular section, before any pollen is produced. This would appear to be nature's way of preventing self-pollination. The pollen is then released from the top end of the spadix in the form of a rather thick paste. In the case of selloum types, a large tablespoon-full can be collected. The spathe continues to close tightly around the spadix and unless you are there constantly you will miss collecting the pollen.

Having observed all of these processes, I thought that if I could prevent the flower from closing until I collected the pollen and pollinated the ovular area, the task would be much easier. I cut a number of pieces of wood, approximately ⅛" thick by ¾" wide with lengths varying from 3 to 6", smoothed and rounded the edges to avoid damage to the flower. When the flower is fully open, I insert

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these pieces of wood into the flower, behind the spadix and strategically place them so as to hold the flower as much as possible in the fully open position. This does work; it gives ample time to collect pollen, gives time to either self-pollinate that particular flower, or to introduce pollen colllected from a previous flower. After removal from the spadix, the pollen may be diluted with clean water. I use two parts water to one part pollen, stir it well and brush it onto the ovular area with a small soft brush. The diluted pollen may be kept in a sealed glass jar in the refrigerator for several days.

PROPAGATION OF *PHORMIUM TENAX* 'VARIEGATA' AND *P. TENAX*'RUBRUM'

ADRIAN G. BOWDEN
Adrian's Nursery
Jandakot, Western Australia

The method we use is division of mature clumps but there are a few points to bear in mind. First, we plant the new divisions and they are left undisturbed for two seasons. New plantings and divisions are made in late spring as the weather begins to warm up a bit. We prefer this time to winter as the new plants start to grow without delay. The method of division is to cut each clump into single pieces using an axe, discarding flowering pieces which do not regrow.

Do not cut the leaves back on new divisions. The new plants are staked in the field to stop movement until established and fed at planting time. They usually lose quite a few leaves before growing away from the centre but after being cleaned up, after about 3 months they look quite reasonable.

When planting into containers we have saleable plants within about 6 mon and have found they too need staking if put straight outside but this can be avoided if they are placed in a shadehouse out of the wind. We are currently producing about 3,000 variegated flax a year by this method and a selection of red-leaf types selected for different colour and size variations.

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PHYSIOLOGY OF ROOTS

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Abstract. General functions of roots are examined and it is concluded the main function of healthy roots of growing plants is a propensity to grow and form branch roots. External and internal factors affecting root growth are briefly reviewed. An important aspect of root growth is a marked sensitivity to the essential micronutrient element boron. A relationship is drawn between the behavior of boron-deficient tomato and squash roots and the inititation and growth of roots on stem cuttings.

Roots are first. When seeds germinate the radicle is the first organ to emerge from the seed, and when cuttings are made roots must be initiated and grow before growth of the cuttings progresses to any extent. Even in the newer methods of micro-propagation by tissue culture a successful result is obtained only when roots develop and, in most of these instances, root organization and formation is an early event and often the first organized growth from callus tissue in a medium containing the correct balance of nutrients and growth substances. It is commonly observed in transplanting seedlings from flats to nutrient solution culture that the shoot of the seedling doesn't begin vigorous growth until new roots are formed and a certain critical mass of roots is present. Overall, a plant is an autotrophic organism (able to synthesize its own food), but only the shoot is autotrophic; the root system is actually heterotrophic (not able to synthesize its own food). For successful growth, roots must supply water and mineral nutrients to the shoot to sustain its autotrophy. In return the root system depends on carbohydrates and other growth substances to sustain its heterotrophy. Thus there is a reciprocal relationship between shoot and root growth but, in the beginning, roots develop first.

ROOT FUNCTIONS

Perhaps the most essential function of healthy roots of growing plants is growth because the root system "mines" the soil to obtain the necessary water and mineral nutrients for the plants. As roots exhaust the water and nutrients in their vicinity they obtain new supplies by growing into new soil masses. By continued growth they invade new areas of soil to supply the steady needs of water and nutrients to sustain shoot growth and, in turn, their own growth. Roots grow in a branching pattern which makes the root system very efficient in extracting available water and nutrients from a given soil volume and also provides a firm anchorage for the plant. Thus, as a result of root growth we can account for the three common external functions ascribed to roots: anchorage, plus water and nutrient absorption.

Internal activities of roots are also keyed to growth relationships. Sites of high metabolic and growth activity are often referred to as "sinks." Growing roots are regions of high sink activity and enhance growth of shoots by using the products of photosynthesis. Roots assimililate nitrate and ammonium nitrogen into organic nitrogen compounds, principally amino acides which, in additon to being available to the root, are translocated to the shoot. Roots also synthesize hormones and other substances for export to other parts of the plant.

From the preceeding we may conclude that if a root system doesn't grow, all other aspects of its functions become of minor consequence since the growth of the whole plant is checked. Thus the most essential function of roots of growing plants is growth.

FACTORS AFFECTING GROWTH

When main or primary roots stop growing due to unfavorable conditions maturation progresses down the root axis to the tip. Branch or lateral roots may emerge close to the tips of non-growing primary roots, but these laterals cease growth and mature if conditions remain unfavorable. Cessation of growth also results in the tendency for suberization to occur up to the tips of all roots. Suberization reduces root absorbing capacity and thereby greatly reduces root activity, resulting in what may be called "dormant" roots. When viewed in this way roots may be characterized as exhibiting a spectrum of growth activity, with vigorous growth at one extreme and complete dormancy at the other. By briefly examining factors affecting root growth we can visualize their position and responsiveness on this growth activity spectrum.

Important external factors affecting root growth are moisture, aeration, carbon dioxide, pH, minerals, salt concentration, and temperature. Although water in itself is not injurious to roots, excess water in soil displaces air from the pore spaces and results in oxygen deficiency and reduced growth (8). If roots are deprived of oxygen for too long a period of time they die. Good aeration assuring sufficient oxygen for metabolism is essential for healthy growing roots. If water becomes deficient growth ceases and the roots tend to mature and suberize up to their tips, resulting in a reduced capacity for absorption of nutrients and water (8). Due to root respiration, high levels of carbon dioxide may occur in the root zone. However, excess carbon dioxide is not thought to inhibit respiration as much as oxygen deficiency. Root growth is inhibited by extremes of pH (less than 3 and greater than 9), but is only slightly affected in the range of 4 to 8, providing sufficient calcium is present and toxic ions such as aluminum and manganese are not present in excess. Excesses of these elements are recognized as major factors in poor plant growth on acid soils (10). It is generally recognized that a complete and balanced mixture of essential elements is necessary for plant growth.

However, information is meager about the effects of specific ions on root growth. It is recognized that phosphorus stimulates root growth, while deficiencies of boron and calcium yield short stubby branch roots and eventually may cause the tips to die (8). Overall high salt concentrations tend to slow down and eventually stop elongation with a resultant hastening in maturation. This yields roots which are suberized to the tips and appear dormant. Species may vary widely in their tolerance to different levels of salt (8).

Root growth is often limited or stopped by low and also by high temperatures. Optimum temperature varies in relationship to species, stage of development and oxygen level, but is generally in the range of 20 to 25°C. Unfavorable temperatures inhibit elongation and, as elongation is limited, roots become differentiated up to the apex (6). However branching often continues in these roots, and laterals occur almost to the root apex. At cool temperatures roots are usually whiter, thicker in diameter, and less branched than at warmer temperatures. At high temperatures roots become filamentous and "weak" in appearance in contrast to the "robust" appearing roots seen at low temperatures (11). In pot experiments with corn it was found that for each degree increase in soil temperature in the range of 12 to 26°C, total seedling dry weights were 20% greater than at each preceding temperature, and 12% smaller with each degree increase from 26 to 35°C (15). Nutritional status, leaf numbers and size, stem lengths, and root numbers were also very dependent on root temperatures. Although corn was chosen for this study because of its known sensitivity to soil temperature, it seems clear that small changes in pot soil temperature can have significant effects on plant behavior. It would seem very likely that similar, if not as pronounced effects, could also occur in container-grown ornamental plants. In another experiment with corn, root growth was found to occur in a series of stages or pulses which were associated with stages of top growth (7). In view of the various influences reviewed, it is evident that root growth and condition is of prime importance to obtain good quality container-grown plants.

Important internal factors influencing root growth are translocation, sink relationships, nitrogen assimilation and the synthesis of hormones. Over the past decade more attention has been given to the synthetic activities of roots and their ability to act as metabolic sinks. An aspect of low temperature effects on roots is a decrease in root growth and a concomitant reduction in their capacity to act as sinks for carbohydrate translocated from shoots. In sugar cane such a slow-down of carbohydrate translocation from shoots resulted in an accumulation of carbohydrates in leaves which depressed photosynthesis and decreased yields (11). Also, in cotton it was found that low root temperature caused carbohydrate content of the tops to increase rapidly, but carbohydrate was very low in the roots (11). Thus, an actively growing root system appears essential for rapid

translocation of carbohydrate from the shoot and a continued rapid growth of the shoot. In many plants most of the nitrogen passing from root to shoot is in the organic form. From these observations it is concluded that the root system as a whole is an active site of amino acids synthesis for transport to the shoot (11). Factors associated with reduced photosynthesis and reduced metabolic activity in roots leads to an accumulation of nitrate nitrogen in plants. Reduced photosynthesis limits carbon compounds able to accept amino (reduced) nitrogen; since nitrate isn't reduced it accumulates (11). In the last 12 years abundant evidence has indicated that normally growing roots synthesize and export gibberellins, cytokinins and abscisic acid to the shoot (3, 12). Although auxin or indoleacetic acid (IAA) is the oldest of the known hormones its role in root growth has been unclear. In a critical review of auxins and roots Scott (12) concluded that auxin moves from the morphological top to the bottom of the plant in accordance with response to gravity. The evidence of xylem regeneration, lateral root initiation, and root maturation all point to development in the root from the basal part to the apex, from the top downward, and auxin regulation of root growth and development appear to be a consequence of this pattern of auxin movement.

BORON, AUXIN AND ROOTING

Of the three nutrients, phosphorus, calcium, and boron, which were previously mentioned as having direct effects on root growth, boron is unique with respect to the small amount required for activity, i.e., 0.1 ppm or less. When tomato and squash plants are grown in complete nutrient solutions with 0.1 ppm boron and then transferred to nutrient solutions with no boron, root elongation ceases as early as 6 hours and routinely is completed by 24 hours. Typical deficiency symptoms are a browning of the root tips and the appearance of lateral roots close to the primary tips. The terminal 2 to 3 mm of the tip is brown and lateral roots, which are normally present 5 to 7 cm behind the tip of the primary root, appear within 5 mm of the tip. Roots deprived of boron will recover and resume elongation if boron is resupplied within 24 hours, but if the deficiency extends beyond this critical time, recovery will not occur. Although elongation of the primary or main root stops in the absence of boron, maturation and differentiation, as evidenced by the initiation of new lateral roots, progresses down the root. If the laterals are not supplied with boron within their critical time they too stop growing. A boron deficient root thus looks stubby and bumpy. The stubbiness from lack of elongation of the primary and lateral tips and the bumpiness from lateral initials that are arrested in various stages of development (1, 2, 4, 6, 9). In this sense, stem cuttings that have many root initials that haven't elongated to produce new roots are similar to boron deficient roots.

If auxin movement is down the root axis as suggested by Scott (12) and as is indicated by the maturation which progresses down the root under boron deficiency, when the roots have stopped elongating, the amount of auxin should be greater in boron-deficient than in boron-sufficient tips. In a study conducted by Bohnsack (4) in which he measured the level of IAA oxidase (an auxin destroying enzyme) activity in squash roots, he found a higher level of IAA oxidase activity in the tips of boron-deficient roots than in the plus boron controls (Table 1.) Assuming a higher oxidase activity is indicative of a higher auxin content, it is clear that boron-deficient roots have higher auxin levels than plus boron controls. Further, in recovery experiments he found that boron added to boron-deficient roots decreased the oxidase activity from higher to iower levels as recovery progressed, until finally it was the same as normal plus-boron plants not subjected to the deficiency treatment (Table 2.).

Table 1. IAA oxidase activity of the apical 5 mm of root tips of squash plants grown with 0 and 0.1 ppm boron added to the nutrient solution.

	+B	−B
Hours of Treatment	μg IAA destroyed x hr $^{-1}$ x mg dry wt $^{-1}$	
6	0.82 ± 0.01[1]	0.85 ± 0.16
9	0.95 ± 0.05	3.5 ± 0.21
12	0.77 ± 0.02	17.8 ± 1.30
18	0.83 ± 0.06	21.6 ± 0.52
24	0.78 ± 0.05	21.6 ± 0.77
36	0.92 ± 0.04	21.1 ± 0.63

[1]Mean of three experiments with standard error of mean.

Table 2. IAA oxidase activity of the apical 5 mm of root tips of squash plants grown with 0.1 ppm boron until exposed to a boron deficient solution for 12 hrs followed by recovery in a solution with adequate boron.

Hours on Treatment	μg IAA destroyed x hr $^{-1}$ x mg dry wt $^{-1}$
12 (−B)	13.9 ± 0.3[1]
6 (+B)	8.2 ± 1.1
12 (+B)	3.5 ± 0.4
18 (+B)	2.1 ± 0.6
24 (+B)	0.86 ± 0.09[2]

[1]Mean of three experiments with standard error of mean.
[2]Adequate boron control: 0.85 ± 0.03.

Since root elongation stops so rapidly when boron is withheld a role for boron in cell division was suspected. To critically investigate this possibility Cohen (5) examined meristems of boron-sufficient and deficient squash roots treated with radioactive thymidine, a chemical necessary for deoxyribonucleic acid (DNA) synthesis. By examining the pattern of radioactive labeling in cells of root tips by autoradiography one can determine which cells are synthesizing DNA and thus capable of division. His results showed that the ability of root tip cells to incorporate radioactive thymidine is correlated with the total root elongation during the boron deficiency treatment period (6). Cessation of elongation and mitosis occurred as early as 6.5 hrs after boron was withheld from the nutrient solution while DNA synthesis occurred for as long as 20 hrs after withholding boron. If boron is not supplied to boron deficient roots very shortly after root tip cells stop synthesizing DNA they will not recover and resume elongation. However, if boron is resupplied within the critical time period the cells regain first the ability to synthesize DNA, then cell division activity is restored and finally root elongation is resumed (Table 3).

Table 3. Root elongation and incorporation of radioactive thymidine in boron-sufficient, boron-deficient, and recovering root tips of squash plants grown *in nutrient solutions with 0.1ppm and 0 ppm boron.*

Treatment	Mean No. Labeled Nuclei[1]	Mean Root Elongation[2] (mm)
+B, 20 hr	52	29.5
−B, 18 hr	58	4.3
−B , 20 hr	0	4.4
−B, 20 hr with +B recovery for:		
3 hr	0	0
6 hr	0	0.2
9 hr	7	0.5
12 hr	48	0.7

[1]Means of 30 roots.
[2]*Means of not less than 40 roots.*

Root elongation is ultimately dependent on cell division of meristem cells and their subsequent enlargement. Under conditions of boron deficiency, cell division and root elongation stop, followed by the loss of DNA synthesis at the primary root tips. When cell division of the primary tip stops, auxin continues to move down the root and, concomitant with that movement, lateral root primordia are stimulated to differentiate. If those primordia receive boron before their critical time without boron is exceeded, they will start to elongate — if not, they too die. Thus we have a series of lateral meristems that go through the same sequence of events as the primary meristems.

The results obtained from the study of boron deficiency in squash and tomato roots are, I believe, strikingly similar to what one may observe in the rooting of stem cuttings using the auxin IBA. There are various reports in the literature (14) on stimulatory responses of boron with auxin on rooting. In two of these studies (16, 17) it was found that boron had a striking effect on enhancing the number of roots produced on cuttings of clematis (30% increase) and English holly (20% to 40% increase). In both of these investigations the boron and IBA treatments were given as a 12 hr soak with the cuttings stuck in sand under mist.

It is common knowledge among propagators that auxin stimulates rooting. However, the rooting response can be divided into two phases, initiation of new root initials and elongation of the initials into roots. Auxin stimulates the formation of root initials, and from the data obtained on boron and root elongation we may conclude that boron is necessary for the elongation of the initials. The appearance on cuttings of many initials that don't elongate may be due to a lack of boron essential for the cell divisions that are necessary for initial elongation and production of roots.

The physiology of boron-deficient root elongation and lateral root behavior is similar to the physiology of root initiation and growth of stem cuttings. Boron is required for the growth of laterals on boron-deficient roots and for the growth of adventitious root initials on cuttings. In both cases auxin stimulates the formation of the root initials. With roots on intact plants the source of auxin is from the top of the plant moving down the root axis with stimulation of initial formation. For stem cuttings the auxin source is the applied auxin treatment, or in non-auxin treated cuttings, the downward migration of auxin from sites of auxin synthesis such as young leaves, buds or the vascular cambium. I believe these observations and conclusions indicate it is appropriate to examine in more detail possible beneficial effects of boron and auxin on rooting responses of stem cuttings.

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GROWTH REGULATORS AND ROOTING OF CUTTINGS OF WOODY ORNAMENTAL PLANTS[1]

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Abstract. Talc formulations of indolebutyric acid plus benzimidazole or benomyl applied as a basal dip have resulted in improved rooting of woody cuttings. Results are not always consistent with all cultivars nor at all seasons with one cultivar and may be affected by changes in endogenous levels of the cytokinin — auxin ratio.

Since the 1930's when it was found that naturally occurring 3-indoleacetic acid (IAA) (15) as well as some synthetic growth regulators (1, 18) could stimulate adventitious root formation in stem cuttings, there have been numerous papers on the subject. More recently it has been reported that auxins alone would not stimulate rooting in some woody cuttings (6, 9).

Skoog et al. (13) demonstrated that morphogenesis of plant parts was regulated by the interaction of auxin and cytokinin. This is now being applied to propagation of leaf cuttings (16).

Recently it has been reported that some systemic fungicides such as benomyl (Benlate) improved rooting of woody cuttings (2, 14). Some reports on this combination of benomyl and IBA attributed the success to disease control (14). However, the stimulating effect of the fungicide has more recently been attributed to that of a growth regulator (10). Benomyl has been reported to stimulate protein synthesis in wheat leaves (12). Other researchers have found that benomyl or the precursor, benzimidazole, also have growth regulator properties (3, 11, 17). Benomyl appears to act as an adenine analog (12, 5, 8).

It was this potential use of benomyl and its precursors as a growth regulator which lead to the work at the Rhode Island Agricultural Experiment Station. Numerous experiments were done with combinations of benomyl, benzimidazole or N^6benzyl adenine with IBA applied as talc dips on cuttings. This work led to the finding that difficult-to-root cuttings of rhododendron can be rooted in high percentages and with larger rootballs when treated with the combination of Hormex 45* and 5% benomyl in a talc basal dip. Other plant cultivars were also tested and found to respond to the treatment in some but not all cases (10). Further, it was found that results with some cultivars varied from year to year as in the case of *Magnolia denudata* (*M. conspicua*) which rooted very well from cuttings made in early July, 1972, but did not root when treated the

[1]Contribution No. 1645 Rhode Island Agricultural Experiment Station, Kingston, R.I. 02881

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same way at the same time in 1973. No test was made in 1974 but when repeated in 1975 at the same time results were again positive.

Results with first flush cuttings of *Rhododendron* 'Dr. H. C. Dresselhuys,' *R.* 'C. S. Sargent,' *R.* 'Nova Zembla,' and *R.* 'Mrs. P. den Ouden' have been consistently good with the talc dip treatment and the treatment is currently being used on a commercial scale by many propagators in Rhode Island. When the same cultivars were propagated from late season flushes in October, rooting was not as good. Current research is now being done to attempt to determine why this variability between seasons or years takes place.

It appears that either benomyl or benzimidazole can act as a cytokinin-like material in promoting growth responses when applied to a talc formulation with IBA. They appear to act in a manner similar to kinetin but not with the same degree of activity.

Results are not consistent in all cultivars every year and are not consistent in the same cultivar at all times of the year. This variability may be due to different levels of endogenous growth regulators needed to act with the exogenously applied material. Hewett and Wareing (7) found that endogenous levels of cytokinins in poplar varied with photoperiod. Heide (4, 5) also found hormone levels fluctuated with photoperiod and temperature.

As for variability among species or cultivars it is possible that not every plant will respond to the same cytokinin or cytokinin-like material to the same degree. Osborne (11) speculated that cytokinins will prove to be species specific. It is also probable that efficiency of uptake is different for each plant and time of application.

Work now in progress at the Rhode Island Agricultural Experiment Station is designed to find answers to the discussed problems. Hopefully it will be discovered in the near future just how the combined treatments of benomyl and IBA stimulate rooting and when the treatment is most effective.

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REGULATION OF PLANT GROWTH BY RAIN AND MIST

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Abstract Rain and mist have many effects upon plants other than providing water, including leaching of important metabolites, and influencing patterns of rooting, development of fall color, dormancy, flowering, and plant interactions. Changes in growth observed in cuttings propagated under intermittent mist are also observed in plants grown commercially with overhead irrigation and in areas of high rainfall. Rain and mist are significant factors in plant growth.

Every plant propagator knows the tremendous influence that mist has had on plant propagation. Cuttings of many plants which were previously propagated as hardwood cuttings in the dormant season can now be propagated much more rapidly as softwood or greenwood cuttings during the growing season. Combined with the use of auxins, mist has revolutionized the plant propagation industry.

The success of mist has been attributed to two major factors (3). Mist cools the leaves and stems of cuttings and raises the relative humidity of the air, reducing the vapor pressure gradient between the plant and the outside air, thus reducing transpiration. Cooling of the leaves reduces the rate of respiration which helps to maintain carbohydrate levels in the cuttings. However, there are other effects, for plants and cuttings grow well under mist and rain.

One of the most important actions of rain and mist is the leaching of metabolites from plants (1, 7). Mineral nutrients, amino acids, carbohydrates, and growth regulators can be washed out of stems and foliage, often in large amounts. Leaching occurs from all types of plants, and the wide range of different metabolites that can be leached makes this an important plant process affecting yield, quality, and pest susceptibility. Substances which are leached from one plant can be reabsorbed by plants growing beneath or nearby with significant effects. For example, inhibitors leached from one plant can completely or partially suppress the germination and growth of other plants nearby. Known as allelopathy (7), this phenomenon is particularly well documented in desert communities but also is known in landscape situations. Junipers make good ground covers due in part to toxic materials which are leached from the juniper foliage. In natural communities, some plants are dependent almost completely for their nutrition upon the materials leached from plants overhead. Thus, the interaction of plants in both landscape and natural conditions is greatly affected by materials which are leached out of the leaves and cycled from one plant to another.

Leaching occurs from cuttings under intermittent mist (1) and it is a common practice for some plant propagators to add nutrients through the mist to those cuttings susceptible to leaching. Nutrient mist applications also provide nutrients for the new growth that occurs under intermittent mist (8). Thus, leaching of metabolites is an important process by which rain and mist affect the development of plants.

Another interesting effect of mist is on the development of dormancy in woody plants (2, 6). Normally, woody plants such as *Euonymus alatus* begin preparation for winter in mid-summer. Growth slows, sugars accumulate, leaves turn red and abscise in the autumn, and the plant becomes dormant, requiring about 6 weeks of cold temperatures to resume growth. However, when euonymus plants were grown under intermittent mist during the late summer and early fall, they did not become dormant and the leaves did not become red and abscise. Instead, leaves remained green and plants continued to grow through the winter season if warm temperatures were maintained. In fact, the plants did not become dormant for periods of up to 2 years if kept under the mist. However, when the plants were removed from the mist, they immediately responded as if it were the fall of the year; red foliage developed, the leaves abscised, and the plants became dormant, even if this occurred during the middle of summer.

Since the growth regulating chemical abscisic acid (ABA) has been correlated with dormancy in many woody plants, we determined levels of ABA in both the misted and non-misted euonymus (2). ABA in non-misted plants increased gradually during the late summer and early fall and then increased rapidly at the time red color was developing and the leaves were abscising. In contrast, in plants under mist, ABA remained at a low level as long as the plants were under the mist, but increased rapidly when the plants were removed from the mist. Further, we detected ABA in the leachates from the misted plants. This suggested that the delay in dormancy was due to leaching of ABA by the mist.

Another example of the effect of rain and mist is in the development of fall color in the foliage of some shade trees and ornamental shrubs (6). The red color which is so prized in the autumn is due to the accumulation of anthocyanin pigments which are derived from sugars stored in the leaves. It was observed that during a rainy autumn the intensity of red colors in maples was not nearly so striking as during a year with less rainfall. This suggested that something having to do with synthesis of anthocyanins might be influenced by the rain, perhaps sugars or some other precursor.

When *Euonymus alatus* plants were grown under mist, anthocyanins did not develop, and the leaves remained green. In control plants grown without mist, anthocyanins developed normally.

Analysis of the misted plants showed that levels of sugars, precursors of anthocyanins, were lower in the misted plants than in the non-misted. Further, the metabolism of the misted plants was altered so that colorless leucoanthocyanins were produced rather than the red-colored anthocyanins. Other factors associated with anthocyanin synthesis, such as nutrition and temperature, were not responsible for the observed effects.

Mist can also have an appreciable effect upon rooting, as we have reported previously (5). When euonymus plants were analyzed for substances associated with rooting, we found that levels of auxins, carbohydrates, enzymes involved in the formation of auxins, rooting cofactors, and other flavanoid compounds were all much higher in plants and cuttings grown under mist than in plants which did not receive the mist. No wonder that cuttings under mist rooted so much more quickly than did similar cuttings without the mist. Therefore, mist affects rooting not only by cooling leaves and reducing transpiration, but also leaching substances from the cuttings, and inducing cuttings to form natural compounds which stimulate the rooting process.

Another effect of rain and mist is in flowering (4). It is commonly observed in the warm humid tropics that plants often flower in relation to rainfall. In the chrysanthemum which is induced to flower by short days, misting the plants can delay flowering if mist occurs before and immediately following the application of short days. In the case of the Japanese morning glory (*Pharbitis nil*) the results are even more striking. If *Pharbitis*, which requires only one short day (one long night) to flower, is grown under intermittent mist, flowering can be completely inhibited regardless of the photoperiod treatment. Here is another example of how rain and mist can completely change the growth patterns of a plant.

These changes in metabolism of ornamental plants induced by rain and mist can be observed in other crop plants growing throughout the world. For example, in the San Joaquin Valley of California, commercial grape growers use overhead irrigation to reduce the mid-day temperatures during summer. The leaf temperatures are indeed reduced, but in addition, the flowering patterns of the grapes are changed somewhat, the sugar content of the fruit is increased and the resulting wine product is of higher quality. This is important because the use of overhead irrigation to ameliorate environments of crop plants is increasing, including fruit and vegetable crops as well as landscape plants.

In the Pacific Northwest and other fruit regions, fruit crops are being grown in closely planted hedgerows with overhead irrigation. Large increases in both production and quality have been noted as compared with plants without overhead irrigation. Tea of high quality is produced in areas of India where mist and fog are prevalent;

leaching by the mist is recognized as an important factor. Gardeners and nurserymen comment on the luxuriant growth of woody plants in areas with rain and mist, such as the British Isles or the Pacific Northwest. In the warm humid tropics, lush plant growth is often associated with the warm temperatures. However, if those same tropical plants are grown at warm temperatures but without the constant bathing of the rain, growth does not occur to the same degree.

Thus, mist and rain affect plants by cooling the leaves and reducing transpiration and respiration, by leaching of substances,and by influencing the development of fall color, root initiation and development, dormancy, and flowering. All of these are good examples of how a research interest in ornamental horticulture can have appreciable implications throughout the world, in production of economic plants and in natural plant communities. Rain and mist assume even greater significance as factors in plant growth and development.

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BILL CURTIS: I want to comment on magnolia propagation; we found that on plants that have pith we get much better rooting if we cut beneath the node. We also use a bottom heat around 80°F, pour the water to them, and *Magnolia grandiflora* roots 100%.

DICK BOSLEY: I started using Benlate and 2% IBA on rhododendrons several years ago and each year our rooting percentage got poorer. Last year we went back to using Captan and IBA and our rooting percentage went back up to where it used to be. I'd like you to comment on the fact that you're using 4% IBA, which I would normally consider to scald rhododendron cuttings, and what is there about Benlate which retards rooting?

JOHN MCGUIRE: I have seen the reports of reduction of rooting with the use of Benlate but I have never observed it in practice. In addition there are 8 nurserymen in Rhode Island who use it regularly and I don't believe any of them have ever experienced this effect.

With respect to the 4% IBA, I'm speaking about the commercial product Hormex which is a very light fluffy material and I don't believe it is the percent in the formulation but rather how much you get on the cutting. Because this material is light and fluffy you don't actually put a lot of it on. I would agree that a 4% quick-dip or a high concentration of Hormodin will burn them. I believe the problem with Benlate has to do with the environmental conditions you put the cuttings under. Apparently if you put the cuttings under a high bottom heat condition, such as they're doing in Holland, you do get injury; however we're using lower bottom heat and we get no injury.

The magnolias were rooted under outdoor mist with no bottom heat but the ambient temperature in the summer may be as much as 90°F.

VOICE: Dr. Albert, if you're using a 2% IBA talc rooting powder how much boron would you put in it to test its effect on rooting of cuttings?

LUKE ALBERT: I wouldn't use any more than 50 to 100 ppm. It is interesting to experiment with boron; if any of your wives are rooting cuttings at home in a glass of water put in a little boric acid from the medicine cabinet; you will often be surprised at the results. Where root initials would be formed and just sit there, with a little boric acid in the solution, the roots will grow out and you will have some nice rooted cuttings.

RAY MALEIKE: Isn't it true that root length will be shortened by the use of excessive IAA?

LUKE ALBERT: Yes and high levels of boric acid will do this also; in this sense high levels of boric acid mimic high IAA.

BILL CURTIS: When Jiffy Grow first came out it had boron in it. That year we had some bearberry and some *Gaultheria* cuttings in the bench which just sat there without rooting. Ed Wood suggested I spray the cuttings with Jiffy Grow which I did and in 3 weeks we were potting them up.

Thursday Morning December 4, 1975

The first portion of the Thursday morning program was moderated by Dr. Dale Herman and the second half by Mr. Leslie Clay.

GROUND COVER SODS — AN ECONOMIC AND PRODUCTION POSSIBILITY?[1]

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Abstract. A ground cover sod was produced experimentally in 12 to 16 weeks using *Euonymus fortunei var. colorata* Rehd., purple wintercreeper, or euonymus; *Hedera helix* L. English ivy; and *Pachysandra terminalis* Sieb. and Zucc. pachysandra. Of the 7 media examined, pine bark mulch, peat moss and perlite, and Metro Mix 300[3] produced the most satisfactory sods. Both euonymus and English ivy became established with a minimum of effort. Costs to produce and install ground cover sod was approximately twice as high as the conventional method. High initial costs were at least partially compensated for by lower maintenance costs during the first year.

Ground covers are used extensively to soften lines and unify plantings in the landscape. They may reduce soil erosion, eliminate mowing and, under ideal conditions, reduce maintenance. Ground covers are tolerant of many conditions including moist or dry soils and high or low light conditions. Ground covers planted 9-12'' on center may require one or more years to cover an area. During the establishment period increased maintenance costs may result from an invasion of weeds or soil erosion. Maintenance and establishment problems and the desire for a finished appearance may warrant the use of a ground cover sod in many landscapes.

The experiments examined three main areas: 1) The feasibility of producing a ground cover sod; 2) the ease of establishing a ground cover sod; and 3) a cost comparison of conventional and sod ground cover production and installation.

REVIEW OF LITERATURE

In 1973 the production of ground covers as a sod in a fiberglass mat with an asphalt paper backing was examined but their establishment was not successful. Research by Decker (1) on the production of grass as a sod showed that by using an impenetrable base the primary roots would rapidly grow together and bind the sod. A patent on his method is pending. Mitchell and Langston (4) investigated the use of plastic netting in sod production to allow for an earlier sale.

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[1]Taken from a thesis submitted by the senior author in partial fulfillment of the Master of Science Degree, Ohio State University.

[2]Graduate student and Assistant Professor, respectively. The Ohio State University, Department of Horticulture, 2001 Fyffe Court, Columbus, Ohio 43210.

[3]Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products.

An impenetrable base has also been used by other propagators in the nursery industry for several years to facilitate production. A plastic-covered case in which the plastic completely enclosed the medium was used by Harvey Gray to root *Tsuga canadensis* cuttings (2). Also, liners have been produced in polyethylene-lined peat pots thus preventing root penetration through the walls of the pot and reducing harvest cost and decreasing damage to the plant during harvesting and lining out (3, 5).

MATERIALS AND METHODS

The methods used to produce a ground cover sod were modified slightly in each of these experiments. By the conclusion of the last experiment, a general procedure of production was evident.

A 4-mil polyethylene sheet was sloped at approximately a 4° angle to insure adequate drainage (Fig. 1). A polyethylene net (5/8 x 3/4'' mesh) was then placed on the polyethylene sheet and a layer of medium 1 inch thick was placed over the net. The cuttings were then stuck at 2 to 4'' spacings and misted for 6 sec every 6 min. The frequency of misting was reduced as rooting occurred. Osmocote (18-9-13, 3-mon. release) was applied at a rate of 4 oz/bu of medium. A preventive spray program for fungus and insects was applied as required.

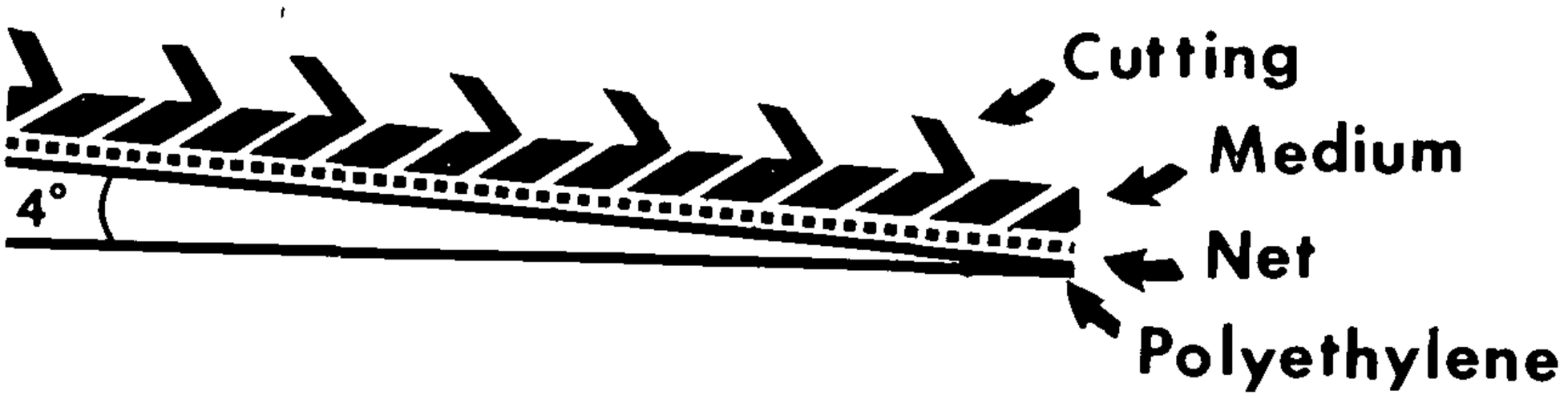

Figure 1. A diagramatic sketch of the end view of a bed of ground cover sod. Sod is placed on a mist bed for propagation.

The first experiment examined the potential of English ivy, euonymus and pachysandra as a ground cover sod. Tip cuttings were stuck at 2 and 4'' spacings in a 1'' layer of peat moss: perlite medium (1:1 v/v). After 12 and 16 weeks 4'' square samples of each sod at each density were taken. Dry weights of the roots and shoots contained in the 4'' sample were then weighed.

The second study examined the effect of the medium on the production and transportability of a ground cover sod. English ivy was stuck at 3'' spacings in each of 7 different media. The media used were pine bark mulch (1/8 - 1/4'' screen size); uncomposted hardwood bark mulch; peat moss: perlite (1:1 v/v); Metro Mix 300; peat moss: Haydite:perlite (1:1:1 v/v/v); peat moss: Haydite (1:1 v/v); and peat moss:sand (1:1 v/v).

The plants after 20 weeks had formed a solid mat in all media and were transferred to a 34°F minimum heat house for overwintering. In May, 1975, one English ivy sod of each medium was shipped to each of 3 growers in Ohio. These growers evaluated the ground covers and then returned them for re-evaluation to the University. The evaluators were asked to rank each medium with the most appropriate rating on each of a series of questions using a scale of 1, unacceptable, to 5, excellent.

In the third experiment, the ease of establishing English ivy and euonymus ground cover sods was examined. A suitable sod of both was produced in pine bark mulch and peat:perlite (1:1 v/v) in 12 weeks and then planted in a test plot. A conventional planting using plants planted 9" on center with a 1" pine bark mulch was included. Half of the ground covers were planted in full sun and the other half in 47% shade. During the first 2 weeks of August, the ground covers were watered six times with 1" of water at each irrigation. Natural rainfall was sufficient thereafter.

To compare the costs it was calculated that 56 sq ft was required to plant 100 ground covers 9" on center. The cost of producing and installing this 56 sq ft was calculated using: 1) rooted cuttings, 2) 2¼" potted plants, and 3) ground cover sod which contained 625 plants 3" on center.

Material, labor and overhead costs of producing and installing each product were identified. Labor activity requirements were based on actual timing of activities at a wholesale ground cover producer, a landscape planting operation and simulations. Production labor was calculated at $3.00/hr and installation labor was calculated at $5.00/hr. Material costs were current in Columbus, Ohio as of October 1, 1975. Overhead expenses/sq ft/day were judged similar for both production techniques while overhead expenses for installation were not calculated because the two methods require approximately the same installation time, tools, and worker knowledge. Costs of production and installation were made without mark-up.

RESULTS AND DISCUSSION

The production of a ground cover sod is dependent on both the species and the density of the plants used. It was found that euonymus produced a larger shoot and root weight than the other plants. After 12 weeks of growth the roots of euonymus appeared to have sufficiently knit to hold the media at both 2 and 4" spacings. English ivy roots, after 12 weeks, at 2" spacing and generally at 4" spacing were sufficiently knit. After 16 weeks, pachysandra developed a more fiberous root system which produced a satisfactory sod at 2" spacings. At 16 weeks all of the sods of euonymus and English ivy were of satisfactory quality.

All evaluators ranked the media for ground covers in basically the same order (Table 1). Pine bark mulch, peat moss and perlite and Metro Mix in general produced the best ground cover sods with all means greater than 4 (good), all other media rated between 3 and 4 (satisfactory to good).

Table 1. Mean evaluation of English ivy sod as a product for landscape use.

Medium	Condition On arrival[z]	Overall Quality[z]	Success of Shipping[z]	Desirability in the Landscape[z]
Pine bark mulch	5.0a[x]	5.0a	5.0a	5.0a
Peat Perlite	4.7ab	4.7ab	4.0abc	4.3ab
Metro Mix	4.3ab	4.5ab	4.5ab	4.5ab
Peat Haydite Perlite	4.0bc	4.0abc	3.7bc	4.3ab
Peat Haydite	4.0bc	3.3c	3.0c	3.8ab
Peat Sand	3.8bc	3.8bc	3.3bc	4.2ab
Uncomposted hardwood bark	3.3c	3.0c	3.3bc	3.7b

[z]Response key — 1 = unacceptable, 2 = poor, 3 = satisfactory, 4 = good, 5 = excellent.
[x]Means separation within column by Duncan Multiple Range Test, 10% level.

Sods grown in pine bark mulch, peat moss and perlite, and Metro Mix arrived in the best condition, rated high in overall quality, and were judged the best for shipping. The media containing Haydite and sand were, perhaps, too heavy for easy shipping. Sods grown in uncomposted hardwood bark lacked the deep green foliage color characteristic of the other media. All of the ground cover sods were judged acceptable as a product for landscape use.

Ten weeks after transplanting in the field, there was a 98% survival of the plants in sun, and 100% in shade. In all treatments the roots of the sod-like ground covers had grown into the soil. In this test, it was observed that a ground cover sod may supress a weed population. This is probably the result of increased competition due to the complete foliar cover of the ground cover sods in combination with the mulching properties of the growing media which were used.

To produce 1 flat of 100 rooted cuttings the cost was estimated at $4.61 (Table 2). It cost $9.79 to produce 100 2¼'' pot plants while it cost $28.94 to produce 56 sq ft of ground cover sod. Of this sum $11.67 is attributed to the cost of the 625 cuttings and $8.23 is due to an increased overhead resulting from a proportionate increase in the required production area. Installation of 100 conventional plants 9'' on center in an area 56 sq ft was estimated to cost $13.94 in labor and material. Labor and material to install 56 sq ft of ground cover sod was estimated to cost $7.79. Higher costs to install conventional plantings are due to costs of mulch and increased planting time.

In examining the total cost of each method the cost of producing and installing 56 sq ft of ground cover sod ($36.73) is 98% higher

than conventionally planting 100 rooted cuttings ($18.55) and 55% higher than 100 potted plants ($23.73). However, a square yard of a conventional planting contains approximately 20 plants 9'' on center and, in a square yard of a ground cover sod, there are approximately 120 plants.

Table 2. The estimated cost of producing and installing 100 conventional ground covers and 56 sq ft of ground cover sod.

	Production				Installation			
Item	Labor	Material	Over head	Total	Labor	Material	Total	Grand Total
100 rooted cuttings 1 flat	$1.26	$3.11	$0.24	$4.61	$4.71	$9.23	$13.94	$18.55
100 2¼'' pot plants 2 flats	4.00	5.31	0.48	9.79	4.71	9.23	13.94	23.73
5.25 sq m ground cover sod	5.25	15.36	8.23	28.94	3.72	4.07	7.79	36.73

CONCLUSION

For many landscape situations the additional cost of a ground cover sod may be worth the investment. The use of a ground cover sod will give a planting an immediate finished appearance and may also prevent soil erosion and reduce mulching and maintenance requirements.

For many of today's consumer's such an effect is often desired. Corporations, small businesses, condominiums, highways, and many homeowners could utilize a ground cover sod. They would use it because it would provide an immediate established appearance and perhaps eliminate some of the problems associated with the initial establishment and maintenance of a conventional ground cover planting.

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VEGETATIVE PROPAGATION OF *PINUS STROBUS* BY NEEDLE FASCICLES[1]

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Abstract. Studies were conducted during 1974 and 1975 to determine the influence of chemical growth regulators for increasing bud development in dwarf shoots of *Pinus strobus* and also to determine effect of rooting of dwarf shoots as influenced by clonal response and sampling date. Results indicate that both single and multi-applications of N^6-BA (N^6-benzyladenine) increased bud development, while PBA (Pyranybenzyladenine), Atrinal (kidegulac-sodium) and MBR 12325 showed no effect. Rate of application of N^6-BA was significant with 1000 ppm being more effective than 500 ppm. Results on rooting of dwarf shoots indicate that no differences in percent rooting of dwarf shoots could be attributed to sampling date, but substantial variation occurred between individual clones.

Research in silviculture throughout the world by both geneticists and physiologists during recent years has been directed toward discovering new methods to improve superior quality clones in forest trees. Particularly in pine, retaining superior clones is important in selection for pulp, paper, lumber, and ornamental value. Commercial methods used by foresters to retain desirable qualities in forest trees have been by sexual reproduction through selection of seed from superior trees and by vegetative propagation. Unlike sexual reproduction, vegetative propagation provides genetically uniform material, multiplication of selected germ plasm for progeny testing and, potentially, could provide large numbers of propagules (9).

Graftage and cuttage have been used to vegetatively propagate hardwood and softwood pines, but stock-scion incompatibility, expense, and limited numbers of plants which can be produced have reduced its practicability as a commercial method of propagation. Although some success in rooting stem cuttings has been achieved, only one species, *Pinus radiata*, has been commercially propagated by stem cuttings in large numbers for distribution (1, 7).

A new method of vegetative propagation which shows promise in the genus *Pinus* is the use of dwarf shoots or needle fasicles. The dwarf shoot consists of 1 to 5 needles and contains a diminutive shoot apex which is formed in the axil of either a terminal or lateral branch (8). When this dwarf shoot is propagated, adventitious roots arise at the base of the needles and a plant genetically identical to its parent is produced. Rooting of dwarf shoots or needle fascicles has been demonstrated in a number of species (4, 5, 6, 8, 10, 11). Al-

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though this method of reproduction has shown promise, difficulty in stimulating development of the fascicular bud within the dwarf shoot after rooting into a growing apex has been successful only in a few cases. As a result, death of the rooted dwarf shoot frequently occurs within several months (11, 14).

The major objective of this study was to evaluate the effect of growth regulators and a cultural treatment as a method to enhance bud development in dwarf shoots of *Pinus strobus*. Number of applications as well as rate of application were studied. Another objective was to investigate the effect of clonal response and sampling date in rooting of *Pinus strobus*.

MATERIALS AND METHODS

Experiment 1. Two separate groups of 3-year-old plants of *Pinus strobus* were root-pruned and placed in 3.78 liter containers containing 3:1:1 bark, sand, and peat mixture. Plants were then transferred on March 8, 1975 to the greenhouse where they received approximately 11 hr of natural light followed by 3 hr of 100 ft-c of incandescent light. From March through May plants received ample water and fertilizer to stimulate new shoot development.

On June 20, as the sheath of the dwarf shoots began to shed, plants were selected for uniform terminal stem length. Each terminal stem was tagged and plants of these two separate groups were arranged in RCBD (randomized complete block design). Three replications of each treatment were used in the first group and four in group two.

Foliar applications of N^6-BA, Atrinal, MBR 12325, and PBA were applied to drip point on June 20 to Group 1 and June 20 and July 18 to Group 2. Application was made with a compressed air stainless steel sprayer applying 50 ml of chemical/plant. Applications of chemicals were made in the early morning when temperatures ranged from 65-75°F.

Buds measuring greater than 2 mm in length were used as a criteria for buds which developed into a growing apex. Number of buds developed within the dwarf shoot on the terminal stem were recorded after 8 weeks following last treatment.

Experiment 2. Five-year-old field-grown *Pinus strobus* were selected for uniform stem and needle growth on January 5, 1974 and 1975. Each of these groups of trees during both years had been pruned the previous summer to assist in stimulating bud development within the dwarf shoot. From each tree during 1974, 30 dwarf shoots were removed from the uppermost terminal whorl on January 15 and February 5, while in 1975 60 dwarf shoots were removed on January 15.

After samples were collected each year, they were placed in plastic bags and submerged in water overnight to prevent evapora-

tion of moisture from the dwarf shoots. Following sampling, dwarf shoots from each tree were divided into equal parts and randomized with other samples from other trees. As a result, during 1974 and 1975, each sample plant was replicated three times, but the number of samples of a particular plant varied between 1974 and 1975.

On January 16 and February 16, 1974 and January 16, 1975, samples were dipped in 0.8% Hormodin talc and placed in a perlite medium under intermittent mist. A plastic tent was also utilized to cover this structure to assist in keeping a high humidity. Temperature in the propagation structure ranged from 80-120°F during the day and 65-70°F during the evening.

Cuttings of these dwarf shoots were evaluated after 120 days for percent rooting and effect of date on rooting.

RESULTS

Growth Regulator and Cultural Treatment Studies. Results indicated that N^6-BA was the only effective treatment for increasing the number of dwarf shoots with developed buds greater than 2 mm in length on a given shoot (Table 1). Differences in rate of application of N^6-BA was not significant. Treatments of other chemicals and removal of terminal buds did not show any difference in the number of buds developed within the dwarf shoot. All chemicals and rates tested indicated no phytotoxicity symptoms.

Results of multi-spray applications indicated that both 500 and 1000 ppm were the best treatments (Table 2). Differences in application rate of N^6-BA was highly significant, with 1000 ppm being more effective than 500 ppm. All other treatments, as in the previous experiment, showed no difference in number of buds developed within the dwarf shoot. All chemicals and rates tested indicated no phytotoxicity symptoms.

Table 1. *Effect of removal of terminal buds and the foliar application of* N^6BA, PBA, MBR 12325, and Atrinal on number of buds developed within dwarf shoots of *Pinus strobus* after 8 weeks (1975).

Treatment	Rate (ppm)	No. of buds formed within dwarf shoots Terminal Stem[1]
PBA	100	0
PBA	200	1
N^6BA	500	37
N6BA	1000	48
MBR 12325	120	0
MBR 12325	240	0
Atrinal	1000	3
Atrinal	3000	0
Pinched		7
Control		0
LSD .05		12.3

[1]Each value is the mean of 3 plants.

Table 2. Effect of removal of terminal buds and the foliar applications (June 20 and July 18) of N⁶BA, PBA, MBR 12325, and Atrinal on number of buds developed within dwarf shoots of *Pinus strobus* after 8 weeks (1975).

Treatment	Rate (ppm)	No. of buds formed within dwarf shoots Terminal Stem[1]
N⁶BA	500	27
N⁶BA	1000	70
PBA	75	10
PBA	150	13
MBR 12325	120	12
MBR 12325	240	13
Pinched		9
Control		10
Atrinal	1000	9
Atrinal	3000	10
LSD .05		17.7

[1]Each value is the mean of 4 plants.

Rooting Studies. Results from 1974 indicate that there was only a slight difference in percent rooting of dwarf shoots as influenced by sampling date (Table 3). Results also showed that differences among clones did exist, and that those variations among clones were substantial. Best overall rooting was attained with clone No. 5, with 36% rooting.

Results of 1975 support the previous years' study in that rootability was largely affected by individual clonal response (Table 4). Average rooting percentages were noted to be higher during the 1975 testing period with an average of 22% rooting of all clones. Of the 45 clones tested, 42% of these had an average percent rooting of 34. Best overall rooting was attained with clone No. 4 with 68% rooting.

Table 3. Percent rooting of dwarf shoots as influenced by clone and sampling date in *Pinus strobus* (1974).

Clone	**January** Percent Rooted	**February** Percent Rooted
1	7	7
2	—	—
3	56	33
4	3	—
5	36	10
6	13	10
7	3	7
8	13	23
9	10	3
10	16	20
11	3	10

Table 3. (continued)

Clone	January Percent Rooted	February Percent Rooted
12	3	3
13	—	3
14	10	20
15	7	—
16	3	10
17	—	3
18	—	13
19	13	3
20	16	16
21	7	10
22	13	20
23	1	3
24	—	7
25	3	10
26	13	3
27	—	3
28	23	23
29	23	30
30	16	3
Avg.	10.4	10.2

Table 4. Effect of clone on percent rooting of dwarf shoots in *Pinus strobus* (1975).

Clone	Percent Rooted	Clone	Percent Rooted
1	2	24	5
2	27	25	3
3	13	26	10
4	13	27	17
5	37	28	10
6	25	29	10
7	15	30	22
8	3	31	47
9	30	32	7
10	20	33	17
11	15	34	5
12	3	35	13
13	30	36	0
14	15	37	50
15	33	38	18
16	40	39	45
17	7	40	12
18	38	41	68
19	30	42	32
20	15	43	45
21	28	44	33
22	10	45	32
23	30		
Avg.			22

DISCUSSION

Results from the growth regulator studies support the theory (12, 13) that cytokinins play an essential role with auxins in bud development as well as altering apical dominance. Early work conducted by Wickson and Thimann (15) reported that auxins inhibit axillary bud growth, but that kinetin could overcome the auxin effect. They also noted that the higher the auxin concentration, the higher the rate of kinetin needed to remove this inhibition. Concha and Montaldi (3) in their study reported that N^6-BA could release axillary bud inhibition of dwarf shoots of *Pinus elliottii*. Cohen and Shanks (2) also have reported that foliar applications of N^6-BA stimulated bud development in dwarf shoots of *Pinus ponderosa* even though terminal buds of long shoots were present.

From these studies, it appears that a similar mechanism of apical dominance via lateral bud inhbibition exists in *Pinus strobus* also. It is speculated that the level of cytokinin and auxin within the bud during the growing season plays an essential role in controlling bud development, and once the level of either compound is "unbalanced," axillary bud development ceases. Only N^6-BA overcame apical dominance and resulted in a reduction in axillary bud inhibtion. Rate was also important, further substantiating the fact that a given level must be present of a cytokinin-like substance if axillary bud development is to occur.

Results of the studies on rooting support the concept that propagation of dwarf shoots was influenced by clonal types. These studies during 1974 and 1975 indicated variation among clones even though, 1) trees were the same age, 2) culturally treated in the same manner, and 3) sampling techniques were the same for all trees. The data also confirmed that there was no difference in overall rooting during January or February. Reports (6, 10) of other investigations support the theory that best rooting occurs during early winter.

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SOME FACTORS AFFECTING PROPAGATION OF DOUGLAS FIR

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Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, is the major softwood timber species in the United States. Although it covers only 7.3% of the commercial forest land in this country, it produces 23.8% of the saw timber (11). Douglas fir is distributed over a north-south range of more than 3,000 miles, e.g., from northern British Columbia to Mexico, and from Colorado and Arizona to the West Coast, occurring from sea level to elevations of 11,000 ft. (11,12). Its wide distribution and uses for heavy structural timber, construction lumber, poles, plywood, pulp, as well as an important ornamental and Christmas tree species has encouraged research aimed at finding improved methods for its production.

Because of the heterozygosity problem involved with seed propagation, there is an immediate need in forest genetics and management research for methods of propagating vegetatively clonal lines of superior phenotypes and genotypes of douglas fir on their own roots. These superior clonal lines, free of rootstock effects and incompatability problems, would be useful in site performance evaluation; and establishment of seed orchards, forest and Christmas tree plantations.

Vegetative propagation has been an important tool in tree improvement programs. Horticulturists have used these methods to perpetuate the desirable characteristics of selected tree fruits and ornamental trees and shrubs. Vegetative propagation of douglas fir on a commercial scale began on the West Coast in the late 1950's with large scale grafting of seed orchards. Problems of scion-stock incompatability (8,9,10) have complicated the establishment of these seed orchards by grafting. Characterization of incompatability, however, is not that distinct. Stock and scion may unite initially, but gradually develop incompatability symptoms with time, due either to failure at the union or to the development of abnormal growth patterns and the grafts will eventually die (14). In a survey conducted at 3 orchards in Oregon and Washington, Copes (9) observed that 78% of the grafts survived after 4 years in one orchard; 46% after 6 years in a second orchard; and 57% after 8 years in a third orchard. For this reason, there has been considerable interest in recent years in establishing douglas fir seed orchards from stem cuttings of selected genotypes.

Although not carried out systematically and in sufficient detail to get basic answers, some work was done in the early 1940's

to demonstrate the feasibility of rooting of douglas fir stem cuttings (13,18). Main objectives of our team work at Oregon State University were to study: a) the seasonal periodicity of rooting; b) optimum rooting environment; and the effect of c) physiological condition of the stock plant; and d) auxin, cold-storage, tree age, shearing, etc., on rooting of douglas fir stem cuttings.

MATERIALS AND METHODS

Stem cuttings of current season's growth were taken from field-grown douglas fir. Needles and buds were removed from the lower 4-5 cm of the 12-cm cuttings. Auxin treatment consisted of a 5-sec. dip of the basal 4-5 cm of the cutting in 10% Jiffy Grow in 95% ethanol. After treatment, the cuttings were placed in the rooting medium (Del Monte white sand E1-8: Canadian sphagnum peat moss, 5:1) to a depth of 3-4 cm with a spacing of 4 cm between cuttings in rows and 7 cm between the rows. The cuttings were left in the rooting medium under mist with bottom heat for 90 days, and then examined for rooting response.

RESULTS AND DISCUSSION

Seasonal Periodicity. In order to establish seasonal periodicity of rooting in douglas fir, stem cuttings were taken at various stages of growth and development at regular intervals throughout the year over a number of years and given a 90 day rooting test. This way, we were able to establish fairly consistent seasonal rooting response curves (5,6,23,24).

Rooting was poor in July and August, none occurring in September and October, and then increased monthly thereafter to a peak in March, then dropped again in April (5). Roberts and Fuchigami (24) concluded that bud dormancy was responsible for unsatisfactory rooting during September and October. Furthermore, we concluded that during September-October, bud dormancy reached a point where auxin alone was not sufficient to stimulate rooting and cold treatment or an 18-hr photoperiod combined with auxin application (3,24,25) was required.

Often the effects of timing are merely a reflection of the response of the cuttings to the existing environmental conditions at the different times of the year (14). It is possible that true bud dormancy (September-October) may occur at different times in different geographic locations or years. Thus, for any given plant, emperical tests are required to determine the optimum time of taking cuttings, which is more related to the physiological condition of the plant than to any given calendar date (14).

Photoperiod. Photoperiod influences cambial and bud activity as well as rooting of cuttings in woody plants (20). Wareing and Smith (29), concluded that photoperiod affects rooting either by influencing the activity of the shoot apex or the hormone production in leaves.

The literature on the effect of photoperiod on rooting is inconclusive and the results are conflicting; this makes generalization difficult. Baker and Link (1) studied the effect of natural, an 18-hr day and continuous lighting on the rooting of cuttings of 26 woody ornamental species and observed no significant difference in rooting with extended photoperiods. Snyder (22), working with *Taxus cuspidata* cuttings taken in December, reported similar results. Lanphear and Meahl (15) observed that *Juniperus horizontalis* 'Plumosa' cuttings rooted significantly better under 24 (77.8%) and 18-hr (79.2%) photoperiods than under normal daylengths (40.3%) when rooted during the autumn. Waxman (30) reported summer cuttings of *Cornus florida* produced twice as many roots in an 18-hr photoperiod as in a 9-hr photoperiod and 1½ times as many roots as cuttings under normal daylengths.

We (2,3) observed that an 18-hr photoperiod of 750 ft-c light intensity significantly increased rooting percentage (13%) and quality as compared with similar cuttings propagated under a 9-hr photoperiod of 1,500 ft-c light intensity (6%). Our data indicated that rooting can be expected with cuttings under an 18-hr photoperiod even during the peak dormancy period (September-October). Our results with douglas fir are in agreement with those of Lanphear and Meahl (15) for *Juniperus* and with Wareing and Smith (29) for *Populus x robusta*. Both reported cuttings rooted significantly better under long photoperiods than short photoperiods.

Rooting Medium Temperature. The controversial role of bottom heat in the rooting of cuttings has been reviewed in detail by Nelson (19). In a study conducted under controlled environmental conditions, we (3) found that the effect of rooting medium temperature varied with sampling date. According to our findings, cuttings rooted significantly better under 18 and 26°C rooting medium temperature than under 10°C. It was postulated that 10°C was too low for optimum metabolic activity for callus formation and root initiation.

Auxin. Prior to 1930's, only the easy-to-root species and cultivars were propagated. Thimann and Went's discovery (26) that naturally occurring auxin (indole-3-acetic acid or IAA) generally exerts primary control over root initiation led to a rapid development of the use of rooting hormones in plant propagation. The use of synthetic auxins IBA and NAA in promoting rooting was first reported in 1935 (31).

In douglas fir, Griffith (13) reported the first successful rooting of cuttings taken in February and March (80%) and treated with 25-50 ppm IBA as a 24-hr soak. McCulloch (18) reported similar results with cuttings from 1-year-old shoots of douglas fir treated with IBA. Our results (5) with douglas fir revealed that

auxin treatment significantly increased cambial activity at the base of the cutting, which subsequently increased rootability during pre- (August) and post-dormancy (December). Auxin treatment alone was not effective in stimulating rooting during the true dormancy (September-October) and during this peak dormancy period long photoperiods (3) or cold-storage (24) either on the tree or in storage (0±1°) was required.

Age and Juvenility. The age of the stock plant in relation to rootings of cuttings is a very important factor. Cuttings taken from juvenile douglas fir trees (6-year-old) rooted significantly higher than cuttings sampled from adult trees (50-year-old)(4). Similar observations have been reported for *Pinus* (16, 17, 21, 27, 28).

In a study of rooting cuttings of douglas fir (7), it was concluded that rooting declines rapidly at ages beyond 9 years and reached a low at age 24 years. Any treatment which maintains the juvenile phase would be of value in preserving the decline in rooting potential as the stock plant ages (14). The hedging or shearing treatments given *Pinus radiata* trees was quite effective in maintaining the rooting potential of cuttings taken from them as the trees aged, compared to nonhedged trees (17). A comparison of the rooting potential of cuttings from sheared and non-sheared portions of the same douglas fir tree revealed that cuttings taken from sheared portion rooted significantly better than the non-sheared portion (7).

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VIRUS-INDEXED PRODUCTION OF RASPBERRIES AND GRAPES

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The introduction of virus-indexed registered red, black, and purple raspberry and virus-indexed registered grape production was created because of a very definite need to improve a decreasing quality level, a quality level concerning both vegetative growth and fruiting. Our red raspberry virus-indexed registered program got underway in 1964.

The procedures are all rather basic; red and black raspberries both wild and cultivated, are very susceptible to a number of viruses. Some viruses are present in plants without producing visible symptoms and in this case, can only be detected by transmitting them to sensitive indicator plants. The cultivar, Henry, is commonly used as a test plant. Viruses are very detrimental to cultivated stock. From a point of economics we are concerned with four diseases; raspberry mosaic, leaf curl, streak, and crumbly berry.

Viral symptoms affect new cane growth in early summer when temperatures are still low. Foliage becomes mottled with light yellowish-green spots and with some cultivars a definite blistering occurs; leaves are usually smaller and cupped. General deterioration becomes more evident with age and with each year's growth dwarfing becomes progressively pronounced. The fruit on plants infected for more than 1 yr becomes very dry, seedy and quite tasteless.

The spread of mosaic concerns a vector identified as *Amphorophora agathonica* Hottes. Leaf curl is spread by the aphid, *Aphis rubicola*. This disease can reduce fruiting yields by as much as 40%. Streak virus brings about a stunting of growth and affects fruiting appearance and size. The specific vector concerning streak has not been identified, but it is acknowledged to be an insect. Crumbly berry is a disease of red raspberry caused by a strain of the tomato ringspot virus which infects a wide range of woody and herbaceous plants. The fruit becomes crumbly and tends to fall apart when handled. The tomato ringspot virus is transmitted by the dagger nematode (*Xiphinema americanum*). This vector is found in soils all across New York.

The control of virus diseases involves the following steps:

1. Plant nursery stock originating from virus-indexed stock.
2. Isolate the new plantings from old plantings and any wild brambles; recommendations suggest up to 1,000 ft of isolation from wild brambles.

3. Keep red and purple raspberry plantings isolated.
4. Rogue raspberry plantings twice a year, preferably in June and August.
5. Establish a preventive insecticide spray program that restricts the build-up of aphids. Fumigation of soil is included where there is evidence of the dagger nematode.

Propagation of red raspberry is comparatively simple. The usual routine is by suckers which arise from the ground. Plants are cut back the beginning of the second year and dug at the end of that year. The suckers are cut free from the mother plant and if grown under good conditions, can yield as many as 15 new plants each. The caliper of canes and the amount of root determines saleability. Generally two grades are sold: A#1 S grade, 3/16" in cane caliper and a transplant grade, at least 1/4" in cane caliper. The root system must be in balance with top growth.

Nuclear stock, meaning new stock, is acquired from the U.S.D.A. located in Beltsville, Md. It is planted in a screenhouse of 100 mesh plastic which restricts aphid flight. Our screenhouse for red raspberry cultivars now measures 50 x 500 ft. Stock from the screenhouse is planted in an isolated, fumigated field with 1,000 ft of isolation from any other plantings including wild brambles. A spray program is incorporated to prevent any aphid population build-up. After 2 years in the field, the plants produced from screenhouse stock are dug and can be sold as Foundation I stock. Our program has been very successful and we now involve Foundation I and, after replanting and growing for 2 more years, we have Foundation II stock. These plants can be planted back and grown for 2 more years and sold as Registered stock. Plants grown from Registered stock are certified but make no reference to virus-free. It is recognized that, in most cases, this certified stock is still better in terms of being virus-free than stock not having been subjected to the controls concerning a registered virus-free program.

Problems encountered include the isolation requirements. One thousand feet of isolation from any wild bramble is difficult to find in our area and forces us to eliminate wild brambles along hedge rows and adjoining fields by means of spraying. We've been using Ammate X with oil coupled with fumigation requirements, screenhouse requirements, and a preventative aphid spray program. All of these factors represent problems that no doubt would have discouraged us if it had not been for the excellent co-operative assistance we've received from the N.Y. State Agric. Dept. which in cooperation with the N.Y. State Dept. of Agric. and Markets has taken over the indexing program and we've been able to move along in a nicely regulated direction.

The registered program of growing black and purple raspberry

is the same as red raspberry. The propagation of black raspberry however, is different in that black and purple raspberry are propagated by means of tip-layering which we schedule for August or September. A well-drained loam or sandy loam is desirable. One-year old plants are preferred for tip-layering. Unbranched laterals of canes are selected as being ideal. Tips are perpendicularly inserted 3 to 4'' below the soil surface, the soil firmed to keep the tips secure in the soil. This is still being done by hand, but we are attempting to develop means of tipping and harvesting mechanically.

Virus-free grape production is a completely different program involving its own rules and regulations. Historically, N.Y. vineyards have not been subjected to any critical reductions or crop yields and/or fruit qualities; however there has been an emphasis on planting premium vines namely, *Vitis vinifera* types and French hybrids. These cultivars are susceptible to virus infections and presently five virus diseases (tobacco mosaic, leafroll, fanleaf, tomato ringspot and tobacco ringspot) have been identified in N.Y. The nematode vector, *Xiphinema americanum*, is also present in grape production. Since 1968 there have been two outbreaks of grape vine decline; specifically, tomato ringspot virus and tobacco ringspot virus have been confirmed pointing out the fact that disease spread can be very rapid especially if adequate controls are not established. Recent surveys indicate commercial plantings of both viniferas and French hybrids showing disease at 1% levels. Symptoms vary from stunted shoots, mottled foliage, poorly developed fruit clusters attributed to poor pollination because of diseased pollen which causes poor fruit set. Due to the soil inhabiting nature of the virus affecting grape production and the vectors involved, control is very difficult to achieve. Real problems in established vineyards involve eradication of infected acreage, but in areas where new plantings are to be established, the soil can be fumigated to reduce the population level of nematode vectors.

Virus-free and resistant rootstocks appear to be the forthcoming approach and is presently under investigation at several state stations. In order to protect the industry which has been growing very rapidly, the N.Y. Dept. of Agric. and Markets promulgated rules and regulations for the production of virus-free grape plants. The program which is voluntary was adopted March 15, 1973. Objectives are: 1) to provide grape plant materials indexed free of known virus diseases, and 2) to assure trueness-to-cultivar type. Indexing in some cases involves chip-budding dormant accession buds into each of four woody indicators. In some cases, symptoms are identified only after 2 years of growth. This is a very detailed program dedicated to provide certification endorsed by all segments of the grape industry.

Unless yields of fruiting and quality further deteriorate, the program will only continue in a state of limbo. Fumigation required on a total acreage basis represents a tremendous cost to the grower. The lack of virus-indexed stock available and an industry that is out of balance in terms of production versus consumption are problems.

Production of many cultivars involves hardwood cuttings of the current year's wood. Cuttings of 8 to 15" in length, 3 buds or more, and pencil-size in caliper are ideal. Depending on the cultivar the hardwood cutting method is acceptable; however there are many cultivars requiring grafting to selected understocks which respond to adverse soil conditions even though climatic conditions are favorable.

The degree of success in rooting is determined to a great extent on the condition of the wood prior to processing for rooting. Cutting wood should be fully dormant and not left to dry out. Special care in making sure that the wood does not dry out is very critical; cutting wood generally is gathered in December and January. Other rooting methods include softwoods taken the middle of June and propagated under mist. This production usually requires potting after rooting in sand benches and holding in a temperature-controlled environment until the following spring at which time the cuttings can be planted to a permanent site. The usual procedure involves sticking hardwoods directly to a prepared field after all danger of frost. Field rooting is generally 50 to 60%. A great deal depends on cultivar as some respond at 80 to 90% rooting where as others respond only at a 15 to 25% level. Carbohydrate content and prior fruiting yields have been identified and correlated into usable evidence for predicting rooting responses.

CASE HOOGENDOORN: Instead of layering these raspberries can't you take softwood cuttings?

HENRY WELLER: We have attempted to root softwood cuttings under mist and at present are making a serious effort to develop a method that would give us a good percentage of take. To date we have not had much success by any of the methods we've tried, which include various hormones and timing throughout the summer period, extending well into the fall using semi-hardwood and hardwood cuttings.

Thursday Afternoon, December 4, 1975

The first portion of the afternoon's session was moderated by Hugh Steavenson and the second half was moderated by Dr. Paul Read.

HORTICULTURAL EDUCATION — DOES IT FALL SHORT OF THE MARK?

HUGH STEAVENSON

Forrest Keeling Nursery
Elsberry, Missouri 63343

I can think of no more challenging or appropriate subject for debate and consideration at this particular time nor is there any group, with an even admixture of the teaching and research profession, the student body and the commercial practitioner, so uniquely qualified to explore the proposition.

As regards the student body, we face both a challenge and a crisis. The faculty members know far better than I that horticultural teaching institutions across the country are bursting at the seams with students. In our own state the horticultural enrollment at the University of Missouri has ballooned from 65 some 5 years ago to 330 at present. Our youngest panel member just 2 years out of college, has seen horticultural enrollment in his *alma mater* double and re-double since he matriculated. At Oregon State University, to pick a western institution, the 1970 horticultural enrollment was 60 students; the 1975 figure is 220. In almost every instance, I am told, the big jump has not been in such horticultural food fields as pomology or vegetable crops, but in ornamental or environmental horticulture. (I note our English friends use the more embracing term, "amenity horticulture.")

One of our panel members asked another, "What are you going to do with all these kids?" His reply was, "Well, at least we'll try to teach them to think." There surely is no more laudable goal, but that still leaves the institutions and industry with the problem and challenge of best utilizing this talent that will come pouring forth from the ivied halls.

At the outset I think all of us should understand the somewhat differing demands and requirements placed upon applicants as between institutional and governmental employment and commercial occupation. The former must, perforce, grant employment acceptance and compensation levels largely on academic skill and achievement. The commercial man basically doesn't give a hoot whether his employee has a fourth grade education or is a Ph.D. He employs people who he hopes can help him succeed in his enterprise. (As a practical matter, however, the handicap of education lack severely and obviously limits progress of most individuals in our increasingly technical and complex industry.)

There is a very thin line between netting 5% and losing 5% in a nursery enterprise, or any other business. Regularly netting 5% spells success; losing 5% for just a few years spells bankruptcy. If the student or instructor gets the notion that the commercial em-

ployer is sometimes ruthless, he may be right. Most businesses do not succeed. Studies by the U.S. Department of Commerce, Dun and Bradstreet, and others reveal about 1/3 of all new businesses do not survive their first year. At the end of 5 years less than a third of the starters survive. At the end of 7 years only one in five is still around. These drop-outs are not conspicuous simply because they do not exist. The venerable outfits so conspicuous and so well represented here are the ones that have gone through the decimating fires of those early years and who have learned to cope. Nor is company age any guarantee of continued success. Each year is a new challenge and a new trial. My remarks should in no way be interpreted as denigrating scholastic achievement.

We commercial operators have perhaps rightly been accused of choosing the lowest common denominator in hiring help, particularly those guys who do the labor. As with nurserymen across the country, I have experienced disappointment as well as tremendous satisfaction in recruiting college-trained people. Our nursery, Forrest Keeling, is a medium-sized business. We have in our employ 9 college graduates, mostly in horticulture or related science, and some others with a couple of years or so of college education. These are the people who manage, supervise, sell and perform technical functions. It isn't that we love them any better than others; it just so happens that they have what it takes to do the work to be done.

Just the other day I read in *Nation's Business* the inspiring story of how Edward Donnell came into a very sick Montgomery Ward Co. in 1962 and turned it around to become a thriving, healthy, prospering major U.S. corporation. Mr. Donnell was asked, "What do you believe is the No. 1 ingredient of good management?" He replied, "The ability to select talented people has to be No. 1."

To the extent our profession and industry can train, select and guide these young people entering our ranks, to that extent will our profession and industry thrive, serving the growing and many-faceted horticultural needs of our nation.

HORTICULTURAL EDUCATION — DOES IT FALL SHORT OF THE MARK?

PAUL L. SMEAL

Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

Over 10 years ago, following the IPPS meetings, members of this group, university personnel, and representatives from the American Association of Nurserymen met to discuss how to get more young people interested in ornamental horticulture and the type of programs that should be offered. Since that time, there has been tremendous interest in ornamental horticulture from youth and adults. The interest has grown in the secondary schools with particular interest in the high school vocational agricultural programs; the vocational-technical schools; the two-year community colleges; the two year program at the four-year institutions; the four-year colleges and universities; and with adult education.

To answer the question given to this panel, "Horticultural Education — Does It Fall Short of the Mark?", I emphatically can answer NO. We may not be "dead center" in the bullseye, but we are on the target.

Those responsible for providing horticultural education have responded to the demand at all levels of education. At these early meetings, discussion was centered around whether the existing high school vocational-agricultural teachers could provide the horticultural education. These teachers have received horticultural training and many of the teachers now are horticultural graduates or agricultural education graduates who have taken several horticulture courses, and the in-service training or workshops have certainly provided good high school programs. The assistance from industry in giving guidance, guest lectures, tours, donating plants and supplies, plus hiring the students has been beneficial, and the teachers are thankful for industry support.

At all of the four-year colleges and universities, there have been large increases in horticultural enrollment. In the short time of 5 years at Virginia Tech, the horticulture enrollment went from 50 to 350 students, which happens to be 60 to 70% girls. Staff, classrooms, greenhouse space, nursery, etc., have not grown proportionately, which means teaching is taking time, space and funds away from research and extension. The larger enrollments are removing the personal contact the staff used to have with the students. College teaching is becoming impersonal, which is detrimental to the student's education. Horticulture and allied courses provide the graduate with many of the "why" answers. But, the graduate has not received the "how" because time and facilities

prevent this from occurring. Students are encouraged to take part in the cooperative work program, summer employment, drop out of college for a quarter or a year to gain some practical experience. Students now recognize the need for practical experience if they are to secure a job in the tight job market today. For this reason, they are more willing and wanting to be on the co-op or work study program today than they were a few years ago. The industry deserves a big thanks for its advice and cooperation in providing jobs to those students on the co-op work study program and summer employment.

There are some weak areas in the college programs. A couple that come to mind are the student taking plant propagation his freshman year and then forgetting most of it when graduating 4 years later, or not being interested as he has no idea what type of job he will be taking. The same could be stated of other courses. I would suggest continuing the freshman course, but then have an advanced plant propagation course the senior year for those entering the nursery industry. This would help to prepare the student better. Also, in the senior year, an oral and written comprehensive exam should be given to see if the student really has a concept of what was taught and how it can be applied.

There are other areas of horticulture education that should not be overlooked. One is the continuing education that is provided by the national, area and state nurserymen's associations, plant societies and the cooperative extension services. This education may be at meetings, short courses, field days, field demonstrations, personal visits and through publications. The progressive plant propagators or nurserymen are those who take an interest in attending and participating at these events. This has always been a strong and important part of horticultural education, and it will continue.

Educating the consumer is another area of horticulture education. It has only been recently that the general public is becoming more aware of horticulture. The American Association of Nurserymen is to be complimented on their efforts through the Green Survival Program. But, the A.A.N. can't do it all, and there has been little or no support from the state nurserymen's associations or individual nurseries. It is time for those within horticulture to know and understand that horticulture is the production, marketing and utilization of fruit, vegetables and ornamentals. Horticulture is now segmented and it is time someone takes the leadership and gets all the segments working together as the problems for all are about the same.

There is one other unnoticed area of horticulture education that is taking considerable time of the state extension specialists and county extension agents. This is the request from individuals and firms wanting to start or enter some phase of ornamental hor-

ticulture. It may be growing flowers, bedding plants, azaleas, trees, or landscaping, grounds maintenance, garden centers, etc. These people are most willing, usually have the capital and land, but the lack of knowledge. It seems more time and effort are being given to these requests than to exisiting nurserymen.

Horticulture education has not fallen short of the mark. The desire and tremendous interest for horticultural education have developed faster than the educational processes can provide the education.

HORTICULTURAL EDUCATION — DOES IT FALL SHORT OF THE MARK?

GARY LONG
University of Missouri
Columbia, Missouri

Four months ago when I agreed to be on this panel it seemed like a rather simple task; after all I have been involved in education in some way or other for most of my life. During the past 4 years of working with commercial nurserymen I have developed some insight into the problems nurserymen face in trying to hire qualified personnel. After 4 months of research and thinking about the subject, I wonder how I could have been so naive about the problems of education in general and horticultural education in particular.

One of the first things that I concluded from this study is that the problems of horticultural education cannot be separated from the problems of education in general. College professors complain that many of the students are coming to college unprepared for college level work. Secondary school teachers have similar complaints. Many of the problems seem to go back to primary school and beyond.

Teachers at all levels reported problems of discipline and increased difficulty of motivating students to want to learn. Part of this can be blamed on our affluent life style, part on our economic system in which in the majority of homes both parents work and thus have much less time to spend with their children and certainly the influence of television has to be mentioned.

There seems to be a great deal of uncertainty among educators at all levels. Many of the educational innovations that were designed to enrich the student, improve his learning ability and foster creativity are now being questioned. We now see what seems to be the start of a trend back to more emphasis on the basic reading, writing and arithmetic that were considered old fashioned a few years ago.

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A reluctance of educators to fail students seems to be a trend at all levels of our educational system. Although some very good reasons can be cited for doing this, most agree that it has resulted in a general lowering of standards. Grade inflation is a popular term among educators today. This makes it difficult to compare the grade averages of today's students with those of a few years ago.

The most unique feature of horticultural education is the tremendous growth it has undergone in the past few years. Many new programs have been developed and student numbers in traditional programs have virtually exploded. Horticulture is now being taught in many high schools in our state. These programs vary from single courses to full time vocational training programs. Vocational technical schools offer training in this field for high school graduates and full 4 year programs are available at most of our state colleges and universities. Special training programs are also available in our state prison system, mental hospitals, and vocational rehabilitation programs.

Many different approaches to horticultural education are being tried in these programs. Unfortunately, most of these programs are too new for us to evaluate their success. Certainly the number of graduates being produced by all of these programs is much greater than can be absorbed into our commercial horticulture businesses. It is interesting to speculate on the impact these graduates might have on the future of this industry.

In looking at these different programs one thing that becomes apparent is the absence of coordination between programs. Very little communication takes place between different programs and most of this is on a personal rather than official basis.

Many of the problems encountered in our University programs are a result of the tremendous increase in student numbers. Most of these new students have no prior experience in the field. Horticultural programs in the past were designed to handle relatively small numbers of students most of which had some background in commercial horticulture.

Most horticulture professors agree that many of our present programs are not adequate to handle the numbers or type of students now majoring in horticulture. Many University programs are undergoing serious review and I think it is safe to say that we will be seeing some significant changes in the future. However, I should point out that in researching this subject I did read some of the material that has been written on the subject. Many of the problems that educators are facing today and many of the complaints that are leveled at our educational system are virtually the same as they were 25, 50 and in some cases 75 years ago. So don't expect to see all of the problems solved very quickly.

HORTICULTURAL EDUCATION — DOES IT FALL SHORT OF THE MARK?

KENT TALLMAN
Forrest Keeling Nursery
Elsberry, Missouri 63343

Having completed 4 years of college and 2 years working experience, I feel that the best education is a combination of classroom instruction and practical experience. Also, good textbooks are needed for outside study.

As to the question of whether horticultural education is up to the mark, I have varied feelings. Number one, I believe that the university can provide the needed education although there are areas I feel need improving. Number two, the individual plays an important part in the type of education he receives.

Let's look at the university first. A student's education in horticulture should consist of both practical experience and classroom instruction. To give you an idea of the courses offered, I have listed the horticulture courses I completed: Greenhouse Management, Bedding and Foliage Plants, Plant Propagation, Garden Flowers, Nursery Management, Turf Management, Arboriculture, Growth and Development of Horticulture Crops, Weeds and Their Control, Entomology, Plant Pathology, Special Problems, and Plant Material. Scheduling courses can be a problem and for one reason or another I missed Floriculture Crops and Production I and II, Vegetable Crops, Fruit Science, Principles of Plant Breeding, and Home Grounds Development and Construction. A great deal of foresight and help from advisors is needed to work in all the classes one would like to take. In general, the variety and depth of the courses offered, I believe, are sufficient to provide the needed education with respect to classroom instruction.

In the area of practical experience, most all the courses included lab periods and field tours. Here the individual must make the best use of this time to sharpen up on the practical aspects of the subjects studied. Other practical experience can be obtained through participation in Horticulture Club activities and Special Problems courses. Outside the university, summer jobs in a related field would be helpful. I believe this area of practical experience is where most students tend to fall short. This is where the individual plays an important part in his education. It's up to him or her to gather up all the practical experience possible.

Enrollment in Ornamental Horticulture has risen rapidly. When I entered the University of Illinois there were only some 70 students majoring in Ornamental Horticulture. A large percentage had families in the nursery business or worked at a nursery prior to enrollment. That number doubled twice in the 2 years I was there and so did the number of students with little or no experience in the

field. The average classroom has increased in number from 20 to 80 and the student-teacher relationship declined. The result is more graduates knowing a little less about the field than those before.

There is also the problem of professors who have little or no practical experience. There is no doubt they can do a good job teaching, especially if they attend meetings of this type, visit nurseries, and become acquainted with nurserymen and the practical aspects. It's important to have professors who can offer counseling to students with respect to where to look for jobs and what to expect from different types of jobs. I am well aware of the need because I was one of those students with no background in Ornamental Horticulture.

I started college majoring in Industrial Technology and never decided to major in Ornamental Horticulture until the end of my sophomore year. Counseling played an important part in my education and I feel I was well prepared as to what to expect from a job in this area.

I've found my education to be especially helpful in many areas. To a large extent it gave me the background knowledge needed. I have a wealth of notes and books to use as reference materials. With these resources, when failure does occur one can find out why faster and do better in the future.

Through my working experience I've learned many things that could not be taught in the classroom. Greenhouse construction, heating and ventilation, watering technique, scheduling work, and methods for propagating large numbers of cuttings are just a few. Through college education one learns what to do, but its on the job experience that teaches one how to do the job efficiently and well.

In summary, I feel that the university can offer the needed horticultural education. A well-prepared graduate should have a broad background in all phases of horticulture, some practical experience, and counseling on the types of jobs and what to expect.

HORTICULTURAL EDUCATION — DOES IT FALL SHORT OF THE MARK?

WAYNE LOVELACE

Forrest Keeling Nursery
Elsberry, Missouri 63343

It has been said there is no better method for resolving the world's problems than by talking them over in a genuine sincere spirit of frankness and open-mindedness. I'm not certain of the magnitude of our topic, but I do know that it is of great concern to educators, students, and nurserymen from coast to coast. There should be no better place to resolve some of these differences than in this unique gathering of educators, students, and nurserymen.

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I am happy to have this opportunity to share and discuss my experience and research in the area of horticultural education. One finds this to be an area of major differences of opinions, not only between the educator, the student, and the nurseryman, but between associates within the respective fields.

The fact that we are assembled here points to the need for continuing education at all levels in a field that is moving at an unparalleled pace and becoming more technical and complex. This offers one of the greatest opportunities available to the horticultural graduate who is willing to enter the field and use his or her background of technical training in a college, university, or the equivalent as a foundation to build on. They must be willing to dig in and through diligent work learn the practical aspects of a varied and complex nursery business.

Due to the wide diversity of horticultural enterprises I'm convinced there is no practical way to develop a course or courses that can substitute for practical work experience in the field. Students of horticulture should never miss an opportunity to take advantage of work experience opportunities in their area of interest during their formal schooling. I personally believe it is extremely difficult for the student who has not been exposed to practical on-the-job experience to catch-up with one who has.

Having received practical work experience and learned to integrate his technical background with a practical approach, gained through experience, and an awareness that combining this background and experience with the basics that Mother Nature has provided, a student is well on his or her way to becoming a specialist and an asset to himself and the company he works for.

It is during this essential and critical period of commencement where most of the problems concerning horticultural graduates seem to emerge. Visiting employers in this field one finds a common pattern of experience. Far too many recently employed graduates become unhappy with their job, primarily because they feel the practical training they are receiving is at a level of responsibility below where they feel they should start, resulting in dissatisfaction and usually moving on to employment elsewhere.

This experience is often followed by the disappointed employer criticising the educational institution, while the student and institution have the same tendency to criticise the employer. When this occurs I'm convinced all three parties are at fault.

To gain better insight into this problem I would like to share some of the ideas and constructive criticism brought forth in meetings and discussions I have had with members of this Society.

A common criticism heard from nurserymen regarding graduates has been a lack of the basic inherent will to work. There

are many ideas as to where the will to work is instilled in an individual. Is it in the home, the secondary school, or elsewhere? After a good deal of soul searching and visiting I asked this question of our local Superintendent of Schools, an experienced and highly respected educator, and got what sounds to be an over-simplified answer, but as near the right one as I found. He feels for the past three or four generations of students the sole emphasis has been to get a good education and it will take care of you. As one generation of parents after another instills this goal of maximum education in their sons and daughters have we not come to accept education alone as an easy way out and a substitute for productivity?

Please don't take this statement as a slap at our educational system. I'm still convinced its the best system anywhere in the world with an excess of 80% of our youth receiving at least a high school diploma and with the doors of our public schools open to every citizen as long as he wants to pursue an education.

It's good to see our public schools coming to grips with these short-comings by instituting programs of career education and on-the-job work-study programs as a part of high school education. These programs have resulted in some excellent career employees in our nursery business. Although these work-study programs were originally patterned for the non-college bound student, we found a good number of our trainees have elected to go to college and expand their education in the field.

Another common area of misunderstanding among nurserymen, students, and educators involving employment and training periods concerns productivity. I feel that the first lesson that a trainee must understand is that the duties he is performing must directly or indirectly contribute to the profitability of the business enterprise. Very few nurseries are large enough to justify actual direct instructional type training as many tend to think of a training program. This should be clearly understood between the student and the employer as they prepare to begin their career.

Ultimately in a discussion of this type salary becomes a point of some controversy. I think one of the real advantages of the nursery industry is its basic make-up of small companies. An individual that is producing, stands out very tall in a small company; likewise a non-producer can hurt the typical-sized nursery operation. I do not believe most nurserymen employing a graduate for future areas of specialization or responsibility expect to get an immediate return on his or her efforts but we all have hopes of seeing that individual progress rapidly to a point where the company is realizing a return on these efforts. When this progress has been recognized the graduates should expect to see their knowledge, experience, and work return them a salary that is commensurate to their contributions to the profitability of the company.

Further discussions reveal that many graduates lack basic business concepts. Some graduates were cited as believing the typical nursery, with such handsome mark-ups and good demand for their products, could afford salaries well in excess of what they were currently paying. My best answer to this argument is that I know of no nursery operation that has escaped the ever present cost-price squeeze. A current example confirming that the nursery business is indeed a part of the free enterprise system is the current selling of certain lines of top quality nursery stock at or below the cost of production. Not to elaborate too long on this point, it should be noted in recent years we have seen outside interest, or big business as some prefer to call them, look towards the nursery industry as possible acquisitions. I personally know of more than one top, well established, and well managed company that was approached, and then saw offers withdrawn after an investigation of their profit potential. Make no mistake, the nursery business is a solid, sound, viable segment of our economy and one that pays just returns, but it should be held in proper perspective when discussing our topic of education.

In summarizing, I feel primary emphasis should go to the areas of practical nursery experience to compliment the excellent technical and scientific background horticultural students are currently receiving. As we see the added numbers of students currently looking towards the nursery industry for employment we will have an unprecedented opportunity to draw on the skills and expertise of trained horticulturalists. To capitalize on this opportunity we must approach it with a sincere and frank determination to resolve the problems that exist.

HUGH STEAVENSON: Jolly Batcheller has asked to make a few remarks concerning the educational program at the California State Polytechnic University.

JOLLY BATCHELLER: At the Pomona campus we have 20,000 sq. ft. of glass and polyhouses, half of which was built by students. We have approximately 20,000 sq. ft. of shade, half of which was built by students and we have 2 acres of container nursery stock. Our budget from the state to maintain this for a year is $8,000 plus $6,000 for expenses, but we sell $45,000 worth of plant materials at retail prices or higher. The nurserymen objected to this at first but there is not a week goes by but they are asking us for trained people who know how to propagate, grow and sell, and it is through these methods that we train students for them. We sell at the nursery only on Fridays from 1 to 5 p.m. We'll sell wholesale if we have excess material but we cannot sell all of it because we have a large faculty and student clientele. We have 11 instructors and 1 technician. Out of the $45,000 worth of material we sell we employ 15 students a month to care for the crops. We get an average of 50 to 75

volunteer-hours a month from students who want to be where the action is. We put in our fertilizer injection system, our spaghetti watering system and are about up-to-date on most modern methods; these have all been put in with student help. By having the money available from plant sales in a Foundation, we can adopt new methods which are being taken up in the industry and don't have to go through making up a budget as much as three years in advance. I say the students want to be where the action is and if you have action you'll have the students.

BRYSON JAMES: Paul Smeal was indicating that we are on target, but I believe that whether or not we're on target depends upon who draws the target. I think we fall short of the target any time we limit that target to uncommercial competence from a student coming out of the university. Just because they have a degree does not mean they are horticulturally educated. I believe the universities are too antiquated in the way they do things. We are in an area of "degreeism" and a degree cannot be equated with education. I spent 3 years in Kent, England and was very impressed with their methods of determining competence which is by a qualifying exam. There the student does not necessarily have to go and attend class; if he can educate himself and pass the qualifying exam this is satisfactory but he must pass the qualifying exams. I think we need to go to a system similar to this here in this country.

JACK SIEBENTHALER: On the television we're constantly being bombarded with the slogan that "A mind is a terrible thing to waste" and one of the speakers commented about the terrible waste which occurred when the modern math system was introduced in our schools. There is a failure on the part of the educators to teach the students to read and write. The education system at the university level should be looked at as a three-way street. We have the educators who are responsible for the program of education, we have the students who must bear their end of the responsibility, and we have the potential employers who should bear some share of responsibility in making sure the students are being taught those things which they need in order to function successfully in their chosen line of work. Employers are often guilty of not taking advantage of the capabilities of the students which they employ, especially the student who is taking a position with him to learn about the industry he intends going into. I think we as employers need to look inward to where we may fail the student. We talk about a need for expanded practical experience during the education process and yet when many of us employ students we often fail to give them a broad base of experience, frequently shunting them off to menial tasks. I will admit it's often a bother to keep up with these people but I feel as employers we are tremendously neglectful when we do this.

JIM WELLS: We have been involved in teaching students for some time now. The English system which Bryson James referred to

is discussed by Dick Martyr in Vol. 24 of IPPS Proceedings. It is referred to as a "sandwich course" and requires that a student already have one year of practical experience in horticulture before he contemplates college. It is assumed that he has graduated from some high school; if not he can take night courses to satisfy this requirement. He spends one full year at the college being taught horticultural subjects, not American literature or art appreciation, but horticulture. At the end of that year he is placed on an approved nursery for a full year of work at the current minimum wage and he must satisfy the employer for that year. He must report back to the college, I believe monthly, as to what he is doing and he must also develop an annual project which he completes during his annual year and he writes a report upon it. He then goes back to college for another year of training in horticultural subjects and if he satisfactorily completes this he is given the ordinary National Diploma in Horticulture.

We have been chosen as a nursery where students can be placed for their second year of training from the Pershore University and we take these responsibilities very seriously. I feel our previous speaker was correct in that one of our big problems is that few of us have taken the trouble to teach people. We do this very assiduously; we will stop work and show all of the students something that is particularly interesting — they will be brought in from whatever they are doing at my request so that they can see what is being taught. In addition, I teach them by weekly discussions throughout the year and once a month we'll take them to a place of horticultural interest on a Saturday. This is fairly demanding upon us, the company, but we feel it is worthwhile.

I've heard a lot about practical and on-the-job training recently; there is a word for this — it is "apprenticeship." Years ago a father would pay a successful nurseryman to apprentice his son to him for 4 years to learn the nursery business. This whole concept has been lost sight of; people gladly pay to go to college to get academic training but then he still has to come out and learn the practical horticulture. I feel that all of what we have heard today about education is designed to train chiefs and I would like to see a method of training the forgotten indians.

HORTICULTURAL THERAPY — HOW IT'S WORKING

RAY E. HALWARD

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Agri-horticulture has been recognized for many centuries as an area with unlimited possibilities in the therapeutic and rehabilitation field. We, in North America, are just beginning to take advantage of these possibilities in the areas of the mentally and physically handicapped, senior citizens, and correctional institutions. The population in all of these areas is increasing rapidly, and we can no longer afford to support them in institutions, particularly if they are trainable and capable of being part of our work force and become self-sufficient. I am thinking particularly of the mentally and physically handicapped. The cost to keep a person in an institution at the present time is in excess of $15,000 per year. Our governments, at all levels, from municipal to federal, are trying desperately to solve the many problems in the rehabilitation field. They need the help and co-operation of all citizens and businesses to help fill some of the gaps.

There are many jobs in the nursery business, parks, greenhouses, etc., that are excellent training grounds for some of these handicapped people. No one really knows their capabilities or potential until they have been given the opportunity. Believe it or not, but trained mentally retarded persons have fewer accidents when operating equipment, and the equipment will last longer with less repairs.

There are many support programmes available to you as a potential employer in order to assist handicapped people. These vary, depending on which programme best suits your needs, and which level of government is supporting it. I would suggest you contact all levels and ask for advice.

In Canada you can take one or more individuals for up to 2 months for an evaluation period with no commitments on your part. If the individuals work out, support programmes which pay half the wages for 1 full year's training are available. It could possibly take less time than a year. These individuals range in age from teenagers into the 50's, both male and female.

Last year a rehabilitation officer and I applied for and received a Local Initiative Programme Federal Government grant to provide training and opportunities for discharged psychiatric patients, many of whom had histories of unemployment for a number of years. I called upon my horticultural friends to assist, and the response was excellent. We supplied them with people to train along with their regular employees at no cost to them for a period not exceeding 6

months. The results were most gratifying. A total of 35 people were tried; some didn't last too long, but when the training period ended, 17 were employed and showed promise. Three of that group now hold permanent jobs and receive $5.00 an hour plus, with very happy employers. The experience gained by the employers was gratifying, as they and their employees found out more about mental health and realized they also could assist in rehabilitation in a tangible way.

I have also been involved in teaching various horticultural subjects to instructors of the mentally retarded, and also of mentally retarded groups; advising them how they may become more horticulturally oriented in order to provide themselves with work opportunities in agricultural and horticultural areas. Lately programme directors for senior citizens are requesting instruction and advice as to how to institute horticultural programmes in senior citizens' complexes. This we are doing as part of our Outreach Programme at the Royal Botanical Gardens.

A year ago a committee was formed representing the mentally handicapped at government level, Ontario Nursery Trades Association, Flowers Canada, and Fruit and Vegetable Growers Associations, parks and recreation and farm groups. This committee provides liaison between the people who need help and the people who can assist in the agri-horticultural area. Further evidence of the interest in horticultural therapy was shown last year when over 200 persons from various fields of rehabilitation, hospitals, senior citizens' complexes, and institutions, attended a horticultural therapy symposium at the Royal Botanical Gardens. Many requests for horticultural input have been received as a result. Some of our correctional institutions are now assisting by manufacturing artificial light growing units which are available, at cost, to therapy programmes.

I urge you, as plant propagators, to assist wherever you can to use your talents as plantsmen, to help with the handicapped in your area. Since 1973 in the United States, the National Council for Therapy and Rehabilitation through Horticulture, Mount Vernon, 22121, has been promoting and encouraging the development of horticulture and related activities as a therapeutic and rehabilitation medium. The Council's activities and services include professional consultation, regional workshops and seminars, placement service and manpower exchange bank.

I have been involved in horticultural therapy and rehabilitation for over 10 years, and each year it becomes more exciting and challenging and I continue to realize how great is the need.

ASEPTIC CULTURE OF CHRYSANTHEMUMS IN THE PLANT PROPAGATION CLASS

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Aseptic culture of herbaceous plants is becoming an important commercial method of plant propagation. For some plants aseptic culture provides virus-free plants and the greatest number of plants produced per year. We developed aseptic culture of chrysanthemums for our herbaceous propagation laboratory. The aseptic culture laboratory illustrates the rapid rate of multiplication possible.

Aseptic culture involves several steps: 1) selection of plant species and plant parts, 2) selection and preparation of a growing medium, 3) development of aseptic isolation procedures, 4) growth and division of plantlets for continued multiplication or rooting, 5) establishment of rooted plantlets into soil.

PLANT MATERIAL

We used chrysanthemums because they are easily propagated by cuttings and propagation procedures using aseptic culture have been reported (1).

MEDIUM

Our medium was similar to that described by Murashige et al. (3). We used a 2.7 g/l agar because Romberger et al. (4) showed that decreasing agar concentration yielded increasing growth. Instead of kinetin, we substituted 4 mg/l of N^6-benzyladenine which proved satisfactory in preliminary trials and 2 mg/l of indoleacetic acid (IAA). We chose these concentrations based upon preliminary studies, but a 50% change in the concentrations still gave acceptable growth. An excellent reference dealing with the preparation of the medium is the article by Romberger, et al. (4). Hartmann and Kester also introduce this subject (2). The stock solution of auxin, whether IAA or IBA, should be clear and colorless.

The pH was adjusted to 5.6 using HCl or KOH, and autoclaved for 15 minutes at 121°C (250°F). We transferred 12 ml of the medium to each sterile, disposable, 60 X 20 mm plastic petri dish. Petri dishes have a large open area that makes division and transfer of the cultures easy for students. We incubated dishes containing the medium for at least 2 days at room temperature before using them to be sure the medium was uncontaminated.

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[1]Associate Professor and Technologist, respectively.

EQUIPMENT

Procedures that required sterile conditions were done in a laminar flow bench (Pure Aire Corporation of America, Van Nuys, CA) which has a fan which forces air through a filter to remove 99.9% or more of all particles 0.3 microns or greater in diameter. This removes all spores and other contaminants from the air. The clean air flow sweeps contaminants out of the work area and minimizes contamination, but contaminated objects placed upwind of aseptic materials can contaminate those materials. The laminar flow bench allowed students to work in a common laboratory instead of a special tissue culture room.

Other equipment needed was: a good analytical balance capable of weighing accurately to 1.0 mg, a pH meter or accurate pH paper, a source of distilled water, a dissecting microscope (convenient but not necessary) and an autoclave. Flasks and pipettes were needed for mixing chemicals and storing stock solutions.

STOCK PLANTS AND MERISTEM ISOLATION

We grew stock chrysanthemum plants in the greenhouse with supplemental night lighting to ensure vegetative growth. Romberger et al. (4) reported that for aseptic culture no surface sterilization of the stock material was needed if overhead watering was avoided. Therefore, we prohibited overhead watering of the stock plants.

We cut terminal stems from stock plants and isolated the meristems (shoot-tips) under a dissecting microscope in the laminar flow bench. The base of the cuttings were held in the fingers without contaminating the meristem. We removed one or two leaves from the cuttings with a sterile scalpel, then dipped the scalpel in 95% ethanol, and flamed to re-sterilize. This exposed the meristem (Fig. 1) and maintained sterility. We transferred about 1 mm of the stem tip to the medium.

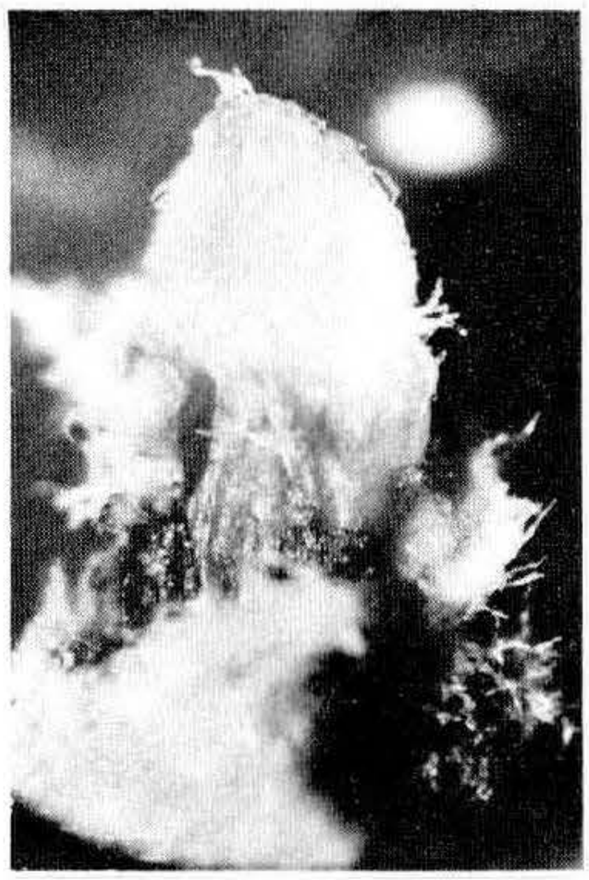

Figure 1. Chrysanthemum shoot-tip ready for separation. Cut was made in smooth area at base of shoot-tip. Distance from tip to base was approximately 1 mm.

We isolated meristems 10 to 12 weeks before the students needed the cultures for division. The cultures were divided to yield the maximum number of new cultures and maximize the time between divisions. When growth was most rapid the number of cultures doubled each week.

STUDENT ACTIVITIES

Students practiced meristem isolation in the classroom. Then they divided and transferred sterile meristem cultures in the laminar flow bench. Students came in one at a time, washed down the inside of the bench with 95% ethanol and ran the fan for 5 minutes to eliminate contamination. With a sterilized scalpel they split the plantlets (Fig. 2) into three or four pieces, and transferred these pieces to new petri dishes (Fig. 3).

Figure 2. Multiple plantlet of chrysanthemum ready for division.

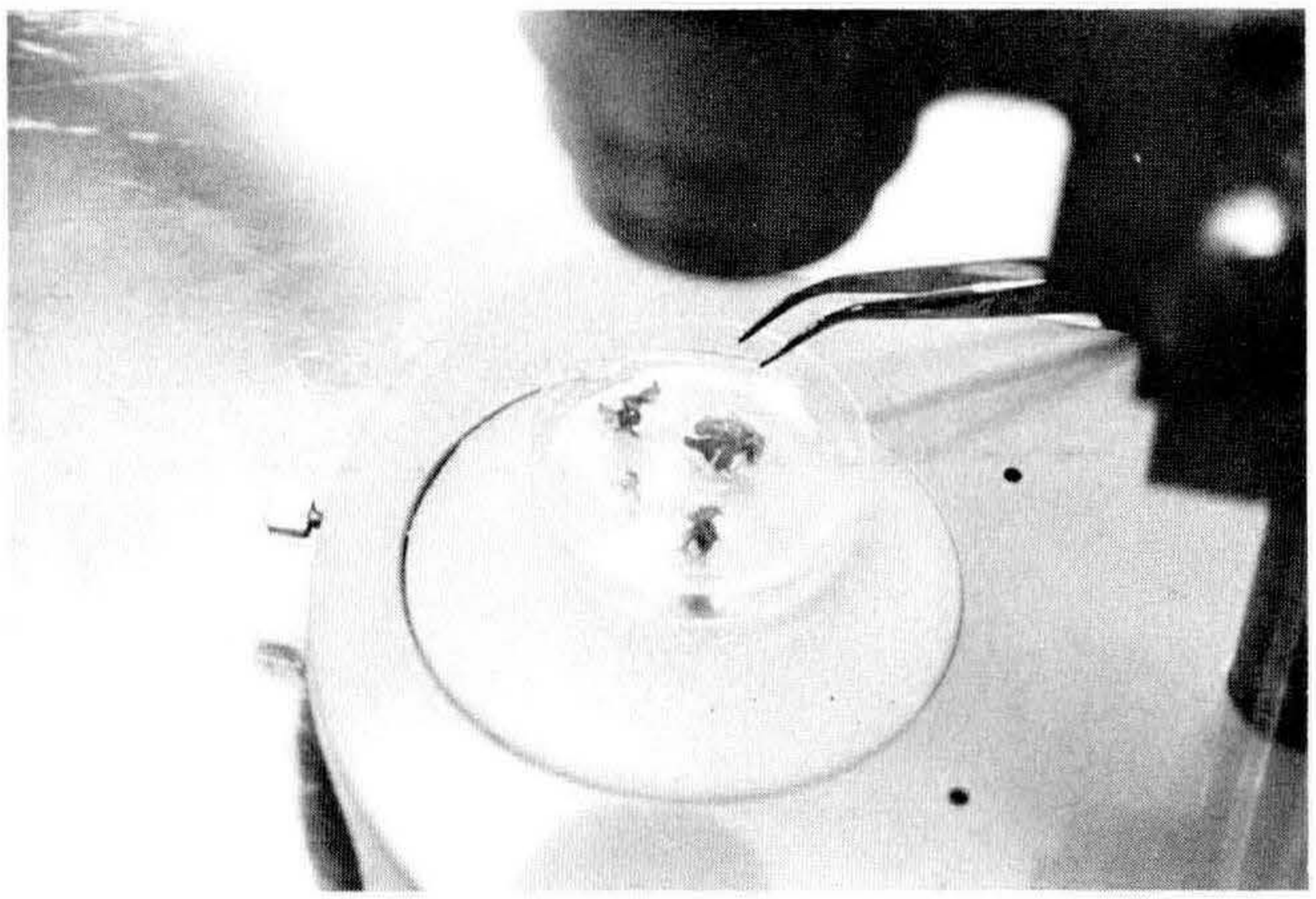

Figure 3. Chrysanthemum plantlets after division ready for transfer to new medium.

The scalpel and other tools were dipped in 95% ethanol and flamed as needed to sterilize. Caution, never put the flaming scalpel back into the beaker·of ethanol. Usually one student, technician, or teaches does this each year, so we keep a fire extinguisher nearby to put out the fire.

One or two students each semester did a special project in aseptic culture in addition to the aseptic culture laboratory. When possible we incorporated parts of their successful projects in next year's aseptic culture laboratory.

SPACE AND ENVIRONMENTAL REQUIREMENTS

The cultures were placed 50 to a clear plastic box (12x18x6 inches) with a beaker of distilled water inside to maintain high humidity, and a second beaker containing some charcoal to absorb gases produced by the cultures. Before using charcoal, we smelled a sweet aroma in the boxes. The boxes were kept at room temperature with continuous fluorescent light. We did not investigate the effects of different light periods, sources, or intensities.

ROOTING

Students achieved successful rooting by treating plantlets with Rootone F and sticking in vermiculite on an intermittent mist bench with bottom heat. Rooting occurred in 1 to 2 weeks with a 60 to 70% success in rooting. Transferring the plantlets to a rooting medium before they are treated with auxin should improve the rooting success.

CONCLUSION

Our plant propagation class introduced students to aseptic culture as a propagation technique. With proper choice of plant material, equipment, and technique the majority of students should be able to successfully propagate plants using aseptic culture.

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EFFECTS OF PROPAGATION CONTAINER SIZE ON DEVELOPMENT OF HIGH QUALITY SEEDLINGS

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Abstract. Seeds of *Pinus thunbergiana*, Japanese black pine, *Sapindus drummondii*, western soapberry, and *Pistacia chinensis*, Chinese pistache were germinated and grown in bottomless containers on wire benches. Containers 3, 6, 9, 12 and 15 inches deep and 1½, 2 and 2½ inches square were constructed from paraffin-coated milk carton stock. Top growth of Japanese black pine was greatest in the 2½-inch square and 9 inch deep container. Top growth of Chinese pistache and western soapberry was about the same in all container sizes and depths. Root growth was greatest in the 2½ square inch containers either 9 or 12 inches deep for all three species. Root development in 1½ and 2-inch containers was erratic for all species. There appears to be an optimum depth for air pruning of the taproot. Root development appears proportional to the diameter of the container.

REVIEW OF LITERATURE

The production of high quality tree liners in the greenhouse, using bottomless containers on wire benches appears to have a great potential in container nursery production. Johnson (3) found that container planting in the plug form may be a viable and economically attractive reforestation method. He found that seedling size is a reflection of diameter and volume of the container. He also concluded that the large size of the seedlings, which were grown in paper pots, was impressive. Hite (2) also reported that field survival of greenhouse grown stock is greatly influenced by the soil volume in the container: the larger the container, the higher the survival. There appears to be a 20% overall gain in survival through the use of container grown stock.

Potter (4) stated, "This revolutionary idea in propagation economized the cost of production, cuts to less than half the time formerly needed to produce a suitable liner and ensures production of liners that are disease-free, with strong root systems that cut the mortality rate to near zero as the plants go into forests or nursery rows or containers." He also reported that no root curling or restriction occurs. The root system is more fibrous, and therefore, summer and fall planting may be possible. The active growing root system sustains the plant; whereas, the bare-root seedling does not have the roots to balance out the top growth of the young plant. In addition, Aycock (1) also reported that the planting season could be extended into June and July by using container-grown seedlings.

Most tube methods developed to date are for reforestation projects. This system of seedling production has been very beneficial to

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[1]Journal Article No. 3005 of the Agricultural Experiment Station, Oklahoma State University, Stillwater.

the forestry industry and should also prove beneficial in production of shade and ornamental trees. Tubes used for reforestation projects to date have been quite small, generally one and one-half inches in diameter or less. For the production of shade and ornamental trees, economics would allow for larger containers if: 1) survival following transplanting increased, or 2) growth of tops and roots increased, thus decreasing production time, or 3) if root quality increased, aiding survival and/or performance in the landscape.

MATERIALS AND METHODS

To determine an optimum propagation container size for production of tree liners, the following experiment was conducted: containers 3, 6, 9, 12 and 15 inches deep and 1½, 2 and 2½ inches square were constructed without bottoms from paraffin-coated milk carton stock. Containers were placed on a wire bench to provide air pruning of roots growing out of the bottoms of containers. Growing medium was a 1:1 by volume mix of perlite and shredded Canadian sphagnum peat. The experiment was conducted in a clear glass greenhouse.

The experiment began March 15, 1974, with seeding of test species: Japanese black pine, Chinese pistache and western soapberry. Each species was replicated 12 times in each container size-depth combination. Seven weeks after planting, all containers were fertilized with Osmocote 18-6-12 at the rate of 1000 lb. N/A/yr. Additional Osmocote at the rate of 2000 lb. N/A/yr was applied July 19, 1974. On August 31, 1974, 5 months from the seeding date, six replications were selected at random and top and root weights determined.

RESULTS AND DISCUSSION

Root development was best in 2½-inch square containers, 15 inches deep for western soapberry (Fig. 1) and either 9 or 12 inches deep for Japanese black pine and Chinese pistache (Figs. 2 and 3). Root development of all species in 1½ or 2-inch square containers of all depths was erratic. This suggests an optimum depth container, at least for the species tested. Of perhaps more interest in the appearance of the root systems, roots from all plants in the 2½-inch square containers 6 or 9 inches deep were very fibrous with many lateral roots developing from the taproot which had been air pruned at the base of the container. In the 12 and 15 inch deep containers, the taproot development had been suppressed less and fewer fibrous roots were present. Containers 3 inches deep were apparently too shallow for good root development of any of the species tested. Air pruning of the taproot greatly stimulated development of lateral roots which often grew to the corners and downward and were again air pruned at the bottom (Fig. 4). Fibrous roots reach every part of the growing medium, thus increasing access to moisture and nutrients. There was no observed kinking or curling of the roots in any depth

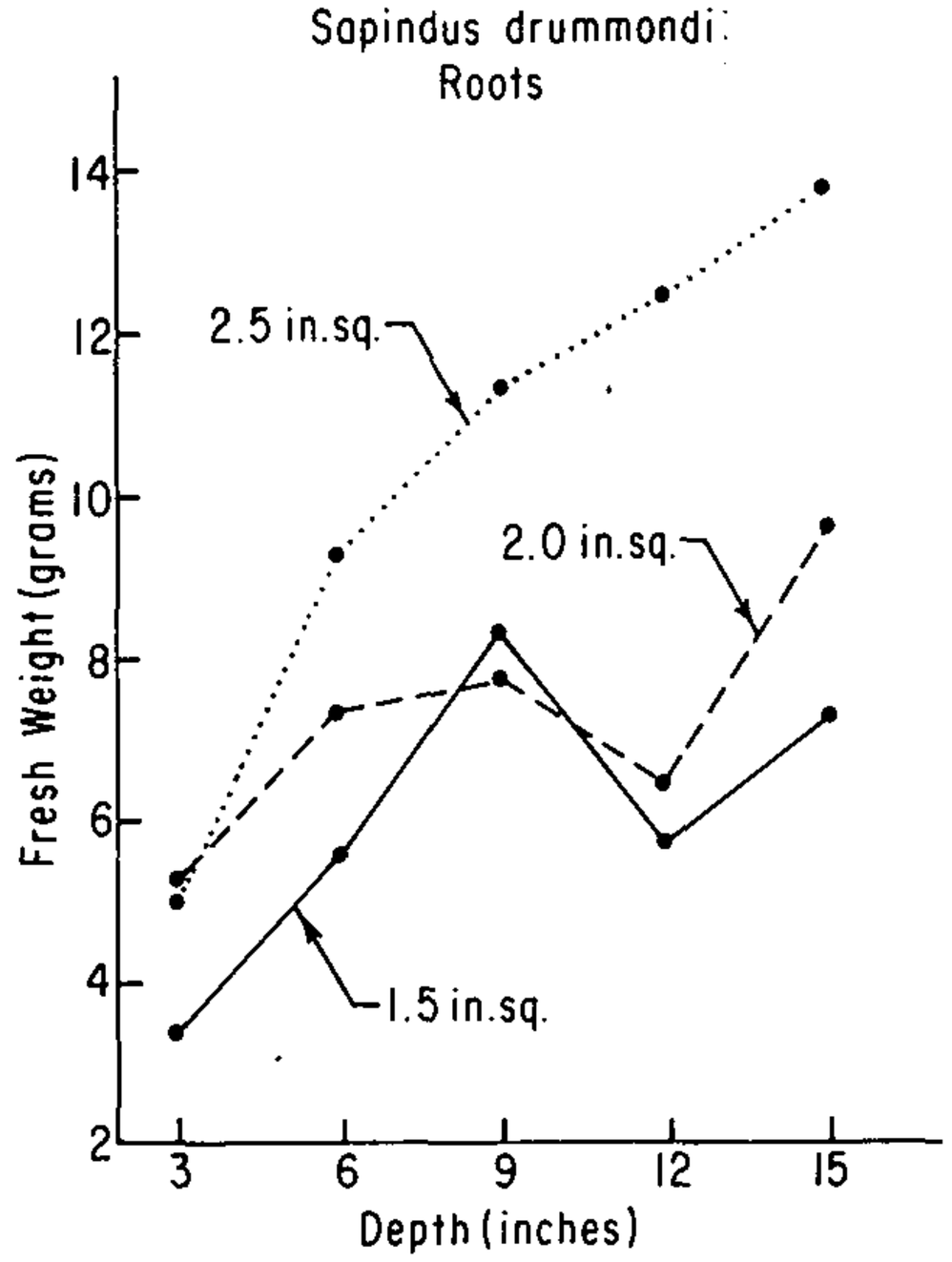

Figure 1. Effects of container size and depth on root development of western soapberry seedlings.

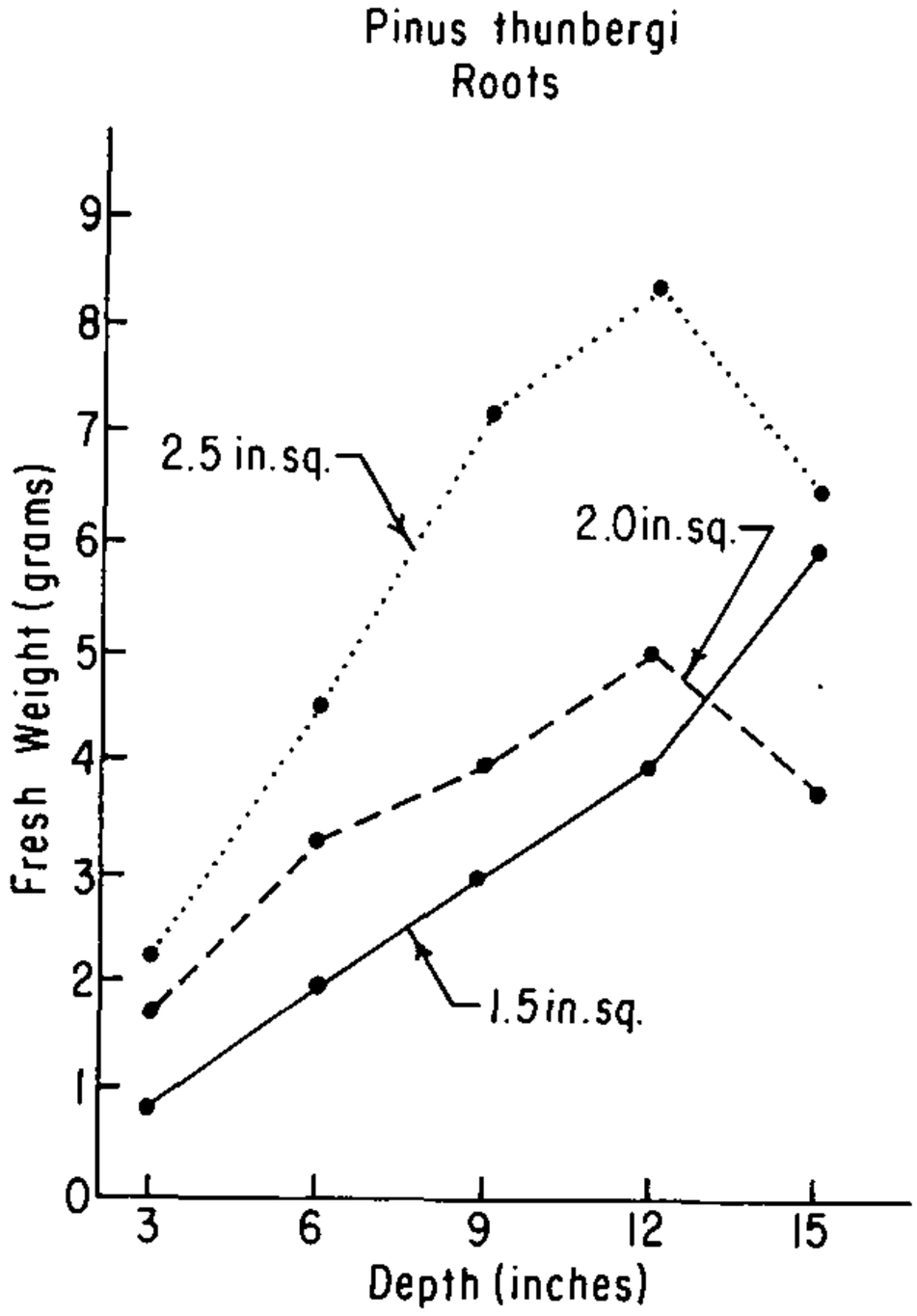

Figure 2. Effects of container size and depth on root development of Japanese black pine seedlings.

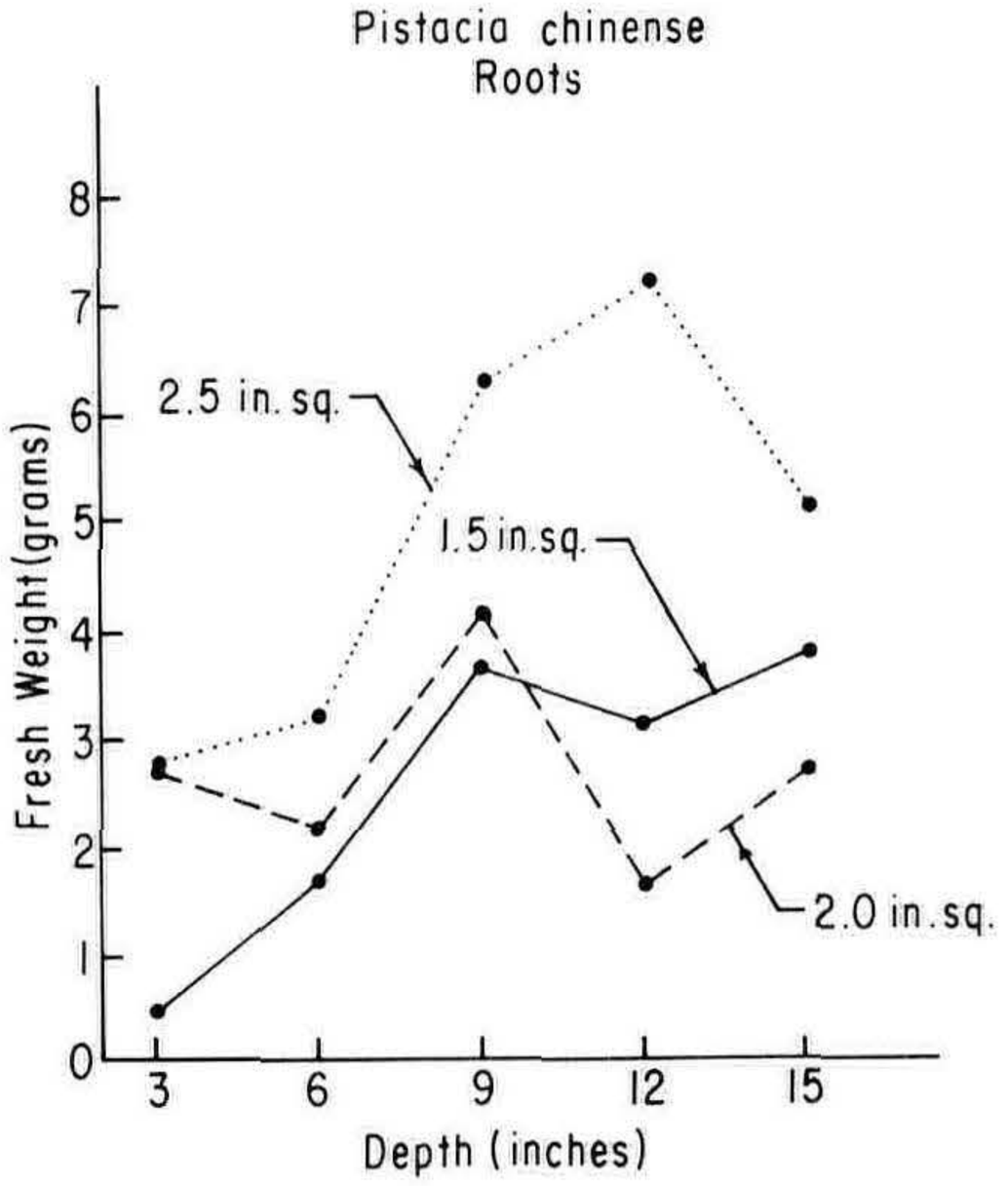

Figure 3. Effects of container size and depth on root development of Chinese pistache seedlings.

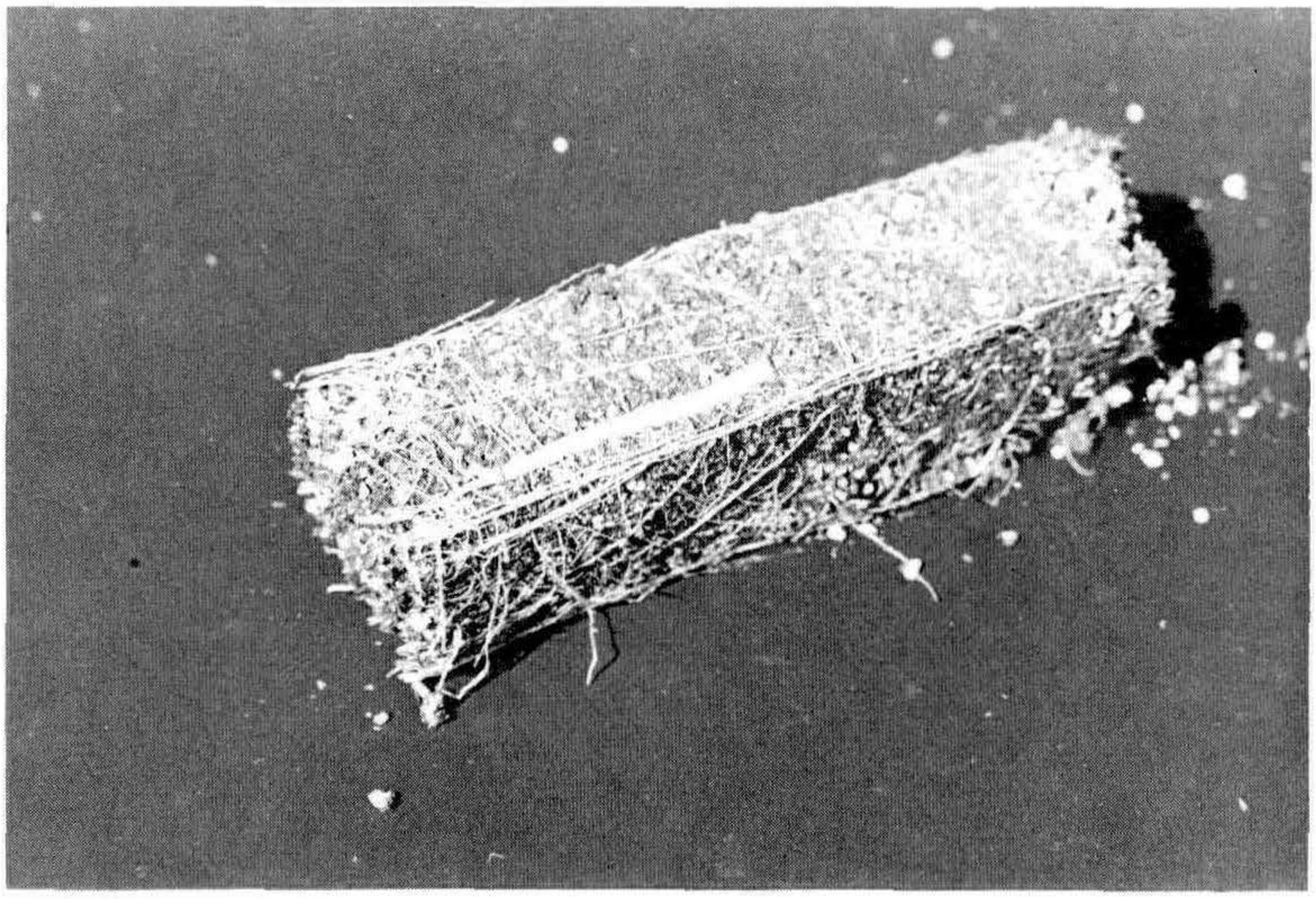

Figure 4. Effect of air pruning and square containers on root development of tree seedlings.

or size container. This may prove very beneficial when growing the seedlings on in a larger container. Reduction of taproot dominance should cause a reduction in wrapping and curling which is a particular problem associated with present container production of trees. In addition, with the undisturbed fibrous root system in the container, summer and fall planting may be possible with little or no transplant shock and rapid establishment.

Top growth of pistache and soapberry was about the same in all container sizes and depths. However, top growth and lateral branching of Japanese black pine was superior in the 2½-inch square container 9 inches deep (Fig. 5). On visual observation, the most healthy and vigorous plants of each species was in the 2½-inch square container 9 inches deep.

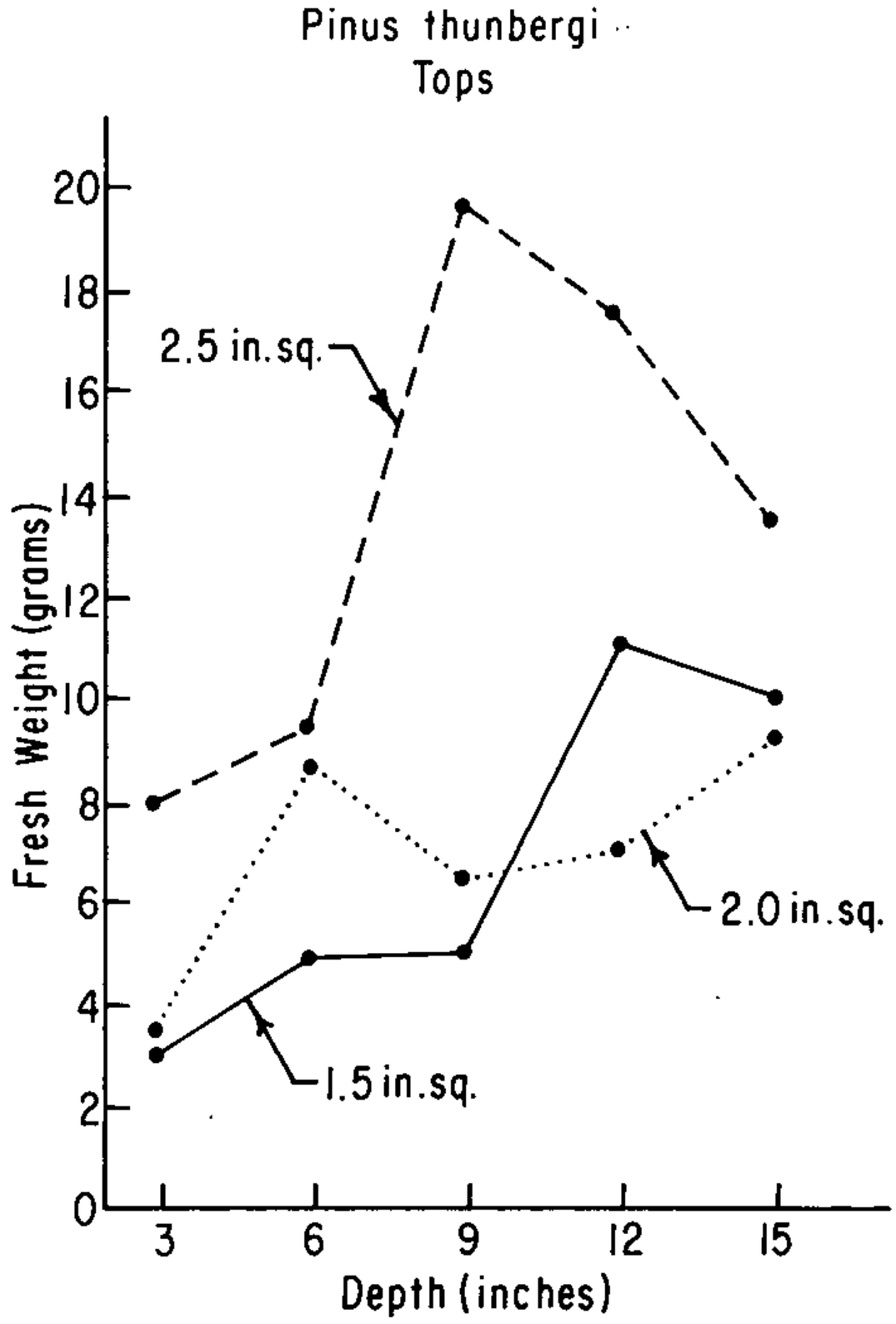

Figure 5. Effect of container size and depth on top development of Japanese black pine seedlings.

The container production and air pruning of roots of tree seedlings results in a very fibrous root system without taproot distortions. Container size particularly affects root development of the seedlings. There appears to be an optimum depth at which the taproot should be air pruned. Development of roots and top is proportional to the diameter of the container. In addition, this technique has considerable merit in preventing "girdling roots" which very subtly cause the early demise of many shade and ornamental trees.

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PETE VERMEULEN: Would you comment more on the use of the square container versus a round container?

RANDY DAVIS: If you use a round container the root will go to the edge and circle, with the square container however, it goes to the edge, goes to the corner and then goes straight down. Some of the newer round containers have a ridge built into them which also stops the root from going around. So if you use a round container it ought to have a ridge down it to stop the root from circling.

PROPAGATION OF ILEX VERTICILLATA[1]

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Abstract. Propagation of *Ilex verticillata* (L.) Gray by hardwood and softwood cuttings was evaluated. In both experiments, peat, as a rooting medium, was superior to a mixture of peat and sand. The polyethylene chambers gave better results than the intermittent mist with hardwood cuttings, but was not significantly different for softwood cuttings. Hardwood cuttings did not root satisfactorily, but basal end treatment with 10,000 or 20,000 ppm IBA was advantageous. Wounding of hardwood cuttings did not provide any better results than unireated controls. The softwood cuttings method was much more successful; the optimum level of basal end auxin application was 7,500 ppm IBA. An advantage was gained by combining the peat medium with the mist environment.

Ilex verticillata (L.) Gray, better known as common winterberry, black alder, or Michigan holly, is a deciduous shrub growing abundantly in bog areas throughout the northeastern section of the United States. In the fall, it bears fruits which are generally colored bright orange-red. At one time, the fruiting branches were very popular for wreaths, table arrangements and other Christmas decorations. In the past two decades, the use of this plant has declined, mainly because of prohibition of trespassing on public and private natural stands of *Ilex verticillata*. Because of this, some thought was given to the development of this attractive plant as a plantation crop. It was also considered desirable to help reintroduce it into landscape plantings. Thus, a successful method of propagation to assure a good supply of quality plants is highly desirable. The objective of this study was to evaluate propagation of *Ilex verticillata* by both hardwood and softwood cuttings.

A survey of the literature on propagation of holly plants revealed that a lesser amount of work had been done on hardwood than softwood cuttings. Also, sample size in most experiments was very small. Chadwick (1) and Laurie (8) reported that peat, as a rooting medium, was superior to sand or a mixture of peat and sand. Zimmerman and Hitchcock (10) indicated that hardwood cuttings rooted better between August and January. They found that rooting was possible in darkness. Optimum temperatures were 24 to 27°C. Coggeshall (2) reported benefits from the use of polyethylene film chambers (where vapor pressure deficits are reduced), and wounding of the cuttings.

Kirkpatrick (7) suggested the use of IBA powder application to the basal end of hardwood cuttings. Hans Hess (6) used 0.8% IBA in softwood cuttings, but Neal and Pease (9) preferred a 16-hr dip in 70

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ppm IBA. The latter obtained 78% rooting; but Floor (5) achieved 92% using 500 ppm IBA. Success was more evident with intermittent mist within the greenhouse than in outside frames. Fillmore (4) reported 58% success in the summer period, and by also using a fungicide. Doran (3) obtained 66% rooting.

MATERIALS AND METHODS

Hardwood Cuttings. Uniform hardwood cuttings (7-8 cm) from female plants were used. The rooting media: peat, and a mixture of peat and sand, were steam sterilized at 85°C for 1 hr. Two environments, intermittent mist, and sealed polyethylene chambers were replicated twice in a split plot design. A wire framework supported the white 4 mil polyethylene, 2 ft above the medium surface. To prevent wilting, the interiors of these chambers were misted every 2 to 3 days. The following six treatments were randomly distributed and repeated five times: control; wounding; 10,000 ppm IBA; wounding plus 10,000 ppm IBA; 20,000 ppm IBA; and wounding plus 20,000 ppm IBA. Each replication was composed of 10 cuttings which had previously been given a 5% Captan dip. Wounding comprised two proximal end cuts approximately 1.2 cm long, the depth of the cambium. Throughout the 62-day experiment, which commenced on March 1, 1972, temperature and humidity levels were recorded by means of thermohygrographs. Rooted cuttings were graded into lightly, moderately and heavily rooted categories.

Softwood Cuttings. Uniform, softwood cuttings (8-10 cm) from female plants were utilized. The environment and medium were the same as for hardwood cuttings. The basal stem treatments, applied in talc, were as follows: control (untreated); 10,000 ppm IBA; 7,500 ppm IBA and 3,750 ppm IBA.

Each treatment of 20 cuttings was replicated three times. The duration of this experiment was 58 days (June 12th to August 9th, 1973). In addition to rooting percentage values, the rooted cuttings were graded into lightly, moderately and heavily-rooted cuttings. Index values were derived by multiplication factors of 1, 3, and 5, respectively. Thus, the maximum value of any treatment replication was 100. The data was analyzed by mean separation of pooled means for basal end treatment; media; the interaction of media with environment, and environment with treatment, using Duncan's Multiple Range Test.

RESULTS

Hardwood Cuttings. Temperatures within the chamber ranged from 15 to 40°C, with an average of 20.2°. Values of relative humidity greater than 90% were a general occurrence; but low levels of 76% frequently existed at noon. Under intermittent mist, greater fluctuations were evident, although temperature patterns were similar; the

maximum recorded was 30°C. Relative humidity ranged from 22 to 94%; but most of the time values were in the region of 50%.

Leaf buds became active after 2 weeks, but the subsequent foliage later wilted on all cuttings that failed to root. Overall rooting success was approximately 14%. Cuttings placed in peat rooted 18.8%; and 8.2% success was obtained with peat and sand.

The polyethylene chamber produced 19% rooted cuttings, whereas only 8% of those under intermittent mist developed roots. All treatments receiving IBA had values larger than the untreated control or wounded cuttings. Statistical analyses were not conducted on these data.

Softwood Cuttings. Temperature and humidity recordings were similar to those measured in the previous experiment. The peat medium gave 82.4% success, whereas 67.2% rooting occurred in peat and sand, and the difference was significant at the 1% level. Under intermittent mist there was 76% rooting and a 73% value was obtained with polyethylene chambers. The interaction of medium and environment was highly significant for each combination. The best combination, a peat medium with an intermittent mist environment produced 87% rooting.

Table 1. Rooting percentage and rooting index for *Ilex verticillata* (L.) softwood cuttings as influenced by the medium.

Medium	Rooting Per Cent	Rooting Index
Peat	82.4	63.6*
Peat-sand	67.2	43.0

*Means significantly different at the 1% level.

Table 2. Rooting percentage and rooting index for *Ilex verticillata* (L.) softwood cuttings as influenced by basal treatment.

Treatment	Rooting Per Cent	Rooting Index
7,500 ppm IBA	82.5	63.4a*
10,000 ppm IBA	75.4	61.3a
3,750 ppm IBA	76.1	55.6b
o ppm IBA	65.2	33.1c

*Means followed by the same letter are not significantly different at the 1% level.

Cuttings treated with IBA rooted significantly better than untreated cuttings (Table 2). The IBA treatments produced a greater percentage of rooted cuttings, and the cuttings were more heavily rooted. The interaction of medium, environment and treatment was highly significant. The best combination was cuttings treated with IBA, and rooted in a peat medium, under mist (Table 3).

Table 3. Rooting percentage of *Ilex verticillata* (L.) Gray softwood cuttings as a function of treatment, environment, and medium.

Treatment	Environment				
	Poly. Tent		Mist		
	Peat	Peat & Sand	Peat	Peat & Sand	$\bar{x}$
Control	70.8	69.2	74.2	46.7	65.2
Treatment #1	69.2	70.0	92.5	70.0	75.4
Treatment #2	83.3	75.0	90.0	81.7	82.5
Treatment #3	85.0	64.2	91.7	63.3	76.1
$\bar{x}$ Envir. x Media =	77.1	69.6	87.1	65.4	
$\bar{x}$ for Environment =	73.3		76.3		

DISCUSSION

Hardwood cuttings of common winterberry did not root readily. The work of Chadwick was substantiated in that better results were obtained with peat as a rooting medium. In this experiment, the polyethylene chamber was superior to the conventional intermittent mist. Wounding was not an advantage. An important difference was the application of auxin. The greatest amount of rooting was obtained with cuttings, treated with 20,000 ppm IBA and inserted in a peat medium enclosed in a polyethylene chamber. The biggest problem encountered with propagation of *Ilex verticillata* by hardwood cuttings was the release of dormant shoot buds. Even with maintenance of a high humidity the leaves on unrooted cuttings eventually wilted and died.

Softwood cuttings propagated in the white polyethylene chamber developed a slight chlorosis, but rooted quite well. However, a considerable amount of suckering was observed to arise from a point just above where the roots emerged. The peat medium gave significantly better results than the mixture of peat and sand. Equal results occurred with both environments but the foliage of cuttings under intermittent mist was in better condition. A highly significant interaction was observed between medium and environment. The superior combination was peat under intermittent mist. The peat medium retained its superiority in the polyethylene chamber. There was an obvious gain with the use of IBA. The optimum level was 7,500 ppm because it was equally effective as 10,000 ppm IBA.

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Thursday Evening, December 4, 1975

The twenty-fifth annual banquet-reception was held in the Big Bend North Room of the Tallahassee Hilton, Tallahassee, Florida. Mr. Al Fordham made the following Award of Merit presentation:

AWARD OF MERIT PRESENTATION

AL FORDHAM

Prior to the establishment of his own business firm in 1945, the recipient of this year's Award of Merit worked for the U.S.D.A. Soil Conservation Service as nursery manager and as director of the Agricultural Bureau of the St. Louis Chamber of Commerce.

In addition to many years of service on various committees, including a number of years as chairman of the Public Relations Committee of the American Nurserymen's Association, he has been active in a variety of nursery associations. He is past president of the Greater St. Louis Landscape and Nurserymens' Association, Missouri Association of Nurserymen, Western Association of Nurserymen, Mail Order Association of Nurserymen and the International Plant Propagator's Society. More recently he was elected to serve on the American Association of Nurserymen's Board of Directors.

One of his most progressive achievements was to institute a training program that would acquaint high school students with vocational opportunities that were to be found in the nursery industry. This course termed the "Vo-Ag Program," proved highly successful. Though the training was directed toward those who did not plan further education, about half the participants were motivated to an extent where they did, in fact, proceed to state universities where they enrolled as horticultural majors. The project has received wide recognition, has been televised in the midwest and now serves as a model for other such programs. It is also a fact that a number of young men who passed through the personnel training program in his business have gone on to become figures of national prominence in the nursery industry.

It is an honor to represent the International Plant Propagator's Society in presenting the 1975 Award of Merit to Mr. Hugh Steavenson, Forrest Keeling Nurseries, Elsberry, Missouri.

Friday Morning, December 5, 1975

The moderator for the morning's program was Mr. Bill Studebaker.

AZALEA RESEARCH

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Azalea culture in containers and soil as late as 1952 involved the use of German peat as a growing medium for both containers and bed/grown azaleas. The fertilization program consisted of the use of phosphate in the soil and corrective additions of sulphur, aluminum sulphate, and frequent iron sulphate sprays to keep the soil acid (1, 2).

My research on azaleas started at the Ornamental Horticulture Field Station in Mobile in 1952. The need for lime, the detrimental effect of excess phosphorus in the soil, and the need for a micronutrient mixture to supply necessary micronutrients, either in the potting soil or in a topdressing soon became evident (5, 6, 8). Monthly applications of a complete fertilizer were also shown to prevent fall leafdrop and make azaleas more cold hardy (9). Additional applications of nitrate or sulfate of potash further hardens and increases cold resistance.

Our research also indicated the value of adding dolomite lime to the 8-8-8 and to the topdress mixture used by the nurserymen (5, 9). With the advent and acceptance of slow-release ureaform nitrogen by the nurserymen, a formulation of 12-4-6 or 12-6-6 plus micronutrients with a dolomite base was found to be equal to the 8-8-8:cottonseed meal:dolomite formulation (3). It had the advantage of being lighter in weight per NPK unit and did not culture the fungus gnat which spreads *Cylindrocladium* blights in the liner beds.

Fertility and potting mixture studies have continued throughout the years with the goal being to produce a slow-release fertilization program which could be incorporated into a mixture suitable both for rooting and growing the azaleas to maturity in the container. This has resulted in development of a potting soil fertilizer to be added to the complete mixture as follows in pounds per cubic yard: 10 dolomite, 2 superphosphate, 2 gypsum, ½ KNO_3, ¼ micronutrients (Tennessee Copper 008 modified form, or FTE 503, or equivalent), ¼ chelated iron, ⅛ chelated manganese, plus either of three slow-release programs to supply N and K: 3.5 lb ureaformaldehyde plus 2 lb fritted potash FTE 519; 2) Sulfur-Coated Urea SCU-15 at 2.5 lb plus 2 lb FTE 519 and 3) Osmocote 18-6-12 at 5 lb or Osmocote 18-5-11 at 10 lb (3). All of these slow-release programs have been highly satisfactory for azaleas and are also very satisfactory for woody ornamental rooting and production. They have been

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used to root azaleas directly in the container to produce finished liners and liners transplanted to 6-inch containers have produced finished plants outdoors under irrigation without additional fertilization. The 1½X rates of the materials outdoors have produced most total growth (14, 16); in the greenhouse the higher rates have resulted in some salt toxicity.

COLD DAMAGE

Sub-zero freezes in 1950 and 1962 lasting for days caused container losses, and in 1960's freeze losses were severe. Research information obtained that will aid in protecting against losses are:

1. Container color — dark cans freeze and thaw fastest; dark color metal cans build up and lose heat faster than plastic cans. Light color cans begin growth slowly in spring due to slow heating (7).

2. Mulch under cans prevent earth's heat from protecting cans (4, 7).

3. Paper barrier or other mulches around cans protect outer rows.

4. Jamming of cans close together gives protection to the inner cans of the bed.

5. Use of growing media with insulation qualities — materials with enclosed air spaces, such as coarse bagasse, peatmoss, shale, perlite, or undecomposed bark, provide minute air spaces (4). Sand, gravel, and topsoil provide no protection and their inclusion in the mix reduces its freeze resistance. In the 1960's greatest freeze injury occurred in those mixes containing topsoil or sandy clay along with the peatmoss (the organic material most used at that time).

6. High potash levels have been demonstrated to increase freeze resistance by "antifreeze" effect.

GROWING MEDIA STUDIES

Pine shavings produce a well-aerated mixture until they rot a few months later. Cedar shavings have proved very satisfactory but mahogany shavings stunt growth due to some toxic factor.

Slate (shale) that has been hammer-milled and expanded by heating to 1400°F has proved very satisfactory to increase aeration and weight of the mixture. Azaleas have been grown in slate alone without chlorosis developing in spite of an initial pH 8.2 with a slow drop to 6.5 with extensive leaching. It contains as beneficial chemical constituents 8.5% iron oxides, 1.8% calcium oxide, 0.8% magnesium oxide, and 3.7% potassium oxide (11).

A simple method of determining air and moisture-holding capacity has been developed (15). An ideal potting mixture has about 25% available air and water each. Several ratios of peat, bark, and slate have been studied and the most promising mix

consists of 3 coarse bark, 1 peat, and 1 slate (12). If this mix is to be used for woody ornamentals, 1 to 2 parts sandy topsoil or coarse sand should be added to make the mix heavier. With fine bark the peat can be eliminated. The addition of topsoil or fine sand to an azalea mix serves no useful function except to make it heavier; both reduce air space and retard root development. A coarse, sharp sand would not reduce air space. Hardwood barks have not performed as well as pine bark in growing media in my experiments.

DISEASE CONTROL STUDIES

1. *Phytophthora* root rot was very severe in many ground beds and in containers in earlier years. The inclusion of lime in the fertilization program and fumigation of the liner beds has reduced losses. Copper sulfate at 1 oz/7sq ft has controlled *Phytophthora*. Drenches of Terrazole at ½ lb has given control but 1 lb rates also control *Rhizoctonia*.

2. *Cylindrocladium* root and stem rots and leaf blights of azaleas and other ornamentals were identified in 1955 (17). Fungicidal compounds were screened for several years. Thirty minute soaks of 6 lb Zineb, 2 lb Thylate or Polyram were recommended. Many workers were allergic to Thylate. Benlate and Daconil were later researched and recommended at 1 lb/100 gal of water. Benlate was used most extensively due to its systemic activity against *Rhizoctonia*, *Cylindrocladium*, and *Botrytis*. For a few years it was very effective and apparently rid the treated plants of *Cylindrocladium*. Very little *Cylindrocladium* is found today (3, 10).

3. *Pestalotia* leafspot, stem blight and crown rot (plant breaks off at groundline) have become very severe on azaleas. This organism was formerly thought to be a very weak pathogen. Continual use of Benlate is postulated to have killed organisms antagonistic to the *Pestalotia*, thereby allowing it to become pathogenic. Research has shown Daconil plus a spreader-sticker to be very effective against it at 1 lb/100 gal. The organism is best controlled by using clean cuttings and a frequent preventative spray program with Daconil, Dithane M-22, or Manzate 200.

4. *Rhizoctonia* root rot has become fairly common in potting mixtures containing pine bark. Research has shown it to be controlled with Banrot, Benlate, Truban (Terrazole), or Terraclor at 1 lb of the wettable powder formulations per 100 gal of water. Terraclor has produced chlorosis on some plants when soil incorporated. Banrot at 4 to 6 oz/cu yd has stimulated azalea growth, presumably by controlling *Rhizoctonia*.

PINE BARK COMPOSTING STUDIES

Azalea mixes containing two parts fresh pine bark, one part German peat, and one part nursery grade slate were composted for

approximately 1, 30, and 60 days and planted February 6-9, 1975. The test was duplicated as closely as possible in the greenhouse and outside under overhead irrigation. All treatments received the basic fertilizer previously described. Ammonium nitrate and urea were compared to ureaformaldehyde, sulfur-coated urea (SCU)-15, and Osmocote 18-6-12 and 18-5-11 at comparable rates based on 6 months release time. In the greenhouse ammonium nitrate and urea performed as well as the slow-release materials because they were not leached out. In the field, they performed very poorly due to excess leaching.

In the greenhouse, the 1X rate of the slow-release materials produced adequate growth and excess salt damage was evident at the higher rates. The 1½X rates were superior in the field with the 15 lb. rate of Osmocote 18-5-11 being superior (3).

Small piles of compost materials had no excess heat. Possibly the coating of Osmocote would deteriorate in large piles. No difference in growth rates was observed between composting dates.

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POTENTIAL HERBICIDE COMBINATIONS FOR WEED CONTROL IN SHADE TREES

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The demand for quality shade trees for landscape use has increased greatly during the past few years. Rising labor and operating costs, the demand for quality plants in a shorter period of time, and the need for improved cultural practices, necessitates the need for more efficient methods of reducing weed populations that compete with nursery crops for water, light and nutrients.

Several problems complicate the control of weeds in the shade tree nursery. First, heavy spring and fall workloads leave little time for weed control practices. Secondly, adverse weather in early spring and late fall make it difficult to cultivate, necessitating a greater dependence on herbicides. Thirdly, nursery crops are generally in the same location for several years and therefore it may be impractical to cultivate and impossible to fumigate. Fourth, most herbicides are developed for use on crops other than shade trees or nursery stock, consequently they usually do not provide the long soil residual desired, or control a wide enough spectrum of weed species to be of significant value to this industry. Furthermore, these herbicides may prove to be too phytotoxic for nursery crops.

No single compound has yet been manufactured that will control all undesirable weed growth and at the same time be non-phytotoxic for all crops. Therefore, it is important that nurserymen not only understand the properties of the various herbicides, but also crop tolerance, and the weed spectrum controlled.

REVIEW OF LITERATURE

Previous studies have indicated that glyphosate can be employed for post-emergent weed control in shade trees and nursery stock with no apparent injury when used as a directed spray (3,5). When applied directly to nursery stock, however, glyphosate has been noted to cause significant injury to California privet, forsythia, Toringo crabapple and American cranberrybush viburnum (2). This material has shown promise in controlling numerous perennial weeds which have been previously considered difficult to control (1,5).

In addition, oxadiazon has shown promise for control of annual broadleaf and grass weeds in both field and container grown nursery

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stock with no signs of phytotoxicity (5,6). Similarly, alachlor when employed singly or in combination with linuron or simazine has given safe effective weed control in a wide range of ornamental plant species with no apparent phytotoxicity (4).

The objective of these studies has been to evaluate several new herbicides, singly or in combination to determine weed control and crop phytotoxicity in commercially produced shade trees over an extended period of time.

MATERIALS AND METHODS

This study was performed at a commercial nursery in Ohio on a gravelly loam soil, using established 1-1½ inch dia Skyline honeylocust (*Gleditsia triacanthos f. inermis*) trees. Each of the separate experiments reported herein was composed of 6 treatments and a control, replicated 3 times in a completely randomized design. Individual plot size was 9 x 10 ft with 6 trees per replicate. The herbicides and formulations employed in this study were alachlor (Lasso-4EC), glyphosate (Roundup-2EC), linuron (Lorox-50WP), methazole (Probe-75WP), oxadiazon (Ronstar-2EC) and simazine (Princep-80WP).

All herbicides, with the exception of gylphosate, were applied on September 13, 1974. The glyphosate treatments, involving single and repeated applications, were begun May 20, 1975. Herbicide treatments were applied with a CO_2 constant pressure sprayer calibrated to deliver the herbicides in the equivalent of 36 gal of water per acre.

In the 3 studies initiated in the autumn of 1974, each had one herbicide which was employed at 2 rates throughout the test, either alone or in combination with linuron or simazine at 1 lb. ai/A (active ingredient per acre) in order to increase the spectrum of weed species controlled and to lengthen the period of weed control. All herbicide rates are in active ingredients per acre.

Evaluations of weed control and phytotoxicity were made at various dates during the spring and summer of 1975, using a 10 to 100 visual rating system with 10 representing no control and 100 representing complete control. The weed species present in the test are included: yellow foxtail (*Setaria lutescens*), large crabgrass (*Digitaria sanguinalis*), field bindweed (*Convolvulus arvensis*), galinsoga (*Galinsoga parviflora*), prostrate spurge (*Euphorbia supina*), lambsquarter (*Chenopodium album*), yellow nutsedge (*Cyperus esculentus*), common ragweed (*Ambrosia artemisaefolia*), giant ragweed (*Ambrosia trifida*), horsenettle (*Solanum carolinense*), daisy fleabane (*Erigeron annuus*), yellow rocket (*Barbarea vulgaris*), pennsylvania smartweed (*Polygonum pennsylvanicum*), redroot pigweed (*Amaranthus retroflexus*), common milkweed (*Asclepias syriaca*), Canada thistle (*Cirsium arvense*), marestail (*Erigeron canadensis*), wild sweet potato

(*Ipomoea pandurata*), and tall morning glory (*Ipomoea purpurea*).

Data was obtained on overall annual broadleaf and grass weed control. In addition, individual weed species were evaluated where populations were uniform.

RESULTS AND DISCUSSION

GLYPHOSATE: Glyphosate is a non-selective, translocatable herbicide that when applied to actively growing vegetation causes an initial loss in chlorophyll, followed by tip-dieback, wilting and eventual death in all but the most vigorous perennials. This material exhibits no residual soil activity or preemergent weed control activity.

When applied postemergently to annual grasses and broadleaf weeds, glyphosate completely killed existing vegetation in 7-10 days, but exhibited no residual control against germinating seedlings that emerged shortly after application (Table 1). Annual weeds controlled by postemergent applications of glyphosate included giant ragweed, lambsquarter, rough pigweed, horsenettle, yellow foxtail, crabgrass, pennsylvania smartweed and galinsoga. By repeated application, glyphosate controlled such perennial weeds as common milkweed, canada thistle, wild sweet potato, yellow nutsedge and field bindweed.

Since glyphosate is a postemergent herbicide, timing of the application is critical. In these studies, the initial application of glyphosate was made on May 20, 1975, followed by a second application 5 weeks later, resulted in excellent weed control. No further applications were necessary and control was equal to treatments which received 3 applications of glyphosate at 3 week intervals (Table 1). At no time was any visual phytotoxicity apparent on the Skyline honeylocust trees.

It appears from our observations that multiple applications of glyphosate exhibited outstanding weed control and that 2 or 3 applications at the 2 lb. rate, properly spaced during the growing season, would be a means of controlling weed growth in shade tree nurseries without building up residues in the soil. In addition, results from other studies would indicate that multiple applications at rates lower than 2 lb. may also be effective in controlling selected perennial weeds (1,2).

OXADIAZON: Oxadiazon and the various combinations employed in these tests exhibited outstanding preemergent winter annual and summer annual broadleaf and grass weed control for a period of greater than 9 mon. Annual grasses which included yellow foxtail and smooth crabgrass were completely controlled for over 9 months following treatment. Annual broadleaf weeds, which included horseweed, daisy fleabane, yellow rocket, prostrate spurge, giant ragweed, lambsquarter and horsenettle were

Table 1. Effect of single and multiple applications of gylphosate for weed control in Skyline honeylocust.

Treatment	Rate lb. ai/A	PERCENT WEED CONTROL (8-27-75) Annual Broad-leaves	Tall Morning-glory	Wild Sweet Potato
Single Application	2	80	97	97
	4	87	100	100
Applied every 3rd week	4	100	100	100
	4	100	93	100
Applied every 5th week	4	100	100	100
	4	100	97	100
Control	-	30	30	20

[1]Glyphosate applications were initiated on 5-20-75.

controlled through the June 26 evaluation, however by late July, 3 lb. of oxadiazon was no longer effective. Both of the 3 lb. rates of oxadiazon when combined with either the linuron or simazine were still giving effective weed control in late July (Table 2).

Table 2. Effect of oxadiazon and various combinations for weed control in Skyline honeylocust.

Treatment	Rate lb. ai/A	PERCENT WEED CONTROL Annual Broad-leaves 6-26-75	Annual Broad-leaves 7-23-75	Annual Grasses Grasses 6-26-75	Wild Sweet Potato 7-23-75	Tall Morning-glory 6-26-75
Oxadiazon	3	97	77	100	77	87
Oxadiazon	6	100	90	100	100	93
Oxadiazon + Linuron	3+1	100	97	100	100	80
Oxadiazon + Linuron	6+1	100	100	100	100	87
Oxadiazon + Simazine	3+1	100	90	100	100	93
Oxadiazon + Simazine	6+1	100	100	100	100	93
Control	-	10	40	40	10	30

Excellent control of the wild sweet potato was achieved with all treatments at all rates except 3 lb. of oxadiazon used singly (Table 2). In general, it was our observation that oxadiazon was the most promising of the preemergent herbicides evaluated. These results are similar to those observed previously when oxadiazon was used to control preemergent weeds in Jade Glen Norway Maple (*Acer platanoides* 'Jade Glen') trees (5).

ALACHLOR: All levels of alachlor and the various combinations employed for preemergent weed control in Skyline honeylocust with the exception of alachlor at 3 lb. applied singly, exhibited excellent control of annual broadleaf weeds on June 26, 1975, 9 mon following herbicide application. However, by the July evaluation period it appeared that none of the alachlor treatments were still effective in controlling the annual broadleaf weed population which consisted of marestail, daisy fleabane, yellow rocket, prostrate spurge, giant ragweed and lambsquarter (Table 3).

Preemergent annual grass control on June 26, 1975 was not particularly outstanding with 3 or 6 lb. of alachlor. When alachlor at either rate was used in combination with linuron at 1 lb., annual grass weed control was greatly improved, however, similar combinations with simazine were unsatisfactory. In addition, alachlor at 6 lb. alone or in combination with linuron or simazine exhibited some control of wild sweet potato (Table 3).

Table 3. Effect of alachlor and various combinations for weed control in Skyline honeylocust.

		PERCENT WEED CONTROL				
Treatment	Rate lb. ai/A	Annual Broadleaves 6-26-75	Annual Broadleaves 7-23-75	Annual Grasses 6-26-75	Tall Morningglory 6-26-75	Wild Sweet Potato 7-23-75
Alachlor	3	70	17	33	77	67
Alachlor	6	80	13	63	97	100
Alachlor + Linuron	3+1	93	43	80	80	53
Alachlor + Linuron	6+1	87	30	80	87	90
Alachlor + Simazine	3+1	87	57	67	87	70
Alachlor + Simazine	6+1	90	40	73	87	100
Control	-	43	40	43	33	10

METHAZOLE: Methazole at all rates and in all combinations gave outstanding annual broadleaf and grass control 9 mon following application. Upon evaluation of the methazole treated areas 1 mon later, annual broadleaf weed control was unsatisfactory where methazole was used singly at either 3 or 6 lb. At this same period, methazole in combination with either linuron or simazine at 1 lb. had lost effectiveness and substantial quantities of annual broadleaf weeds had germinated. Similarly, annual grass weed control with methazole was beginning to lose its effectiveness in the 10 mon following application (Table 4).

Table 4. Effect of methazole and various combinations for weed control in Skyline honeylocust.

Treatment	lb. ai/A	PERCENT WEED CONTROL			
		Annual Broadleaves		Annual Grasses	
		6-26-75	7-23-75	6-26-75	7-23-75
Methazole	3	93	60	100	73
Methazole	6	100	77	100	83
Methazole + Linuron	3+1	100	87	100	67
Methazole + Linuron	6+1	97	80	100	80
Methazole + Simazine	3+1	100	83	100	83
Methazole + Simazine	6+1	100	83	100	80
Control	-	10	30	30	30

SUMMARY

From these studies, it appears that several new herbicides may be available in the future which will give not only a longer period of weed control in the commercial shade tree nursery but will provide control over a much broader spectrum of weed populations especially when combined with another herbicide.

Early fall applications of promising new herbicides appear to be a means of obtaining long season weed control, particularly through the busy spring period, with no observed phytotoxicity to Skyline honeylocust. In particular, the herbicides oxadiazon and methazole appear to be the most promising in providing this type of extended weed control. In addition, multiple applications of glyphosate during the active growing season appeared to be a highly successful means of controlling annual and perennial weeds.

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Friday Afternoon December 5, 1975

The afternoon session was moderated by Mr. Charlie Parkerson.

EVALUATION OF EIGHT HERBICIDES IN CONTAINER NURSERY STOCK

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Abstract. Eight herbicides were evaluated for their effectiveness in reducing weed growth in 32 plant cultivars of containerized nursery stock. Oxadiazon at 4 and 8 lb. ai/A (active ingredients per acre) gave excellent weed control with only slight phytotoxicity. Oryzalin at 4 and 8 lb. gave excellent weed control but exhibited sever phytotoxicity. The combination of alachlor at 8 lb. and simazine at 2 lb. gave good weed control and were only slighty phytotoxic. Alachlor at 8 lb. gave fair to good weed control and was slightly phytotoxic. Profluralin at 4 and 8 lb. gave fair weed control and damaged the nursery stock the least of any of the herbicides tested. Napropamide at 4 and 8 lb. gave fair weed control and was slightly phytotoxic. Simazine at 1 and 2 lb. gave fair weed control and was slightly phytotoxic. Trifluralin at 4 and 8 lb. gave the poorest weed control of all the materials evaluated, but since most of the weed population were broadleaf weeds this result was not surprising. Trifluralin was only slightly phytotoxic. Pronamide at 2 and at 4 lb. gave poor control of weeds and was the second most phytotoxic.

With the increasing competitiveness in producing container nursery stock and the recession we have just experienced, it became evident that there was a need to decrease the production cost of a containerized plant. Therefore, we began to look for areas to save money while simultaneously improving the quality of our nursery stock. Fretz (6) demonstrated the adverse effect of weeds on Japanese holly 'Convexa' due to reduction in the dry wt of the plant, reducing fullness and quality.

In 1974, we spent $19,286 in Texas in hand weeding 21.2 A of containerized nursery stock. This translates to a cost of $910/A. Until this time herbicides had not been employed inside the containers. Several tests were begun in the summer and fall of 1974 to gain insight and experience in using herbicides in containers. Alachlor, oxadiazon, DCPA, trifluralin, profluralin, and Destun were evaluated. It was decided to talk with as many professionals within herbicide research as possible so that an extensive test could be conducted in the spring of 1975. After those discussions and a review of literature comparing the effects of various individual preemergent herbicides, and evaluation of the herbicides in Table 2 was conducted. DCPA (Dacthal) was eliminated because of its high cost per application ($432.00/A), relatively poor effectiveness, and short length of weed control. Destun was eliminated due to some severe phytotoxic symptoms on plant material.

MATERIALS AND METHODS

The test was established on May 8, 1975. The 32 kinds of plants listed in Table 1 were used in the study. There were 228 plants of each type selected by uniformity of growth from one of our standard beds of 1206 plants. These plants had been planted in 1-gal polyethylene nursery containers and allowed to establish for a minimum of 4 weeks. Each of the herbicides and the combination of alachlor + simazine were evaluated using 12 plants x 32 varieties x 2 rates, bringing each test block to a total of 384 test plants per herbicide rate x the 2 rates. All rates given are in active ingredients per acre. The total experiment contained 7,296 1-gal plants.

The plants were grown in a high organic mix consisting predominantly of screened pine bark. The granular herbicides were applied with a Gandy herbicide applicator which was carefully calibrated before each application. The wettable powder formulations were applied with a 1-gal CO_2 constant pressure sprayer calibrated to deliver a 6½' band at a volume of 30 gal/A. The treatments were completed on May 9, 1975, and the containers irrigated with 1/4" of water with overhead sprinklers to incorporate the herbicides. Each container was fertilized prior to the herbicide treatments with one teaspoon of 18-9-13 Osmocote. They also received supplemental overhead fertilization when test results indicated a need for fertilizer.

Weed control and phytotoxicity symptoms were evaluated on July 22, 1975, 75 days after the herbicide applications. Actual weed counts were made and those results are in Table 2. The predominant weeds encountered were: bittercress, (*Cardamine hirsuta*), weeping woodsorrel, (*Oxalis corniculata*), barnyard grass, (*Echinochloa crus-galli*), and sowthistle (*Sonchus oleraceus*). Each plant variety was given a phytotoxicity rating of 0 to 10, with 0 representing no physical damage and 10 representing death of every plant within the variety tested.

RESULTS AND DISCUSSION

Oxadiazon (Ronstar 2G) gave excellent weed control at 4 and 8 lb., however it was slightly phytotoxic to several of the plant varieties tested, particularly to *Yucca aloifolia*. This damage was due to the granules being trapped in the leaf blade axis. The granules dissolved slowly with overhead irrigation and this greatly increased the phytotoxicity symptoms due to enhanced foliar absorption. All of the yucca recovered, however, their growth was stunted. For this reason it would be much better to use a liquid spray application to prevent the granules from lodging in the leaf axis on plant materials that have this leaf arrangement. Other plant varieties also exhibited damage when evaluations

were made on May 23, 1975, 14 days after treatment. They were *Chamaerops excelsa; Ilex cornuta* 'Rotunda', *Ligustrum japonicum* 'Lusterleaf' (syn. *L. texanum*), *Ligustrum x vicaryi, Photinia fraseri, Trachelospermum asiaticum* (syn. *Rhynchospermum a.*) and *Viburnum supensum*. This damage can best be described as small purple spots on the upper leaf surfaces, as though the herbicide granules dissolved at this location. Neel (7) described similar damage on *Ligustrum japonicum* 'Recurvifolia'. The plants, although exhibiting foliar damage initially, recovered quite remarkably. At the end of the test, July 22, 1975, it was difficult, if not impossible, to notice any undesirable effects. Oxadiazon was still maintaining excellent weed control at the conclusion of the test, and it is showing considerable promise for container use. Since it gave such good weed control, we plan to evaluate it at lower rates and explore the possiblity of liquid applications to lessen the phytotoxicity problems.

The combination of alachlor (Lasso 15G) and simazine (Princep 4G) at 8 and 2 lb. respectively, gave good weed control as did the lower rate of 4 and 1 lb. Only slight phytotoxicity symtoms were noted, mainly in the form of slight stunting. Weed control was 6 to 8 weeks in duration. Dean et al. (2) has reported severe damage to plant materials with the second application of simazine. Therefore, in next year's test we plan to follow up the initial application at six-week intervals with alachlor to see if this would give longer and better weed control.

Alachlor at 8 lb. gave much better weed control than when applied at 4 lb. with no appreciable difference in chemical damage to plant materials. Alachlor is still a standard for other chemicals to be measured against. Because of its relatively short duration of weed control (only 6 to 8 weeks) it must be reapplied at those intervals to give desirable weed control.

Profluralin (Tolban 2G) at 4 and 8 lb. gave fair weed control and exhibited the least amount of phytotoxicity of all the herbicides tested. Profluralin reduced bittercress (*Cardamine hirsuta*) by 75% when compared with the control.

Napropamide (Devrinol 5G) at 4 and at 8 lb. gave fair overall weed control and excellent control of bittercress. It exhibited slight phytotoxic properties but shows some promise and will be evaluated in further studies.

Simazine at 2 lb. gave better weed control than when applied at 1 lb. The reverse was true when phytotoxicity was considered. As mentioned previously, only one application of simazine should be applied.

Trifluralin (Treflan 5G) gave very poor weed control of bittercress at 4 lb. and was only slightly better at 8 lb. Since broadleaf weeds predominantly give us more problems than grasses, triflura-

lin rated very low in our evaluation. Fretz (5), in a similar type test, reported poor overall broadleaf weed control but excellent control of grass weeds at 4 lb.

Pronamide (Kerb 50W) exhibited poor weed control at 2 and 4 lb. Pronamide was also the second most phytotoxic chemical of the herbicides tested. Only oryzalin (Surflan 75W) was more phytotoxic. Several weeks after the tests were completed a heavy infestation of postrate spurge (*Euphorbis prostrata*) was noted at both rates. Since pronamide's strength is in controlling grasses rather than broadleaf weeds, these results could be expected.

The results of oryzalin were disappointing. Both Elmore (3) and Skimina (9) had made favorable reports when they evaluated oryzalin. Excellent weed control was obtained at 4 and at 8 lb. but oryzalin was extremely phytotoxic at both rates. At 8 lb. oryzalin severely damaged 17 of the 32 plant varieties tested. The plants damaged most severely were the *Ilex cornuta* cultivars, in fact, most of the hollies were killed with 8 lb. Other plants severely stunted were *Gardenia jasminoides* and its cultivars 'August Beauty' and 'Mystery', 'Silver King' euonymus and oleander. Elmore (3) reported that he was able to apply a maximum of 8 lb. of oryzalin without injury on *Ilex cornuta* 'Rotunda', oleander and euonymus, however, in this study, oryzalin proved to be quite phytotoxic. This, of course, could be due to differences in growing media, weather conditions, or possibly other factors. In order for oryzalin to be acceptable, extensive phytotoxicity tests would have to be conducted at much lower rates.

Table 1. Plants used in herbicide evaluation in spring, 1975.

1. *Buxus microphylla var. japonica*	Japanese boxwood
2. *Chamaerops excelsa*	Windmill palm
3. Eleagnus macrophylla 'Ebbengi'	Ebbengi eleagnus
4. *Euonymus japonica* 'Aureo-marginata'	Golden euonymus
5. *Euonymus japonica 'Aureo-variegata'*	*Gold spot euonymus*
6. *Euonymus japonica*	Japanese euonymus
7. *Euonymus japonica* 'microphylla'	Dwarf euonymus
8. *Euonymus japonica* 'Silver King'	Silver King euonymus
9. *Gardenia jasminoides* (syn. *G. radicans*)	Dwarf gardenia
10. *Gardenia jasminoides* 'August Beauty'	August Beauty gardenia
11. *Gardenia jasminoides* 'Mystery'	Mystery gardenia
12. *Gelsemium sepervirens*	Carolina jasmine
13. *Ilex cornuta* 'Burfordii'	Burford holly
14. *Ilex cornuta* 'Dwarf Burford'	Dwarf Burford holly
15. *Ilex cornuta* 'Carissa'	Carissa holly
16. *Ilex cornuta* 'Rotunda'	Dwarf Chinese holly
17. *Ilex crenata* 'Compacta'	Compact Japanese holly
18. *Ilex crenata* 'Hetzii'	Hetzi Japanese holly
19. *Ilex* hybrid 'Nellie R. Stevens'	Nellie R. Stevens holly
20. *Juniperus horizontalis* 'Wiltonii'	Blue rug juniper
21. *Lagerstroemia indica*	Red crapemyrtle

22. *Lig. jap.* 'Lusterleaf' (syn. *L.j.* 'Texanum')	Waxleaf ligustrum
23. *Ligustrum x vicaryi*	Golden privet
24. *Lonicera japonica* 'Purpurea'	Purple leaf honeysuckle
25. *Nerium oleander*	Red oleander
26. *Photinia x fraseri*	Fraser photinia
27. *Pittosporum tobira*	Green Pittosporum
28. *Pittosporum tobira* 'Variegata'	Variegated pittosporum
29. *Pyracantha koidzumii*, 'Victory'	Victory pyracantha
30. *Trachelospermum asiaticum* (syn. *Rhynchospermum a.*)	Asiatic jasmine
31. *Viburnum suspensum*	Sandankwa viburnum
32. *Yucca aloifolia*	Spanish dagger yucca

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Table 2. Counts of nine weed species made July 22, 1975, 75 days after herbicide application to 32 container-grown broadleaf ornamental shrubs in spring, 1975, at El Campo, Texas.

	Herbicide and rate applied in lb. ai/A																		
	Con-trol	Kerb		Lasso		Princep		Lasso Princep		Ronstar		Surflan		Tolban		Treflan		Devrinol	
Weed Species		2	4	4	8	1	2	4:1	8:2	4	8	4	8	4	8	4	8	4	8
Cardamine hirsuta (bittercress)	100	26	13	27		28	6	11	5			7	2	27	30	105	58	9	6
Cyperus esculenta (umbrella plant, chufa)	1	2	2											2		1			
Echinochloa crus-galli (barnyard grass)	2				3	2	4	1								2			1
Euphorbia prostrata (prostrate spurge)			4							1									
Gnaphalium pennsilvanicum (cudweed)			1																
Oxalis corniculata (weeping woodsorrel)	9	8	28	4	1	1	6									1		8	21
Salix humilis (prairie willow)			1																
Sesbania emerus (*S. macrocarpia*) (indigo weed)			1															1	1
Sonchus oleraceus (sowthistle)	1		3			1				1				1	1	1			
Total weeds per treatment	113	36	53	31	4	32	16	12	5	2	0	7	2	30	31	110	58	18	29

PRODUCTION SYSTEM FOR JUNIPERUS HORIZONTALIS CULTIVARS IN THE SOUTH — CUTTINGS TO FIVE GALLON SIZE

JOHN B. WIGHT, JR.

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Horizontal juniper production is handled by two departments at Wight Nurseries, Inc.: Propagation and Conifer Container Growing. All of our propagation is done by a crew who spends its entire time in propagation. We have attempted to divide our system into as many simple jobs as possible and through various means determine a piece-rate basis for paying for each job. For instance, we have a piece-rate price for filling peat pots; for sticking juniper cuttings three per peat pot; for sticking juniper cuttings one per peat pot. We also have piece-rate prices per employee for filling 1-gal cans; for canning peat pots to 1-gal cans; for shifting 1-gal cans to 2-gal; or for shifting 1-gal cans to 3-gal.

We have found that the people who are paid on a production basis are the most productive people on the nursery. They make the most money and they are the happiest and best employees, while still giving us the lowest unit cost. Now that combination is hard to beat!

All of you who have heard me speak before know we have two key words associated with our production of plants. One is UNIFORMITY and the other is PREVENTION. UNIFORMITY everywhere, the size of the cutting, the mix, the container, the watering system and many other things. PREVENTION means the prevention of disease, insects, weeds and all potential problems. I mentioned these words many years ago and I continue to think they are the two most important in the scheme of production.

We will assume that an intelligent determination has been made of the quantities of any given cultivar of juniper or other plants that are to be produced. With this assumption in mind we start with the taking of juniper cuttings from a clean, sanitary mother block. That's clean as far as disease, weeds, insects and other problems are concerned — that's PREVENTION!

The junipers that are particularly prostrate are grown in large cans with the bottoms out planted in the field to keep the weeping limbs out of the dirt. We also take a great many cuttings from the 1-, 2- and 3-gal sizes and this serves a two-fold purpose of pruning the plants, plus the juvenility feature here that is very desirable in rooting as you all know.

Our next step is to take a uniform cutting from these clean plants and put it in a wire basket. As a preventative, we dip the

cuttings in a mix containing Benlate and other things to clean them up. We make our own rooting hormones using IBA, alcohol and water. Strengths are varied according to past history of the cultivar and our rooting records.

The mix we use to root in is mixed on concrete slabs and the ingredients are clean. They are not all sterilized, but they are clean. The sand is kiln-dried and uniformly graded. The pine bark is screened for uniform particle size. The shale, a by-product of the steel industry, is sterile and uniform. These are mixed and put into new peat pots in flats, both on a piece-rate basis, as well as the piece-rate basis being used for sticking of the cuttings themselves.

We use well water exclusively in propagation. Much of our water for the nursery is from lakes, but we determined long ago that for propagation, the water needs to be of excellent quality and clean.

In conifer propagation we use ground beds for some cultivars which gives us a bare root liner; however, most every prostrate juniper is grown in jiffy pots, in a flat and in outdoor beds. The cuttings are taken in January and February.

Once the liners are ready and we believe this is a relatively short time compared to other nurseries, we plant into gallon cans, which are in the field, on a piece-rate basis. Even if we use our canning machines, we have incentive programs to keep production up. Most of our canning is not done with machines.

These plants are placed in the field by canning crews as part of the piece rate planting procedure. Our peat pot liners are kept in the flats only about six months from the unrooted cutting stage to planting. I know many of you use much larger liners but we believe that ours should be canned before the peat pots grow into each other. Because of the variations in speed of rooting, we can some cultivars in June but some have to wait a little longer.

We place these junipers into areas where the roads, ditches and surrounding areas are kept clean. We believe prevention of disease and insects and weeds is necessary and those of you who saw the nursery will remember that we keep the surrounding areas as clean as possible.

Fertilization is done at each irrigation using Milton Roy injection equipment. Soil tests every month help us determine quantities of fertilizer to inject into irrigation water.

We shear the plants as many times as is necessary to make a good plant and normally no cold protection is required for juniper cultivars in Cairo, Ga. We do use cold protection for our broad-leaved plants which consists of jamming them together with a 6 inch Kraft paper wrapped around the outer edges to cut down on

the effects of the wind and the chill factor. Historically, we don't get much below 17° or 18° although 3°F was recorded in 1962. At that time all *Ilex* and many other broadleaf cultivars were killed because they sat on 1 ft centers in the field.

We pre-label on a piece-rate basis during slow periods so that when the shipping season comes we will have that done.

Shifting up from 1-gal to 2-or-3-gal is done on a piece-rate basis around a large soil mix pile. Although this method may not seem as efficient as a potting machine we have found it to be quite efficient and in our opinion it beats the canning machine.

Basically, this is how we produce the horizontal juniper.

In summary I would say:

1. Simplify your jobs so that they can be done on a piece-rate basis.
2. Have a uniform mix, container, bed size, irrigation heads, everything as uniform as possible.
3. Prevent every problem you can with preventive spray programs, herbicide programs, disease programs and you will probably have a very successful juniper production operation.

MODERATOR PARKERSON: What is your piece-rate for making 'Blue Rug' cuttings?

JOHN WRIGHT: For most operations our people work as a crew and I assure you they will purge a crew of a man who does not work. The piece-rate for making the cutting and sticking it in a peat pot is $5 per thousand; we do stick some 3 cuttings per pot and that rate is $15 per thousand. This is paid to the crew and each man on the crew receives the same amount.

LARRY CARVILLE: What do you shear with the sickle bar which we saw at your nursery?

JOHN WIGHT: It is used on wax-leaf ligustrum, gardenias, *Ilex crenata* and certain *I. cornuta* hollies and some of the more upright low-growing junipers. On 'Blue Rug' and 'Bar Harbor' we still have to do it the old hard way — by hand.

LARRY CARVILLE: How do you fill the peat pots in the trays?

JOHN WIGHT: If we had one location we would probably run them under a filling device and rake them off but we have several areas where this is done. The workers scoop them much like filling an ice cream cone and then set them in the trays. We don't much care how they do it; we've tried telling them how we think it should be done but it's much like buying a Ford truck for a foreman who wants a Chevrolet — he'll make sure it doesn't last very long. All of us here are plant lovers, but on a piece-work basis you don't need plant lovers; you need someone who is highly motivated by money.

ORDER FILLING AND SHIPPING OF CONTAINER-GROWN PLANTS

JOHN GILES

Polk Nursery Co.
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Polk Nursery Co. is a 100 acre container nursery located in central Florida. Shipping of container plants is an integral part of the program of any wholesale nursery. This year we shipped 2,000,000 containers; this included 600,000 container rose bushes in bud and bloom. We do not use cardboard boxes in our operation.

Order filling and shipping is a challenge itself. The first problem in our operation is a logistical one being divided into two locations, 5 miles apart. Order filling starts in our office which is staffed by an extremely talented group of individuals. Orders are normally phoned into our office by the customer, or by our two salesmen.

Orders are figured by hand to fill a truck with maximum number of units within a specific route or geographical area within economic reason. The next step is on to the computer for customer invoicing, extending of total plant quantity and size, and print-out pick-up sheet for our field pick-up crew. Plant tags are then assembled for plants not previously tagged on our potting machine.

The field shipping crews receive each pick-up sheet containing all pertinent information for their particular truck load. The crew is informed as to what types of shipping racks to use, quantity of each plant, location — bed number, and what color load they are assigned.

The shipping racks are designed to mechanize our operation since we deal heavily in "Quick Turn" plants. Shipping racks are divided into three categories. Two tier with 52 inch spacing between shelves, three tiers with 36 inch spacing between shelves and four tiers with 26 inch spacing between shelves. The racks are built and repaired in the nursery by our full-time welder.

The four tier rack is utilized whenever possible because it allows us to get the maximum number of units in a truck load. Plant height is the determining factor and double stacking is permissible if that particular group of plants will adhere to double stacking without breakage. So many of the tropicals and subtropical plants we grow will not withstand double stacking. Woody ornamentals are in a different class and most will withstand double or triple stacking.

The total number of 1-gal (6") containers we can ship in a trailer would range from 3600 to 6000 if we double stack and fill

our trailer aisle with wood shelves. The shipping crew is usually composed of three or four members. The crew chief in charge accepts responsibility for the quality of the load. The racks are loaded onto a tractor-drawn four-trailer train with a forklift. Field pick-up begins with random stops throughout the field to select and load the particular plants and quantities designated by the pick-up sheet.

When the racks are filled they are unloaded by forklift, and lined up by color load in our loading dock. Shipping racks are forklifted directly into the delivery trailers and are ready for delivery. The truck driver begins disseminating plants from the racks to fill the invoice of each individual customer. All delivery trailers are equipped with two side doors and rear double doors. All plants are tagged to facilitate the customer and eliminate the driver uncertainty as to plant name.

Our fleet of trucks number 13 at the present time. We have 16 field tractors (35-40 H.P., PTO rated), and 18 four trailer field trains. Our total work force fluctuates with the time of year, with spring being our busy season.

Cost of order filling is approximately 2¢ per unit on a 6'' container. Delivery cost in Florida is figured at 50¢ per mile. However, we do not charge freight in Florida. Trucks leaving Florida carry a delivery cost of approximately $1.00 per mile and freight rates are calibrated accordingly. For example, a 6'' container delivered to the Atlanta, Georgia area would carry a freight rate of 10¢.

I believe our system of order filling and shipping has a great number of advantages over growers that utilize other means. However, we are constantly searching for better means of improving our system. Ours is a never ending search for better days through better ways with a touch of economic fortitude and a strong desire to service our customers.

EFFECT OF COMPOSTED HARDWOOD BARK AND PEAT CONTAINER MEDIA ON GROWTH OF SELECTED ERICACEOUS PLANTS[1]

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Abstract. Hardwood bark compost proved to be an excellent container-growing medium substrate for production of *Pieris japonica* and *Rhododendron* 'Nova Zembla' and 'Roseum Elegans'. Growth indices and root growth ratings were greater for test plants produced in a composted hardwood bark-sand medium than for plants produced in Michigan peat-sand and Michigan peat-sand-Haydite media. Some root rot caused by *Pythium irregulare* was observed on all plants grown in peat-sand and Haydite-peat-sand media, but not on plants grown in bark compost. Increased root growth in the bark-sand medium may be due in part to the absence of root rot.

Composted hardwood bark has physical and chemical properties that appear to make it an excellent substrate for container plants. It is relatively low in weight, provides adequate drainage and has an ion exchange capacity similar to that of peat. It contains all minor elements required for plant growth (2). In addition to these excellent chemical and physical properties, composted hardwood bark also is free of plant pathogens (4). Furthermore, evidence shows that this compost suppresses *Phytophthora* root rots (5) and nematode diseases of susceptible plants (6).

In a previous but small-scale study, growth of *Rhododendron* 'Roseum Elegans' in a hardwood bark compost was compared with that in two peat media (3). We report here the growth differences of *Pieris japonica* and *Rhododendron* 'Nova Zembla' and 'Roseum Elegans' in a large-scale trial. Growth media included: i) a composted hardwood bark; ii) a Michigan peat-sand and iii) a Haydite-Michigan peat-sand medium. The bark medium contained 2 parts bark and 1 part silica sand with 6 lbs. ammonium nitrate, 5 lbs. superphosphate and 3/4 lbs. elemental sulfur per cubic yard. The peat medium contained 15 lbs. dolomitic lime, 5 lbs. superphosphate, 1 lb. GU-49 (63% iron oxide) and 1 lb. fritted trace elements per cubic yard. The peat-sand medium consisted of 2 parts Michigan peat and 1 part sand (v/v). A hammermilled hardwood bark received from Pallet-All Corp., Millersburg, Ohio was also evaluated. However, because of the lack of uniformity of this latter product, growth data are not presented. All media were mixed with a flail-type manure spreader and stockpiled for 6

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weeks. The composted bark medium was turned once after 3 weeks.

Plants (140 one-quart-plants/treatment) were potted May 20, 1974 in 2-gal green-colored containers and arranged in contiguous blocks in an uncovered polyhouse. The pH readings at the time of potting of the bark, peat, and the Haydite media were 5.2, 5.9 and 5.8, respectively. Percentage drained airspace (1) of the media were 20, 15 and 25 and soluble salts readings were 2.2, 0.20 and 0.26 millimhos/cm (1 part soil in 2 parts water, v/v), respectively. A reading of 1.8 is considered undesirable for many plants. The high salts reading of the compost indicates that the composting process had not been completed. Evergreen hardy azalea 'Boudoir' plants originally planned for this experiment died within a few days after potting in the bark mix due to high salts. Azaleas are not discussed further here but have grown successfully in composted hardwood bark, which had stabilized before potting.

At the end of the second growing season properties of the bark, peat and Haydite media were as follows: i) pH 5.4, 6.4 and 6.3, ii) soluble salts 0.1, 0.2, and 0.1 millimhos/cm and iii) air-drained pore space 18, 13 and 14%, respectively. The low soluble salt readings reflect the low nutrient levels maintained in this experiment. The high air-space in the bark mix as compared to the other mixes after two growing seasons demonstrates the resistance of hardwood bark to further breakdown after composting.

In September 1975, a growth index was determined of a randomly-selected number of plants (15/treatment). The growth index represents one-half of the sum of plant height and maximum plant width (cm). The number of flower buds per rhododendron plant and the number of inflorescences per pieris plant were also counted. Root growth ratings, made by a group of nurserymen and the authors, were on a scale of 1=poor, 2=fair, 3=medium, 4=good and 5=excellent sized root ball. A rating of five was assigned to roots that had filled the entire 2-gal pot. The average rating is based on four ratings of five randomly-selected plants per treatment. Because of the size of the project, replication and randomization of treatments was impossible. Therefore, data have not been subjected to statistical analysis.

Throughout the 2-yr period, plants in the bark medium appeared to be growing at a faster rate than those in the peat or Haydite media. However, considerable variability existed among plants in each medium. Growth indices of pieris plants in the bark, peat and Haydite media ranged from 28-47, 17-34, and 24-33 cm, respectively, and for 'Roseum Elegans', 46-67, 49-66, and 41-55 cm. Numbers of inflorescences ranged from 0-15, 0-7, and 0-7 on pieris plants in the bark, peat and Haydite media, respectively. Bud counts on 'Nova Zembla' ranged from 6-11, 4-8, and

4-13; for 'Roseum Elegans' 0-8, 0-6, and 0-8, respectively. The average number of inflorescences, the growth indices for each plant and root growth in the three media are presented in Table 1. Although all three plant types responded best in the bark medium, growth of pieris in the bark medium was almost 50% greater than in the peat or Haydite media. The increased top growth of 'Roseum Elegans' in the bark medium perhaps was insignificant but root growth was considerably better. Some root rot caused by *Pythium irregulare* was observed on all plants in the peat and the Haydite media but not in the bark. The increased root growth of all plants in the bark mix, therefore, could be due to the absence of *Phythium* root rot.

In a previous publication (3) we reported the increased growth of 'Roseum Elegans' in the bark medium as compared to other media. It now appears that hardwood bark compost is an excellent substrate for production of other ericaceous plants as well.

Acknowledgement. We wish to thank James Sabo and Dick Hart from Cottage Gardens, Inc., Perry, Ohio for supervision of plants througout the two-year period. In addition we thank David R. Dugan, R. James Schroeder and Jeff Henrietta for assisting in the rating of plant growth and Dr. James Q. Aylsworth for assistance in setting up the experiment.

Table 1. Effect of container medium on the average number of inflorescences per plant, average growth index and root growth rating.

Medium	Average Number Inflorescences			Average Growth Index			Average Root Growth Rating		
	PJ[1]	NZ[1]	RE[1]	PJ	NZ	RE	PJ	NZ	RE
Bark-Sand Compost	2.7	8.2	1.4	37	44	58	4	5	4
Peat-Sand	0.9	6.1	0.8	26	40	55	2	2	2
Haydite-Peat Sand	0.5	8.5	2.0	27	40	49	2	2	3

[1]PJ = *Pieris japonica*, NZ= 'Nova Zembla', RE = 'Roseum Elegans'.

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EFFECT OF AUXIN COFACTORS ON ROOTING AND THE EFFECT OF GIBBERELLIC ACID ON SHOOT GROWTH OF LILAC SOFTWOOD CUTTINGS[1]

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Abstract. Lilac cuttings obtained from parental trees during flowering time root better than those cut later. Pyrogallol and indole increased the number of rooted cuttings per plot and showed synergistic effects on the number of roots and root length per cutting. Ascorbic, nicotinic, and boric acids used in talc with NAA increased additively, or synergistically, the total length and number of roots per cutting. H_3BO_3, $ZnSO_4$, and $MnSO_4$ sprays on the cuttings markedly stimulated rooting. Spraying the leaves of rooted cuttings with GA promoted their development.

Long term observations made in the Kornik Arboretum show that own-root lilacs grow more intensively, exhibit more viability and are more resistant to disease than grafted plants. They are also easier to maintain since root sprouts are the same cultivar and need not be removed. The use of auxin for rooting softwood lilac cuttings has been shown to be advantageous (4, 12, 20); however, some cultivars root poorly even with auxin. The purpose of the experiments described here was to test substances which increase the auxin effect and to check other substances that stimulate rooting and cause additive or synergistic effects with auxin. Rooting stimulators often cause excessive root growth and further development of the cuttings is inhibited due to root competition. An effort was made to overcome this condition by stimulating shoot growth with gibberellin.

MATERIALS AND METHODS

Experiments on rooting softwood cuttings of lilac have been conducted at the Institute of Dendrology, Kornik, Poland from 1971 to 1974. Two cuttings were taken from every stem of 1-year-old shoots of 10-year-old shrubs. All cuttings had one internode 5-8 cm long and one pair of leaves, reduced by half to reduce transpiration. The lower cut was made 2-3 mm below the lower node.

Auxin and other root-stimulating substances were supplied in talc. The microelements were applied twice to the cuttings as leaf sprays, immediately after sticking and 2 weeks later. The cuttings were stuck in a greenhouse bench in a 5 cm perlite layer placed over composted soil mixed with peat (2:1 v/v). During rooting the benches were covered with sash. The cuttings were watered by hand as needed depending on greenhouse temperature which varied from

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[1]Student Award paper. Not presented at meeting.

20 to 28°C. Every 2 weeks the cuttings were sprayed with 0.05% Benlate.

The experiment was replicated three times with 8 or 16 cuttings per plot. The results were recorded 4 and 8 weeks after planting. However, only the results obtained after 8 weeks are presented. The following data were collected: 1) number of rooted cuttings, 2) average number of roots per cutting and 3) total length of all the roots per cutting. In the following vegetative season the cuttings treated with the stimulating substances had very strong root systems but relatively small shoot system.

In order to stimulate shoot growth, gibberellic acid was used at 50 and 100 ppm. The spraying was performed four times according to two time schedules: *I schedule*: June 23, 29, July 3, 6; *II schedule*: July 27, 30, August 2, 8. The height of the plants was measured before spraying and in the fall after extension growth had terminated.

In order to perform statistical analysis of the number of rooted cuttings the proportions were converted to angular values by the Freeman-Tukey transformation. The remaining readings were subjected directly to analysis of variance and differences were compared by the new Duncan multiple range test at $P = 0.01$.

RESULTS

The time of collecting lilac cuttings from parental shrubs is of considerable significance for their rooting ability. The earlier the cuttings were collected the higher was the percentage of rooting; at the onset of blossoming, 85% rooted; after blossoming, 57% rooted. Earlier collected cuttings also formed stronger root systems (more and longer roots). NAA at 0.2% and 0.4% was equally effective in promoting rooting of the cuttings (Table 1). There was no effect of Benlate on the formation of adventitious roots.

Table 1. The influence of the date of taking cuttings and of the growth stimulator used on root production in *Syringa* 'Prof. Hoser'.

Date of taking cuttings	No. rooted (per 8)	No. roots per cutting	Total root length per cutting
May 17 (beginning of bloom)	6.1 cb*	4.4 b	40.7 b
May 22 (full bloom)	6.8 c	3.5 a	29.8 a
May 29 (end bloom)	5.2 ba	2.8 a	24.8 a
June 5 *(after bloom)*	4.6 a	2.8 a	23.2 a

Table 1. continued

Treatment			
Control	4.5 a	2.2 a	16.5 a
NAA 0.2%	5.8 b	3.9 b	39.6 c
NAA 0.2%+Benlate 0.5%	5.9 b	3.6 b	30.0 b
NAA 0. 4%	6.5 b	3.8 b	32.2 bc

*The numbers with the same letter do not differ significantly at $P = 0.05$

Indole and pyrogallol increased the number of rooted cuttings as effectively as auxin (by about 160% relative to the control). When given together with auxin the effect is similar to that of auxin alone. Indole at 0.2% and 0.4% as well as mixtures of indole and pyrogallol significantly increased the number of roots per cutting relative to the control. These substances, applied mixed with NAA, showed an additive or synergistic effect on the number of roots per cutting. The effect on total length of the roots per cutting was insignificant (Table 2). Vitamin C, nicotinic acid and boric acid had no effect on the number of rooted cuttings but they strongly affected the growth of the root system (Table 2). When used separately, only nicotinic acid at 0.02% increased the number and length of the roots on cuttings relative to the control. These substances, used together with auxin, caused an additive effect on the growth of the root system. A mixture of the two vitamins and NAA did not improve the number or length of roots in comparison to one of them mixed with the auxin. Boric acid had the greatest effect on the growth of the root system and appeared to act synergistically with auxin on both the number and length of roots.

Table 2. The influence of indole, pyrogallol and auxin on the rooting of cuttings of *Syringa* 'Katherine Havemayer' taken on May 17.

	No. rooted per plot*		No. roots per cutting*	
Treatment	without auxin	with auxin	without auxin	with auxin
Control	3.6 a		2.5 a	
NAA 0.2%		6.6 bc		5.8 c
Indole 0.2%	6.0 bc	6.3 bc	4.1 b	10.1 de
Indole 0.4%	5.6 b	7.0 bc	3.7 b	10.1 de
Indole 0.8%	5.6 b	7.0 bc	3.1 ab	9.1 d
Pyrogall. 0.05%	6.3 bc	7.3 c	3.4 ab	10.4 e
Pyrogall. 0.1%	6.6 bc	6.3 bc	3.4 ab	10.6 e
Pyrogall. 0.4%	6.6 bc	7.0 bc	2.4 a	9.9 de
Indole 0.4%+ +Pyrog. 0.1%	6.3 bc	7.0 bc	5.2 bc	10.5 e

*Numbers followed by the same letter do not differ significantly at P = 0.05.

Table 3. The influence of vitamins, boric acid and auxin on the rooting of cuttings of *Syringa* 'Felix' taken on May 26.

Treatment	No. rooted per plot*		No. roots per cutting*		Total root length per cutting*	
	without auxin	with auxin	without auxin	with auxin	without auxin	with auxin
Control	4.0 a		1.8 a		8.5 a	
NAA 0.2%		9.3 cde		2.8 bc		14.9 ab
Ascor. acid 0.01%	5.3 ab	9.4 de	1.9 a	3.3 cd	12.9 a	23.2 cde
Ascor. acid 0.02%	6.6 abcd	9.6 de	2.3 ab	3.8 de	16.7 abc	27.8 ef
Nicoti. acid 0.01%	6.0 abc	10.6 d	2.3 ab	2.9 bc	17.0 abc	25.9 def
Nicoti. acid 0.02%	7.6 abcde	10.3 de	2.9 bc	3.9 de	20.5 bcd	26.5 def
Nic. acid +Asc. 0.02%	5.0 a	9.6 de	2.3 ab	3.8 de	16.4 abc	30.4 ef
Boric acid 0.1%	5.3 ab	10.0 de	2.0 a	4.3 e	15.3 ab	32.1 f
Boric acid 0.2%	6.6 abcd	8.6 bcde	2.6 abc	4.1 e	19.9 abcd	31.2 f

*Numbers with the same letter do not differ significantly at P = 0.05.

Spraying NAA-treated plants with microelements such as zinc, manganese and boron increased the number of rooted cuttings relative to the NAA treatment alone (Table 4). Manganese and boron at 50 and 100 ppm increased the root system of the cuttings relative to the control and, when combined with the auxin treatment, their influence on the number and length of roots was additive. Also a synergistic effect of zinc at 100 ppm with the auxin was observed on the growth of the root system.

The rooted lilac cuttings reacted to gibberellic acid (GA_3) only when this was sprayed in the first time schedule (Fig. 1). At 100 ppm GA increased shoot extension growth by a factor of four relative to the control. Frost injury was not observed on GA-treated plants and laboratory studies indicated that they can stand temperatures of -35°C as well as the control plants.

Table 4. The effect of nutrient spraying and auxin on the rooting of cuttings of *Syringa* 'Ludwig Spaeth' taken June 7.

Treatment	No. rooted per plot*		No. roots per cutting*		Total root length per cutting*	
	without auxin	with auxin	without auxin	with auxin	without auxin	with auxin
Control	0.6 ab		0.6 ab		0.6 a	
NAA 0.2%		3.0 cd		2.5 def		24.8 de
$ZnSO_4$ 100 ppm	1.3 b	5.0 ef	1.1 abc	4.3 gh	2.7 a	34.7 fg
$ZnSO^4$ 200	0.3 a	4.6 de	0.3 a	2.8 ef	0.3 a	31.2 efg
$FeSO_4$ 100	1.3 b	3.0 cd	1.0 abc	3.6 fg	1.8 a	29.5 e
$FeSO_4$ 200	1.0 ab	4.0 de	1.3 abc	3.1 efg	3.6 ab	28.3 ef
$MnSO_4$ 50	1.0 ab	6.6 f	1.6 bcd	4.8 h	4.6 ab	32.6 efg
$MnSO_4$ 100	1.0 ab	5.0 ef	2.0 cde	4.5 h	10.3 bc	34.7 fg

Table 4. continued

Treatment	No. rooted per plot*		No. roots per cutting*		Total root length per cutting*	
	without auxin	with auxin	without auxin	with auxin	without auxin	with auxin
H_3BO_3 50	1.3 b	6.3 f	1.6 bcd	5.3 h	12.0 bc	38.8 gh
H_3BO_3 100	1.6 bc	6.3 f	2.3 cde	5.8 h	11.6 bc	44.2 h
$K_2SO_4$2500	1.6 bc	4.0 de	1.3 abc	2.4 de	7.3ab	25.4 e
$K_2SO_4$5000	1.6 bc	3.0 cd	1.6 bcd	3.0 efg	11.6 bc	26.9 e
$H_3PO_4$2500	1.0 ab	4.0 de	1.3 abc	3.0 efg	8.0 abc	16.9 cd
H_3PO_4 5000	1.0 ab	3.0 cd	1.3 abc	3.1 efg	10.0 bc	29.9 ef

*Numbers with the same letter do not differ significantly at P = 0.05.

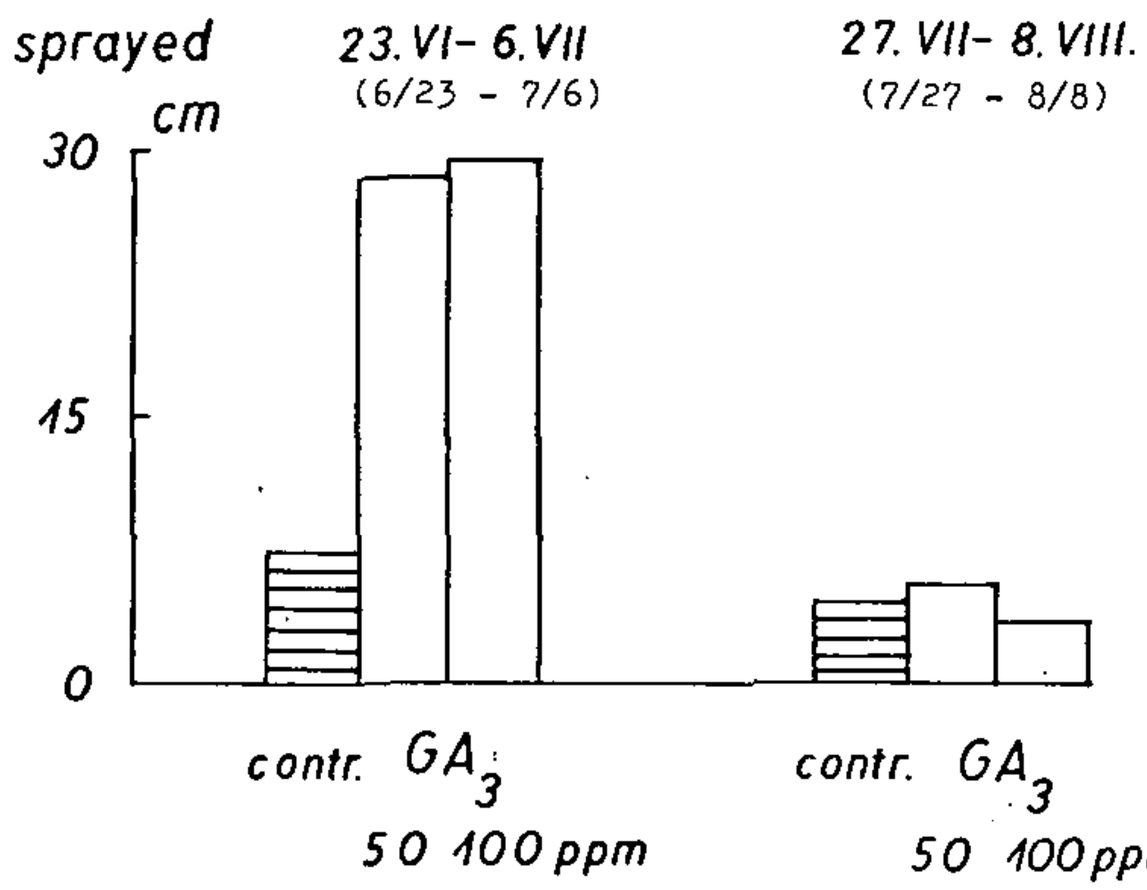

Figure 1. Differences in shoot growth as result of GA_3 spraying.

DISCUSSION

The natural ability of a cutting to root is dependent upon the time of collecting as has been indicated by several investigators (6, 17, 24). Komarow (13) reported the best time for rooting cuttings of a majority of lilac cultivars is the time between the peak and the end of flowering. Our observations show that the cuttings of many cultivars rooted best when collected at the onset of flowering. Those collected towards the end of flowering or after rooted less satisfactorily. Similar observations were made by Sonnenfeld (17). The periodic variation in the ability to root may be caused by fluctuation in the levels of endogenous auxin, rooting cofactors, or rooting inhibitors (23, 24). Since the period of optimal lilac rooting is very short (about 2 weeks) its extension would be important from a practical point of view. This was achieved with some lilac cultivars (4).

A synergistic effect between indole or phenols with auxin has been observed by Hess (11), Basu (2), Gorter (9). There were, however, only a few experiments reported on woody plants (12, 14). In

our work, additive or synergistic effects of indole and pyrogallol with NAA was observed on their influence on the total root length and number of roots per cutting, but not on the number of cuttings rooted. The mechanism of action of these substances is not well known yet. They may slow down the action of some enzymes and protect natural auxin by inhibiting their oxidation (21) but this does not explain their synergism with synthetic auxin (16). They may interfere with auxin transport (3). Vitamins are known to act as root stimulators in some plants (1, 10). In the studies described here ascorbic and nicotinic acid, together with auxin, had additive effects on the growth of the root system but none on the number of cuttings rooted. This indicates that the vitamins do not stimulate root initiation but rather act on already formed root primordia, lowering the competition among them. Stimulating rooting by spraying mineral nutrients on the leaves of cuttings was reported earlier (5, 8, 15). Of the elements studied, boron, manganese and zinc have given the most spectacular effects (7, 15, 25). Some reports indicate that boron is not effective (16). Probably the effect of an applied microelement depends upon how much of it has been accumulated in the plant tissues before the cutting was collected.

Gibberellic acid is a strong growth stimulator for lilacs. In the work of Tamberg (19) lilacs seedlings treated with gibberellic acid were 10 times taller than the control. In our experiment gibberellin caused a strong promotion of shoot growth which reduced the disproportion between the partly inhibited shoot system and the over-grown root system. Possibly gibberellins may help in restoring proper balance between the above-ground part and the root system in cuttings of many other species.

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METHODS OF APPLYING CYTOKININS TO LEAF CUTTINGS OF RIEGER BEGONIAS

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Certain species of plants can be reproduced asexually by means of leaf cuttings. A leaf cutting is composed of an entire leaf (lamina and petiole), or part of a leaf, which is removed from a plant — without an auxillary bud or a piece of stem — for the purpose of propagation. Of great importance in the propagation of leaf cuttings is the development of numerous adventitious buds at the base of the petiole. These buds develop into full, bushy self-supporting plants more readily than from a bud on a stem cutting.

There are two types of Rieger begonias *Begonia bertini* 'Compacti' x *B. socotrana*: The Schwabenland type is commercially propagated from leaf cuttings which produce multiple vegetative basal shoots and has an upright form. The Aphrodite type is propagated by vegetative stem cuttings and is a pendulous form; leaf cuttings do not consistantly produce adventitious buds at the base of the leaf petiole.

The cytokinins are a growth regulator group reported to stimulate bud initiation from leaf cuttings (2, 3, 4, 5). Experiments were conducted to examine possible methods of applying cytokinins for commercial propagation of leaf cuttings.

MATERIALS AND METHODS

Experiments were performed with 2 cultivars of Rieger begonias *Begonia bertini* 'Compacti' x *B. socotrana*, cultivars: 'Aphrodite Cherry Red (AR) and 'Schwabenland Red' (SR).

Stock plants were grown from rooted cuttings supplied by Mikkelsens, Inc., Ashtabula, Ohio, which were potted in a 4:1:1 peat:perlite:soil mix and maintained in the greenhouse under 70°F night temperature with 3 hr. night light interruption. Noon temperatures were 72-91°F and light intensity was no greater than 2500 ft-c at mid-day.

Cuttings were inserted in flats containing a 1:1 peat:perlite mix with 1 lb. of dolomitic limestone/ft^3, and were grown in the greenhouse under the same temperature regimes as the stock plants. Cuttings were intermittently misted during daylight hours for the first 13 to 16 days, at which time rooting had taken place.

The crystalline forms of 6-furfurylamino-purine (kinetin), 6-benzylamino-purine (BA), and 6-benzylamino-9-(tetrahydro-2-pyryl)-purine (PBA) were brought into aqueous solution. For

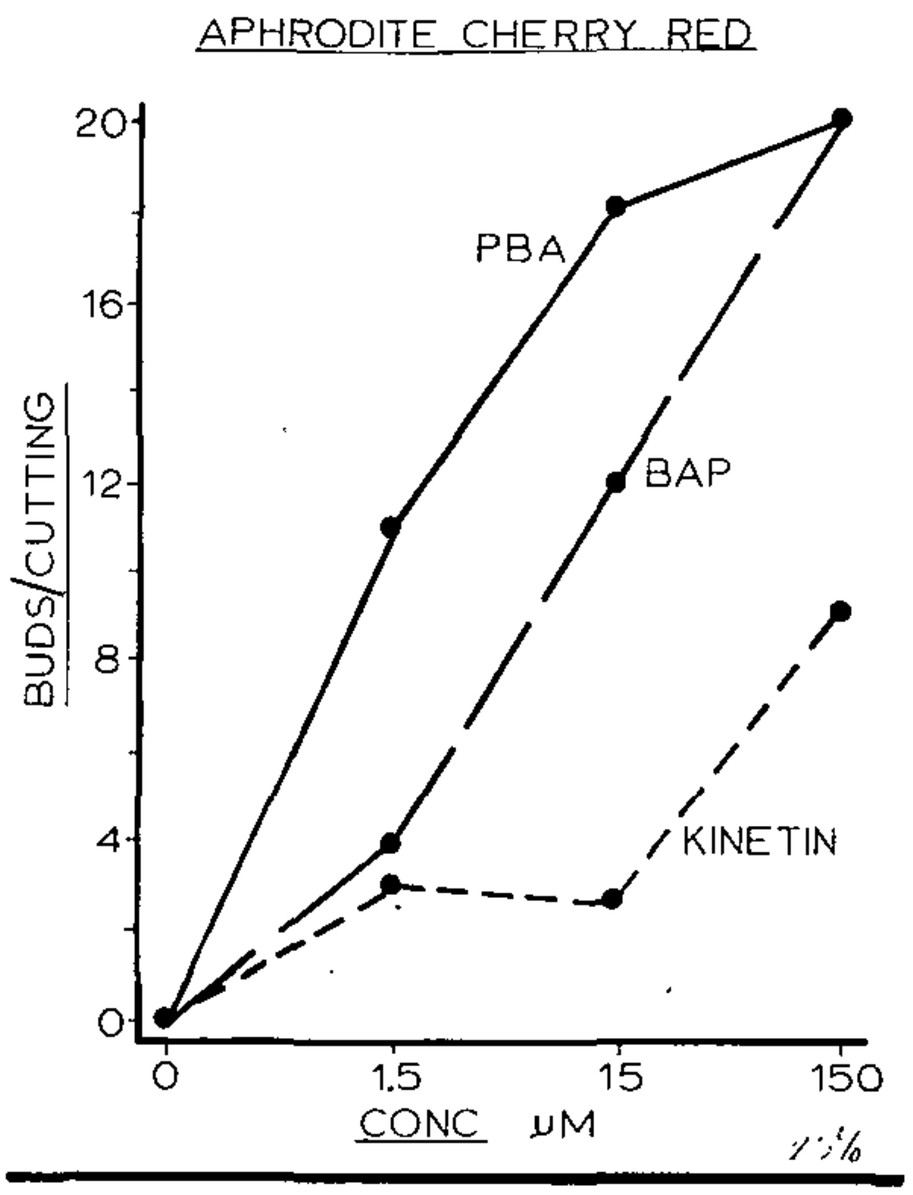

Figure 1. Effect of kinetin, BA, and PBA on the number of buds per cutting. 'Aphrodite Cherry Red'.

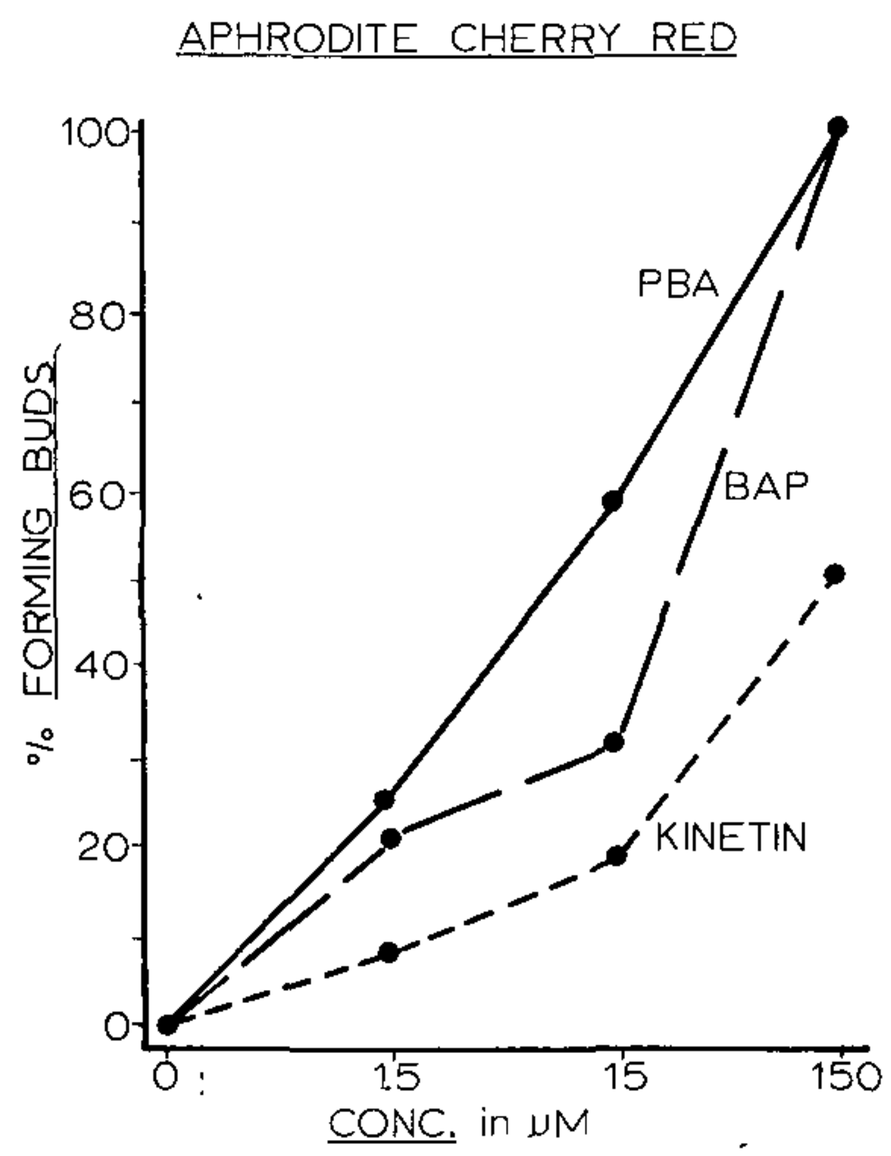

Figure 2. Effect of kinetin, BA, and PBA on the percent cuttings which formed buds. 'Aphrodite Cherry Red'.

"quick-dips" (0.1 min.), a 50% solution of ethyl alcohol was used. When applied with a talc carrier, the cytokinin was measured and brought into solution with 95% ethyl alcohol, and weighed talc was added. The slurry was repeatedly mixed until the mixtures reached a dry powder state. No surfactants were used.

could accurately be measured was twenty. A randomized block design was utilized with 12 observations per treatment. Mean values reflect the average of the twelve cuttings per treatment.

RESULTS

In a preliminary experiment the cytokinins: 6-furfurylamino-purine (kinetin), 6-benzylamino-purine (BA), and 6-benzylamino-9-(tetrahydro-2-pyryl)-purine (PBA) were applied at 1.5, 15, 150 μM to leaf cuttings via a 12 hr basal-petiole soak. Comparing cytokinins (Figs. 1, 2) PBA was the most effective in stimulating bud initiation, followed by BA and kinetin. Too high a concentration (150 μM) of either PBA or BA caused a large proliferation of buds with subsequent poor shoot development (Fig. 3). At 15 μM PBA (Table 1), bud regeneration was reduced as expressed by weight of buds and shoots (Fig. 4). However, 'Aphrodite Cherry Red' responded positively in both bud and shoot regeneration (Table 1).

To determine the relationship between concentration of cytokinin and length of treatment, cuttings were basally soaked for 0.6 to 300 min. at 20 to 1500 μM PBA. With increasing concentration of cytokinin there was a decrease in treatment time to stimulate optimal bud initiation and shoot development (Table 2).

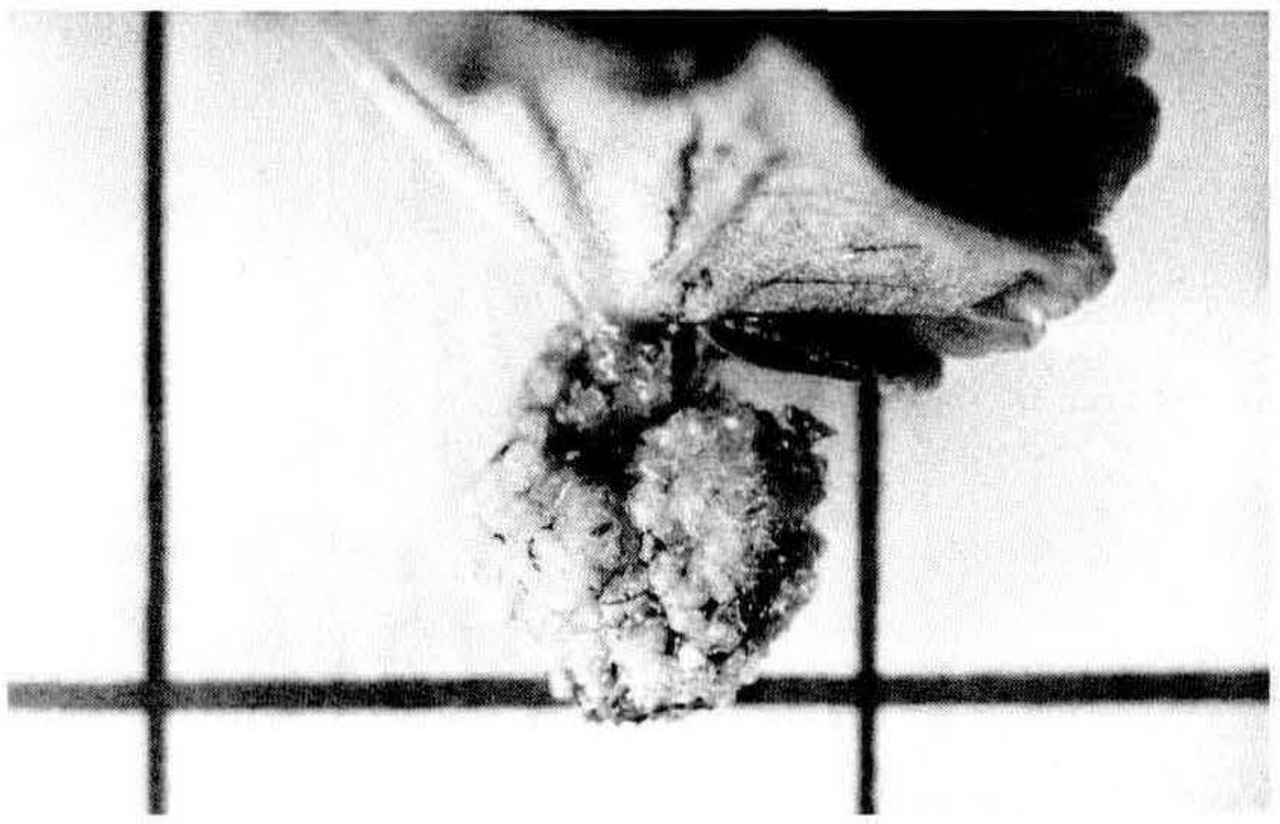

Figure 3. 150 μM PBA. 'Schwabenland Red'. Roots were removed before photograph was taken.

Table 1. PBA at 15 μM. 'Aphrodite Cherry Red' (AR) and 'Schwabenland Red' (SR).

Cultivar	Treatment	% Forming buds	Buds	Wgt of buds & shoots
				(gm)
A.R.	Control	0	0	0
	PBA	58	18.2	0.5
S.R.	Control	92	20.0	2.6
	PBA	100	19.2	1.3
Lsd (0.05)		17	3.9	0.4

Table 2. Optimal duration time for respective PBA concentration. 'Aphrodite Cherry Red'.

Treatment	Time (min.)	Buds	% Buds[1]	Shoots	% Shoots[2]	New green leaves
Control	—	2.6	33	1.3	33	1.0
PBA 20μM	300	7.7	83	9.4	83	4.3
100μM	30	9.3	92	8.1	92	2.3
500μM	10	9.0	92	9.4	83	2.7
1500μM	'Q-dip'	15.0	92	7.8	92	2.5
Lsd (0.05)	5.2	33	3.3	42	1.6	

[1]Percent cuttings which initiated buds.
[2]Percent cuttings which developed shoots.

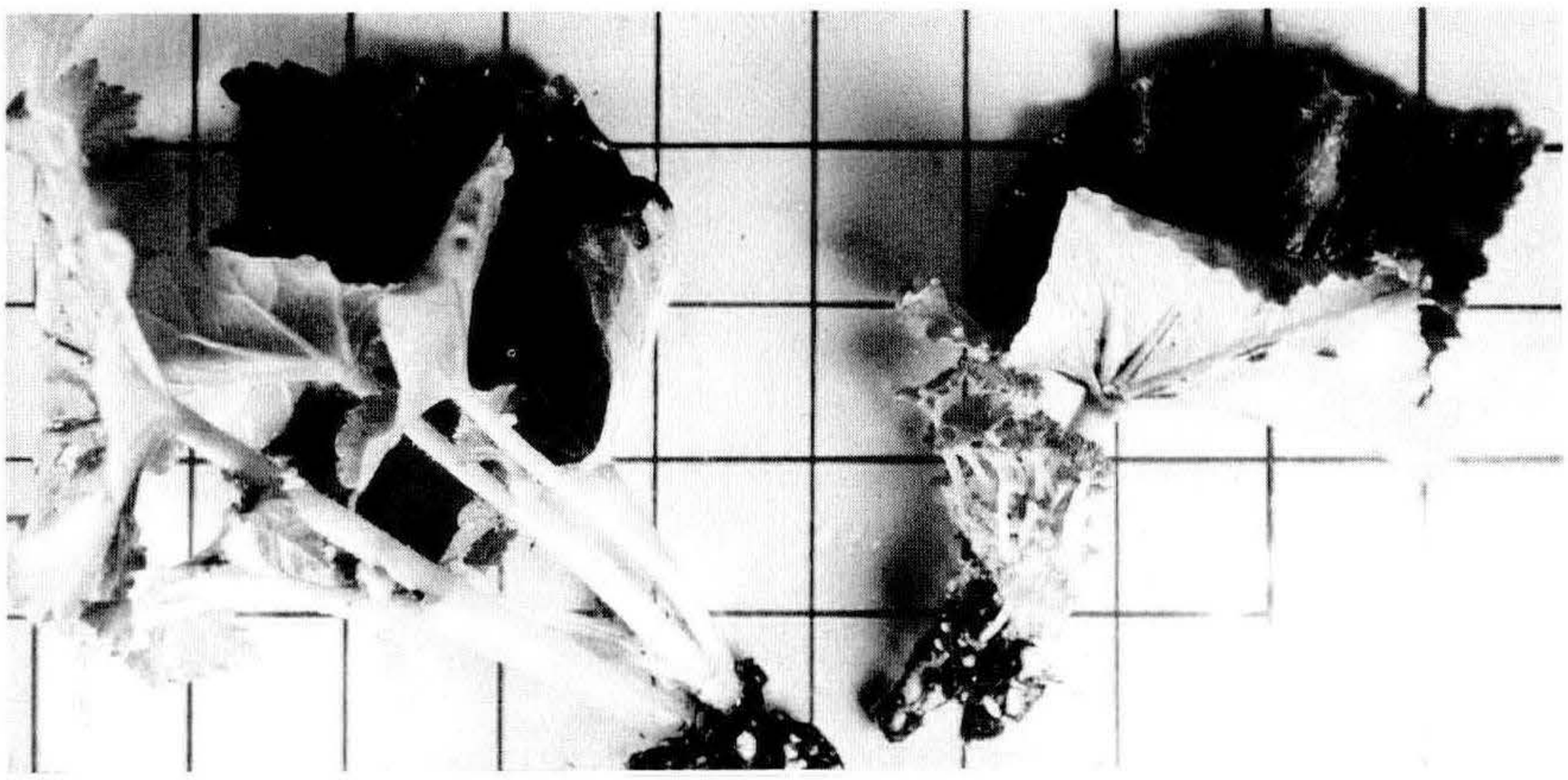

Figure 4. 'Schwabenland Red.' *Left* Control. *Right* 15μM PBA.

Application methods included a basal petiole soak plus a 6-second "quick-dip" treatment, dry talc, and spray applications.

Experiments were terminated 10 weeks after the cuttings were inserted. Data collected included the number of buds, shoots, and new green leaves which developed from adventitious shoots, and weight of buds and shoots. The maximum number of buds which

A more convenient time in employing a basal-petiole soak was via a 6 second "quick-dip." PBA at 4,170 to 12,500 μM was applied to 'Aphrodite Cherry Red'. At the time data was taken (Table 3), 4,170 and 6,250 μM yielded taller, thicker-stemmed, more horticulturally desirable new plants, but when some cuttings were potted and grown on as stock plants, the difference between concentrations was negated in 50 days (Fig. 5).

To determine the critical time period in which cytokinin must be applied to cuttings, 'Aphrodite Cherry Red' was treated with 10, 100, 1000 μM PBA, using a spray application at either 4, 13, or 26 days after insertion of the leaf cuttings. Applying PBA at 4 days after

insertion was superior to either 13 or 26 days in stimulating bud, shoot, and formation of new green leaves (Table 4). When PBA was applied at the 26th day there was no response to chemical treatment.

A talc dip is commercially desirable for applying growth regulators during propagation. Leaf petioles were dipped in talc containing PBA. Responses from the talc dip were consistent with other application methods (Table 5), with PBA at 0.01% stimulating optimal responses (Fig. 6).

DISCUSSION

The results demonstrate that the cytokinin PBA can effectively be applied as a basal-petiole dip, "quick-dip," talc dip, or as a spray.

Table 3. "Quick-dip" application of PBA. 'Aphrodite Cherry Red'.

PBA (μM)	Buds	Shoots	New green leaves	Weight (gm)
0	0	0	0	0
4,170	10.0	11.4	12.8	8.8
6,250	16.7	16.1	15.3	10.7
8,338	15.4	16.3	13.8	9.3
10,420	15.4	16.2	15.9	11.7
12,500	19.2	17.7	15.8	11.2
Lsd (0.05)	3.9	4.3	4.4	3.5

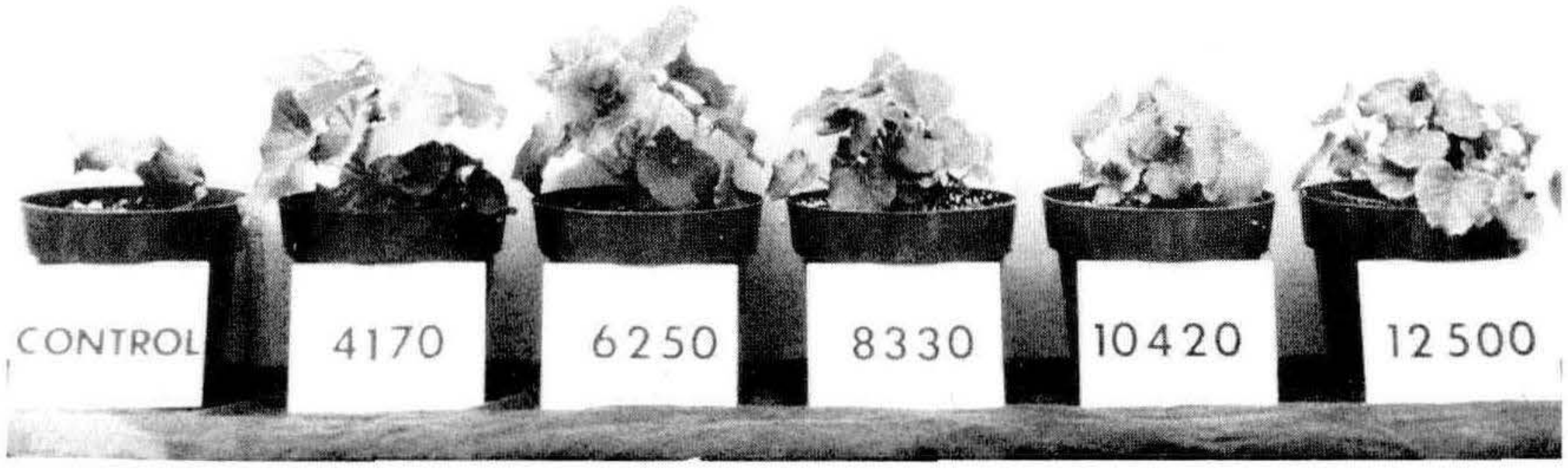

Figure 5. "Quick-dip" application of PBA at 0 to 12,500 μM. 'Aphrodite Cherry Red'.

At a 12-hour basal petiole soak, intermediate levels of PBA (15μM) could effectively stimulate bud and shoot formation in 'Aphrodite Cherry Red'. In 'Schwabenland Red', with increasing PBA concentration shoot development was retarded, as expressed by bud and shoot weight. This would suggest that higher levels of cytokinin:auxin exist in 'Schwabenland Red' vs. 'Aphrodite Cherry Red'. By increasing the cytokinin:auxin level via exogenous cytokinin, a supraoptimal response occurred in 'Schwabenland Red' with a profuse number of buds developing, causing poor shoot development which led to a stunted, less desirable new plant. It became clear that

Table 4. Spray application of PBA at three different intervals after insertion of cuttings. 'Aphrodite Cherry Red'.

Treatment	Buds	Percent Forming buds	Shoots	New green leaves
Control	0.8	17	0.3	0.3
Day #4				
10μM	3.3	17	0.1	0.4
100μM	12.5	100	5.8	4.0
1,000μM	20.0	100	11.7	5.8
Day #13				
10μM	0.8	42	0.6	0.2
100μM	4.1	33	1.5	0.3
1,000μM	11.7	100	8.6	3.9
Day #26				
10μM	0.4	8	0	0.1
100MM	0.8	17	0.3	0.1
1,000μM	2.9	33	0.5	0.2
Lsd (.05)	4.0	22	4.3	3.6

Table 5. Applying PBA with talc as a carrier. 'Aphrodite Cherry Red'.

Percent PBA	Buds	Percent Buds[1]	Shoots	Percent Shoots[2]	New green leaves	Weight (gm)
0	0.4	8	0.7	8	0	0.4
0.001	2.5	25	2.0	25	2.0	1.3
0.003	3.3	50	2.7	50	3.0	2.2
0.01	17.9	100	10.5	100	10.1	8.5
0.03	20.0	100	10.8	100	7.7	3.8
0.1	18.3	100	12.6	100	7.1	2.7
0.3	20.0	100	11.7	92	1.1	2.7
1.0	18.8	100	4.3	67	1.4	2.5
Lsd (.05)	2.8		4.4		4.0	1.9

[1]Percent cuttings forming buds.
[2]Percent cuttings forming shoots.

stimulating large numbers of buds was not desirable from a horticultural standpoint.

The 4th day after insertion was the optimal time to apply PBA via spray; 100 μM stimulated the more desirable results. At the 13th day 1,000 μM PBA stimulated optimal results, while at the 26th day after insertion no concentration of PBA stimulated a response. This would suggest that there is a critical time in which a mechanism(s) must be triggered if optimal bud initiation and subsequent shoot development is to be achieved. High concentration (1,000 μM) of PBA could trigger this process through day #13, but later application proved ineffective. With other species of begonias, investigators

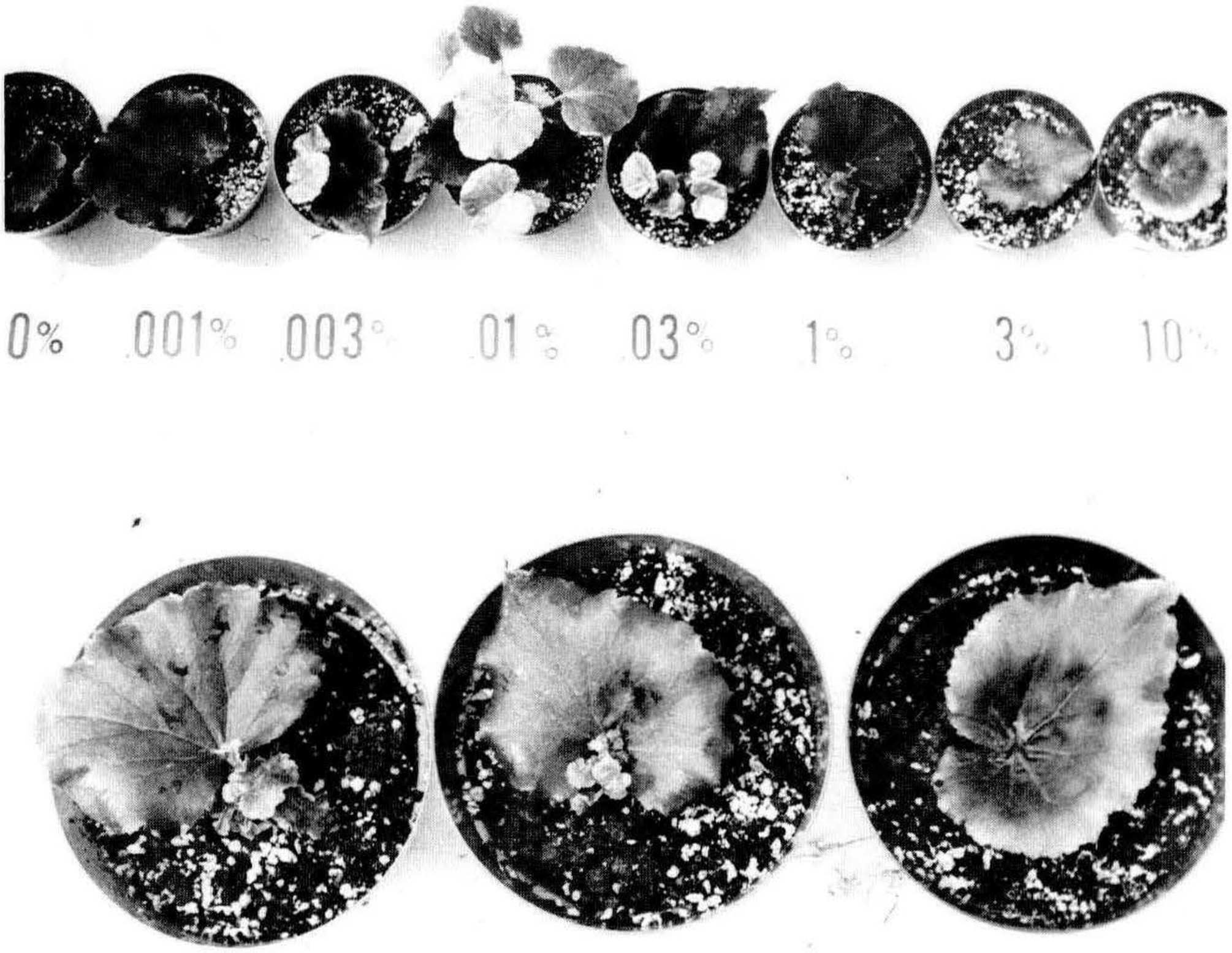

Figure 6. Effect of PBA applied as a talc dip to 'Aphrodite Cherry Red'. *Top:* 0 to 1.0%. *Bottom: left to right:* 0.1%, 0.3%, 1.0%.

(3) have observed that the first 10 to 20 days were critical for bud initiation.

Use of a talc dip is a common method of applying auxins to stem cuttings. However, no attempts have been reported in the literature where cytokinin was successfully applied as a talc in bud and shoot regeneration of leaf cuttings. Responses from the talc dip were consistant with other application methods of PBA.

There are many species where a multi-stemmed plant would be an alternative and/or more desirable form for commercial propagation. With certain species of *Begonia, Peperomia, Saintpaulia,* etc., use of leaf cuttings is the common method of propagation. With other species, leaf cuttings form roots but bud formation is poor or nonexistant. The chemical PBA represents a cytokinin with good mobility, sufficient self-integrity when in the plant system, and/or ability to get to the metabolic site of action. With the good success obtained with PBA in the Rieger begonia system, avenues are opened for testing other species of plants whose propagation by leaf cuttings would be highly desirable.

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QUESTION BOX

This session of the program convened at 3:15 p.m. with Dr. William Snyder and Mr. Charles Parkerson serving as moderators.

MODERATOR PARKERSON: Isn't some caution needed in applying Lasso in polyhouses? This was not brought out in the papers presented at the meeting today.

I reported on problems of using Lasso in polyhouses at the Chicago meeting. This material should not be used in polyhouses because it will kill plants in there. We are still experimenting with it and we don't have any trouble as long as we keep it out of polyhouses.

WAYNE LOVELACE: I know of one instance of the use of Lasso in a polyhouse which effectively put the house out of use for one full year. Lasso was spread on a chat floor and bedding plants were set on this; the crop was a complete loss. Charcoal was used to try to tie up the material but it did no good and crops placed in the house after the bedding plants also were badly affected or completely killed. The plastic had to be stripped from the house and it was 1 year before it could be used again.

BRYSON JAMES: One other comment needs to be made with respect to this compound and that is, if you are using sprayers with PVC valves or piping, you will need to wash them out thoroughly after using Lasso. Lasso or some solvent or carrier in its formulation will dissolve PVC and turn the material to almost a mush; if your sprayer has any plastic parts and you use Lasso in it I would certainly recommend that it be thoroughly washed out immediately afterward.

ED KINSEY: Is there any danger from applying Lasso in the spring and then placing treated plants in a polyhouse in the fall?

BRYSON JAMES: No, the material won't last that long, but I would not apply it in the fall just before moving plants into houses. This material should not be applied within 2 or 2½ months of putting the plants into polyhouses. (There were comments by several members advising the use of EXTREME CAUTION in applying any type of herbicide in or near a closed structure.)

MODERATOR SNYDER: Dave Dugan, are there any materials that will control the black vine weevil?

DAVE DUGAN: Yes there are, but at the moment they are not cleared for use for that purpose. At a meeting with EPA officials which I attended in Cleveland it was brought to the attention of the administrator that one material which can be sprayed on the *Taxus* for control of mealy bugs will also control black vine weevil. A nurseryman asked the administrator why he could not therefore spray this same material on *Taxus* for control of black vine weevil and the administrators reply was "I think we have a problem here."

At the moment that is where the situation stands.

MODERATOR SNYDER: Are eucalypts, in general, subject to blowing over as young trees?

KEITH MACINTYRE: In general, I would say no, but they are subject to root-curl especially when planted into very small pots when they are young. This condition will often persist when potted into a larger container and I have seen trees as much as 30 to 40 ft tall blow over, but when they were checked they all had root-curl.

MODERATOR SNYDER: What is the longevity of seeds of *Eucalyptus gunnii* and *E. camphora* when stored at room temperature?

MARIANNE MACMILLAN: We kept these in glass jars at about 75°F for 3 years with little loss in viability; after that there is a gradual decline. The time and rate of decline is dependent upon the quality of the seed at the time it was collected. In general I would say they should last 10 years or more.

MODERATOR SNYDER: How do you handle *Franklinia alatamaha* from seed?

JIM KAUFMANN: Each flower on the plant forms a seed pod about the size of a marble which turns a dark grey to brown in late October. The pods are harvested and it breaks up into three or four sections with many small seed in it. As far as I know there are no stratification requirements for it. We sow the seed indoors in December in a half sand, half peat mix. Germination is usually good and they must be kept inside during that first winter. Seedling growth is quite variable from 2 to 14 inches for the first year.

I did try some cuttings this year with fairly good results as far as rooting goes; I could not get them to flush again but I understand they can be propagated from cuttings.

MODERATOR PARKERSON: Is *J. c.* 'Hetzii' a satisfactory understock for *Juniperus virginiana* clones?

JOHN ROLLER: *J. c.* 'Keteleeri' is the only one that has given me any trouble on "Hetzii."

ELDON STUDEBAKER: Is there any problem with winter hardiness of 'Hetzii' as a stock? We had 2-yr-old liners in the field, some on 'Hetzii' and some on *J. virginiana* and we lost almost all on *J. c.* 'Hetzii.'

HUGH STEAVENSON: In the milder areas of Canada and up in the northeast 'Hetzii' is satisfactory but in the cold climates up in Minnesota, the Dakotas and the colder areas of Canada you would have to use *J. virginiana.*

MODERATOR PARKERSON: Has anyone succeeded in reproducing woody plants by tissue culture; if so, what plants and who is doing it?

CHARLIE HESS: There is considerable work at the University of California, Riverside by Dr. Murashigi who has a lab that is specialized in the propagation of plants by tissue culture. It is also being done on a commercial basis by George Oki. For information on media and techniques I would suggest you contact Dr. Murashigi or if you want insights as to the commercial application contact George Oki. Bill Cunningham in Indiana is also doing this on a commercial basis using mostly herbaceous perennials. At the moment, I'm not sure what, if any, woody plants are being propagated but they are trying citrus, English ivy, possibly sweetgum, and eucalyptus also.

JOHN ROLLER: I was talking to George Oki and he indicated that they were trying about a hundred different plants. He also told me that in order to do this properly you are going to need an investment of about $50,000.

MODERATOR SNYDER: Has anyone successfully used growth regulators for grafting? The answer to that is if you survey the literature there is usually a negative response from using growth regulators in the grafting operation.

MODERATOR PARKERSON: What is the shelf life of IBA crystals stored under dark, refrigerated conditions?

CHARLIE HESS: I would say 5 to 10 years under the conditions described; however under liquid conditions especially if exposed to light the UV light will break it down rather rapidly. The talc powder formulations should also be relatively stable. If you had some which you wanted to check you could treat a relatively fast-rooting plant, such as chrysanthemum, with some of the old material and some new material to make sure it is responding properly.

MODERATOR PARKERSON: Why must technical papers prepared and presented by our learned members be presented in such scholastic lingo that less scholastic members cannot convert the information received into usable knowledge? Statements such as 0.01 ppm might have more meaning and tried more often if presented as 1 level teaspoon per 10 lbs, or 300 ppm as 1 drop from an eye dropper to 3 oz of water.

I think this is a good point and probably the directions sent out to speakers ought to contain a note to this effect. I know this has often caused me problems in being able to put information immediately to use.

MODERATOR PARKERSON: Have growth regulators been used on root pieces to stimulate vegetative growth?

BILL SNYDER: The auxin type of growth regulators will stimulate the formation of roots on root pieces but will inhibit the formation of buds. This past year we've been working with PBA, which is a cytokinin, and have found that it will increase the bud formation on certain types of root cuttings. We have not gotten too far along

with this work but we are continuing our studies in this area. One problem in working with root pieces is to first establish the buds and then to get roots formed on them. It may well be that we will have to use a sequential treatment to establish whole plants.

MODERATOR PARKERSON: How long can a peat-perlite propagation mix be reused with proper pasteurization before it breaks down?

WAYNE LOVELACE: We have done this for 5 years so far and have found no problems.

MODERATOR SNYDER: Is there any work being done in growing *Eucalyptus* from cuttings?

KEITH MACINTYRE: Fairly good success has been had with *Eucalyptus grandis* by wounding the tree, such as girdling it with a wire, close to the base which forces epicormic shoots which will strike roots. If they arise close to the ground they do not seem to have the inhibitory substance which prevents rooting. Several nurserymen are trying this at present with some success. I think this is particularly applicable to the eucalypts which have lignotubers, which are the swellings just below the soil.

MODERATOR SNYDER: Can *Kolkwitzia amabilis* be propagated by cuttings, hard or soft?

LARRY CARVILLE: We do this from softwood cuttings taken about the middle of June treated with No. 8 Hormex placed outdoors in raised beds with washed sand as a medium and they root quite readily. We take tip cuttings about 4 to 8 inches long with no wounding other than stripping off the lower foliage.

MODERATOR PARKERSON: I would like to graft *Cedrus atlantica* 'Glauca' but can find no understock other than *C. deodara*, which I have been told is not hardy in the north — the root will freeze out after grafting. Is this true?

CASE HOOGENDOORN: Years ago we used to use *Cedrus atlantica* seedlings but we switched to *Cedrus deodara* because it has a much better root system. It may not be as hardy but we have had no trouble and some of these plants are now huge trees in cemeteries and on estates.

MODERATOR PARKERSON: Is there any difference in root structure in light vs. heavy container media which might have substantial effect on transplanting to heavier landscape soils?

HUGH STEAVENSON: I think it is worthy of note that plants grow well in the light-weight mixes but when they are planted out in the heavy soils they don't do well.

BRYSON JAMES: I don't believe there's any difference in the structure of the root; I think the problem to which Hugh is referring has to do with the interface between the light-weight media and the

heavier soil. There is an apparent water barrier which is set up here and the roots just never penetrate out of the lighter weight mix.

GEORGE GOOD: There are some precautions which need to be taken with respect to appropriate backfill and disturbance of the root when planting container-grown materials into a landscape setting. I think some of these things need to be taken into consideration when we sell the plants to the customer so that it doesn't reflect back on us.

DAVE DUGAN: I think we forgot what we learned back in the 1920's, and that is, when you bought plants out of the east in those fine sandy loam soils and planted them into soils which were much heavier you sold the customer a bale of peat to properly amend the backfill. I think we need to go back and look at some of the old literature; the reason it didn't work is you didn't sell them a bale of peat when you sold them the plant; in other words, you didn't sell them the complete package.

MODERATOR PARKERSON: Can paraquat be sprayed over deciduous azaleas and birch seedlings during the dormant season to get post-emergence weed control in these potted materials? I don't think that it can; if the tissue is green the paraquat will kill it.

ARTHUR CARTER: In Great Britain crops get weedy; I don't know why they do, but they do. Having budded roses in 1975, they're headed back in January or February of 1976 and often they are covered with chickweed. Several growers are spraying them with paraquat; I would never recommend this but they are doing it and getting away with it. This practice is happily accepted by some rose growers there.

I would also like to comment on glyphosate. It should be used only prior to planting, not when there's a crop in. In tests where drift has occurred the azaleas looked all right the first year but the second season some of the new growth formed a rosette instead of growing on. This same sort of damage has occurred on black currant and strawberries.

We grow our containers on sand on poly. Normally paraquat had been used to clean the weeds out of the sand but when glyphosate came out we tried it and conifer roots picked up the glyphosate from the sand. This was surprising because it is supposed to go in through the green portion of the plant but in fact it was picked up by the roots and we had damage 2 years in a row.

MODERATOR SNYDER: Does anyone do any storage of rooted or unrooted cuttings for an extended period of time? If so, have you seen any beneficial or adverse aspects from your procedure. If not, do you have any suggestions for why one might want to store cuttings. I am a graduate student working on storage and would like some grower input for my research.

LARRY CARVILLE: I talked to this student and he is working up a project on vacuum storage for nursery stock and he feels the

minimum investment for this type of equipment would be about $60,000. I told him that we and several other nurserymen on the island do store fresh and rooted cuttings but we store them in a different unit than the type he intends working on. Perhaps we might have some comments on storage techniques at this time.

WAYNE LOVELACE: We store deciduous cuttings bare-root in poly bags at about 34°F with no trouble at all.

DAVE DUGAN: We take *Taxus* cuttings out of the bench in February and place them into poly bags with just the tops sticking out and store them in an apple storage. I have been concerned with how far we can extend this with the apples in there because of the ethylene gas that is evolved. I would like to know if anyone has had any damage under similar conditions.

ARTHUR CARTER: About 3 years ago there was some work at East Malling in which they stored apple rootstocks along with apple fruits and, as a result, the stocks were seriously damaged even though they were in a dormant condition. As a result we do not recommend storing any type of plant material with apples.

MODERATOR PARKERSON: At Tulsa last year we saw workers at some of the nurseries making cuttings as rapidly as they could and putting them into coolers with sticking being done during February and March. They said this was standard operating procedure for them because they like the condition of the wood in December and January.

MODERATOR SNYDER: How can one get more than one flush of growth per year on *Euonymus alatus* 'Compactus', spruce, and pines? Can photoperiod, cold treatment, gibberellic acid, or chemical defoliants on deciduous material be used to stimulate more than one flush per year?

JOHN ROLLER: I tried getting an extra flush of growth on *Euonymus alatus* 'Compactus' by putting them in a polyhouse which I could heat. I applied intermittent lighting during the night but I don't believe I kept them cold long enough before heating because what I did was to prevent growth next spring.

LARRY CARVILLE: I think all of us see this when we take softwood cuttings of euonymus, forsythia, weigela, etc. and put them under mist; they root and while you're hardening them off under the mist they make a flush of growth. It is a weak flush but it is a flush, nevertheless. Dr. Tukey was attempting to stimulate us into thinking along these terms of extending the growth period by regulating the natural factors to which a plant responds.

MODERATOR SNYDER: With many woody plants the cessation of growth is controlled by photoperiod. One of Dr. Moser's students has shown that this stoppage of growth may start as early as July in some species and last as late as September with others. Once photo-

period has brought on dormancy, additional light will not induce the plant to grow more until it has had a cold period. There are some plants, of which I believe euonymus is one, which if they are growing in long days and are switched to short days they will stop growing but when changed back to long days they will start up again; many other plants will not do this.

ARTHUR CARTER: A few years ago we investigated the effect of leaf removal on the growth of black currant the subsequent year. We were interested in this from the standpoint of a mechanical harvester. We normally harvested the plants in July and to stimulate this we removed all the leaves, half the leaves, half of each leaf, etc. and we found that where we took off all of the leaves the plant became confused and was flowering at Christmas time. I think this would be analogous to the use of defoliants which was suggested in the question. We also did some of this with roses and if we defoliated too early the plants broke growth in September.

CASE HOOGENDOORN: Several years ago we had a hurricane in September and I had a bed of 2-yr-old grafted Japanese maples and they lost all of their foliage. Shortly after that they threw a flush of growth and people visiting the nursery commented that they didn't look like they were hurt at all but I said wait until next spring and they'll all be dead. When spring came I was right — they were all dead.

ED KINSEY: We grow *Euonymus alatus* 'Compactus' in containers; it has been an expensive plant to grow because it takes about 3 years before it is ready to sell. If it were possible to defoliate it in early summer and get a strong flush of second growth, perhaps it would be economically feasible to carry it over in a heated polyhouse and have it ready to sell sooner. This may also be a possibility with pines and some other plants; I think some research is needed in this area.

LARRY WATSON: In Colorado the Forest Service has an intermittent lighting program to promote growth. Pine and spruce grown in this manner for 2 years is giving them fantastic growth. The spruce were 2 to 2½ ft and we are then set out the following spring. They were also beginning to do some work with lilac and other deciduous materials; this may prove to be a fruitful avenue.

MODERATOR SNYDER: I did some work in growing some of the woody ornamentals under continuous long day conditions without a cold period with the possibility of using them indoors for interior decorating and design. One of the plants we were using was Atlantic cedar and, under short-day conditions they stop growing almost immediately; under long day conditions they keep on growing continuously. Some continued to grow on into the third year. Within 1 year the terminal buds and the branch buds of the short-day plants died and the plant died from the top to the bottom. After 3

years of growth under continuous long-day conditions these plants also stopped growing and began to die from the tip back also. As a word of caution, you can't continuously grow some of the plants which have a cold period requirement.

TOM MCCLOUD: We had an experience with rooting hardwood cuttings of *Euonymus alatus* 'Compactus' late in the year; they rooted readily and we potted them but it was too late to put them outside so we put them in the greenhouse. They did not grow by spring so we set them in a coldframe and they sat there all year without growing. They did not grow until the following spring after having gone through the winter cold period; they did break and grow fine after that.

GEORGE GOOD: The work of Dr. Tukey's students with this plant showed that the only thing which was reliable to cause it to break growth and grow normally was to subject it to about 8 weeks of cold temperature.

MODERATOR SNYDER: One of my students found that they did require a cold treatment before they would start to grow and up to a certain point the longer the cold treatment the more growth you would get, not only in number of plants breaking but in the amount of growth that would occur. Up to about 659 hours you would get an increase in growth, depending upon hours of cold, but beyond that there was no additional benefit. He used a number of plants and all of them did not require the cold treatment; some of them required only defoliation. So there are all sorts of combinations and you cannot take what occurs with one plant and apply it directly to another.

If there are no other comments, we have come to the end of the questions and both Charlie and I thank you for your participation in it.