PHASIC DEVELOPMENT AND PHYSIOLOGICAL CONDITIONING IN THE ROOTING OF DOUGLAS FIR SHOOTS

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Timing the taking of cuttings of woody species to coincide with their achieving maximum rooting potential is still one of the goals of propagation research. Determining the physiological status of the stock plant and/or its cuttings at these optimum periods for root regeneration and developing means of physiologically conditioning the shoot before and during the rooting process are providing refinements in vegetative propagation techniques.

The rooting potential of Douglas fir stem cuttings has been correlated with distinct phases of development, both in source tree aging (11) and in annual shoot periodicity (9). Even phases of adventitious root initiation and development after cutting excision respond to specific stimuli (12).

THE STOCK PLANT

Aging and flowering. The loss of rooting potential of cuttings with increasing plant age in many species has been attributed to phase changes during the transition from juvenile to adult. Black (3) found that cuttings from juvenile Douglas fir seedlings under 9 years of age had the potential for rooting 100 percent, but that there was a rapid decline in rootability after this age to less than 5 percent between ages 14 and 24 years, the implication being that the loss in rooting potential coincided with vegetative maturity and the onset of flowering. However, he found little or no difference in cutting rooting potential in different crown levels of trees up to 24 years from seed, as would be expected if the transition from juvenile to adult was progressive from the base of the tree upward. Achterberg (1) reported that Douglas fir cuttings from the lower parts of the crown rooted best. Roberts and Moeller (11) found no reduction in rooting potential of Douglas fir shoots from seedlings up to 15 years of age, at which time they were considered to have reached vegetative maturity since 4 out of 14 trees had been cone bearing for 3 years. However, the cuttings were always taken from the lower one-third of the crown which was possibly juvenile in character.

1978 Experiment. Cuttings from the above mentioned trees were again taken in January, 1978, to determine any change in

rooting potential with advancing age and/or increased flowering and cone production. Instead of taking all the cuttings from the lower crown level, 40 cuttings were taken from the lower, mid, and upper one-third of the crown of each of the 14 seedlings. The cuttings were given a standard 5 sec. dip in a 10% Dip 'n Grow- 95% ethanol solution (Dip 'n Grow is a commercial preparation containing 1.0% 3-indolebutyric acid, 0.5% naphthaleneacetic acid, 0.0175% boron, 0.1% Phygon (Dichlone), and 20 % methyl sulfoxide (DMSO)). Twenty cuttings from each crown level were rooted under open-bench misting and another 10 under poly-tent fogging.

RESULTS AND DISCUSSION

The average rooting percentage for cuttings taken from the lower crown level of these trees during their 12th-16th year are given in Table 1 along with the approximate number of cones produced by each tree in 1978. Rooting potential of shoots in the lower portion of the trees did not change significantly over the first 16 years of their existence, although all but 3 of the trees are now producing cones and 4 have produced cones for the last 4 years. However, it appears that the rooting potential of cuttings out of the upper two thirds of these trees is significantly less than in the lower one-third (Table 2). We have no record of when this position advantage developed. It is evident, however, that some trees in the population exhibit this relationship more strongly than others, and that it is not dependent on cone production for expression. This would suggest that loss in cutting rooting potential in Douglas fir with increasing source plant age is not dependent on flowering, cone production or loss of juvenility *per se*, but rather other factors related to physiological maturity. It would appear also that this loss in rooting potential is localized somewhat in certain parts of the tree. This would seem to provide evidence that juvenility persists in the lower parts of the tree, except that many of the cones on the heavy bearing seedling 33 were on the lowest branch whorl and near the ground.

Physiological conditioning. Manipulating the stock plant environment and/or otherwise physiologically conditioning the source plant with chemicals or physical treatment have been used to enhance cutting rootability in a number of species. Light and temperature modifications, as well as feeding organic and inorganic nutrients prior to cutting excision have had significant effects on subsequent rooting. Shoot girdling is another example of attempts used to control movement or accumulation of rooting factors at rooting sites. Whether cuttings are taken when the growth phase and environment interact to produce shoots of high rooting potential, or the stock plant is artificially

manipulated to bring about the optimum physiological condition for rooting, it appears that stock plant treatment may be more effective or at least as effective as cutting treatment in bringing about root regeneration in cuttings (4).

Table 1. Changes in rooting potential (rooting percentage) of Douglas fir cuttings with increasing age of source trees and onset of flowering. Cuttings taken from lower crown level.

Seedling	Tree Age in Years				
	12	13	14	15	16
22	—%	100%	85%	65%	85%
30	100	100	55	87	95*
31	—	95	80	68	83
32	—	100*	50	79	100
33	90	75	55	78	85
34	90	80	80	87	85*
35	100	45	35	60	73*
36	25	10	40	49	30*
37	85	55	50	46	80*
38	65	75	60	68	73*
39	—	25	50	81	37*
106	85	45	80	59	53
107	80	85*	95	66	95
109	25	5*	5	32	15
Average	75	64	63	66	71

* First year of cone production.

Table 2. Effect of cutting source (crown level) on rooting potential of Douglas fir stem cuttings from 16-year-old trees, 1978

Seedling Number	Crown Level			Number Cones/Tree
	Upper ⅓	Middle ⅓	Lower⅓	
22	63%	95%	85%	0
30	83	78	95	17
31	60	48	83	0
32	40	55	100	625
33	65	60	85	540
34	53	75	85	90
35	58	40	73	1
36	18	35	30	150
37	73	47	80	7
38	63	85	73	1
39	45	35	37	300
106	35	65	53	0
107	60	50	95	425
109	3	5	15	360
Average	51%	53%	71%	

Means of 2 replications of 20 cuttings each or total of 560 cuttings per source.

Whitehill, *et al* (13), working with *Pinus sylvestris*, demonstrated that rooting potential of cuttings was determined largely by growth phase of the stock plant. He found stock plants subjected to short days (SD) and cold stored for 60 days at 0°C be-

fore excision and then rooted under a 17-hour photoperiod (LD) rooted significantly better (85%) than those under LD (5%) and actively growing at time of excision and cold stored. Rooting *Ilex crenata* 'Hetzii' cuttings was improved by increasing the number of SD given the stock plants during the summer growing period over that of stock plants under LD (6). The opposite results have been obtained with *Salix undulata* (7) and *Populus canadensis* (8), where LD treatment of stock plants has favored the subsequent rooting of cuttings.

1970 Experiment. To determine the effect of stock plant lighting on the rootability of shoots subsequently used for cuttings, trees of several Douglas fir clones were moved into growth chambers for two months under continuous, 16-hour (LD) or 9-hour (SD) illumination. Two trees of each cultivar were given the three light regimes. During the first 5 weeks the air temperature in the chambers was 5°C both day and night and the light intensity during the light periods was 1186 $\mu\omega cm^{-2}$ nm^{-1}. Ten shoots to be used as cuttings were girdled at the future cutting base to determine if rooting factors would accumulate above the girdle and favor subsequent rooting. The 10 girdled cuttings and 10 not girdled were taken from the trees at the end of 5 weeks, given a standard 5 sec dip treatment in 10% Jiffy Grow- 95% ethanol solution (Jiffy Grow is a commercial preparation containing 0.5% 2-naphthaleneacetic acid, 0.5% 3-indolebutyric acid, and o.0175% boron), and rooted under open-bed intermittent misting with 21 ± 3°C bottom heat, in a 5:1 (volume) washed sphagnum moss peat mixture. Room temperature was near 10-15°C.

During the second 4-week period, the air temperature was raised to 15°C and held constant where lighting was continuous. The air temperature for the SD and LD treatments was 10°C during the dark period and 15°C during the light period. Ten cuttings from girdled and non-girdled shoots were again taken for rooting tests. Rooting percentage was determined after 120 days in the rooting bench.

RESULTS AND DISCUSSION

The data presented in Table 3 suggests that stock plant lighting can significantly affect the rooting potential of cuttings subsequently taken from these plants. However, further study is needed to determine whether this rooting response is a photoperiodic one or related to photosynthesis and net assimilation or other physiological processes. The results are similar to those obtained by Whitehill (13) with *Pinus sylvestris* and Kelly (6) with *Ilex crenata*. It is interesting in these experiments, as well as our own, to note that the stock plant SD treatment enhanced

the rooting of cuttings taken from these plants, while it has been established that LD or additional light favors rooting of cuttings after excision and during the rooting process in Douglas fir (2). We have never been able to establish a consistent rooting response from girdling in this species.

Table 3. Effect of stock plant lighting and shoot girdling on rooting of Douglas fir stem cuttings excised from these plants after one month's treatment, 1970.

Period I. Air temp. 5°C day and night, Jan. 6-Feb. 14. Light intensity 1187$\mu\omega cm^{-2}$ nm^{-1}.

	Lighting Regime					
Clone 40	Continuous		16-hours		9-hours	
Replication	Girdled	Not-girdled	Girdled	Not-girdled	Girdled	Not-girdled
1	0%	8%	40%	60%	80%	100%
2	0	0	60	20	100	80
Av.	0	4	50	40	99	90

Period II. Air temp. 15°C with continuous lighting and 10°C during dark period and 15°C during light period for long and short day treatment, FEb. 14-Mar. 14. Light intensity was 2723$\mu\omega cm^{-2}$ nm^{-1}.

	Lighting Regime					
Clone 40	Continuous		16-hours		9-hours	
Replication	Girdled	Not-girdled	Girdled	Not-girdled	Girdled	Not-girdled
1	0	0	0	60	40	100
2	0	0	20	40	40	60
Av.	0	0	10	50	40	80

THE CUTTING

Shoot's seasonal periodicity and rooting. The shoot apex of Douglas fir is characterized by a remarkable growth periodicity. The close relationship of this periodicity to the rooting potential of stem cuttings has been established (9). No treatment has been effective in rooting Douglas fir cuttings during maximum bud dormancy (rest) which coincides with the cessation of initiatory activity of the apex (10). Cutting rooting potential increases progressively in the shoot from this peak of rest (based on speed of bud break) to a maximum in January and February when the chilling requirement of the buds has been fully met. At mid-rest (November) the shoot has reached the physiological-morphological state at which exogenous auxin treatment will promote rooting of excised cuttings. At the end of rest (January) cuttings will root in fair percentage without added auxin.

Rooting environment. Within limits rooting can also be enhanced by environmental manipulations during the rooting process. Responses to rooting temperature, photoperiod, light energy, misting, aeration have been reported for a number of

species of woody plants and the requirements are quite specific for a given species. A number of these treatments have been used with Douglas fir to change the physiological status of the cutting during rooting and thus further enhance rooting percentage and quality of roots. Bhella and Roberts (2) found that an 18-hour photoperiod (LD) significantly increased cambial activity, rooting, bud respiration, and also hastened bud break of stem cuttings as compared with similar cuttings propagated under a 9-hour photoperiod (SD). Rooting response was modified by stage of rest at which the cutting was taken and by the temperature of the rooting medium. Daylength response was greatest in December. Optimum rooting temperature was 26°C during early rest (September-November) but shifted to 18°C toward the end of rest (December-January).

1974 Experiment. It appeared in Bhella and Roberts' experiments that the LD enhancement of rooting was related to rest, because cuttings taken from September 15 to December 15 initiated significantly more roots under LD than SD, but those taken at the end of rest (January 15) showed no response to photoperiod. Since this was considered an important point in elucidating the nature of the LD effect on rooting, we essentially repeated Bhella and Roberts' experiment in 1974 taking cuttings in October, December, and January for rooting. We are reporting here only the results for cuttings taken in January.

Cuttings from clones 45, 48, 111, and 150 were taken on January 24 from the field and given the standard cutting treatments reported earlier in this paper. After treatment, 10 cuttings of each cultivar were placed in growth chamber rooting trays (2) maintained at 10°, 16°, 21°, and 27°C rooting temperatures. On series of trays were placed in a growth chamber under LD conditions (18-hour photoperiod with light intensity at 8 klx or 750 ft-c) and another in a chamber under SD conditions (9-hour photoperiod at 16 klx or 1500 ft-c). Half of the cuttings were harvested at the end of 120 days to determine rooting percentage. At that time the air temperature in the chambers was raised from 10°C to 16°C for the next 80 days, after which the remaining cuttings were harvested for evaluation of rooting. These results are presented in Table 4.

RESULTS AND DISCUSSION

Contrary to Bhella and Roberts' earlier results, there was increased rooting in this experiment with LD or increased lighting even after rest (January) and this has been verified more recently by Haugh (5), who has also demonstrated that it is not a photoperiodic response but one related to light energy levels and carbohydrate status in the cutting. As observed by Bhella,

Table 4. Effect of daylength and rooting temperature on rooting percentage of Douglas fir stem cuttings after 120 and 200 days in rooting trays. 1974.

Series 1. 1/24 - 5/24, 10°C air temp., 120 days in rooting tray.

	Cutting base temp.							
	27°C		21°C		16°C		10°C	
Clone	SD	LD	SD	LD	SD	LD	SD	LD
45	0%	0%	30%	20%	20%	20%	0%	0%
48	0	0	0	50	0	10	0	0
111	0	20	10	30	0	20	0	0
150	0	10	0	30	0	20	0	0
Av.	0	7.5	10	33	5	18	0	0

Series 2. 1/24 - 8/14, 10°C air temp from 1/24 - 5/24 and 16°C from 5/24 - 8/14; 200 days in rooting tray

	27°C		21°C		16°C		10°C	
Clone	SD	LD	SD	LD	SD	LD	SD	LD
45	0%	0%	0%	10%	30%	90%	0%	40%
48	0	0	40	10	10	60	0	0
111	0	0	10	10	10	90	0	10
150	0	0	20	30	10	40	0	0
Av.	0	0	18	15	15	70	0	13

the rooting response to lighting in this experiment showed an interaction with rooting temperature.

One should not try to explain what physiological changes are taking place with such environmental manipulations without in-depth studies, but they do illustrate what can be done in conditioning cuttings during the rooting process. Hansen, et al. (4) and Haugh (5) have shown that carbohydrate status and carbohydrate-auxin balance may be the mechanisms by which increased light energy increases root initiation and development in the cutting bench.

CONCLUSIONS

Evidence continues to accumulate that the current season's shoot, that we excise for vegetative propagation of woody species, has a predetermined potential for rooting that may far outweigh any after-the-fact chemical stimulant we might give for predisposing it to root. The shifting physiological balances occurring during stock plant aging and in the seasonal periodicity of shoot development seem to have controlling influence over root regeneration potential. Our ability to identify the morphological stages and the physiological status of these shoots at time of maximum rooting potential and to manipulate the stock plant and cutting toward these optimum balances is one of the challenges of propagation research. When we fully understand these developmental stages and how to physiologically condition them, then we will be in a position to produce

two or three generations of rooted cuttings a year in growth chambers as an assembly line.

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ROOT REGENERATION OF EVERGREEN PLANTS

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Abstract. The root regeneration potential of 6 species of bare-rooted conifers and broadleaf evergreens was studied in raised sawdust beds under natural conditions at Corvallis, Oregon. All plants were successfully rooted; how-

ever, a definite seasonal periodicity in rooting was found for all species studied except for *Prunus laurocerasus* 'Otto Luyken' which rooted relatively well throughout the sampling periods. All species rooted well during the July harvest period, and all but *Rhododendron* 'Mrs. G.W. Leak' and *Picea jezoensis* rooted well at the December harvest date. Generally, poor rooting was found among most species between the August through November harvest periods. Auxin and night interrupt with incandescent light treatments did not influence the rooting pattern. Root regeneration was significantly reduced in the 6- and 8-year-old versus the 4-year-old *Abies procera* plants, but n o difference in rooting was found among 4- and 6-year-old *Picea pungens* plants.

INTRODUCTION AND LITERATURE REVIEW

Relatively large evergreen plants are "balled-and-burlapped" at harvesting to insure maximum transplanting survival. This practice is costly, time consuming, and requires skilled labor and/or expensive equipment. The work involved is heavy and difficult, making it unattractive to laborers which has resulted in nurserymen having difficulty in obtaining the required personnel. If this situation continues, nurserymen must either find a better alternative to produce these plants, or harvest them by a less expensive procedure. Because of this problem, the primary objective of this study was to determine whether bare-rooted evergreens could regenerate new roots under the natural conditions of Corvallis, Oregon.

Generally, it is agreed that root regeneration following harvesting is necessary for transplant survival (43). Failure to produce new roots results in a retardation of plant growth or even death. Because of this fact, one of the criteria for this study was to determine whether it was possible to regenerate new roots from bare-rooted evergreens.

From literature, there is general agreement that the important factors influencing root regeneration are the physiological condition of the plant at harvesting and the environment to which the plants are exposed during the root regeneration process. It is well known that rooting of transplants are periodic, and the exact nature of this periodicity in rooting is unclear (2,14,15,24,25,26,41,42). Most researchers believe that periodicity arises as a result of two low temperatures, moisture stress, poor aeration, and low light intensities (10,11,17,21,27,28 31,34). Others, however, believe that periodicity is caused by the physiological status of the plant (14,24,25,26,41,42).

Of the environmental factors, temperature, moisture, aeration and light intensity were found to be most important for root generation. Generally, relatively warm soil temperatures (1,12,17,22,27,28,43), prevention of water stress (11,12,14, 31,32), good soil aeration (18,19,29,30,35), and relatively high light intensity (7,20) are beneficial to rooting.

Physiologically, the plant's age and developmental status

are important in the root regeneration of transplants. The influence of tree age on root regeneration potential is not well understood. Most of the reported work has been done on plants less than 3 years of age. Generally, the older the plant, the less root regeneration potential it has, and thus the greater the risk of transplanting.

There is good evidence suggesting that the observed seasonal periodicity in rooting is a result of the physiological status of the plant at the time of harvesting and during the rooting period. Some researchers believe that roots become dormant and in this physiological condition rooting is nil (16). Others do not follow this belief and claim that root growth can occur at any time (10,11,13,17,21,27,28,31,34,37).

Recently, Veerkamp (unpublished data) at Oregon State University and others (40,41,42) have reported that seasonal periodicity in root regeneration does occur in conifers. Plants harvested at periodic times throughout the year and transplanted under several controlled controlled environmental conditions suggest that rooting was best after January until spring growth began at which time rooting dropped slightly. After the spring vegetative flush of growth ceased, rooting potential again increased for several weeks. Later, during the summer and fall period, rooting was nil or very poor. The fact that the environment during the rooting period was kept constant throughout the sampling period suggests that the physiological status of the plant at harvesting was important in regeneration of new roots.

Attempts to explain the rooting periodicity on the basis of the chemical makeup of plants were not well established. Nutritional (3), carbohydrate and hormonal (4,5,6,33,34) relationships have been associated with the potential of root regeneration.

Physical methods to increase the root surface area prior to transplanting is commonly done and generally this procedure improves transplanting survival. Undercutting, root pruning, and wrenching practices are designed to provide planting stocks with compact, fibrous root systems with low shoot/root ratios (9,23). In such situations, as much as 50% of the root system may be severed without causing detrimental effects to the growth and transplantability of most plants studied (9,23,38).

Another factor that should be considered in root regeneration studies is the differences that may exist between different genetic materials. Although this is considered to be important, little research has been designed to show this relationship.

In order to partially satisfy the primary objective mentioned earlier, the following experiments were designed to determine whether 1) it is possible to regenerate roots from bare-rooted evergreen plants under natural conditions in Oregon, 2) the age

of plants influences rootability, and 3) different plant types have similar root regeneration potentials.

MATERIALS AND METHODS

The plants used in these studies were dug with shovels and the majority of the soil remaining on the root system was removed by vigorous shaking. They were then placed in an open pickup bed, watered, and transported to the rooting area (approximately 2 hours away, Portland and vicinity to Corvallis, Oregon. At Corvallis, the roots were immediately washed of remaining soil with a high pressure water stream, root pruned to approximately 25 cms, and transplanted into approximately 1-year-old Douglas fir, *Pseudotsuga menziesii*, sawdust contained in a 8 m × 4 m × 50 cm raised bed. The plants were then watered manually until the sawdust was completely soaked, after which time an automatic irrigation system was turned on for 5 minutes every 2 hours between 6 am and 6 pm. Low angle pulsating Rainbird sprinklers with a 7/64" orifice were placed 2 meters above the top of each corner of the raised bed. Each sprinkler watered a 90° area from one side of the raised bed to the other side. Preliminary testing by spacing 250 ml beakers spaced 1 meter apart throughout the surface of the sawdust suggested that the distribution of water throughout the area was relatively equal.

Three separate experiments were conducted. In the first study, the objectives were to determine the relationship of harvest dates, auxin, and night interrupt treatments on root regeneration of bare-rooted evergreen plant. To answer these objectives, twenty each 7-year-old *Picea jezoensis* unpruned seedlings were bare-rooted on 7-19-71, 8-20-71, 9-21-71, 10-27-71, 12-8-71, 2-25-72, and 3-21-72. On each sample date, the plants were cleaned and root pruned as described previously and divided equally into the following treatments: 1) control (C); 2) 4 hr night interrupt (NI) between 10 pm - 2 am with incandescent light providing approximately 63 $\mu w/cm^2$ of irradiance; 3) roots sprayed until run-off with a 10% Jiffy Grow treatment. The plants were transplanted into the sawdust beds, and 3 months later the data on new root development were determined.

The second study was designed to determine the relationship of harvest dates on rootability of 3 broadleaf evergreen plant species, *Rhododendron*, 'Mrs. G.W. Leak' (8-years-old from cuttings); *Prunus laurocerasus* 'Otto Luykens' (5-years-old from cutting); and *Mahonia aquifolium* (4-years-old from cutting). Forty plants of each species were harvested on 7-19, 8-8, 8-29, 9-19, 10-10, 10-31, 11-21, and 12-12-73. The numbers of new roots produced were determined 3 months after planting in the sawdust beds.

The objectives of the final study were designed to determine the relationship of harvest dates and age on root regeneration of 120 *Abies procera* (4-, 6-, and 8-years-old) and 80 *Picea pungens* (4- and 6-years-old) seedlings. Plants were harvested on 7-10, 7-31, 8-23, 9-12, 10-1, 10-22, 11-12, and 12-3-73, and placed in the sawdust beds for 3 months before determining the number of roots produced.

The temperature 75 cm and 2.5 cm above the sawdust surface and 25 cm within the sawdust bed was monitored with a Weather Measure thermograph from September 15 to December 9. The daily maximum and minimum temperatures were plotted (Figure 1).

The data were analyzed statistically by analysis of variance and the difference between the means was determined by Snedecor's planned comparison test (39).

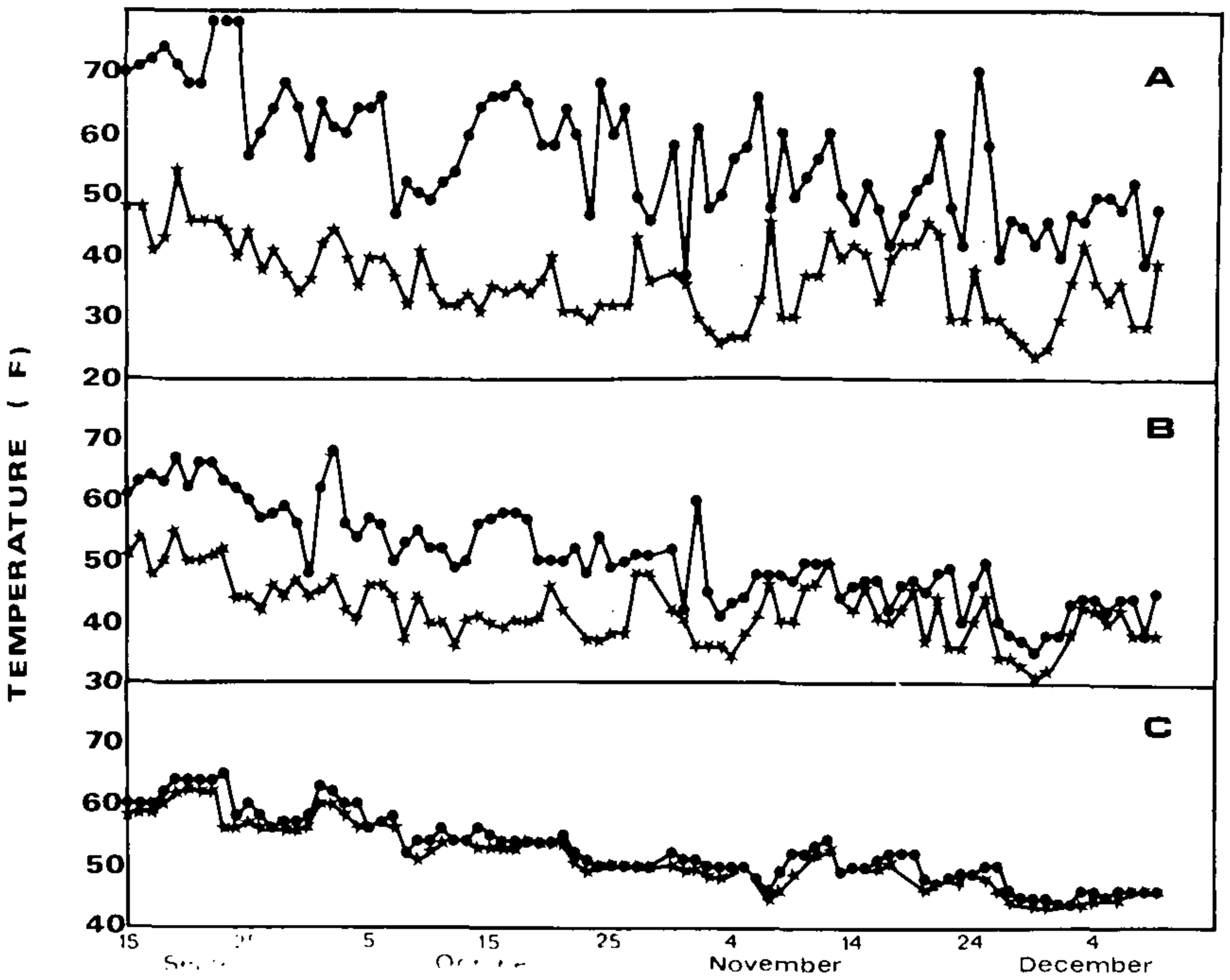

Figure 1. Daily maximum and minimum temperatures (°F) at 3 positions: A. 75 cm above the sawdust, B. 2.5 cm above the sawdust, and C. 25 cm below the sawdust surface.

RESULTS AND DISCUSSION

Seasonal periodicity in root regeneration was established for nearly all plants studied (Figures 2,3,4). The only exception occurred in *Prunus laurocerasus* 'Otto Luyken' which regener-

ated new roots relatively uniformly throughout the sampling period (Figure 3). In all other plants studied, generally good regeneration of roots occurred in plants sampled during July. In addition, *Abies procera*, *Picea pungens* and *Mahonia aquifolium* rooted well in the December sampling period. Generally, these results are in agreement with those reported by others. One exception to previous findings is the consistently good rooting observed on all plants studied during the July sampling date. Prior studies have shown this to be a poor time for root regeneration to occur. Although an explanation for this difference is not possible, we do know that the plants and the environmental conditions studied were different from those used by others. The fact that all the plants rooted well during the July sampling period suggests that the environment could be a

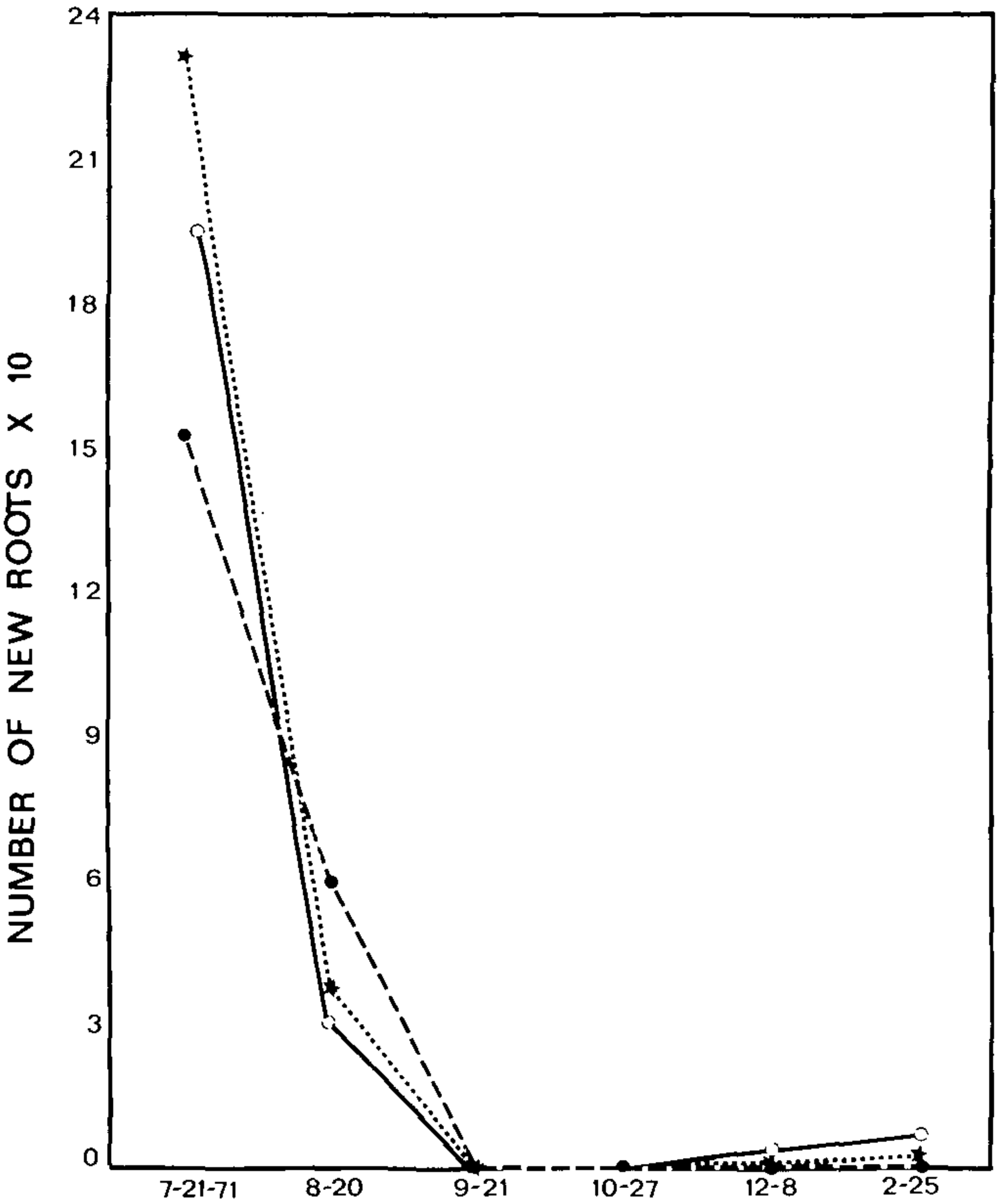

Figure 2. Numbers of new roots produced on 7-year-old seedling of *Picea jezoensis* transplants treated with either 1) 10% Jiffy Grow (★-----★), 2) 4 hrs night interrupt (○——○), and 3) natural conditions (●——●) at 6 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed.

primary factor responsible for the good rooting. In Oregon, this period usually has warm temperatures and high light intensity. These factors, in addition to good aeration (provided by the sawdust beds), and adequate water to reduce water stress (over-
head irrigation) are considered to be important environmental factors essential to root regeneration (1,7,8,11,12,14,17, 18,20,22,27,28,29,30,31,32,35,36,37,43). The explanation for the results at the other sampling periods could be due either to the unfavorable environmental or physiological conditions.

The relatively good regeneration of roots observed throughout the sampling period in *Prunus laurocerasus* 'Otto Luyken' suggests that its root regeneration potential is less sensitive to either environmental or physiological influences as compared to that of the other plants studied. This finding is an exception to that reported by others (16,41,42,43).

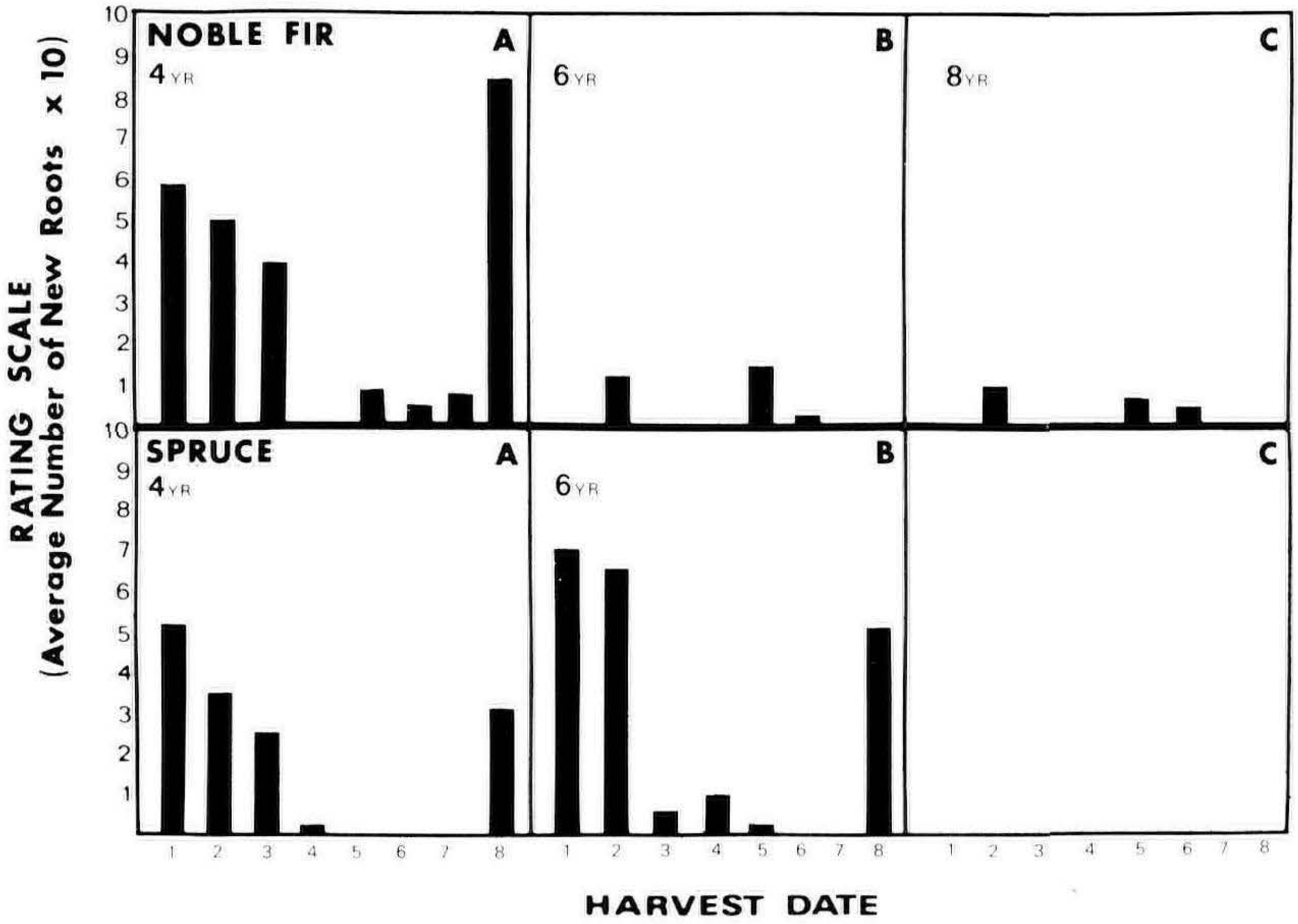

Figure 3. Numbers of new roots produced on bare-rooted 4- and 6-year-old *Picea pungens* and 4-, 6-, and 8-year-old *Abies procera* at 8 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed. Harvest date: (1) 7-10, (2) 7-31, (3) 8-23, (4) 9-12, (5) 10-1, (6) 10-22, (7) 11-12, (8) 12-3-73.

In *Picea jezoensis*, no significant differences in rooting were found among the auxin (Jiffy Grow), NI and the control treatments (Figure 2). The rooting pattern was similar throughout the sampling period. Best rooting occurred during July, followed by a significant decrease during August. No rooting occurred during the September and October sampling dates and

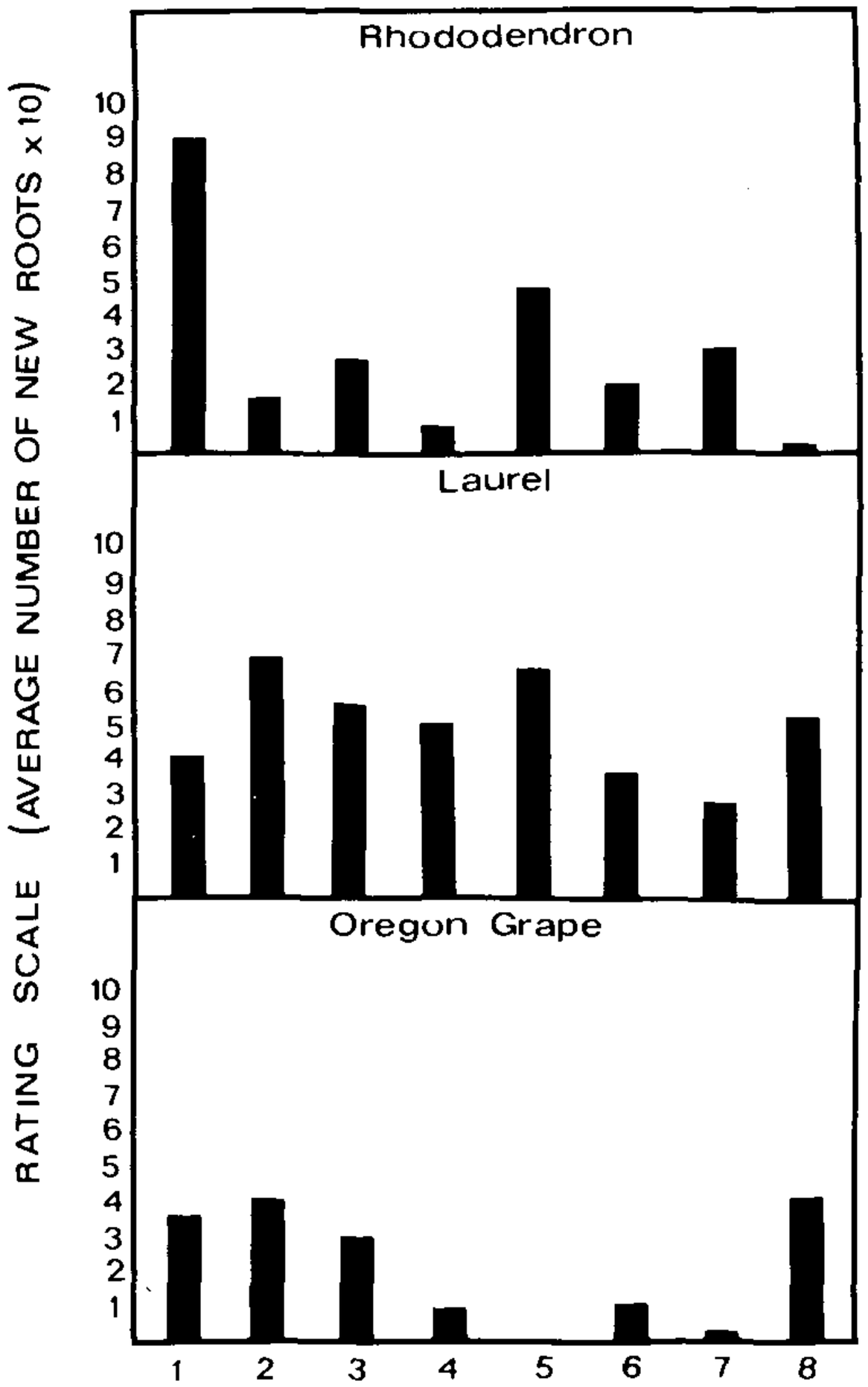

Figure 4. Numbers of new roots produced on bare-rooted 8-year-old *Rhododendron* 'Mrs. G.W. Leak', 5-year-old *Prunus laurocerasus* 'Otto Luyken' and 4-year-old *Mahonia aquifolium* at 8 harvest dates 3 months after transplanting in a raised Douglas-fir sawdust bed. Harvest dates: (1) 7-19, (2) 8-8, (3) 8-29, (4) 9-19, (5) 10-10, (6) 10-31, (7) 11-21, (8) 12-12-73.

only marginal but non-significant rooting occurred in the December and February sampling periods. As with the other studies, these results are preliminary and only suggest that auxin and NI treatments have no effect on root regeneration under the conditions studied.

Statistical differences in root regeneration were found between plant ages in *Abies procera* but not in *Picea pungens*. Generally, good rooting was found during the July, August, and December sampling dates in 4-year-old *Abies procera* and poor to no rooting at the other sampling periods. Poor rooting was observed for the 6- and 8-year-old at all sampling dates. In *Picea pungens* no differences between the 4- and 6-year-old plants were found at all sampling dates studied. Generally, root-

ing during the July and December sampling periods was good and poor rooting at the other times.

Although the differences observed for the different age groups in *Abies procera* may be a result of age effects *per se*, it should be pointed out that plant size (increasing with age) may have imposed a different stress level on the plants, thus affecting rooting. The 6- and 8-year-old plants were at least 1.5 and 2.5 times the size of the 4-year-old plants, respectively. Since no tests were conducted to measure stress conditions, these observations are speculative. Strangely, although the 4- and 6-year-old *Picea pungens* plants were of different size (approx. 1.5 x) no differences in rooting were observed. It's possible that in this species either age differences may not have an effect on rootability or their capacity to tolerate stress conditions may be better.

As stated previously, the overall objectives of these studies were to determine whether root regeneration was possible under the natural environment of Corvallis, Oregon. From these studies we can conclude that root regeneration of evergreens is possible. In addition, these studies suggest that successful rooting may depend on the sampling and rooting period, genetics of the plant, and the age or size of the plant. Auxin (Jiffy Grow) and NI treatments were not found to influence rooting. Better controlled studies are in progress to determine the influence of specific environmental factors and the physiological condition of the plant on the root regeneration of evergreen plants.

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THE USE OF PERIODIC MOISTURE STESS TO INDUCE VEGETATIVE BUD SET IN DOUGLAS FIR SEEDLINGS

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Abstract. Periodic moisture stress of up to -16 bars prior to irrigation was not effective in inducing vegetative bud set in Douglas fir seedlings. Increasing stress decreased terminal bud dimensions, root weight and shoot weight and caused slight increases in shoot/root ratio but did not result in reduced shoot growth after outplanting.

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An additional -8 bar stress treatment with 8-hour photoperiod and low nitrogen nutritional regime showed the smallest bud size, root and shoot weight, and root collar diameter in the experiment; however, no practical effect on shoot growth was observed.

REVIEW OF LITERATURE

The induction of vegetative bud set in the production of containerized Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings is a means of regulating when the seedling enters the first stage of dormancy, as well as controlling seedling height and root development. Proper dormancy induction and conditioning are tremendously important to the attainment of high survival and growth potential, yet are often overlooked in nursery cultural programs (6). One of the management procedures most often used in inducing vegetative bud set in seedlings is reduction of irrigation to induce moisture stress. Short photoperiods have been used experimentally but most nursery managers regard shortening the photoperiod to be too expensive for large scale usage. One commonly used procedure is to remove nitrogen from the nutritional schedule and to reduce the amount of watering during the late summer. This creates a condition of nitrogen level reduction and moisture stress during a period of naturally shortening photoperiods.

The literature on control of shoot growth in temperate climate conifers suggests that moisture stress during the period of vegetative bud set can be correlated with reduced shoot growth the following year (5,9). This raises the question whether moisture stress is an advisable and effective management procedure for the induction of vegetative bud set in order to condition seedlings for high growth potential. What level of moisture stress will effectively induce bud set without detrimentally affecting shoot growth potential the following year? This study was designed to quantitatively answer this question as a basis for developing specific managerial procedures that would allow the production of seedlings with a predictably high growth potential.

MATERIALS AND METHODS

Two seedlots of coastal Douglas fir, one from 500 ft. elevation near Sekiu, Washington and one from 1000 ft. elevation near Seaside, Oregon were sown into Styroblock 4 containers filled with 1/1 peat/vermiculite in March, 1977. The seedling containers were arranged in units 5.8 ft. × 6 ft. in size. Each of four greenhouse benches contained five of these units, one unit per bench receiving each of the five treatments. the assignment of treatments to units on a bench was done at random. The

units were separated by 3 feet of open bench to prevent accidental overspray during treatment.

The seedlings were cultured until December, 1977, utilizing the nutritional regime developed by the British Columbia Forest Service (personal communication with Helmut Mueller, Koksilah Forest Nursery, Duncan, British Columbia). On August 1, when seedling height over all the units reached approximately 18 cm. the moisture stress and photoperiod treatments were initiated. Prior to the initiation of the treatments the seedlings were irrigated excessively with water to leach out excess fertilizer salts. The first four treatments were -4, -8, -12, -16 bar moisture stress, all on the 0-52-34 nutritional solution. The fifth treatment was -8 bars moisture stress, an 8-hour photoperiod and the 10-52-16 nutritional regime. Moisture stress treatments consisted of monitoring the predawn moisture stress of each unit of seedlings using a Scholander pressure bomb (PMS Instruments, Corvallis, Oregon), sampling three seedlings per unit per day. The operation of the pressure bomb has been described by Waring and Cleary (11). When the mean predawn moisture stress of all four replicate units reached the treatment level they were watered to field capacity with the designated treatment solution. Photoperiod adjustment was done by putting Simshade fabric tents over the designated units late in the afternoon and removing them in the morning to allow the 8 hour photoperiod.

Table 1. Nutrition Schedule

Plant Condition	Week	Nutrition Schedule, NPK	g/1000 liters
Use Until Roots Well Developed	4-5	10-52-16*	625
Rapid Shoot Growth	6-16	20-20-20** + *ferrous sulfate*	500 *155*
Dormancy Induction***	17-18	0-52-34	625
Root Growth and Stem Diameter Development	19-Shipping	10-52-16 + ferrous sulfate	625 155

* Contains microelements.
** Occasionally replaced by 12-0-0 at 500 g/100 liters.
*** Except for short photoperiod -8 bar stress treatment which was given 10-52-16.

When vegetative bud set was completed (September 9), the moisture stress and photoperiod treatments were stopped and the seedlings were irrigated as needed with the 10-52-16 nutritional regime. The first week of October, 25 seedlings of the Seaside seed source were sampled from each replicate of the -12

bar treatments and put into 2°C storage as a test of the effects of early storage on shoot growth the following year. The second week of December, 12 seedlings to be used for measurement were selected at random from each seed source in each replicate, totalling 48 seedlings per treatment per seed source. The four rows of seedlings closest to the edge of each unit were eliminated from sampling to reduce edge effects. Height, root collar diamete, length and diameter of the terminal bud, and dry weight of the shoot and root were measured on each seedling. Twenty-five seedlings of each seed source to be used for field tests were selected at random from each of the four replicates of each treatment. These seedlings were tagged, placed in polyethylene lined boxes, and stored at 2°C until randomization just prior to outplanting.

Field plantations were installed in February near Sekiu, Washington and near Seaside, Oregon. At each location 100 replicate single tree plots of each treatment were installed in a totally randomized design. In the plantation near Seaside each seedling was surrounded with Vexar tubing to prevent animal damage. The site index (a productivity index consisting of height at age 100 years) of the Seaside plantation is 160 and the index of the Sekiu plantation is 155.

In September, 1978, after vegetative bud set, the total height and 1978 height growth was measured on each tree in each plantation. Seedlings damaged by animals were eliminated from growth measurements.

The data were subjected to analysis of variance procedures utilizing the Statistical Analysis System Version 76.6 program (SAS Institute, Box 10066, Raleigh, North Carolina 27605).

RESULTS

The analysis of variance of seedling size parameters (Table 2) indicates that differences in all of the characteristics measured before planting except height were related to treatment (Figure 1).

There was a reduction in root weight with increased moisture stress during vegetative bud set (Figure 2). There was also an overall reduction of shoot weight with increasing stress; however, there was not a definite trend due to a decreased shoot weight in the -8 bar treatments. The shorter photoperiod-low nitrogen treatment had lower shoot and root weights than the same moisture treatment with natural photoperiod and without nitrogen in the nutritional solution.

The shoot/root ratio was lower for the low moisture stress treatments than for the higher stress levels (Figure 3). This was due to the pronounced trend toward reduced root weight at

Table 2. Analysis of Variance Calculations.

Variable	N	Error Mean Square	Error DF	Treatment DF	F	Probability of a Greater F
Shoot Weight	480	0.1393	27	4	2.4570	0.0689
Root Weight	480	Q.0378	27	4	6.9422	0.0008
Shoot/Root Ratio	480	1.0435	27	4	1.7782	0.1617
Root Collar Diameter	480	0.0918	27	4	4.0024	0.0113
Bud Diameter	480	0.1686	27	4	11.3224	0.0001
Bud Length	480	0.4151	27	4	6.9422	0.0008
1978 Height Growth — Sekiu	480	21.9500	328	4	1.1800	0.3190
Total Height 1978 — Sekiu	480	29.8518	328	4	2.110	0.0791
1978 Height Growth — Seaside	480	62.7400	553	5	1.0400	0.3956
Total Height 1978 — Seaside	480	77.1290	553	5	2.3300	0.0407

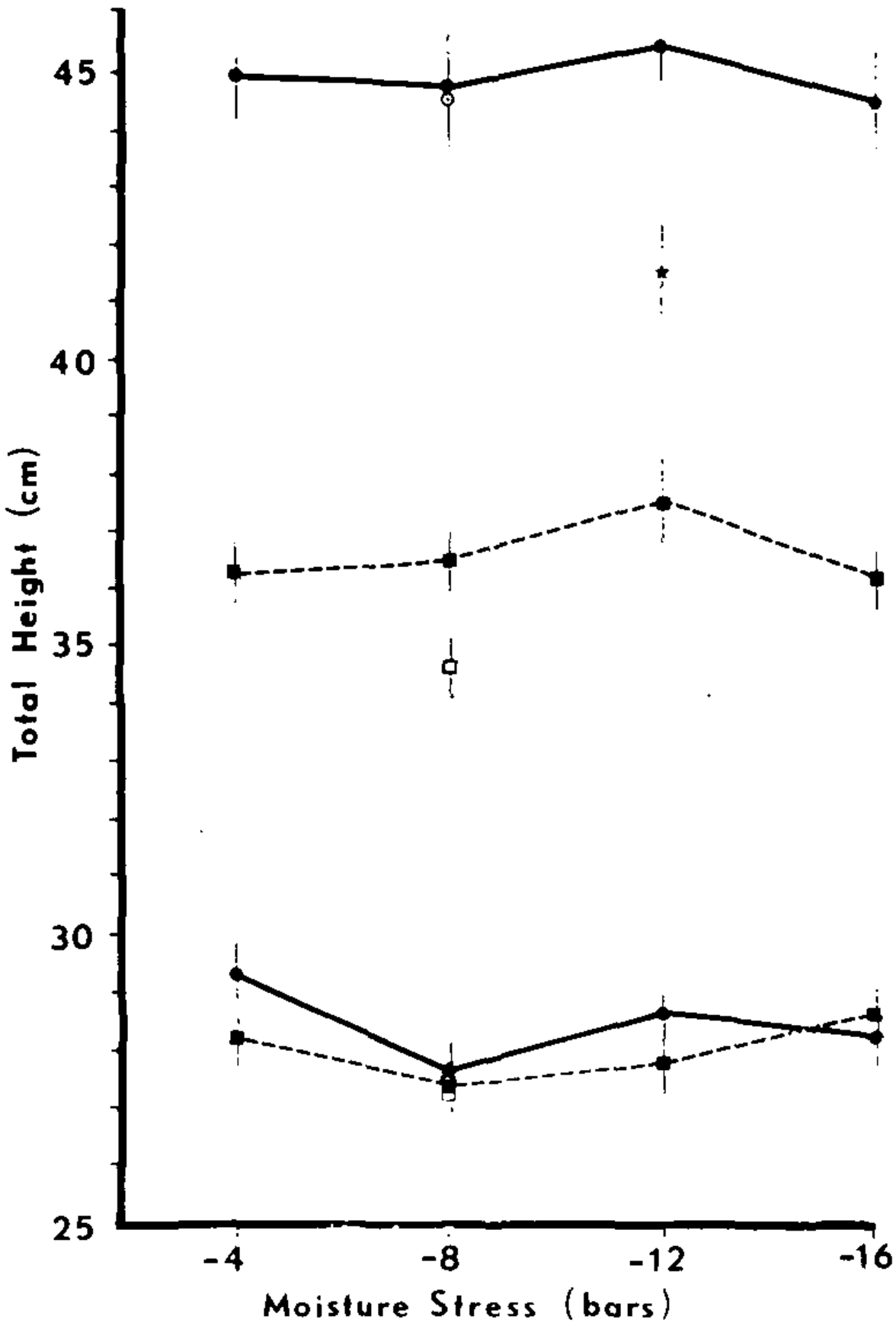

Figure 1. The total height of seedlings from Seaside, Oregon, ————, and Sekiu, Washington, -------. Seed sources after nursery culture (lower lines) and after one year in the field (upper lines).

Treatment during vegetative bud set: four levels of moisture stress + a 0-52-34 nutritional regime, Seaside, ● ; Sekiu, ▪ ; -8 bar moisture stress, 8-hour photoperiod - 10-52-16 nutritional regime, Seaside, ○ ; Sekiu, □ ; -12 bar moisture stress, 0-52-34 nutritional and early storage treatment on the Seaside seed source, ★ .

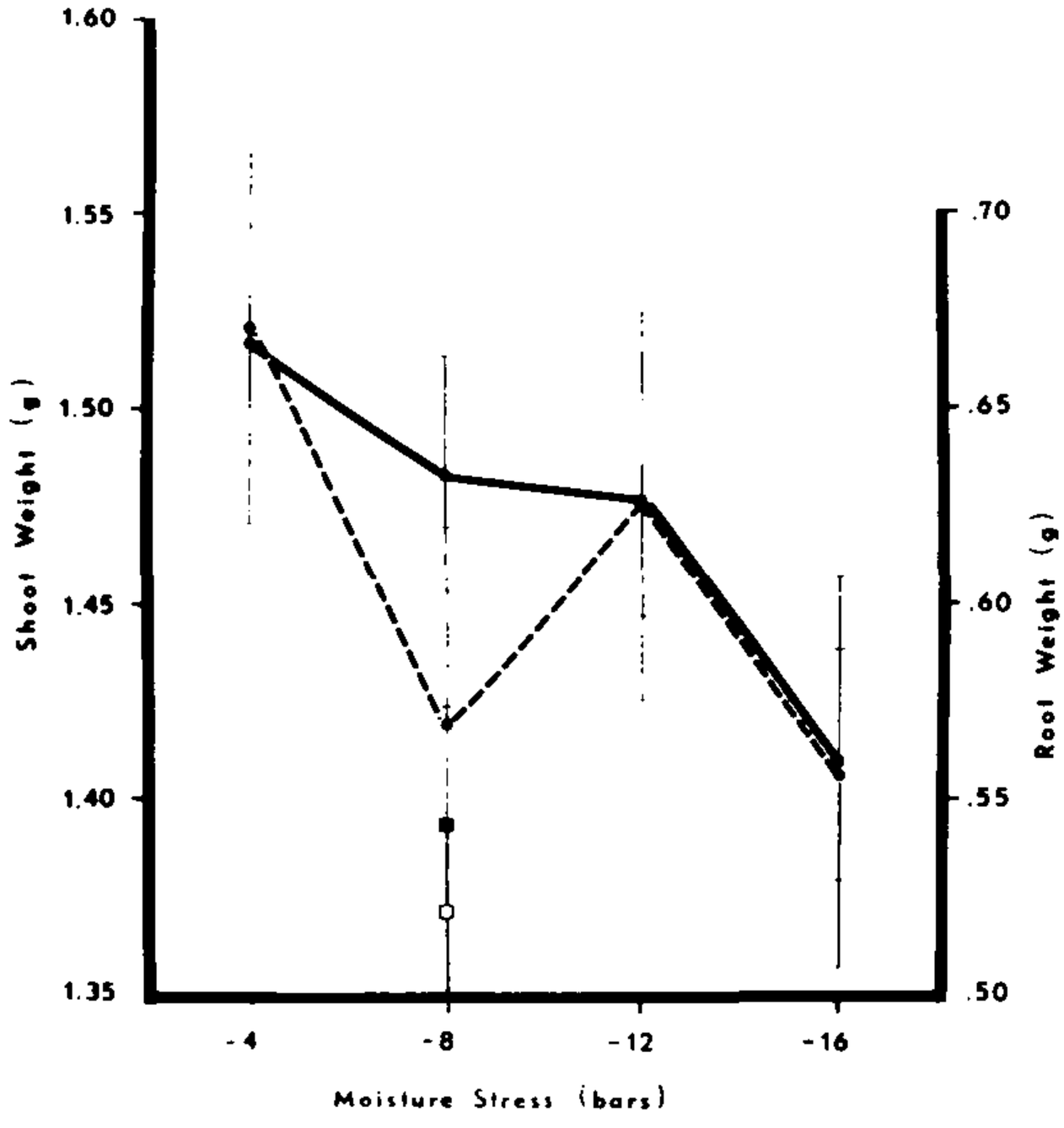

Figure 2. The shoot weight, -----, and root weight, _____, of seedlings receiving various moisture stress - 0-52-34 nutritional regime treatments, ● . Shoot weight, □ , and root weight, ■ , of seedlings receiving -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional regime treatment.

higher stress levels (Figure 2). The 8-hour photoperiod-low nitrogen treatment had the highest shoot/root ratio.

Root collar diameter followed the same trend as shoot dry weight (Figures 4 and 2). The -8 and -16 bar treatments had the lowest diameters in the moisture stress treatments, and the 8-hour photoperiod-low nitrogen treatment had the lowest diameter over all treatments.

Terminal bud dimensions decreased with increasing stress with the exception that the -8 bar stress-low nitrogen treatment had the smallest buds overall (Figure 5).

Periodic moisture stress during vegetative bud set had no practically important effect on height growth the following year in the field (Figure 1). In both locations the -12 bar treatments had the greatest mean height and the early stored seedlings had the smallest mean height in the Seaside plantation (Figure 1).

DISCUSSION

The results of this study suggest that periodic moisture stress of up to -16 bars has little or no effect on bud set in the nursery. Perhaps higher stress levels would be more effective in that regard. Hahn (2) has recently suggested that withholding water until the seedling wilts then watering it back to field ca-

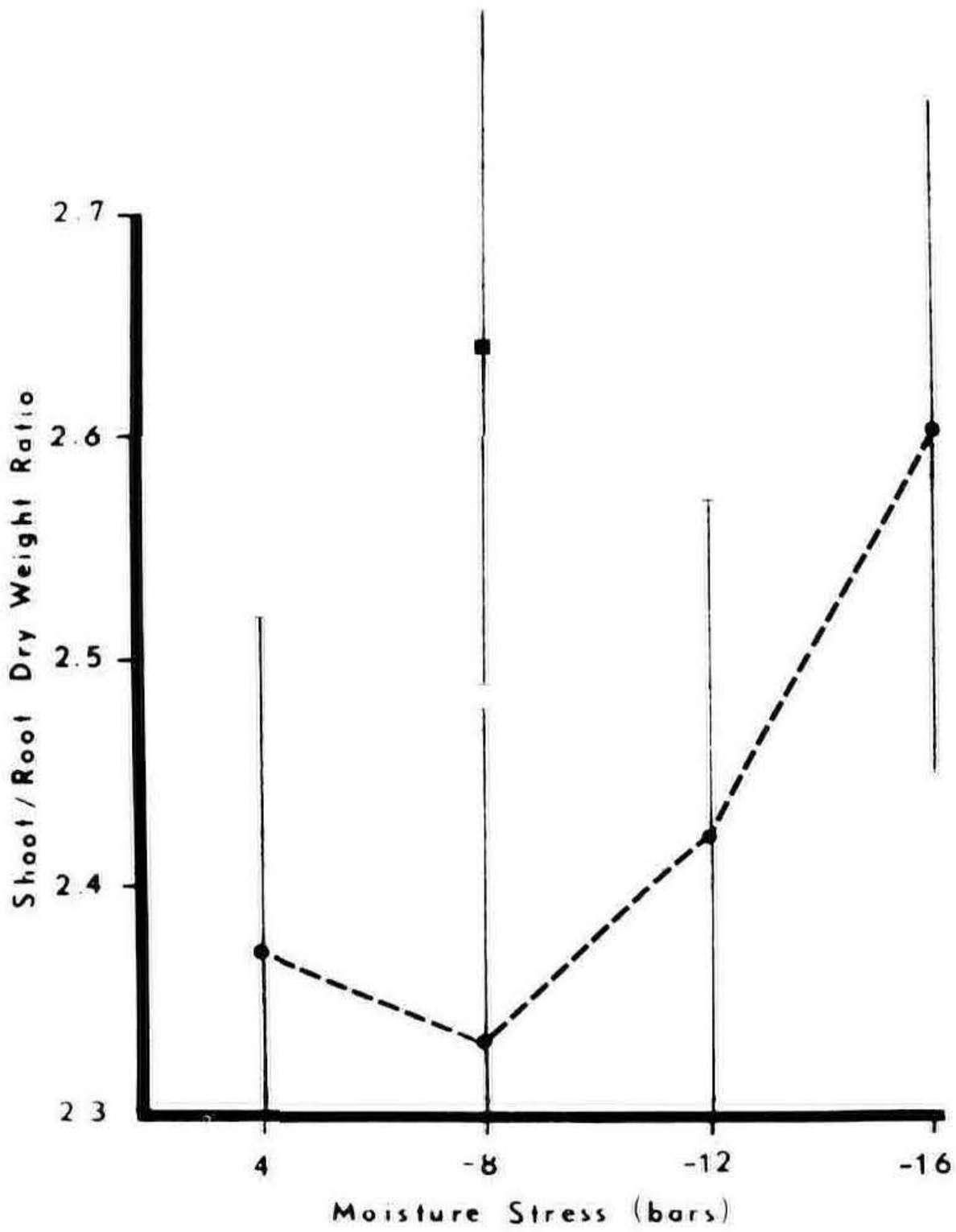

Figure 3. The mean shoot/root ratios of seedlings treated with one of four moisture stress levels and an 0-52-34 nutritional regime, ● ; treated with a -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional regime, ■ .

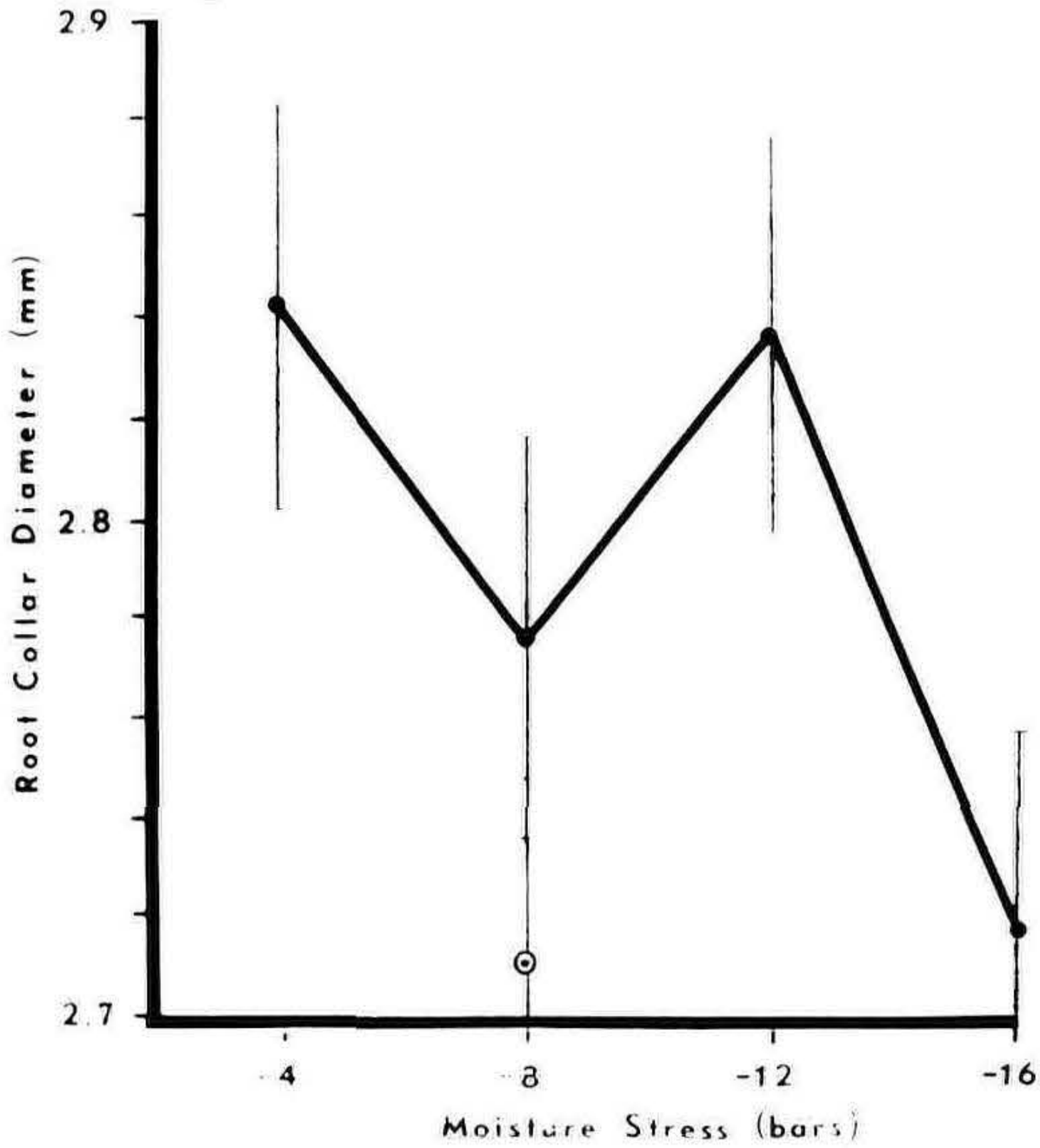

Figure 4. The effects of various moisture stress treatments and a 0-52-34 nutritional regime, ● , or an -8 bar stress, 8-hour photoperiod and 10-52-16 nutritional regime, ○ , during vegetative bud set on the root collar diameter of the seedlings.

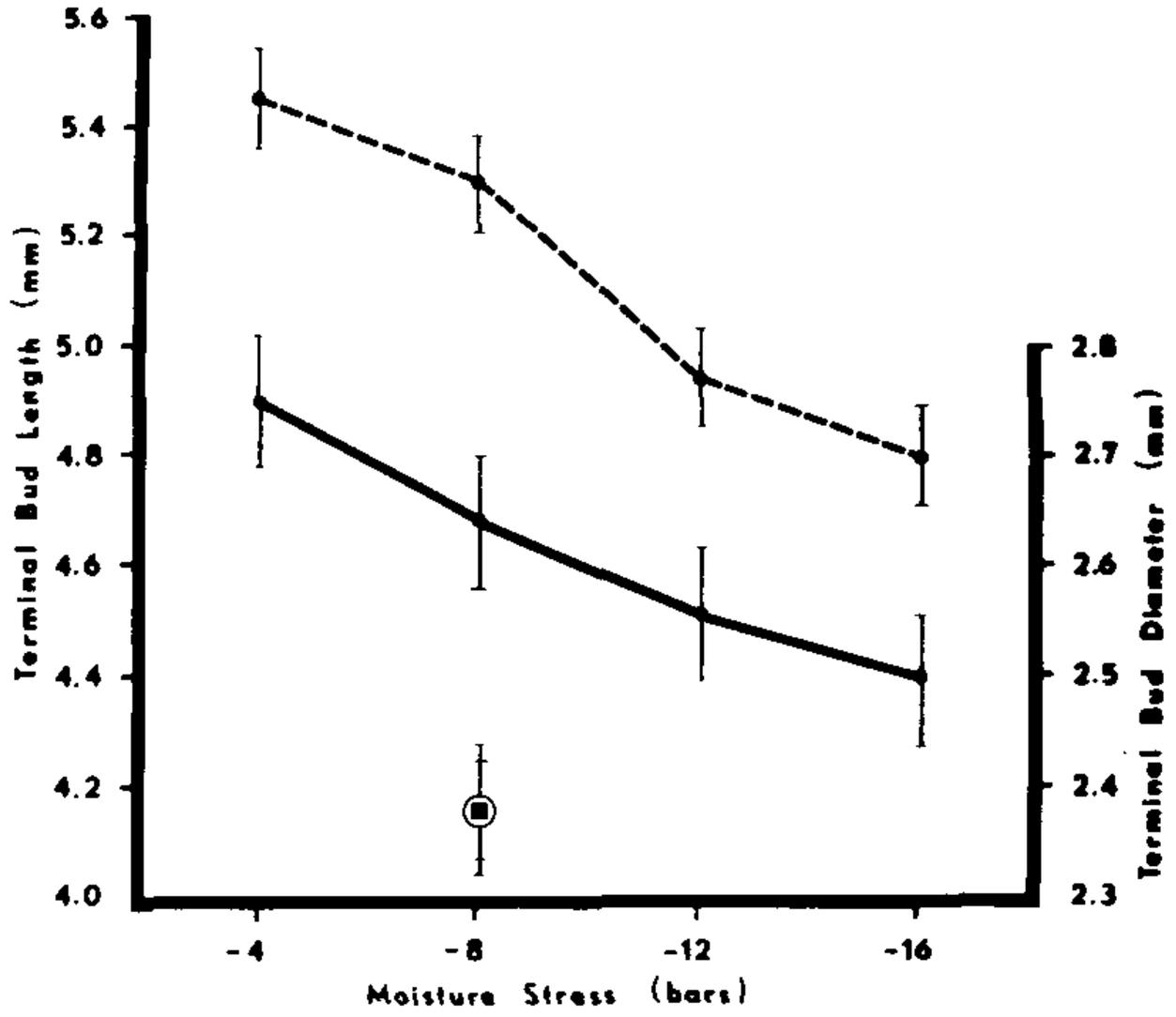

Figure 5. Terminal bud dimensions of Douglas fir seedlings treated with various levels of moistures stress and 0-52-34 nutritional solution, bud length, ------ ; bud diameter, _____ . Bud length, ○ , and bud diameter, ■ , of seedlings treated with -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional solution.

pacity with clear water is an effective technique. Our results in recent unpublished tests indicate that Douglas fir seedlings that have wilted for one day have a predawn stress of -22 bars.

Our tests up to -16 bars show only a small detrimental effect of stress on height growth the succeeding year. It is possible but in light of the data presented here not probable, that sustained stress leading to higher stress levels such as -22 bars at wilting could cause detrimental effects not observed up to -16 bars.

Hahn (2) suggests that reduced photoperiod makes moisture stress more effective in inducing bud set in Douglas fir. The data presented here indicate that while the -8 bar stress, 8-hour photoperiod-low nitrogen treatment did result in shorter seedlings the effect was small. It is possible that some low intensity light leaks reduced the effectiveness of our treatment (8).

Terminal bud size, shoot and root weight and root collar diameter were reduced by the -8 bar stress, 8-hour photoperiod-low nitrogen treatment. Reduced production of photosynthate due to decreased energy input could explain the general size reduction. Shoot weight was reduced considerably less than root weight. Timmis (10) noted increased root weights in seedlings deprived of nitrogen during bud set. It is possible that the low nitrogen level added to the -8 bar stress, 8-hour photoperiod treatment changed the allocation of photosynthate toward the shoot thus reducing root weight proportionately.

Terminal bud size was reduced by the moisture stress-no

nitrogen and the -8 bar stress, 8-hour photoperiod-low nitrogen treatments; however, this was not reflected in a similar trend in reduced height growth. Perhaps the treatments affected reduced cellular elongation but did not otherwise alter bud development. This hypothesis is supported by the fact that the mitotic index[1] in the bud was not adversely affected by the stress treatments, whereas early cold storage, which caused cell division in the bud to be reduced to the December level in early October, did reduce shoot elongation the following spring. If stress treatments only reduced cellular elongation, then the shoot elongation rate in the next growing season would be expected to be similar in all of treatments because the small differences in bud size would be undetectable in the elongated shoot.

The Seaside plot in which each seedling was surrounded by Vexar tubing showed considerably more growth than the Sekiu plots even though all animal damaged seedlings were eliminated from the measurement group. The productivity index of the two areas is very similar. It is possible that the shade provided by the Vexar tubing allowed additional growth; however, other factors such as short term weather trends could be involved.

Root collar diameter, shoot/root ratio, and size of the root system are often used as quality parameters in culling seedlings on shipment from the nursery. The ranges of these parameters found in this study were small; however there was no detectable effect of their variation on shoot growth. Others have found that over a moderate range of shoot/root ratios, other quality parameters are more important indicators of shoot growth potential (4,7). Root growth potential is probably poorly described by root mass at time of planting. Hahn and Hutchinson (3) have suggested that with high quality container seedlings the root mass increases considerably prior to bud break. Large increases in root mass prior to shoot growth would probably minimize the effects of small differences in root mass at time of planting on shoot growth.

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[1] The mitotic index portion of the study is to be published elsewhere after further work.

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ROOT SYSTEM CONFIGURATION IS IMPORTANT TO LONG TREE LIFE

RICHARD W. TINUS[1]

Rocky Mountain Forest and Range Experiment Station
U.S. Forest Service Shelterbelt Laboratory
Bottineau, North Dakota

Abstract. Circling roots can stunt growth or increase susceptibility to wind breakage and blowdown. The problem can be largely avoided by growing tree seedlings in containers with vertical ribs or grooves, without sharp horizontal corners, and with an egress hole at the bottom for air pruning roots. Root configuration control is standard forest nursery practice in 30- to 700-ml containers, but now has been demonstrated in 10-liter containers intended to produce potted trees for the retail market. Additional egress holes near the pot surface may correct insufficient root production of outplanted trees.

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Horticulturists have known for a long time that circling roots can stunt growth and increase susceptibility to wind breakage and blowdown. Whenever container trees or shrubs are outplanted, it is standard practice to dig a larger hole than the rootball and then straighten the roots before planting. Alternatively, the circling roots at the bottom are pruned off and shallow slices made in the sides of the rootball to cut circling roots and to stimulate development of new lateral roots.

What can happen if trees are allowed to grow to large size with roots circling the main axis has been vividly documented at the symposium: "Root Form of Planted Trees."[2]

As a tree seedling grows, root deformity develops in the following manner. Roots tend to grow in the same general direction until the growing tips strike an impenetrable object. When growing tips encounter the container wall, they turn and grow along it. If the container is circular, the roots may make one or more complete horizontal revolutions around the stem axis. After the tree is outplanted, the circling roots continue to grow in diameter until they contact the taproot, if there is one, or completely fill the volume they once surrounded (Figure 1).

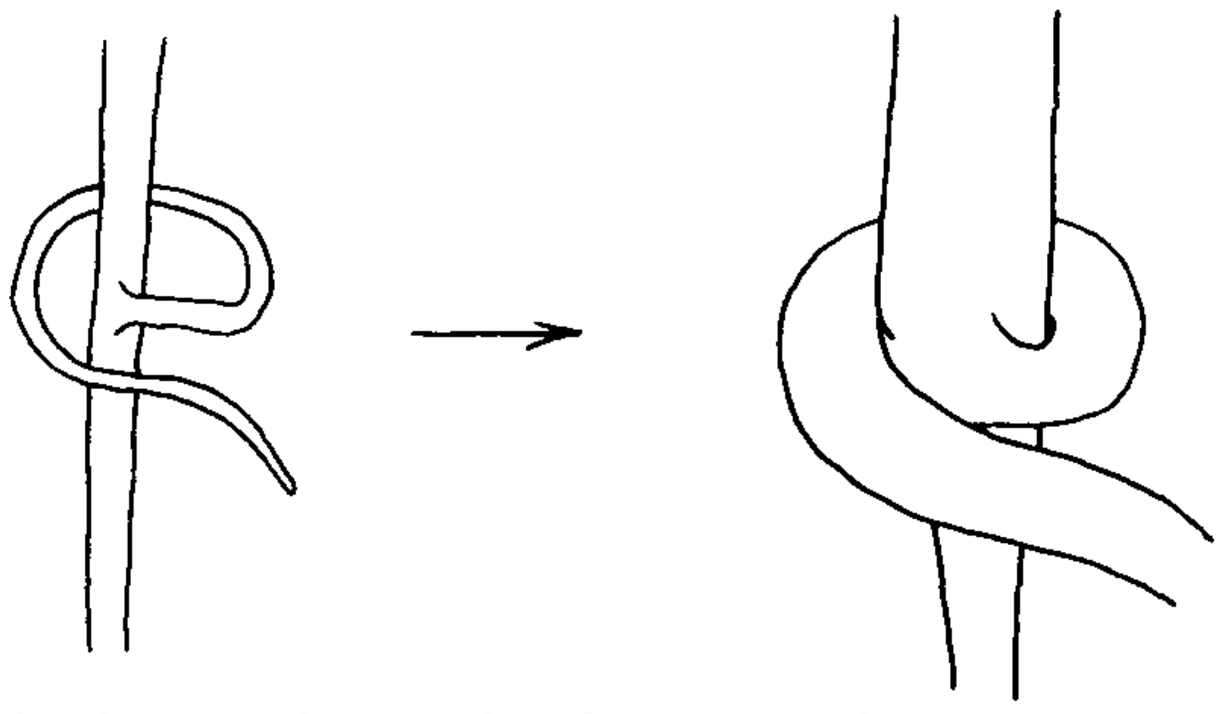

Figure 1. Growth of a root that circles the stem and taproot.

Sometimes the circling root may strangle the taproot, and the tree will become stunted or die. In other cases, the circling root grafts to the taproot and the tree continues to grow. The stem above the circling root continues to increase in diameter, but the taproot inside the circling root cannot increase in diameter. As a result, the core of vertical wood fiber of constant diameter is surrounded by an enlarging doughnut of horizontal fibers which do not increase in strength in proportion to the size of the above ground stem (Figure 2). Although fusion of the encircling root with the main stem and taproot appears complete and sturdy from the outside, a weak spot susceptible to

[2] Kinghorn, James, and Evert van Eerden (eds.) 1978. Root Form of Planted Trees. Pac. For. Res. Cent., 506 Burnside Rd., Victoria, B.C. V8Z 1M5 (in press). [Symposium held in Victoria, B.C., May 16,19, 1978.]

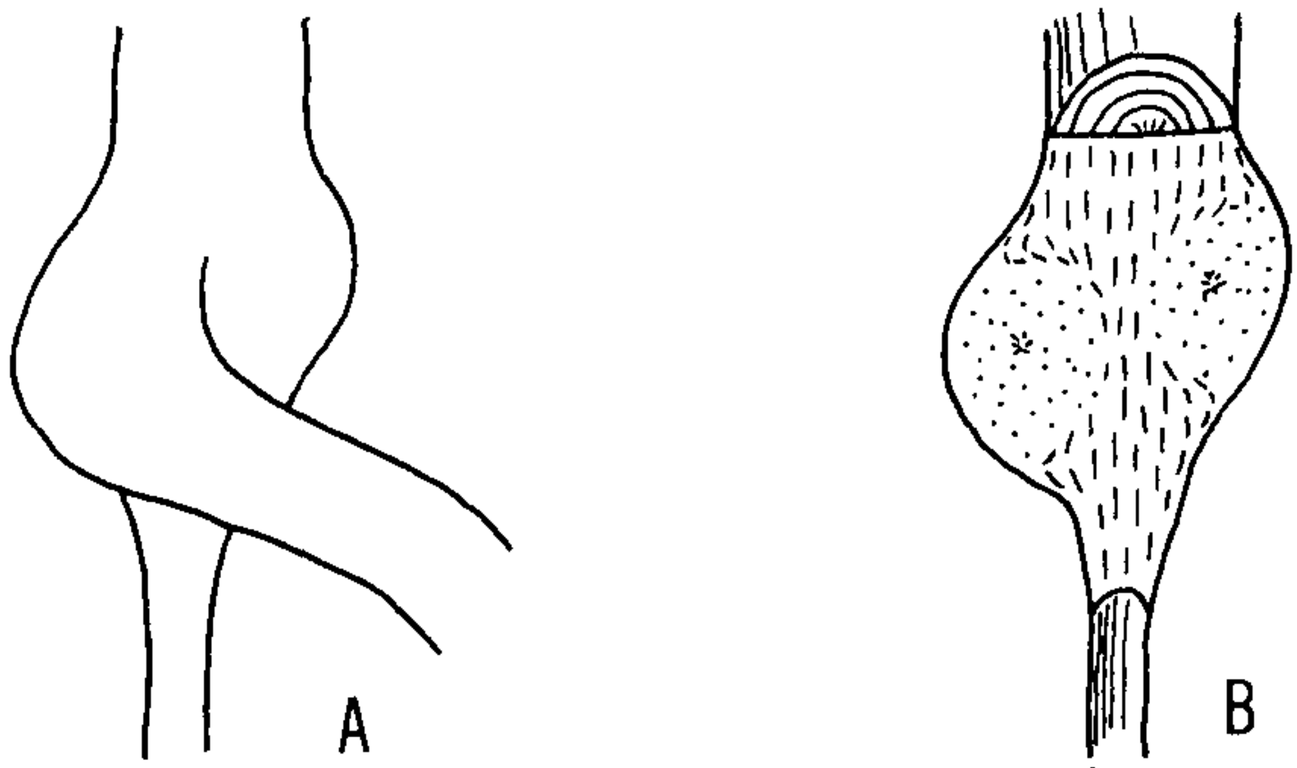

Figure 2. Further growth of a circled root may fuse it with the taproot. The graft may appear healed (A), but in cross-section (B) shows structural weakness. Dashes are vertical grain, and dots are horizontal grain.

wind breakage remains, right where the tree needs to be the strongest.

In addition, a balled root system tends to remain self-contained after outplanting. Few lateral roots emerge, and a taproot may not develop. The tree does not have adequate access to water and mineral nutrients and becomes stunted. The tree is also susceptible to windthrow, because it lacks surface lateral roots to adequately anchor it.

As mentioned, horticulturists have found ways to prevent these disasters, but foresters cannot afford the individual tree care needed. Instead, forest tree seedlings are grown in specially designed containers in such a way that most roots are oriented vertically and none circle horizontally. The seedlings are removed from the container and planted with the rootball intact. No extra large planting hole, or hand modification of the shape of the root system is needed.

How is this done? First, containers with impenetrable walls are made with vertical ribs or grooves. When lateral roots encounter them, the roots are directed downward and prevented from circling. Second, there are no sharp horizontal corners, as there are in conventional pots where the sides meet the bottom; instead, the container walls gently taper to the bottom. Such corners have the same root-directing properties as the vertical ribs or grooves, but cause the roots to circle. Third, the roots are directed to a relatively large egress hole at the bottom of the container. Roots must find a way out of the container, otherwise they either ball up or grow upwards again. Fourth, the containers rest on open benches or racks so that their egress holes are open to the air with enough ventilation so that the root tips desiccate and stop growing, a process called "air pruning". New root tips are then produced higher in the root ball.

Another way to keep the roots from balling up is to grow the seedlings in containers with walls permeable to roots or media blocks without any walls. If there is an air space between containers, the roots emerge from the sides and bottom, and they are air pruned. If the containers are adjacent and the roots pass from one container to the next, these roots will be broken when the containers are separated for planting. However, this is permissible only when the roots broken are small and unlignified, otherwise the seedling will be heavily damaged and much of the advantage of growing the seedling in a container is lost.

There is a wide variety of containers on the market for raising forest tree seedlings, but the largest of them is only about 700 ml. I have fabricated several prototypes of a 10-liter container which have all of the root control features described above for impenetrable wall containers. Ten-month-old seedlings of Scots pine and Siberian larch grown in 400-ml containers were transplanted into these 10-liter containers and grown for another season in the greenhouse. They are now 76 and 102 cm in height and 1.5 and 1.8 cm in caliper, respectively, and probably suitable for retail sale. Estimated production cost is about $3 per tree. It should be possible to simply lift these trees from their containers and plant them without having to manipulate or prune the root systems in any way. The trees should grow root systems that will not be defective; trees with intact root systems at outplanting should result in better top growth than from trees whose roots have been pruned. Vigorous top growth is something every buyer likes to see.

Does that mean we have in hand the ultimate tree growing container? No. The containers I have described have two deficiencies. Even with a large egress opening at the bottom, large numbers of root tips may accumulate, blocking the opening and reducing drainage. Waterlogging and root rot may result. The already large opening on many containers cannot be enlarged further without losing too much growing medium. Second, new root development after outplanting develops mostly from the air-pruned root tips at the bottom of the rootball. There are few laterals near the surface, which is likely to reduce the windfirmness of the tree (Figure 3).

We are currently testing the addition of holes or slits in the upper sides of containers to see if seedlings will produce growing points that will develop into surface laterals after outplanting (Figure 4). If they do, we may have solved the windfirmness problem. Also, fewer root tips may accumulate at the bottom, which should reduce obstruction of drainage. However, we have found already that more exposure of the rootball to air requires more careful control of humidity and air flow. It

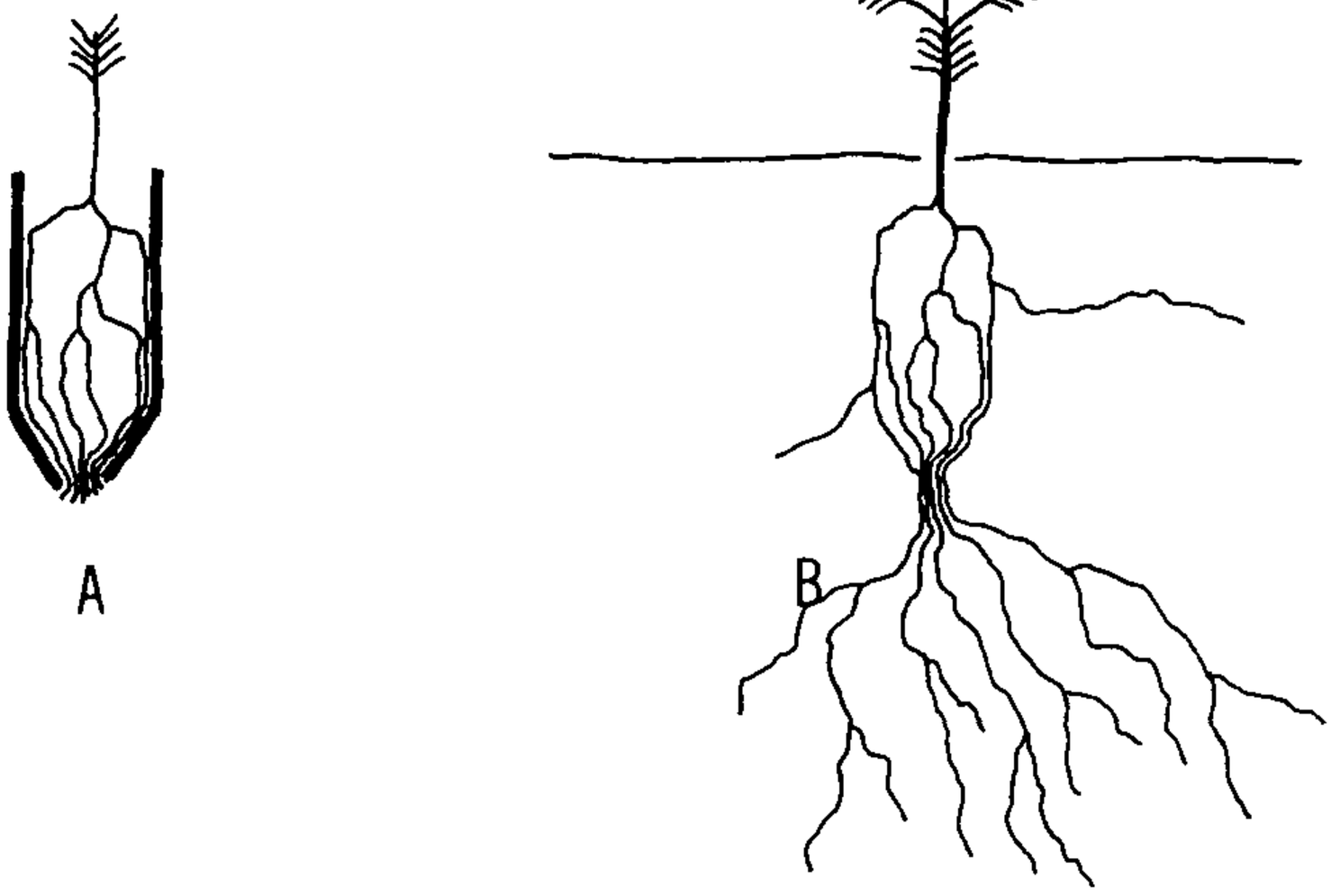

Figure 3. Root configuration commonly produced by currently used forest tree seedling containers (A) in the container, and (B) one season after outplanting.

will probably take another 2 years to work out the remainder of the problems with container design and greenhouse culture of the trees.

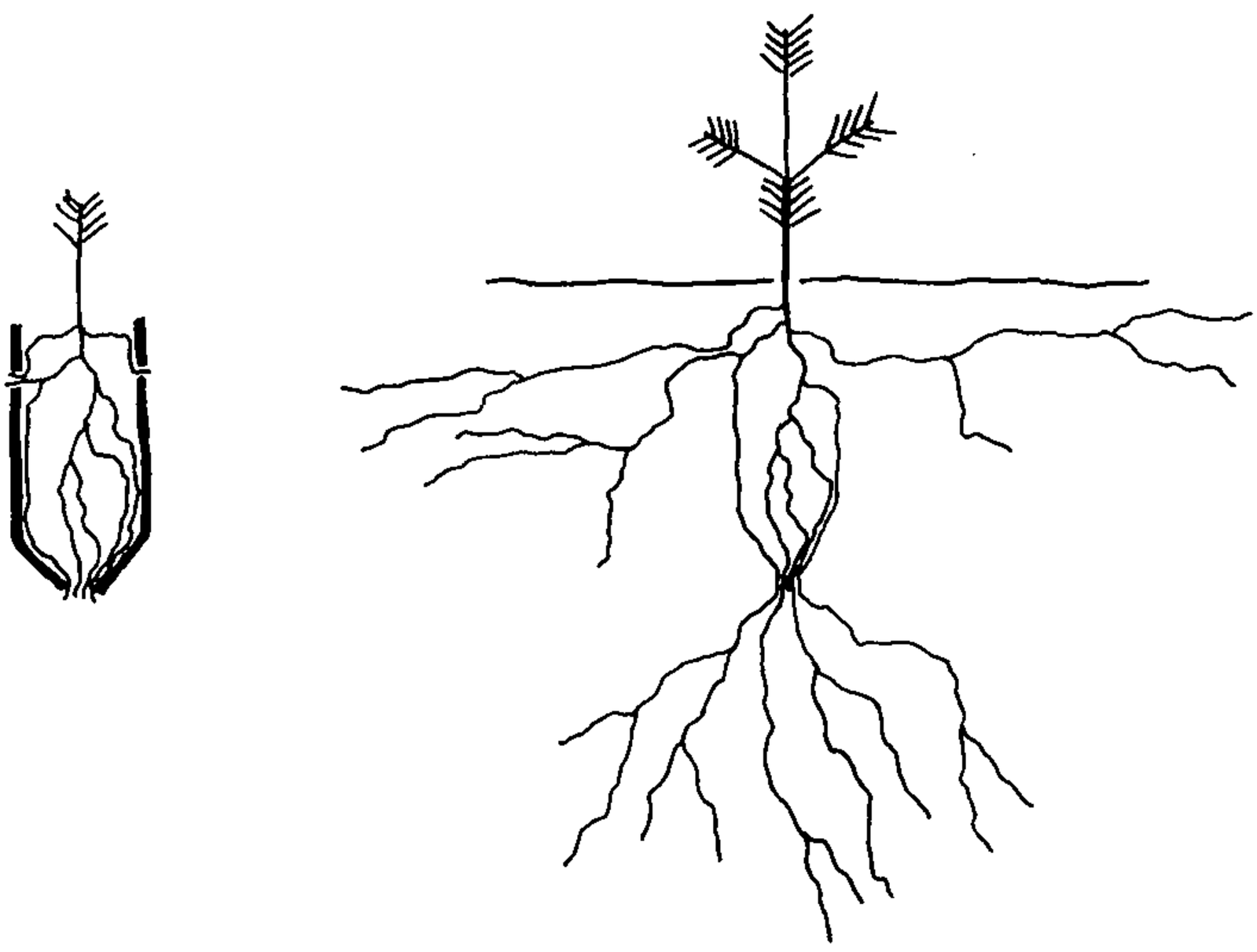

Figure 4. Anticipated root configuration to be produced by forest tree seedling containers with holes in the upper sides to promote growth of surface lateral roots.

SUMMER ROOTING OF STONE FRUIT UNDERSTOCK CUTTINGS

RICHARD BUSH

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Where we have had success in rooting, I think the key is the taking of a butter-soft cutting in summer and propagating in an air-conditioned environment.

We will consider specifically mahaleb Mazzard crosses — called M×M. The mahaleb × Mazzard (M×M) stocks are assumed to be natural hybrids resulting from open pollination (1). The optimum time for taking cuttings in Canby, Oregon is in July to the middle of August. The percentage of success drops after the third week in August and in September. As the cuttings are so soft, we like to take them early in the morning. The wood is cut 12 to 14 inches in length, the bottom 3 inches is stripped of leaves, and a ½″ diagonal bottom cut is used with a short back cut to keep the end from being too pointed. We soak the cuttings in a solution of Diazinon and Benlate for 15 minutes; when damp dry the cutting is dusted with Hormodin #3. We have tried many types and combinations of rooting media but for dependability and ease of use, we use straight perlite. We insert the cuttings into a 5″ deep, 2¼″ square, slightly tapered open bottom pot or band. A Portland flat will handle 48 of these pots.

These flats are set under intermittent mist. Even though it is summer we maintain 70°F bottom heat. The first few days, the cuttings take a severe wilt. In the afternoon 2 to 3 inches of the tips will droop. After a few days those tips which are not erect in the morning are cut off although the percentage is low. Roots start appearing in about 4 weeks. Then we start feeding with a full NPK fertilizer in the water. In another week or two, misting is discontinued and the flats are kept on bottom heat in this condition until October, when they are put outside under lath.

In summer our greenhouse is shaded externally with quick lime and, inside over propagating benches, a 55% shade Saran cloth is hung above misting nozzles. We used to cool with vertical excelsior pads, but now thanks to an article in the IPPS Proceedings (Volume 26), we have converted to horizontal cooling pads of excelsior, 4″ thick. No more dry spots, and even on those days over 90°F we are able to keep inside temperature in the low 80°F range. Most of the summer we hold the maximum inside temperature at 78°F.

We have had good results in summer rooting of *Prunus*

besseyi. Marianna plum (*Prunus cerasifera* × *P. miunsoniana?*) and myrobalan plum (*Prunus cerasifera*) root easily as hardwood cuttings directly in the field row so we don't use greenhouse space for these.

One might ask why go to all this trouble to root M×M in the summer. We do this because it is a root we like to use and we are unable to obtain it elsewhere. We have seen no crown gall on M×M and haven't inoculated with an antagonist when planting in the field. It is compatible with all the cherry cultivars we use. We are able to bench graft these newly-rooted cuttings by bringing the flats back in to the greenhouse in late January. We force root activity with bottom heat and graft using the chip bud and the whip graft.

When all danger of frost is past, we plant directly in the field with actively-growing scion and rootstock. All of this process has taken only seven months starting from scratch, as opposed to the conventional method of two or three years.

LITERATURE CITED

1. Westwood, M.N., A.N. Roberts, and H.O. Bjornstad. 1976. Comparison of mazzard, mahaleb and hybrid rootstocks. *J. Amer. Soc. Hort. Sci.* 101(3) 268-269.

A STUDY OF POTTING MIXES

RICHARD G. MAIRE

Cooperative Extension
University of California
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At the request of the California State Department of Food and Agriculture a study was made of commercial potting mixes available on nursery shelves for purchase by the general public. This request was made because of complaints from consumers based on the performance of some of the mixes.

Twenty-nine potting mixes were purchased off the shelves of all type nursery outlets. The following are the mixes that were tested and these include the U.C. mix which was used as a standard or check, since knowledge of its performance was well known.

APG Potting Soil
Angel City Potting Soil
B's Worm Castings, an Organic Planting Mix
Bandini Potting Soil
Best Potting Soil
Black Magic Complete House Plant Mix
Eager Beaver Potting Soil
Earth and Sea Brand Live Earth Potting Soil

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49'er Gold Strike Potting Soil
Garden Potting Soil
Greenall Potting Mix
Jungle Growth Enriched Organic Potting Soil
Kellogg's Indoor and Outdoor Potting Soil
K-Mart Potting Soil
Nurseryman's Potting Soil
Original Supersoil Steam Sterilized Potting Mix
Payless Potting Soil
Potting Soil
Queen Turf Indoor Outdoor Potting Soil
Rescue Planter Mix
Roger's Potting Soil Mix
Sierra Potting Soil
Soil-Prep Potting Mix
Super Blue Tag Potting Mix
Super Earth Enriched Potting Soil
Superior Potting Soil
Sur-Gro
Vigoro Potting Mix
U.C. Mix (Check)

We did not attempt to determine the components in the mixes. Information on the bags ranged from simple "Potting Mix" to a very long list of ingredients. It was obvious from the wide range of colors and textures that the mixes contained a variety of ingredients.

All the mixes were tested for pH., salinity, boron, chloride and heavy metals prior to planting. Most of the mixes were in a satisfactory range with respect to these analyses but there were exceptions. All had adequate to excellent drainage.

In the plant growth tests all mixes were irrigated regularly with water containing 150 pm nitrogen and 150 pm potassium. They were also rotated daily on the bench to avoid microclimate effects in the greenhouse.

During the progress of the tests it became suspect that some of the plants were showing phosphorus deficiency symptoms so additional tests were made adding 2½# single super phosphate per cubic yard of mix. In some cases this application of phosphorus made a dramatic change in plant growth, in others no response was observed. This informed us that some of the formulators were not incorporating phosphorus in their mix.

Another observation was an extreme drop in pH. during the three months of plant growth in some of the mixes. This was positively correlated with the concentration of ammonium nitrate in the saturation extract of the initial mix. Some mix formulators add an ammonium form of nitrogen as a preplant fertilizer. This is a desirable practice; however, it can be over done.

Toxicity, due to a very high concentration of heavy metals was a problem in several of the mixes. The source of these toxic materials was suspected to be sludge which was incorporated as part of the mix ingredents.

Each formulator has been contacted by Dr. Branson, Dr. Rible, Dick Maire and Ralph Strohman to inform them of the tests — what was done — how it was done — how their mix performed in relation to other mixes — what the problem was if we could determine the cause, and what they could do to cor-

rect it. Reception by the formulators has been most gratifying, each welcomed our report and our suggestions for improvement in formulation where advisable.

Through these tests and our work with the formulators it is hoped that the industry will regulate itself so that all mixes produced are high quality and are consistent.

PEAT, PESTS, AND PROPAGATION

WILBUR L. BLUHM[1]
Oregon State University
Salem, Oregon 97301

Peat has been a standard component of propagation and growing media for many years. Bunt (3) describes peat as by far the most widely used material for making plant growing media. Its water-holding capacity is valued in propagation. In growing media, its nutrient holding capacity, "buffering" capacity against rapid pH changes and excessive soluble salts accumulation, and ability to improve aeration are additionally useful.

Peat is far from being a uniform product (3,11). Nursery and greenhouse growers experience variable performances with use of different peat sources.

Varying physical and chemical properties of peat depend primarily on the nature and origin of the plant remains of which it is composed and their degree of decomposition (14). Commonly used peats consist mostly of decayed sedges, mosses, reeds, and grasses. Different types of peat, in varying states of decomposition, occur at specific locations throughout the world, mostly in the boreal climates of the Northern Hemisphere — Canada, Scandinavia, and Russia.

Contaminants also contribute to the variable results in using peat and affect its value. Resulting disease and pest problems may occasionally occur to adversely influence plant performance.

Contamination of Peat. Increased concern with contamination of peat has been expressed in recent years (2,8,10,12). Although some products are labeled "sterilized," "no fungi," or "weed free," peat has been detected as a source of pathogenic fungi, weeds, and nematodes (1,2,4,8).

Peat, as a source of pathogens and pests, is a controversial subject. Peat has traditionally been regarded as being relatively sterile and some have questioned the need to be concerned

[1] Marion County Extension Agent

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Peat has been a standard component of propagation and growing media for many years. Bunt (3) describes peat as by far the most widely used material for making plant growing media. Its water-holding capacity is valued in propagation. In growing media, its nutrient holding capacity, "buffering" capacity against rapid pH changes and excessive soluble salts accumulation, and ability to improve aeration are additionally useful.

Peat is far from being a uniform product (3,11). Nursery and greenhouse growers experience variable performances with use of different peat sources.

Varying physical and chemical properties of peat depend primarily on the nature and origin of the plant remains of which it is composed and their degree of decomposition (14). Commonly used peats consist mostly of decayed sedges, mosses, reeds, and grasses. Different types of peat, in varying states of decomposition, occur at specific locations throughout the world, mostly in the boreal climates of the Northern Hemisphere — Canada, Scandinavia, and Russia.

Contaminants also contribute to the variable results in using peat and affect its value. Resulting disease and pest problems may occasionally occur to adversely influence plant performance.

Contamination of Peat. Increased concern with contamination of peat has been expressed in recent years (2,8,10,12). Although some products are labeled "sterilized," "no fungi," or "weed free," peat has been detected as a source of pathogenic fungi, weeds, and nematodes (1,2,4,8).

Peat, as a source of pathogens and pests, is a controversial subject. Peat has traditionally been regarded as being relatively sterile and some have questioned the need to be concerned

[1] Marion County Extension Agent

about its possible contamination. Others suggests peat be sterilized prior to use for propagating and growing plants (4,5,10,13).

Only weed, insect, and nematode problems with peat will be further discussed here since pathogenic fungi are presented in another discussion.

Weeds Associated With Peat. A group of weeds is consistently observed in Western Oregon nursery and greenhouse operations when peat is used. While peat cannot positively be identified as the source, circumstantial evidence indicates it is the source for at least some of them.

Most common of this group are common chickweed (*Stellaria media* (L.) Cyrill.), sheep sorrel (*Rumex acetosella* L.), yellow wood-sorrel (*Oxalis stricta* L.), and several grasses, including annual bluegrass (*Poa annua* L.).

Several other weeds are found in media made with peat, and are suspected as often coming from the peat. Included are little western-bittercress (*Cardamine oligosperma* Nutt. var. *oligosperma*), red dead-nettle or henbit (*Lamium purpureum* L.), and speedwell (*Veronica* L. spp.). Common groundsel (*Senecio vulgaris* L.) may be among these, but this is difficult to ascertain because of wind distribution of its seed. Pearlwort (*Sagina* L. spp.) is reported as probably coming from peat by a California nurseryman (1). Willow (*Salix* L. sp.) seedlings were reported by an Oregon nursery grower as probably coming from the peat in which rhododendron liners were propagated. Kim (7) has found weed seeds in peat, but has not identified the species.

All of these weeds are widespread in their distribution. Some are of European origin and have become widely distributed throughout North America. Others are native to the Pacific Northwest or the larger Pacific Coastal region. Much of the peat used by Western Oregon growers comes from British Columbia bogs. These weeds are common to the Canadian province as well (6), making infestation at the source site a possibility.

Actual number of weed seeds in a bale of peat appears to be relatively small. The problem increases as these few seeds germinate, grow, reproduce, and increase the seed supply. Nursery and greenhouse conditions are nearly ideal for growth and increase of these weeds.

Insects and Peat. Few, if any, reports implicate peat with insect problems. Heller (5) is concerned with the potential for infestation of fungus gnats (Mycetophilidae) in peat and peat mixes in open storage. Fungus gnats are attracted to moist organic media. He suggests sterilization of peat prior to use. Fun-

gus gnat larvae, feeding on plant roots, can be a serious problem, particularly with greenhouse crops. They are capable of rapid reproduction and population growth. Their control requires persistent effort. Fungus gnats are common, often numerous, in Western Oregon greenhouses. It is likely that a peat medium could quickly become infested, even with gnat-free peat.

The Nematode Potential. Free-living non-parasitic nematodes have been found in peat (8). While these were not considered a potential problem, perhaps they serve as a warning that peat might be a source of parasitic nematodes.

Possible Sources of Contamination. Any time peat is exposed to wind, water, or soil, contamination is possible. There are numerous possibilities during the harvesting, distribution, and use of peat for this to occur.

Peat removal methods have changed considerably in recent years (3,9,14). From the hand methods of earlier years, excavation of peat became mechanized with use of draglines, scoops running on endless cables, power shovels, clamshell dredges, and specialized equipment. Bogs were first drained, a process requiring up to five years. Occasionally the equipment was on scows floating on a lake or pond, in which case the bog was not drained.

The long time needed to drain a bog, and other factors, caused further changes in harvesting many Canadian peat bogs (9). "Hoverbarges," supported by an air cushion above the bog surface and with a large clamshell crane mounted on each, scoop out bites of peat from the bog. The peat is dropped into hoppers on the barge where peat and debris are separated with water pressure. Peat is then piped from barge in form of a slurry to a dewatering station at the edge of a bog, dewatered, and trucked to a nearby processing plant. The peat is stockpiled, dried, sometimes ground, and bagged at the processing plant.

The many opportunities for contamination during these harvesting processes are apparent. There is some speculation that newer wet harvesting methods may increase the potential or infestation of pathogenic fungi. Contaminants may possibly enter bogs prior to peat removal. Wind and water-distributed weed seeds, fungal spores, nematodes, and insects could be present in peat before harvest. From this it seems logical that peat from deeper in the bog may be more free of contamination than that from surface layers.

There are ample opportunities, and concerns, for contamination of peat at the nursery and greenhouse sites where it is used (12). Broken bags, open storage, unsanitary conditions, and other situations may contribute to this problem. Commer-

cial growing mixes containing peat and sold by many industry supply firms are reported to often contain pathogens, apparently contaminated during the mixing progress (7).

CONCLUSIONS

It should not be implied from the foregoing that peat is an inferior material or inferior to other materials as a propagating or growing medium or medium component. Peat continues to be an important and useful product to the nursery and greenhouse industry. The growing concern with peat quality may, in part, be due to more available information and higher production standards than in earlier years.

Most reports indicate relatively low levels of contaminants when they do occur. This, however, does not eliminate the need for concern. A low level of contamination may grow into a serious problem.

It is important that peat be properly handled and used to avoid contamination. Sterilization of peat may be beneficial and economical for many production operations. Without sterilization, peat can be a source of disease, weed, and insect problems.

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PATHOGENS ASSOCIATED WITH PEAT MOSS USED FOR PROPAGATION[1]

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The use of peat moss as a constituent of media for growing and propagating plants is an old and well accepted practice. Although its properties may vary slightly, depending on its origin, peat moss generally has a high moisture-holding capacity, a low pH and contains a small amount of nitrogen (3). Its primary function as an additive to propagation media is to increase moisture-holding capacity.

Introduction of plant pathogens in peat moss has received little attention among plant propagators. Kim, *et al.* (4) isolated several pathogenic fungi from foreign and domestic sources of peat moss and stated that peat may serve as a vehicle for the entry of plant pathogens from foreign countries. Their observations also suggest that plant propagators might introduce pathogenic organisms into cutting beds, seed flats, etc. through the use of contaminated peat moss.

An example of such contamination occurred several years ago in Oregon when *Penicillium spp.* infected the basal portion of rhododendron cuttings and caused serious losses. Infected cuttings developed dark brown discoloration of the wood at the base of the cutting (Figure 1). Sporulation of the fungus on the decayed wood produced a powdery, bluish-green deposit.

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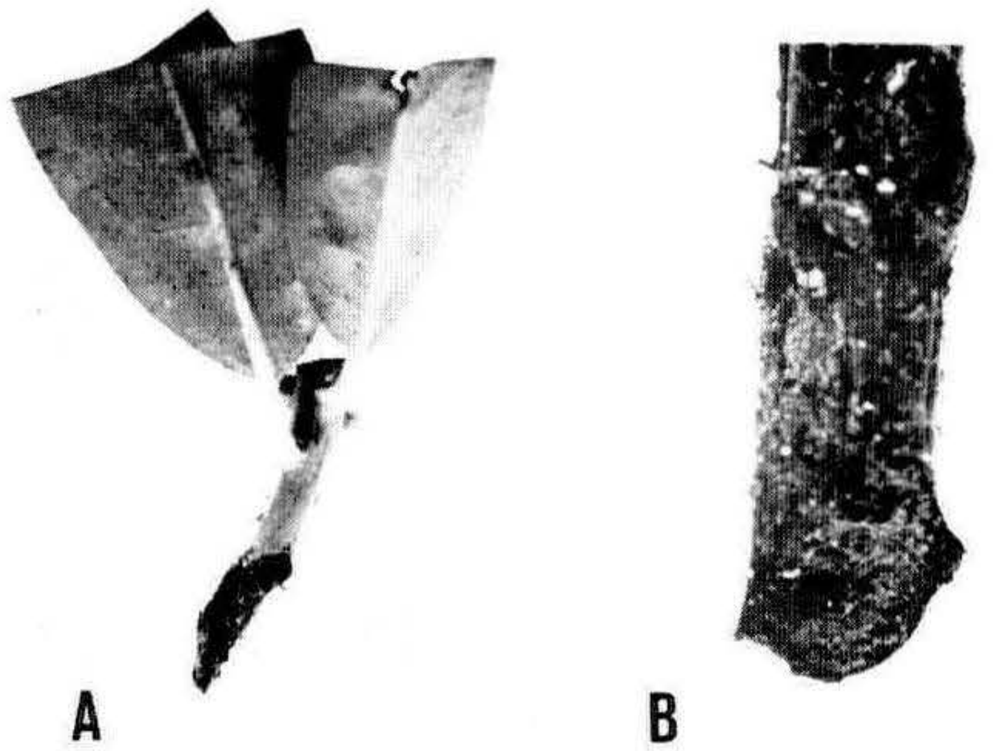

Figure 1. Basal decay of rhododendron cutting caused by *Penicillium sp.*
A = Entire cutting showing decay of basal portion.
B = Enlargement of decayed section.

In order to determine the source of infection, peat moss and perlite samples used in preparation of the propagation beds were collected and assayed for the presence of *Penicillium sp.* Contamination from the cuttings by epiphytic *Penicillium* spores appeared unlikely because the cuttings were immersed in a solution of 5% Clorox (5.25% sodium hypochlorite) for surface de-contamination before planting.

No *Penicillium sp.* or other fungus propagules were recovered from perlite samples. However, peat moss samples contained propagules of *Penicillium sp.*, many other fungi (both pathogens and non-pathogens) and bacteria (Table 1). The amount of contamination varied widely among the samples assayed., but *Penicillium sp.* were detected in every sample.

Table 1. Fungal and bacterial propagules isolated from several sources of peat moss[a]

Sample No.	Colony Counts[b]		
	Penicillium sp. (Thousands)	Other Fungi (Thousands)	Bacteria[c] (Thousands)
1	100	19,900	5
2	3	3,197	83
3	10	9,990	100
4	41	3,959	1
5	12	15.998	Trace

a) Assayed by planting on potato dextrose agar.
b) Counts are the average of three replicates and represent numbers of colonies per gram of peat moss.
c) Counts include bacteria and yeast-like colonies.

Strict sanitation procedures are followed by most successful plant propagators; however, the most stringent sanitation procedures will not provide satisfactory results if contaminated peat is not treated to destroy plant pathogens. Heat or chemical treatment of peat mixtures is recommended in California when

such mixtures are to be used for plant propagation (6). Other sources suggest that steam sterilization of peat mixtures used for seeding bedding plants is not beneficial and may even cause undesirable results (2,5); however, no data were provided, nor were details of the sterilization process given. Total sterilization is not necessary for the control of most plant pathogenic fungi and bacteria (1). Pasteurization of the propagating medium with aerated steam at 60°C (140°F) provides satisfactory results and eliminates all but the most resistant fungi and bacteria.

Chemical fumigation is frequently employed to eliminate pathogens from propagation media, particularly in locations where steam is not available. Satisfactory results are often achieved when label directions are carefully followed. Special attention must be given to completely eliminate all chemical residue following treatment to prevent injury of sensitive crops.

While many plant propagators have overlooked the potential of peat moss as a carrier of disease organisms in the past, more attention should be given to this possibility. Peat moss is a valuable additive for mixtures used to propagate and grow a wide variety of plants and should not be discarded. Rather, elimination of the pathogens should become a routine part of the sanitation program.

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BIOLOGICAL CONTROL OF *PHYTOPHTHORA CINNAMOMI*

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Abstract. *Phytophthora cinnamomi* root rot of avocado is biologically controlled in Queensland, Australia by intensive cover cropping and applica-

such mixtures are to be used for plant propagation (6). Other sources suggest that steam sterilization of peat mixtures used for seeding bedding plants is not beneficial and may even cause undesirable results (2,5); however, no data were provided, nor were details of the sterilization process given. Total sterilization is not necessary for the control of most plant pathogenic fungi and bacteria (1). Pasteurization of the propagating medium with aerated steam at 60°C (140°F) provides satisfactory results and eliminates all but the most resistant fungi and bacteria.

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Abstract. *Phytophthora cinnamomi* root rot of avocado is biologically controlled in Queensland, Australia by intensive cover cropping and applica-

tion of chicken manure and dolomite limestone. This is now standard practice there. Root rot of pineapple in Queensland, caused by the same fungus, is now commercially controlled by a preplanting application of sulfur to lower the soil pH below 3.8 Root rot of eucalyptus in Western Australia forests, caused by *P. cinnamomi* has been experimentally controlled by changing the understory from highly susceptible *Banksia* spp. to highly resistant *Acacia* spp. through controlled burning. All of these successful procedures involve both biological and ecological control by mechanisms not yet fully understood, but under further investigation.

In August 1969 I gave a lecture before the Australian Nurserymen's Association in Queensland, Australia, and included my usual request for growers and others closely associated with a given crop to tell investigators of areas where the pathogen is thought to be, but the disease is not (1). One nurseryman then told me of a healthy 30-year-old avocado grove on Tamborine Mt. surrounded by groves sustaining severe losses from root rot caused by *Phytophthora cinnamomi*. The grower had followed an unusual cultural regimen from the beginning and had one of the most productive groves in Queensland. The next day we went there and found a beautiful grove well protected by clouds of mosquitos. Root root was essentially non-existent, but was prevalent in nearby severely diseased groves. Soil samples were collected and baited with white pineapple leaf bases. The typical fruity odor of pineapple invaded by *P. cinnamomi* developed, but the fungus could not be cultured until a selective medium was used that inhibited bacterial growth. The pathogen was present, but the disease on the highly susceptible crop was not. Why?

Sterile alfalfa stem baits were placed in this soil and in soil from a badly diseased grove. One inch of the stem from the soil of the diseased grove developed an average of 311 sporangia; that from the healthy grove developed only 10. Mycelial mats placed in extracts of these soils gave similar results, and there was considerable mycelial endolysis in the suppressive soil. Filtrates from suppressive and conducive soils passed through Millipore filters to remove microorganisms gave no endolysis of *P. cinnamomi* mats placed in them, indicating an active microbiological relationship. Dilution plates of soils showed suppressive soils to have more pseudomonad bacteria and actinomycetes than conducive soils. After treatment with aerated steam at 140°F/30 min. and reinoculation with the fungus the soil was still suppressive, but after a 212° treatment it had completely lost its suppressiveness. This was confirmed by growing susceptible jacaranda seedlings in nontreated suppressive soil and that treated at 140° and 212°F, all inoculated uniformly with *P. cinnamomi*. The fungus grew through 1¾ in. of suppressive soil treated at 212°F/30 min. and survived there for 6 weeks; there was little survival in such soil treated at 140°F/30

min. Antagonists were diminished, but survived the 140° treatment. Disease incidence paralleled the results with mycelial mats. Suppression of the pathogen by antagonists had been protecting this grove for 30 years, and the effective biocontrol apparently was due to heat-tolerant bacteria and actinomycetes (2, 3).

Thus began a study that is still continuing to clarify the many fascinating angles of this problem. I have returned to Australia three times for a total of 23 months studying it, and it has been continuously studied there by P. Broadbent in New South Wales, K.G. Pegg in Queensland, and N. Malajczuk in Western Australia. The complex story is being clarified, but the application of the biocontrol has far outstripped our understanding of the mechanisms involved. Most of the avocado growers of Queensland and New South Wales now use this so-called "Ashburner system" and the disease losses have been greatly reduced (7). The sequence of the system: New Zealand blue lupine is planted in the fall (March-April). This is disced down in spring (October-November) when in flower, and chicken manure (2 tons/acre) broadcast, plus an NPK fertilizer (1 lb. per tree). A mixture of *Lablab purpureus* and corn or sorghum is immediately thickly planted. This is disced in fall, and chicken manure (2 tons/acre) and NPK (1 lb. per tree) applied. Dolomite limestone is added whenever the pH falls below 6.0. Blue lupine is then planted, and so on *ad infinitum*. This procedure supplies a great deal of organic matter on the surface of the soil. Surface roots are never disturbed by cultivation or plowing. These cover crops are grown in place two years before a new planting of avocados is made. The organic matter is piled around the base of young trees, but not against the trunk, for the first five years. After that, fallen leaves maintain the organic matter under the trees, but organic matter (barley straw, sorghum, or Rhodes grass hay) may be added. Use of container-grown trees free of *Phytophthora* is emphasized in planting (3).

Old diseased groves may be pulled and started anew with the above procedure. One such orchard (Ware) has been monitored by Pegg (7) during the four years since replanting. Population of the pathogen has been below the detectable limit for the last two years, and the trees are making excellent growth. Other diseased orchards have been severely pruned and heavy applications of straw made in addition to the cover crops. Trees injured in Ashburner's grove in the extraordinarily wet year of 1974 (150″ rain; 55″ in 3 days) were so treated. They put out new growth that reached 6 feet in the first year and were sizeable trees in two years.

Pegg (7) has made extensive surveys in Queensland, correlating levels of exchangeable Ca with severity of root rot on a

range of crops. Almost without exception severe root rot and low Ca levels have been linked, and high Ca with slight root rot, in hundreds of samples studied. Frequently these sites are adjoining or across the road from each other. In one instance the first row of avocado trees below a vegetable field was free of root rot, but the rest of the grove was severely damaged. Calcium and fertilizer had washed into the first row of trees from the vegetable area.

Ashburner's soil is suppressive to *P. cinnamomi* and *P. citrophthora* and lyses mycelium of *Pythium ultimum*. *Phytophthora cinnamomi* disappeared from infested soil treated by the Ashburner method in the Ware grove, but has remained in detectable amounts in Ashburner's grove, although root rot control was very good in both cases. Suppressiveness may be temporarily lost when soil is waterlogged (2,3), probably because of a slight shift in balance of antagonists. Depending on the duration of submersion, it may take a month or more to recover suppressiveness. This feature of soil may also be lost by application of excessive masses of inoculum, temporarily destroying the microbial balance. The roots of volunteer avocado seedlings growing underneath completely healthy avocado trees in suppressive soil usually are mostly rotted, but seedlings growing in the tree interspaces will have little or no root decay (7). Although this has not been studied, it is probable that root exudates from shade-grown seedlings are more favorable to *P. cinnamomi* infection than are those from sun-grown plants. In any case, this provides a good means of fungus survival in suppressive soils.

There are at least two general means by which suppressive soils operate to decrease activity of *P. cinnamomi*. The fungus requires a stimulatory compound produced by soil bacteria to form abundant zoosporangia in soil. These bacteria occur in all soils, but may be repressed by inhibitory microorganisms, or the compound may be destroyed by them. This apparently is the dominant effect in the Ashburner suppressive soil. The inhibitors seem to be inactivated in waterlogged suppressive soil, and infection then occurs. Other antagonists may operate more directly by attacking the mycelium, chlamydospores, vesicles, or zoosporangia of the pathogen (3,4). This is clearly shown by the Ware soil, in which the fungus produces copious zoosporangia. Why then is it suppressive? Probably the germ tubes of the zoospores are attacked, preventing infection. This is shown in Table 1.

It is of interest how Ashburner first devised his system 40 years ago. He felled rainforest for his planting area. Reading that avocado was a rainforest tree in Central America, he tried to maintain rainforest conditions in his grove. He was told that

Table 1. Mechanisms of biocontrol of *Phytophthora cinnamomi* in avocado soils in Queensland, Australia.

		Pathogen	Sporangial Stimulators	Sporangial Inhibitors	Lytic Micro-organisms	Root Rot
SUPPRESSIVE SOIL	Moist	Sporangia sparse (Ashburner)	+	++++	+++	Slight
		Mycelium lysed (Ware)	++++	+	++++	Moderate
	Water-logged	Sporangia and mycelium moderate	+++	+	+++	Moderate to severe
CONDUCIVE SOIL		Sporangia and mycelium abundant	++++	+	+	Severe

this meant high organic matter on the surface, fairly high calcium, magnesium, phosphate, and nitrogen (mainly in the ammonium form), and a pH near neutrality. The trees he planted were from a nursery that supplied trees to many others who subsequently sustained heavy root-rot losses. Probably the trees were infected, or at least infested, when planted. The rest is history! Ashburner might well be called a precocious organic gardener, and the pertinence of his reasoning was exceptional.

In rainforests, nutrients are brought up from deep soils by roots and are recycled in the surface by fallen leaves. Calcium is locked up in the organic cycle, with almost none lost, but is one of the first cations to be leached from mineral soil. Thus, Queensland rainforests have 3,200-10,400 ppm exchangeable Ca, but the organic matter is lost and Ca is quickly reduced to 180-270 ppm in cultivated pineapple fields. Suppressive avocado soils range from 3,000 to 6,000 ppm (3,7). The highly conducive Western Australia Gosnell sand has only about 160 ppm. Cultivation has, in this sense, been a largely exploitive process. Nitrogen (as NH_4) and Mg are also involved in the organic cycle. With loss of organic matter and Ca, the soil becomes too acid for bacteria. Microorganisms also decline because of loss of Ca and N, and the soil rapidly becomes biologically impoverished (1,3).

It is not surprising that *P. cinnamomi* has not been recovered from "undisturbed" Queensland rainforest soils (7). It may be present in amounts too low to be detected by present methods, but more likely is present only in small pockets of most favorable sites. Several such areas have been observed in which the lowest spot has no *P. cinnamomi* susceptible plants.

Seedlings of susceptible plants start growth in drier years on the margins of the spots, but are killed in moist years. Thus, the size of the area varies directly with rainfall, and the pathogen survives at the fluctuating margins of the spot. In very wet years such sump areas overflow and spread the pathogen more widely, but a series of dry years restrict the pathogen to the original small center. Such areas are difficult to detect in rainforests, and are apt to be attributed to hog wallows or disturbance by man when they are observed. In such situations the fungus is maintained in balance with the vegetation, the environment, and associated microbiota, and disease expression is rare (3). There is no basis in fact for the assumption that absence of root rot means absence of *P. cinnamomi*.

The possible ways this rainforest ecology suppresses activity of *P. cinnamomi* may be enumerated.

1) High organic matter, Ca, and N stimulate antagonistic microorganisms. The soil is biologically very active.
2) Soil pH of 6.0-7.0 is favorable for bacteria.
3) High organic matter and Ca improve soil structure and drainage.
4) High Ca possibly may affect host resistance.
5) Healthy plants remove much water from soil and decrease waterlogging.

The ability of suppressive rainforest soil to control *P. cinnamomi* is impressive. One severely damaged avocado grove was located just above a remnant of rainforest similar to that which had been removed to plant the orchard. Although the fungus has been washed into the rainforest from the grove for many years, it could not be recovered from soil in the rainforest.

PINEAPPLE

Pineapple becomes chlorotic if lime is added to soil, and the Ashburner method, therefore, cannot be used to control *P. cinnamomi* in this crop. Pegg (7) tried soil acidification in Queensland by applying elemental sulfur to the soil surface and discing it in to a 6-inch depth. In some soils *Thiobacillus thiooxidans* had to be added with the sulfur. When the pH was lowered to 3.7, *P. cinnamomi* root and heart rot were controlled. The method is now widely used by Queensland pineapple growers. The low pH of the soil greatly reduces zoospore production and release, increases cation concentration which reduces disease incidence, causes nitrogen to be in the disease-reducing ammonium form, and favors the antagonist, *Trichoderma viride*, and its antibiotic gliotoxin.

The valuable timber tree, jarrah (*Eucalyptus marginata*), is susceptible to *P. cinnamomi*; marri (*E. calophylla*) is more resistant but of less value. In moderately suppressive loam soil both are resistant, but in the prevalent conducive lateritic soil jarrah is quickly killed and marri remains. When suppressive soil is sterilized, both species are susceptible because the suppressive microflora is destroyed, but if a small quantity of nontreated soil is added, suppressiveness is restored. Extracts from the rhizosphere of either species in suppressive soil lyses mycelium and decreases sporangium formation, but in conducive soil lysis and inhibition of sporangia occur only in extract from marri rhizosphere. Rhizosphere microflora from suppressive soil protected both species; that from conducive soil protected marri but not jarrah. Since mycorrhizae are poorer in suppressive than in conducive soil, they are not likely involved in resistance (5,6). Actinomycetes and bacteria are active agents in the rhizosphere. (3,4,5,6)

A shift from the highly susceptible *Banksia* spp. understory to resistant *Acacia* spp. gives good control of *P. cinnamomi*. High-intensity burning brings this about by inducing *Acacia* seed germination and causing litter accumulation, but low-intensity burning favors *Banksia* and decreases litter. *Phytophthora cinnamomi* population is depressed when jarrah is grown in pots with *Acacia*. Sporangial formation is inhibited in extracts from soil where *Acacia* is growing, apparently due to antagonistic bacteria in *Acacia* rhizosphere. There may be injury to eucalyptus from high-intensity burn, so they may have to use low-intensity burn and heat-treated acacia seed. (8)

Eucalyptus dieback occurs in Western Australia, Victoria, and Queensland, always on infertile soil low in humus, and microbiologically poor.

Suppression lies in the organic fraction. Surface litter is conducive at the top but becomes more and more suppressive as it decomposes. The most suppressive area is the zone of interface of mineral soil and organic matter; it declines in both directions from that zone (Broadbent and Baker, unpublished). That generally is the zone of feeder roots. This led to the idea of transferring suppressive microflora to the nursery mixes. Since we could not do it by transferring soil, we tried the organic fraction. Decomposed mushroom compost was tried as recipient, as it is somewhat similar to the organic matter from the Ashburner system. We transferred suppressive microflora from decomposed organic fraction to mushroom compost treated at 140° or 212°F/30 min. Suppressive microflora from organic matter extract was transferred to a *P. cinnamomi* mycelial mat and

then the mat to mushroom soil treated at 212°F/30 min.

The hope is to develop a suppressive nursery mix so that the transplants will carry the suppressive microflora to the field. This must be combined with use of cover crops to supply abundant organic matter, and maintenance of high Ca and NH_4 nitrogen in the field.

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ROOT WEEVILS: FROM CUTTINGS TO LANDSCAPE

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I want to stress the importance of knowing *which* root weevil is causing problems, because the steps to take to alleviate the situation vary, depending on the species of weevil involved and the stage of development of the plant. Many nurserymen and some trade journal articles discuss the "strawberry root weevil" *Otiorynchus ovatus* as if that were *the* problem. In fact, I have never seen it seriously injuring, or even commonly associated with, woody plants.

There are many, perhaps a hundred, "root weevils", larvae

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There are many, perhaps a hundred, "root weevils", larvae

of the family Curculionidae, which feed on roots of plants. Some have very few hosts; others are nearly omnivourous. Some root weevils are widespread and some have a limited range. Nationally, the one of greatest concern to those who produce or maintain woody plants is *Otiorynchus sulcatus*, the black vine weevil (BVW).

Cutting Bench. I have seen cutting benches with yew, juniper, arborvitae, *et al.* cuttings stuck into wet, coarse sand or perlite with hundreds of BVW larvae causing nearly 100% mortality of the cuttings. With high populations of the weevil all new roots are consumed, the callus tissue is eaten away, and the bark girdled up to the medium surface. Almost always, the cases I have seen are in old wooden greenhouses that aren't as tight as they used to be, so it is easy to understand how a few adults could have gotten in. Since BVW adults are all female and lay an average of 6 eggs per day, with some laying 10 per day and since they can live for 2 years in a protected environment, one can understand both how the high number of larvae get to the plants and how one can prevent that from happening.

Sanitation and exclusion are the only tools we have in this case. There are no registered or recommended insecticides in the U.S. that can be used to eradicate the grubs; cuttings are often so severely injured before the problem is discovered that they cannot be saved. Checking the progress of rooting by periodically pulling a few cuttings at random will usually be sufficient to indicate problems in time to allow for resticking viable ones into a new clean bench if necessary.

Liners. Once out of the cutting bench, and either lined out or containerized, the plants face increased chances of root weevil damage. If stock is planted into an infested field or is subjected to heavy oviposition before there is a chance for good root establishment, grubs of BVW can again cause problems. Nurseries with sandy soil are much more likely to be prone to this than are those with clay soils. And the nurseryman should be aware of sources of likely adult migration in the proximity of new plantings. Established field stock is not so often badly damaged by grubs, although I have seen severe problems with some kinds of rhododendrons, hemlock, and especially yew, when such plants are grown in sandy soils. Again the best solution is sanitation and exclusion. There are no pesticides registered for elimination of an established grub population. Nielsen in Ohio has worked out a procedure for control of adult BVW which he has detailed in Ornamentals Northwest (1) and American Nurseryman (2). This is a procedure to try if there are recurring BVW problems in field-planted nursery stock. The adult BVW is not often very destructive, but reduction in their num-

bers reduces oviposition and subsequent grub problems. They are generally present and laying eggs for about 4 months out-of-doors.

The adult BVW feeds on above-ground plant tissue, generally leaves, and does little damage. Sometimes when leaf tissue is scarce they will destroy buds and this can be very serious. This usually occurs in spring before leaf break or, occasionally, in the autumn after leaf drop.

Containers. Plants in containers are a bigger problem than those in the field. BVW larvae can be very destructive to many kinds of plants in wood, metal, or plastic containers, much more so than in field-planted stock. I guess that this is so because of two factors. First of all, the larvae have a restricted area to search for new roots. In the field, through chance, many are probably lost or move to a different plant when they seek a new feeding site. In a container they don't have far to go before they encounter an impervious barrier and are turned back toward the root area. Also, vigorous, new, susceptible roots are often along the wall of the container making them even more readily found by the grubs. Secondly, the grubs have much more protection from natural enemies in containers than they do in the field. Predatory ground beetle larvae cannot leave the soil and climb into a container, for example. The container mix may not be so easily colonized by pathogenic fungi as is field soil, and fungus is a major killer of BVW in the U.S. Pacific Northwest. A third *possible* factor is vigor of plant growth in container stock versus field stock. Damage to foliage or buds of container-grown stock by adult weevils is not usual and is easily detected.

We need a good material for control of weevil larvae in container-grown nursery stock, ideally one which, once applied, will last long enough to provide season-long protection and one effective enough to eradicate established populations. Unfortunately there are no good candidates. None of the currently marketed insecticides, nor any now under development, have that potential. The best hope for the forseeable future is exclusion and, perhaps, use of the Ohio adulticide program.

Landscape. In established public or private landscape plantings root weevil larvae are sometime involved with decline of yew and some rhododendrons, such as 'Olive', but are not usually a problem. Apparently, older plants have enough roots that they can stand the loss of a few; in addition fungi and other natural enemies become established and keep the weevil numbers down. At any rate, we seldom see established landscape plants damaged by root weevil grubs and treatments with insecticides are seldom warranted.

The adult BVW is not a serious threat to foliage or buds in

established landscapes either. However, there are some other kinds of root weevil adults which are very serious as destroyers of the esthetic value of landscape plants and which, if not controlled, can reduce leaf tissue to the point where the hardiness and health of the plant is endangered. In the U.S. mid-Atlantic states the pretty little weevil *Pseudocneorhinus bifasciatus* feeds heavily on California privet, azalea, weigela, and a dozen other ornamentals, creating havoc with the homeowners' carefully manicured landscaping. The grubs, however, seem to be inconsequential. Also in this area are the Asiatic oak weevil and Pales weevil. California has the cribrate weevil. All of these are more injurious as adults than as larvae.

On the west side of the Cascade Mountains of Oregon and Washington, up into British Columbia and down into California we have the most serious problem with adult root weevils. A dozen different species, notably the obscure root weevil (*Sciopithes obscurus*), the woods weevil (*Nemocestes incomptus*), *Otiorynchus singularis*, and three species of *Dyslobus* cause unacceptable damage to the foliage of rhododendrons, viburnums, roses, ivy, currant, fuschia, clematis, primrose, azalea, salal, and many more. These, *especially* the obscure root weevil and the woods weevil, tend to remain active in much cooler weather than BVW and cause considerable early spring and late autumn havoc. My best collecting ever was in a red raspberry field in early May from 10 PM to midnight when the temperature was 33°F where two of us collected several hundreds of weevils from the canes for use in lab studies. They were feeding on the buds and newly-expanding leaves.

Table 1. Effect of various chemical treatments as a deterrent to leaf damage to rhododendron caused by adult root weevils, 1976.

Treatment (lb. a.i./100 gal.)		Treatment interval, weeks	Mean feeding per leaf, sq. cm.	Percent reduction from check
Untreated check		—	1.10	—
Orthene 75 S	(1)	4	.02	98
Orthene 1.3 EC	(0.75)	4	.03	97
Orthene 75 S	(0.75)	4	.03	97
Imidan 50 WP	(1)	4	.05	95
Orthene 75 S	(0.5)	4	.06	95
TH-6041 25 WP	(0.25)	4	.10	91
Orthene 75 S	(1)	6	.16	85
Malathion 5E	(1)	2	.24	78
Sumithion 8 EC	(1)	4	.58	47

For these foliage-destroying "root" weevils, none of which is usually serious in the grub stage, we have determined that the systemic organophosphate insecticide acephate (marketed as Orthene® by Chevron Chemical Company) is the best foliage

protectant (Table 1) and there is a 24c (local need) label for that use in Washington and Oregon.

Our current research effort is in the study of the reasons for different susceptibility of various *Rhododendron* species and hybrids to feeding by adult root weevils, in the hope that we may be able to exploit any differences we find for protection of existing plants and/or development of resistant new hybrids.

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CHEMICAL CONTROL OF ROOT WEEVILS

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Root weevils, the black vine and strawberry, continue to be a serious problem of nursery stock in British Columbia. Since the loss of pesticides such as chlordane and aldrin from our market, weevils have been increasing in population. Weevils infest almost every species and cultivar of plant from rhododendrons to maple and arborvitae.

Leaf notching caused by adult feeding is unsightly and renders an infested plant unsaleable. The larvae feed on roots of both established plants and liners, restricting uptake of nutrients and water. High mortality in liners results from girdling at the crown by larvae.

There is *usually* only one generation of weevils per year. The adults emerge from pupae in late May to early June and begin laying eggs in 2 to 3 weeks. Eggs are laid throughout July, August and September. The insect overwinters as a larvae and pupates in May.

We are now finding that with container growing, the use of heated propagating benches and polyethylene covered houses, more than one generation of weevils may occur in one year. Therefore populations, in these circumstances, increase very rapidly.

Adults, pupae, and young adults, as well as larvae, have been found simultaneously in polyethylene-covered houses in early spring.

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Adults, pupae, and young adults, as well as larvae, have been found simultaneously in polyethylene-covered houses in early spring.

If a larval infestation in containers is to be prevented, control measures must be aimed at the adults. Control measures must be taken in the 2 to 3 weeks between adult emergence and the start of egg laying, making the timing of insecticide application critical. The first foliar application of an insecticide must occur when the first leaf notch appears, and must be continued until the last adult has emerged. Adults emerge in British Columbia from the last week of May to mid-July. Ideally, an insecticide with residual activity lasting for six weeks or more would require only one application.

A field trial was conducted this summer on a local nursery to test the efficacy of Belmark, Orthene and Guthion for control of adults. Belmark, a new synthetic pyrethrin, provided excellent control. Orthene provided good control and Guthion fair control. All three insecticides significantly controlled adults compared to the control (See Table 1).

Although a second application was applied at three weeks, only one may be required. Other studies have shown Belmark (Pydrin as it is known in the U.S.) to have residual activity for up to 70 days (1).

Table 1. Efficacy of foliar sprays applied May 19 and June 20 to *Rhododendron* spp.

Material	Rate (lb ai /100 gal)	3 weeks after first application	3 weeks after second application	Total at six weeks
Belmark (EC)	0.2	1.5	1.1	2.7
Orthene (S)	0.75	4.3	4.0	8.3
Guthion (50 WP)	0.5	12.2	5.0	17.2
Check		30.5	33.7	64.2

Larvae are more difficult to control than adults. Most soil drenches tested for controlling larvae have not been effective. Norm Tonks (Agriculture Canada Research Station, British Columbia) is having good results with Orthene, Furadan, Diazinon, Permethrin, Thiodan and others when the drench is applied early, and the larvae are very young. Treatments begin in mid-July and continue through fall. So far, Furadan is showing the most promising results giving up to 18 weeks residual control. Orthene provided control for 1 month. No control was obtained when insecticides were applied in spring.

The key to effective control of weevils is the timing of spray application. Close observation of the insect is required to regulate the timing properly. Calendar dates can only be used as a guide. The life cycle must be closely monitored where the environment is altered with heating cables or polyethylene-covered houses.

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WEED CONTROL IN ORNAMENTALS WITH GLYPHOSATE[1]

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The herbicide glyphosate is well established as an important chemical for controlling many kinds of perennial weeds. These include Canada thistle (Cirsium *arvense*), field bindweed (Convolvulus *arvensis*), Japanese knotweed (*Polygonum cuspidatum*), mugwort (*Artemesia vulgaris*), bracken fern (*Pteridium aquilinum*) leafy spurge (*Euphorbia esula*), nutsedge (*Cyperus esculentus* and *C. rotundus*), and many perennial grasses such as quackgrass (*Agropyron repens*), Johnsongrass (*Sorghum halapense*), and Bermudagrass (*Cynodon dactylon*).

This report will not attempt to review in detail the great amount of work that has been done with glyphosate for weed control in ornamentals. Instead it will call attention to certain aspects that may influence successful use of this herbicide *when it becomes available for use on ornamentals*, and may account for some variability that is observed in weed control and crop response.

Timing of applications. To properly evaluate the effectiveness of a translocated herbicide such as glyphosate, observations should be made on regrowth after initial kill of weed foliage. What happens later in the year, or next year? Glyphosate is relatively slow acting. What is important is not how quickly the weed dies down, but how completely the root or rhizome system is killed, as measured by regrowth later.

On the basis of such an evaluation, the most effective time to apply glyphosate on Johnsongrass is in late summer or early fall when the grass is in the boot or full head stage of growth

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[1] Scientific Paper No. 5249. College of Agricultural Research Center, Washington State University, Pullman. Project No. 1423.

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(15). August or September applications on quackgrass generally have given better control through the following year than May or June applications (12,22). However, there have been reports of excellent results from May applications (2).

Quackgrass is unsightly and a vigorous competitor in a nursery or ornamental planting. Rather than leave an infestation uncontrolled through the summer, it should be sprayed after it reaches the 4- to 6-leaf stage at a height of 8 to 10 inches. This will give control for two or three months during the summer, and a second application in the fall should result in minimum regrowth the second year (13,16).

Applications of glyphosate at late bud stage or full bloom have given better control of Canada thistle and field bindweed than earlier or later applications (19).

Even with a properly timed application, some regrowth of perennial weeds usually occurs later in the same year or the following years, and additional treatments are required for complete control (10,13,19).

Cultivation. Plowing or cultivating after glyphosate application to quackgrass or Johnsongrass generally appears to have little or no effect on control if it is delayed for at least 4 days after treatment (3,9,15). However, in one case there was no adverse effect from plowing one day after application (8) and there are reports of increased control from plowing or tilling one or more days after spraying (9,22).

Climatic effects. Rain within 8 hours after application of glyphosate may reduce effectiveness by washing off some of the herbicide before it has penetrated weed foliage (3). On the other hand, high humidity favors penetration (2), and wetting the foliage after herbicide treatment may enhance performance (11). Adequate soil moisture is essential. Control has not been satisfactory on Johnsongrass (13) or field bindweed under moisture stress.

Temperatures of 75°F or higher following application are less favorable for control than 60°F or lower temperatures (3, 5, 11).

Combinations with residual herbicides. Residual herbicides applied with glyphosate may reduce its effectiveness in controlling perennial weeds (4,17,23). Usually the effect is greatest at threshold rates of glyphosate, and in some cases it can be overcome by increasing the rate (4,17). Diuron apparently is less antagonistic than simazine or terbacil (17,18). In some cases the residual herbicide affects only how rapidly the glyphosate activity occurs, but does not reduce the final effect (18).

Combinations with other herbicides. Addition of amitrole to glyphosate resulted in less control of perennial grasses when evaluated the following summer (18). On the other hand the effects of 2,4-D and amitrole were at least additive and sometimes synergistic with glyphosate on nutsedge (23).

Effects of other chemicals. Addition of ammonium sulphate at 2.2 or 4.5 lb/A[2] to glyphosate at rates as low as 0.2 lb/A resulted in control of nutsedge and quackgrass equal to control from glyphosate alone at rates 2 to 4 times as high (7,23).

Tolerance of ornamentals. When glyphosate is registered for ornamentals it probably will be for preplant use, and also as a directed spray in plantings, avoiding contact with crop foliage. Most ornamental plants are injured to some degree if glyphosate is sprayed on foliage or on green bark. Out of 45 species or cultivars on which two or three branches were sprayed with glyphosate at 3 lb/A in August, 12 kinds did not show injury at the end of one month following spraying (21). More than half of these were conifers or broadleaf evergreen covers. Conifers in general are more tolerant than deciduous plants, and conifers are more tolerant when dormant or fully mature than when growing (1,6).

When only the lower 15 to 18 inches of trunk was sprayed two successive years on 45 kinds of shade and small ornamental trees, most were not injured. Slight trunk or foliage injury occurred on some kinds, especially the first year. Unacceptable foliage injury occurred on *Tilia cordata* 'June Bride' at 3 lb/A, and unacceptable bark discoloration on *Gleditsia triacanthos* var. *inermis* 'Sunburst' (20).

Glyphosate has great potential for solving a number of weed problems in ornamentals as it is now doing in other crops. One of its important uses should be for preplant elimination of perennial weeds. This is the best time to control perennial weeds, when there is no problem of possible injury to ornamental plants. More than one year should be allowed for preplant cleanup where possible, to permit the re-treatments that are usually necessary for complete control of difficult weeds.

When glyphosate becomes registered for directed application in ornamentals, it should be extremely useful, but care will have to be taken to avoid problems. Research in California in fruit trees and vines has led to the conclusion that glyphosate, in direct foliar applications or through drift, causes fewer immediate symptoms but more actual plant damage than other

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[2] Rates are in pounds of active ingredient per acre.

translocated herbicides, including the oil soluble amine of 2,4-D (14). Glyphosate translocates rapidly in most plants and moves farther into the unsprayed portions of trees and vines than other translocated herbicides. It is important to understand the potential damage from improper use of this herbicide, as well as its potential value when used carefully as labeled and recommended.

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GETTING THE MOST OUT OF HERBICIDES

BRUCE A. BRIGGS

Briggs Nursery
Olympia, Washington 98501

A continuously on-going program is necessaryy to get the most out of herbicides. Products are constantly being removed from or added to the market. Research projects are underway in many geographical areas and on many different products and combinations of products. I cannot begin to cover even our own experience in the allotted time, so I shall try to give some of the highlights in graphic form with slides and an attached table showing the products which have been most effective for us.

We started our chemical weed program in the 1950's with a few basic chemicals. In the years since then, we have added to the numbers of chemicals to develop an on-going program of application to a wide range of ornamental plant material on our 80 acres, including field plantings and some half a million containers. In the past, because of the risks and liability involved, I tried to do the major part of the application myself. Now, with a backlog of information and better new chemicals, this responsibility is gradually being delegated to others.

Along with field and container applications, each year we have run research and check plots to collect more information. We also cooperate with other growers, research stations and chemical companies to get more accurate evaluations. It is so very important to work with research and industry people, both

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in an exchange of information and in support, to develop together workable programs for the whole geographical area.

Proper and Safe Use. In developing a weed control program, it is wise, first of all, to keep a healthy respect for the potential damage a chemical can cause, both to the applicator and to the crop, while it is hopefully killing the weeds. In setting up, provide a dry, safe storage area which can be locked and a facility for safe disposal. Measure accurately and carefully calculate the actual ingredients per acre (a.i.a.), taking into account the percentage of actual material as printed on the label. Read the entire label carefully and check the crop registration. State and Federal laws can vary as to application and exception by area. Get information on the actual applications made in your area from other growers and research facilities. Use a small scale application against a check block to test out new chemicals or to test different rates and combinations. Observe and try to measure any damage carefully. You may eventually need to make an economic tradeoff: accepting some predictable damage in preference to the additional costs of labor for hand hoeing and a loss of growth from competition with weeds.

Keeping Records. Keep accurate records of applications: date, rate, plant cultivar, weeds, soil mix, time of day, temperature of air and soil, rain or sun before and after, growth stage of the plants and weeds, and any other pertinent factors. The type of soil mix could have a bearing on possible root damage; this should be checked at intervals afterward, as it may not show up for awhile above the ground. Eventually, of course, root damage could result in considerable loss of overall growth and vigor. There can be a pronounced difference in plant reaction among cultivars of the same species. Some plants are even stimulated to increased growth by some herbicides. Cultural practices, especially as related to heat, light and water stress can make a big difference in reaction. An already stressed plant will show damage from the added stress of a chemical application much more quickly and severely than would a vigorous and healthy plant.

Records of application need to be carefully footnoted with results shown at subsequent periodic checks. The evaluation of the results are the key to planning the next applications. Unfortunately, you will soon realize that there is no single herbicide or rate of application which can be used for all nursery crops. Your own records are your best guideline for the most effective use of herbicides on your own nursery.

Some of the Problems. Sometimes the results seem dramatic on the first application of a herbicide. After a few years, you may note a serious build-up of some few weeds, which the

chemical is not reaching. Without the competition from a broad spectrum of many weeds, the few kinds not eradicated will increase at an alarming rate and require further measures of control. Sometimes a combination of chemicals in one application will give a broader control. Sometimes spot spraying or hand weeding is necessary to take out the most resistant ones. Other times, a special type of weed may be treated with a second application: for instance, apply Kerb to kill residual grasses, or use 2-4-D to kill broadleaf weeds in a block of conifers.

As you work along in your herbicide program, guard against a false sense of security when one problem seems to be solved and try to keep an open mind in considering new herbicides and possible substitutes. There is that constant threat that the herbicide you have come to rely on might someday be taken off the commercial market. For example, as new products have become available, we have changed our program to include some of the better ones such as Surflan, Devrinol and Ronstar. We keep trying more combinations and testing new chemicals — it must be a continuously on-going program.

Some Guidelines for Use. Following is a listing of the herbicides we have found most effective at our nursery. However, I want to caution you that these application rates are only the ones used for research at our nursery. They may not be suitable for your use. They should be considered only as guidelines and you should work out the proper rates for your own specific needs.

CHEMICALS USED IN WEED CONTROL PROGRAM AT BRIGGS NURSERY

Key: a.i.a. — amount of active ingredient to be applied per acre.
C — application on clean field.,
S — application on small weeds of two leaves or less.
E — application on established weeds.

ATRAZINE (attrex) (1 lb. aia) C, E	Used on weeds too large to kill with Simazine. Up to 5 lbs. on large Christmas trees. Toxic to many plants. Long residual in the soil. Avoid over-use.
AMINO TRIAZOLE (amitrole) (1-2 lbs. aia) S, E	This may be applied over the tops in the early spring on special plants before they start growth, but after the weeds have begun actively growing. It is a good clean-up during the winter, when most herbicides fail. Use only the powder and not the liquid form, as the oil in the liquid will cause burning. Do not use on dogwood or junipers.
CASORON G.4 (dichlobenil) (4 lbs. aia) C, S, E	Useful in both field and containers. Use only when needed, because it does build up in the soil. The only chemical we have for many weeds such as horsetail.

CASORON W (dichlobenil) (3 lbs. aia) C, S, E	Better coverage than Casoron G.4; more toxic. One of the best weed-killers in the winter and fall. Requires a great deal of water and cooling when used during summer. May damage firs, euonymus, *Cotoneaster dammeri, Viburnum davidii, leucothoe, mugho pine* and other low-growing shrubs. Do not use in a closed house.
CHLORO I,P.C. G.10 (chlorpropham) (6 lbs. aia) C, S E	Winter control only. No toxic effect in plastic houses. Best on grass and chickweed.
DACTHAL (chlorthal) (12 lbs. aia) C	A safe herbicide, but gives poor results in our climate.
DOWPON (dalapon) (8 lbs. aia) S, E	Used for grasses only. Useful in combinations: 8 lbs. + 4 lbs. Atrazine + lbs. Amino triazole for quack grass.
DEVRINOL (napropamide) (4 lbs. aia) C	Strong on grass, but poor on some broadleaves. More effective in combination with Casoron, Simazine, Ronstar, or Tenoran.
DINITRO (dinoseb) (1-2 qts. per 30 gals. water) C, E	A contact killer. Needs warm temperatures. Hard to work with. Good on tender broadleaved weeds. Use in early spring on conifers for groundsel (*Senecio vulgaris*).
GOAL (oxyfluorfen) (1-4 lbs. aia) C, E	A new broadleaf weed killer. Gives excellent control on groundsel for up to six months.
LASSO (alachlor) (2-4 lbs. aia) C	Apparently used effectively in the Southeast U.S., but not as useful under our conditions here. Useful here only in combinations, giving poor to fair results.
LITHATE (95% 2-4-D. W.) (1-1½ lbs. aia) S, E	Used over the tops of conifers when they are not in active growth. Control for broadleaved weeds.
KERB (pronamide) (1-3 lbs. aia) C, S, E	Effective only in late fall and winter. Use over the tops for grass control. Use at heavy rate for quack grass. Useful in combination with other broadleaf herbicides.
PARAQUAT (Gramoxone S) (¼-½ oz/gal aia) E	A contact killer for spot spraying. Keep off ornamental tops. Not as effective on hot days or when the plant is under stress. Use spreader-sticker on hard-to-kill weeds. Use higher rates on cold days.
PRINCEP 4G (simazine) (2-3 lbs. aia) C, S	Still our most reliable chemical for the fields. Also used in combination in the field. For containers, use ½ lb. added to Surflan, Tenoran, Devrinol and others to increase the percent of total kill. Do not use around boxwood, euonymus, leucothoe, nandina, enkianthus or many of the deciduous plants. Only low rates are safe

	around evergreen and deciduous azaleas, forsythia and young magnolias.
ROUND UP (glyphosate) (½-1 oz/gal aia) E	Useful in control of morning glory (*Convolulus arvensis*) as spot spray. Use at least 2 times the concentrations of Paraquat. Needs at least 6 hours before a rain to work.
RONSTAR 4G (oxadiazon) (2-4 lbs. aia) C, S	The best new control for bittercress (*Cardamine oligosperma*). Foliage must be dry. Some damage to some broadleaves in tender growth. One of the more safe chemicals for small containers.
SINBAR (terbacil) (1 lb. aia) C, S, E	Use in combination with amitrole for a strong combination to use for non-selective killing.
SPIKE (2-3 lbs. aia) C	Non-selective killer for can lots and driveways. Avoid plant root systems. Long lasting. *Juniperus sabina* 'Tamariscifolia is tolerant of this at low rates.
SURFLAN (Oryzalin) (3-5 lbs. aia) C, S	A better weed control than Treflan. Used mainly for grasses. Used in combination on containers.
TENORAN (chloroxoron) (3 lbs. aia) C, S, E	Good control on fireweed (*Epilobium angustifolium*), groundsel, and bittercress. Not very effective on grasses. On new plantings in the field, use 3 lbs Tenoran with 2 lbs Simazine and 1½ lbs Kerb. On established weeds in the fall, use 3 to 4 lbs Tenoran with 1¼ lbs Atrazine; or 3 lbs Tenoran and 1½ lbs Amino triazole. On containers, use in combination with ½ lb Simazine and 3 lbs Tenoran on conifers and 2 to 2½ lbs on broadleaves. Kerb at 1½ lbs may be added for grasses in fall and winter. Causes some damage to broadleaves, especially when they are in new flush of growth. Reduce the concentration for use in plastic houses and during hot weather.
TOK (nitrofen) (2-4 lbs. aia) S	Our Pacific Northwest weather is usually too cool to use it effectively. Goal appears to be much superior for our use.
TREFLAN (trifluralin) (2-4 lbs. aia) C (incorporate)	Does not work very well in our weed control program.

NOTES ON PROPAGATION OF CERTAIN *ACERS*

J. D. VERTREES

Maplewood Nursery
Roseburg, Oregon 97470

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veal this. Even so, we continually receive requests for information on recent propagation procedures for production by seed and by asexual methods. As I accrue information from successful propagators across the U.S. and in other countries, I am increasingly impressed by the variations in methods and procedures.

This fact of procedural variation should be stressed, along with the fact that completely differing procedures do not indicate that one propagator is more correct than another. It simply means that there are several successful variations, and that these should be adapted to the particular needs of each propagator as to his particular time, facility, and condition of plant handling.

SEED

Variation in seedling germination in the Series *Palmata* seems to be quite disappointing with some producers. It is my experience that success in germination is directly involved with the dormancy of the seed when it is put into stratification. Seed from some local sources, and especially dried seed from overseas, will be quite dormant. We have experienced dried seed from Japan that germinated annually in seed beds over a five-year period, even though the seed had been pre-treated and stratified in the normally accepted procedure.

With *Acer palmatum*, and others of the Series *Palmata*, we collect our local seed while it is still rather green. In our area this is usually about mid-September when the "wings" of the seed are brown, but the nutlets are still green and the samara will separate quite easily. This will vary in timing with different stock plants and among sub-species. *A. japonicum* usually is slightly later in reaching this stage of development. Our native species related to "Japanese maples" — *A. circinatum* — will give excellent germination when picked with the entire samara still green (perhaps in late August). Dried *A. circinatum* seed can be very erratic in germination.

After the seed is picked, it is immediately cleaned, the samara separated, lightly dusted with Captan or equivalent fungicide, and stratified. We mix equal parts of moist (not wet) peat moss and cleaned seed. This is then tied tightly in a plastic bag, labeled, and stored at 1 to 4° C (34 to 40°F.) for at least 90 to 150 days. We then plant in seed flats or in outdoor seed beds. The seed may be sown directly in seed beds outdoors in the fall immediately after picking and cleaning. The beds must be strictly guarded against soil fungi, soil insects, rodents, etc.

When using dried seed from other sources, a pre-stratification soaking is important. We soak seed for 48 hours,

starting with water at about 43°C (110°F.) covering the seed. The container is kept in a warm room, letting the solution gradually cool to room temperature.

We find that such species as *A. davidi*, *A. capillipes*, *A. tegmentosum*, *A. maximowiczii*, *A. micranthum*, *A. buergerianum*, *A. truncatum*, and A. truncatum var. mono (Syn: *A. mono*), all respond to the procedure of stratifying semi-dry seed. High percentages of germination result when the seed is harvested with a slight green color remaining in the samara.

When very dry seed is received, the 48-hour soaking in warm water will speed up the germination rate the first year. Even so, in these species, some germination will take place the second season. We received several pounds of *A. buergerianum* seed from Korea which was not only very dry but arrived in late summer, too late for our planting schedule. That fall the seed was soaked and stratified. About 20% germination occurred the first spring, but the following season a very heavy germination took place.

In the Series *Grisea*, seed production is even more frustrating. I have soaked, heated, dried, acidified, frozen, or used a combination of the above prior to stratification. No increase in germination was apparent. The only germination took place after the second spring following treatment. We try to collect seed before the nutlet turns brown. We stratify in damp peat moss for at least 150 days at about 35°F. Planted in seed beds, or in flats, we experience very little germination the first season (less than 1%). Left undisturbed, we get very good germination compared to the amount of viable seed planted. *Acer triflorum* and *A. nikoense (A. maximowiczianum)* respond the same way. Extremely dry *A. triflorum* seed from Korea germinated very well the second season. It had pre-treatment and stratification prior to planting.

GRAFTING

Grafting remains the predominant method of propagating the many cultivars of "Japanese maples" and varieties of other Asiatic species of ornamental value. It is true that some propagators use budding, layering, and air-layering. Some of these methods are more tedious than side-grafting, while some are limiting in volume because of the procedure.

The standard side or veneer graft is easily accomplished. The care and attention to the understock preceding grafting and close care and culture of the plant after grafting are most critical. Probably the majority of "Japanese maple" grafting in the U.S. is done during the dormant season. Some propagators start in late November or December; others graft in March. We find

mid-January to February a good time for us, although this cannot be too late because our scions on the outside stock plants begin to break dormancy in late February. We prefer to use fresh-collectd scions, although they can be refrigerated fairly successfully for a short time.

Summer is the second most popular time for grafting in the U.S., but the most preferred in Holland. The mechanics of the side-graft procedure is about the same, but the pre-grafting handling of the understock is, of course, different. After finishing spring growth, potted understock should be dried somewhat to establish "summer dormancy," and should be kept dry prior to grafting. As soon as the graft is made we immediately place it under an automatic mist system which prevents any dessication until the callus forms. We do not "wax" in summer grafting. Scions are collected fresh as grafting progresses. We prefer not to store scions for more than an hour or two in summer grafting, even under refrigeration.

There are advantages as well as disadvantages in both time-methods of grafting. Propagating schedules on other nursery items may influence the choice of time. Both methods are extremely successful.

CUTTINGS

"Japanese maples" have been propagated by cuttings for at least two or three decades here in the U.S. There are still differences of opinion among some nurserymen as to the vigor of the plant (several years after propagation) which was cutting-produced. There needs to be further serious study of own-root vs. grafted plants with many of the cultivars of *A. palmatum*.

Our trial with *A. palmatum* and its cultivars was for two purposes: (1) to study the growth habits of cutting vs. grafted plants of the same cultivars for a period of years; (2) to produce certain cultivars on own-roots for bonsai fanciers who object to the appearance of the graft union on dwarf types.

We have data from many propagators who show success in rooting cuttings at various times of the year. We find reports of success with dormant January cuttings, late dormant March cuttings, semi-hardwood in June, and late summer in August.

Most of our recent trials were in the late June, semi-hardwood period. Cuttings were current season growth, stripped of the lower 3 or 4 pairs of leaves, with only the tip pair remaining. After the slanted end cut, light wounding was made about ¾ inch long, and immediately dipped in a rooting compound (Hormodin #3; 0.8% I.B.A.) which consistently gave better results than other commercial dry compounds.

The cuttings were inserted in a 90:10 perlite/peat moss mix under an automatic intermittent mist system. Bottom heat cables supplied heat at 70°F (22°C). Rooting in all cultivars was sufficient for repotting in 6 weeks.

Twenty-four cultivars of 50 cuttings each were in the trials. All were successful, but the most dwarf cultivars rooted poorly at about 40%. The more upright cultivars ranged from 70 to 100% well-rooted. While there may be a relationship to the growth habit of the cultivar, it is also possible that the stage of maturity among these widely varying cultivars was an important influence.

Trials were also included on some of the lesser known species of *Acer* to obtain comparative data. In some cases we needed information on species which are difficult to graft, or for which we cannot find compatible understock species, or for which it is difficult to obtain seed, and finally those about which we were just curious as to their development as cutting produced plants.

Cuttings were treated and handled as in the brief description given above in the latter part of June. Rooting results are as follows:

A. acuminata — 50%
A. buergerianum — 95%
five various cultivars of *A. buergerianum* — 75-95%
A. campestre 'Compactum' — 25%
A. campestre 'Pulverulentum' — 90%
A. carpinifolium — 90%
A. coriaceum — 0%
A. crataegifolium — 100%
A. crataegifolium 'Veitchii' — 75%
A. fulvescens — 0%
A. lobellii — 90%
A. monspessulanum — 50%
A. morrisonense — 95%
A. orientale — 20%
A. pentaphyllum — 30%
A. pycnanthum — 50%
A. syriacum — 100%
A. truncatum cultivars — 0%
A. truncatum var. mono cultivars — 0%
A. tschonoskii var. rubripes — 100%

It is felt that several of the failures were due to the variance of plant growth at the time of sticking the cuttings. Some were perhaps too mature and some too soft. Expanded date-trials are planned. Also, from previous experience it is felt a higher percentage of success will result from the use of liquid hormone dips or soak containing 1.0% IBA.

THE PLANT PROPAGATOR AND NEW PLANT CULTIVARS

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The plant propagator, in our nursery community, is confronted with daily challenges and for those of us who grow plants from seed, added challenges present themselves. The so-called "new plant" is quite often there before us, but due to lack of motivation, lack of interest and too often the overemphasis on numbers, we do not take the time to explore seed beds for the unique and unusual seedling that could indeed give us the "new" plant.

When one reviews the past issues of the Proceedings of our beloved Society, we read papers discussing plant discoveries and new woody ornamental cultivars. In 1971 Donald Egolf (1) told us that a new cultivar may arise as a selection from a seedling population derived from introduced seed, a naturally occurring or induced mutant, or a hybrid resultant from a controlled pollination. I shall limit my discussion to the former — selections from seedling populations. I will try to point out the unlimited possibilities in the selection of outstanding plant material from seedling beds.

I am the first to recognize that the glamour and mystique of plants discovered in exotic lands has more romance than that unusual seedling found in your own back yard. It would be my wish that when all of us relate plant expeditions to the four corners of the earth we include our own nurseries. We have all read of people bringing plants from one part of the world to another since the earliest days of civilization. It most definitely is fascinating reading, and many of us have marveled at the journeys of one of the most famous of all plant explorers, Ernest Henry "Chinese" Wilson. At the combined Eastern and Western Region meeting in St. Paul (1970) an excellent paper was presented by David Paterson (2). Dave reviewed for us the contributions made to all of us by the plant explorer. He also pointed out the role of arboretums in sending forth the plant collector, as well as the USDA and various plant societies. Dave Paterson said it well, with the words, "plant exploration has had an exciting and valuable history, has a viable present, and a promising future."

The pure facts of life are that very, very few of us in this room are going to have the opportunity to visit the four corners of the world and bring back to our nursery that unusual plant that is going to be of economic importance to our nursery. In my opinion, we do not have to journey to Tibet or the U.S.S.R.

to introduce worthwhile ornamental plants to the American landscape. Andy Leiser (3) speaking at the above-mentioned St. Paul meeting mentioned that members of the IPPS are "plantsmen in the best sense of the word." I wholeheartedly agree with Andy, and this attribute is what sets the plant propagator apart from his fellow nurseryman.

In discussing this topic with Harold Clarke, he asked that I slant this topic to the newer members of the Society, and try to point out various areas in which the propagator can assist in the findings of the so-called "new plants." In the slides which shall follow these brief remarks, I hope to point out, with specific examples, plant material which has enjoyed good acceptance by the American gardener, and the derivation of the plant. The slides will show the seed bed and, with a stretch of the imagination, from those beds the cultivars that came forth. Table 1 shows the species seedling in the left hand column and the resulting cultivar in the right hand column.

Table 1. Species where one or more cultivars have been developed from seedlings.

SPECIES	CULTIVAR
Berberis thunbergii 'Atropurpurea'	B. thunbergii 'Rose Glow'
Crataegus spp.	C. 'Toba'
	C. punctata 'Ohio Pioneer'
Fraxinus americana	F. *americana* 'Rose Hill'
	'Autumn Purple'
Gleditsia triacanthos var. inermis	G. 'Majestic' P.P. No. 1534
	'Skyline' P.P. No. 1619
	'Sunburst' P.P. No. 1313
	'Green Cascade'
Malus domestica	M. d. 'Coralburst' P.P. No. 2983
	M. d. 'Red Jewel' P.P. No. 3267
	M. d. 'Royal Ruby' P.P. No. 3056
	M. d. 'Snowdrift'
	M. d. 'White Cascade' P.P. No. 3634
	M. d. #71-53
Pyrus calleryana	P. 'Aristocrat' P.P. No. 3193
	P. 'Bradford'
	P. 'Select'

All of us as plant propagators have a responsibility to ourselves, our company, and our community to be constantly aware of the unusual and different plants in the seedling population. The mutual love of plants which we all have does not make this a chore but rather a very pleasant duty. To the younger propagators in the room this afternoon, I would ask you to return to your nursery and spend just a bit of time walking and observing your seed beds or rows. If you find a particular plant which looks interesting to you, flag it immediately, then at harvest track it carefully and transplant the chosen plant into your R&D test area. It is important, in my belief, that an

area be set apart on each nursery for testing and evaluation of the type of plant material to which I am referring to.

What of the future? Several years ago, at this meeting, Phil Barker (4) gave an excellent paper on *Acer grandidentatum*. The challenge of perhaps locating the unique, different canyon maple is there everytime I walk the seed bed in which they are growing. We have been watching *Myrica pennsylvanica* for many years, annually evaluating seedlings but to date we have not found a seedling worthy of introduction. However, "hope springs eternal in the human breast" and someday — maybe!

Repeating again to the seedling propagator, as you walk your seed beds or rows be attentive and keep your eyes open. Admittedly after your selection there are many years of evaluation and reflection, but it has been done many times prior by others, why not you? Could it have been one of our brother propagator's who motivated the poet, Stanley Foss Bartlett, to write:

"Whoever planted rows of trees
Beside the rows and lanes
God rest his soul in heavenly peace
And bless him for his pains;
For he who gave of time and toil,
Who gave of heart and hand
To nurse the tender shoots that were
To shade of ways of man,
Was quite as great as those who built
Of stone and minted gold —
No need to cast his name in bronze,
His deeds need not be told."

The above words, my friends, say it all. Those words point the nursery propagator's role in society — yesterday, today, tomorrow. Be alert and observant, that "new" plant is right before your eyes.

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EFFECT OF SLOW RELEASE FERTILIZER SOURCES ON FLOWER FORMATION AND NUTRIENT COMPOSITION IN RHODODENDRONS

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Abstract. Eight slow-release fertilizers supplying the same amount of N were applied twice during the growing season to 'Vulcan' rhododendrons growing in bark mixes with two ratios of calcium to magnesium, with and without trace elements. Poorest growth and flower bud set occurred in 3 nitrogen-only treatments. One nitrogen-only treatment (Organiform 23-0-0) had the highest number of well-budded plants. There was greater response to trace elements in the high magnesium treatment.

REVIEW OF LITERATURE

Leaf analysis surveys of several rhododendron cultivars have established tentative standards for the foliar mineral content (2,4). Higher levels of nitrogen, phosphorus, manganese, and boron were found in good than in poor plants. More calcium in relation to magnesium was also characteristic of the good plants (3). 'Vulcan' rhododendrons grown in containers at the North Willamette Experiment Station during 1977 (Table 1) had lower nitrogen, manganese, and boron, higher phosphorus and potassium, and a lower ratio of calcium to magnesium than good field-grown plants.

Table 1. Comparison of foliar analysis values from good and poor field-grown 'Vulcan' rhododendrons with container-grown plants which received Osmocote 18-6-12 top dressing.

	Percent of Dry Weight					ppm of Dry Weight					
	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
Good Plants	1.84	0.22	0.43	1.39	0.19	1260	138	3	33	29	106
Poor Plants	1.78	0.18	0.62	1.15	0.27	637	59	2	30	38	66
Container Plants[1]											
1977 Crop on 1/27/78	1.69	0.22	0.62	1.28	0.31	233	869	1	20	15	23
1978 Crop on 6/12/78	1.19	0.18	0.64	1.53	0.41	437	371	3	19	56	24
on 9/14/78	1.61	0.24	1.29	0.72	0.31	108	763	3	16	43	14

[1] Top dressing fertilizer applied 6/20 on 1977 crop and 6/19 and 8/29 on 1978 crop.

METHODS AND MATERIALS

Two ratios of calcium to magnesium were used in ¼" minus Douglas fir bark potting mixes. Dolomite 65G (34.4% magnesium carbonate 44.2% calcium carbonate), 3 lbs. per cubic yard, was compared to 2 lbs limestone (93.0% calcium carbonate 0.7% magnesium carbonate), plus 1 lb. dolomite 10G (42.6% magnesium carbonate, 54.7% calcium carbonate). Other

components of the potting mix were 11.1 lbs Osmocote 18-5-11 (2 lbs. N/yd, 3.76 lbs of 0-45-0, and 1.5 lbs of gypsum per cubic yard.

Eight sources of slow-release nitrogen were used to supply the same amount of nitrogen to each plant in two surface applications on both June 19 and August 29, 1978. Four sources contained nitrogen only: IBDU (31-0-0), isobutylidene diurea; Organiform (23-0-0), a methylene urea reacted leather tankage; Osmocote (40-0-0), a plastic coated urea; and SCU (36-0-0), sulfur-coated urea. Four sources were complete fertilizers: Osmocote 18-6-12, plastic coated 8-9 month formulation; Scott 25-10-10 and 31-5-3, based on methylene urea; and Webfoot 10-6-4, with 50% ureaform nitrogen and the balance from leather tankage and ammonium phosphates.

Cuttings of 'Vulcan' rooted in 2¼" square by 3½" deep plastic pots during the summer of 1977 were placed into 1 gallon plastic pots during February 1978. The night temperature was raised from 35° to 45°F when potting started. On March 1st, the night temperature was raised to 55°F and cool white fluorescent lights were turned on to provide a 24 hr day until May 26 when the lights were turned off. The plastic cover was removed from the house on June 5th and the plants remained in full sun during the growing season.

Trace elements were applied to half of the plants in each calcium-magesium slow-release fertilizer treatment resulting in 32 treatments. Ten plants which were randomized on the benches during the growing season were used in each treatment. S.T.E.M. (Soluble Trace Element Mix) from Peters was used at 2 ounces per 25 gallons and one cup of the solution was applied to each treated plant on May 23 and June 26.

Three leaves from each of the 10 plants in a treatment were collected for chemical analysis on September 14th. The leaves, after washing and drying, were sent to the Plant Analysis Laboratory in the Horticulture Department at Oregon State University for analysis. A Direct Reading Spark Emission Spectroscope (1) was used to determine the amount of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), copper (Cu), boron (B), zinc (Zn) and aluminum (Al) in the leaf tissue. Total nitrogen (N) was determined by the Kjeldahl method.

Since the 32 treatments were not replicated, the 4 calcium-magnesium treatments served as replicates for the slow-release fertilizer treatments (Table 2). The 8 slow-release fertilizer treatments were used as replicates for the calcium-magnesium treatments (Table 3).

Physical measurements, height to tip of the tallest bud,

maximum width between buds, and the number of vegetative and flowering shoots were recorded on September 23rd.

Table 2. Number of 'Vulcan' rhododendron plants with five or more flower buds per plant following surface application of several slow release fertilizers. (10 plants per treatment with 4 reps.)

Fertilizer	Grams*/6" Pot	No. Budded of 10 Plants	Duncan's Multiple Range Comparison 5 percent level
Osmocote (40-0-0) Sulfur Coated Urea (36-0-0)	4.79	6.0	A
IBDU (Fine) (31-0-0)	5.56	6.25	A
Osmocote (18-6-12)	9.58	7.0	AB
Scott (25-10-10)	6.9	7.75	ABC
Scott (31-5-3)	5.56	8.5	BC
Webfoot (10-6-4)	17.25	8.5	BC
Organiform (23-0-0)	7.5	9.0	C

* Based on manufacturer's recommendation of 6.9 grams per 6" pot for the 25-10-10. Same amount of nitrogen applied in each treatmenmt on 6/19 and 8/17/78.

Table 3. Number of 'Vulcan' rhododendron plants with five or more flower buds per plant in potting mixes containing dolomite or both dolomite and calcium carbonate with and without trace elements.* (10 plants per treatment with 8 reps.)

Calcium-magnesium Treatments	Amount in lbs. 1 cubic yard	No. Budded of 10 Plants	Duncan's Multiple Range Comparison 5 percent level
1. Dolomite 65G	3	6	A
2. Dolomite 10G + Calcium Carbonate	1 2	7.5	B
3. Dolomite 10G + Calcium Carbonate + Trace	1 2	7.75	B
4. Dolomite 65G + Trace	3	8.25	B

* Trace elements = Peters S.T.E.M. (Soluble Trace Element Mix). Used at 2 oz/25 gallons and applied at 1 cup/6" pot on 5/23 and 6/26/78.

RESULTS

There were marked differences in flower bud formation between the plants with and without trace elements in the dolomite only treatments. Examples include SCU 8 plants with 5+ flower buds with, and 3 without, or Webfoot 10-6-4 which contains some fritted trace elements, 10 with and 6 without. These differences were not as noticeable in the dolomite-calcium carbonate combinations.

Three of the four nitrogen-only treatments resulted in the fewest flower buds. The fourth nitrogen-only treatment, Organiform (23-0-0), which had the highest number of flower buds

of any treatment, is based upon natural organic materials.

The next highest flower bud formation occurred with the two complete fertilizers having the lowest amount of potassium. The differences among the four complete fertilizers were not statistically significant.

Average plant height for the 8 nitrogen treatments varied by a maximum of 0.63 inches whereas the average width varied by a maxium of 0.97 inches. The calcium-magnesium trace element average plant height varied only 0.3 inches but the width range was greater — 1.6 inches. The plants receiving trace elements in the dolomite-only treatment averaged 1.6 inches wider than those without trace elements.

Table 1 shows leaf analysis data from plants receiving dolomite-only from 1977 and 1978 trials which were top-dressed with Osmocote 14-14-14 in 1977 and 18-6-12 in 1978. Nitrogen was low in 1977 from one application so two were used in 1978. The first 1978 sample was taken before any top application and is very low in N. The second sample, one month after the second application, is still low in nitrogen.

Potassium was very high after two applications in 1978. After the first Osmocote application there was a better ratio of Ca to Mg than after the second application.

Statistical relationships between surface-applied fertilizers and leaf analysis data are shown in Table 4. Only one treatment, Organiform, resulted in a nitrogen level statistically different from the others. This low level, 1.44%, was associated with the highest number, 36 of 40 plants, having 5 or more flower buds per plant. The two treatments which had 34 of 40 well-budded plants, had the highest level of N — 1.70%. These were Scott 31-5-3 and Webfoot 10-6-4.

There was statistical separation among the foliar phosphorus levels resulting from the different slow-release fertilizer applications. Again, the lowest level of P was in the Organiform treatment and the highest in the 10-6-4 treatment.

Contrary to our field experience, the lowest potassium levels were associated with the least flower bud formation. The intermediate levels, 1.17 to 1.24%, were associated with the highest flower bud formation.

There were no significant differences in calcium content of the foliage. Again, contrary to our field observations, the three highest magnesium levels were associated with the greater flower bud formation.

Only one top-applied fertilizer, Webfoot 10-6-4, which contains some fritted trace elements, had a boron level different from the others.

There was no statistical difference in the calcium or magnesium content of the leaves from the two calcium/magnesium treatments. The level of boron was significantly higher when S.T.E.M. was applied.

Table 4. Foliar analysis values of rhododendron 'Vulcan' on September 14, 1978, following surface application of slow release sources of nitrogen on June 19 and August 29, 1978.

	Percent of dry weight					ppm of dry weight
	N	P	K	Ca	Mg	B
IBDU 31-0-0	1.67B*	0.205A	1.09A	0.71 N.S.	0.27A	21A
Organiform 23-0-0	*1.44A*	*0.20 A*	*1.23BC*	*0.71 N.S.*	*0.31AB*	*19.3A*
Osmocote 18-6-12	1.65B	0.258D	1.35C	0.73 N.S.	0.29A	23.3A
Osmocote 40-0-0	1.66B	0.22AB	1.14AB	0.69	0.29A	23.8A
Scott 25-10-10	1.66B	0.248C	1.24BC	0.69	0.27A	19.3A
Scott 31-5-3	1.70B	0.24BC	1.17AB	0.68	0.30AB	18.5A
SCU 36-0-0	1.63B	0.23BC	1.06A	0.71	0.28A	23.3A
Webfoot 10-6-4	1.70B	0.273E	1.24BC	0.79	0.33B	47.3B

* Mean separation within columns by Duncan's Multiple Range Test, 5% level.

DISCUSSION

Plant appearance was better when a complete N-P-K fertilizer was used instead of a nitrogen-only treatment. One nitrogen-only treatment did have the most flowers, 36 of 40 plants with 5 or more flower buds per treatment. The highest average number of flower buds, 9.7 per plant, was from the 10-6-4 treatment. This treatment resulted in the highest (but not statistically significant) levels of most elements, except potassium.

There was a visible growth response from the application of trace elements to the dolomite-only treatments. The plants receiving both calcium, limestone and dolomite were the most uniform in appearance.

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SEED GERMINATION OF STONE FRUITS[1]

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There are nearly 200 species of *Prunus* or stone fruits and they include plums, apricots, peaches, cherries, cherry-laurels (which are evergreen) and almonds. They appear in nature mostly in the north temperate zone. All can be cultivated and most kinds are hardy in the north and are not particular as to soil. They are usually propagated by seeds. Named cultivars of stone fruits can often be propagated by hardwood cuttings but usually they are budded on closely related stock. Seed germination of these rootstocks is the focus of this paper.

In nature the ripe stone fruit is eaten by an animal, depulped in digestion and worked on by the stomach acids. However, for reasons that are not clear, scarifying stone fruit seeds with abrasives or sulfuric acid (as is done with numerous other seeds) does not seem to help and may harm. On the other hand, thorough leaching with water does help, especially with seeds that have dried out. Occasionally there can be a seed lot ready to germinate which should be planted without leaching. Careful examination of the seed is essential.

To leach, seeds may be placed in running water in a porous sack for a period of three days to two weeks, depending on the seed. We have had good results with myrobolan plum by placing it in our irrigation water collection box on the mountain and allowing the water to run through the seeds for four or five weeks. We have also placed plum and apricot seeds in running creeks. We have had success putting seeds of some species under mist. If seeds must be placed in a container, the water should be changed about every 12 hours and then let drain for 12 hours. Aeration during leaching is essential to maintain seed viability. Five days in soak is about right for seeds of many species. In general, people do not leach seeds enough. Consideration should be given to the background of each seed lot: when and where was it harvested? How was it processed and stored?

Remember that seeds of stone fruits need to afterripen and may require warm, moist stratification for this. A cold stratification period is required following the warm period. This means that if seed is sown in late summer or fall, there must still be enough warm days to give the required warm period. The cold requirement is then fulfilled over the winter. Seeds of some

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[1] Presented by John E. Bennett.

stone fruits like American plum and *Prunus domestica* can take two years in the field or a year in the cooler. Other times they do not require this; it depends on the seed. Careful examination and patience are necessary.

In climates too warm to give the amount of cold necessary, you can succeed by controlled stratification, but not by planting seeds in the field after harvest. For example mahaleb cherry seedlings are grown at Modesto, California, by stratifying the seeds in a refrigerated building before planting.

It should be stressed that germination techniques vary with the species and even the seed lot. Since seeds of American plum (*Prunus americana*) and mazzard sweet cherry (*P. avium*) are often difficult to germinate they will serve as examples of stratification techniques.

If you are willing to tie up your ground for two years, you may plant the whole fruit of *P. americana*. Years ago, when we were first starting to grow this species we gathered wild plums in our county and planted them by hand, spacing and hitting them with a hammer after placing them on the bed to push them into the soil and start the pulp decomposition. The second spring 95% germinated and the spacing was great but, of course, that method is impractical for any large scale production. If the fruit can be gathered early and depulped promptly and planted so that the seeds get 60 days of warm stratification in the ground followed by cold stratification through the winter, they will usually come up the next spring. This method is not fool-proof, however, as a very wet summer or too much irrigation can cause the seed to rot.

Our best results with stored seed are obtained from placing dry seed in churning water for two weeks and planting them by mid-July. *Prunus americana* seed then germinated the next spring and an even stand was obtained. We plant the seed by machine at the bottom of furrows 1 to 1½ inches deep and fill the furrows with a sawdust mulch.

For controlled stratification with fresh seed, we recommend about six weeks of warm stratification at 60° to 70°F. followed by a cold period at 41°F. for 90 to 180 days, the average time being 120 days. It is essential to examine the seed periodically and plant when it shows signs of germinating. Figuring back from the time you wish it to germinate determines the time you should begin stratification.

In the case of our second example, mazzard cherry, freshly extracted ripe seed may be planted without soaking (usually in mid-summer). After-ripening and warm stratification, plus cold stratification, takes place in the field. This is the simplest and most used method and usually gives good results.

A second method applies to stored seed. After harvesting and cleaning, seed is stored, preferably for one year. (Best results are obtained with seed stored for a full year.) The temperature of storage should be just above freezing (32° to 38°F.) with the seed having a moisture content of 7% to 10%. The Woody Plant Seed Manual mentions *Prunus avium* with a moisture content of 11% and stored in sealed bottles at 34°F. for 4½ years as only dropping from 93 to 84% viability. During storage time some after-ripening occurs. The mazzard seed is then soaked thoroughly for at least one week (using the alternating soak and drain method) and then stratified in sand. It is essential that the sand be moist but not wet. A good way to tell if the moisture content of the stratification medium is correct is to squeeze a small handful. If it forms a ball that crumbles when you touch it with your index finger, it is just right. If it doesn't form a ball, it is too dry and if the ball doesn't crumble when touched, it is too wet.

Four to six weeks of warm stratification at 60° to 70°F. is followed by up to five months of cold stratification at 41°F. The sand must be kept moist, but not wet, or the seed will rot. After about three months in the cold, the seed should show swelling signs. Frequent inspection is now necessary and when most of the hulls start to crack, the seed should be planted. In our climate it is best to have beds prepared in the fall and even sow on snow rather than let the seed stay too long after cracking occurs. Here again, in scheduling stratification, figure backwards from your last spring frost so that the seedlings will not come too early. We plant *P. mazzard* seeds one inch deep and cover with one inch of sawdust. Planting too deep in heavy soil can produce crooked seedlings. Remember to allow for some attrition of the covering.

Apricot seeds have much less cold requirement then cherries; 30 days is enough. In fact, some seed will sprout in storage if the moisture is high.

Another method sometimes beneficial in germinating *Prunus* seed is soaking dry seed in 200 ppm (average) gibberellin, but this treatment cannot be relied on to always be effective. It can replace some of the cold treatment and is sometimes helpful with old or weak seed. We usually soak the seed overnight in gibberellin solution. We are in general agreement with Heinz Jansen who, in his book, *Wuchs-und Hemmstoffe im Gartenbau* — published by Ulmer in Germany gives the recommendations in Table 1.

We find that a gibberellin treatment is more effective if the seed moisture content of the seed is below 10 to 12% when it is immersed for 12 hours (two such soaks at least are recom-

Table 1. Gibberellin Treatment for Seeds of Prunus Species

Species	GA Concentration	Effect
Prunus *armeniaca*	100 ppm	Dormancy completely overcome
P. avium	100 ppm	Dormancy ⅔ overcome when followed by 4 months (*sic*) stratification
P. cerasifera	Up to 500 ppm	No effect
P. mahaleb	100 ppm	Shortens dormancy
P. persica	500 ppm	Dormancy overcome

mended). Thus the seed takes up the gibberellin. If seed that has already been soaked is immersed in gibberellin, the effect is much less or even nil. We think that gibberellin often helps but is not to be depended on. We know that gibberellin overstimulates seed of some species such as *Robina* and *Corylus* and has little or no effect on oily seeds such as pines. Gibberellin can be purchased from Merck & Co. or locally in areas where it is used on grapes.

Finally, to successfully germinate seeds of *Prunus* species, the key to success is careful examination of each seed lot both before and at frequent intervals during seed manipulation and stratification. This involves cutting and examining a sample of the seeds under magnification. Development of the epicotyl and expansion of the cotyledons are the things to watch. You must then decide if your seed needs longer leaching or stratification or if it is ready to plant.

Failure with stone fruit seed germination comes mostly from not properly pretreating the seeds. Avoid failure by careful attention to leaching, temperature, and time factors of stratification and by frequent inspection of seeds.

BUILDING AND USING A GROWING ROOM FOR SEED GERMINATION OF BEDDING PLANTS

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Intensive use of greenhouse space to maximize one's turnover rate is a key factor in having a profitable bedding plant season. In this situation, the propagator must often compromise ideal germination and growing conditions in an attempt to produce the seed flats in the space available. Valuable time is spent in their maintenance if they are placed in different areas of the range to provide different conditions for germination. At Skagit

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Mount Vernon, Washington 98273

Intensive use of greenhouse space to maximize one's turnover rate is a key factor in having a profitable bedding plant season. In this situation, the propagator must often compromise ideal germination and growing conditions in an attempt to produce the seed flats in the space available. Valuable time is spent in their maintenance if they are placed in different areas of the range to provide different conditions for germination. At Skagit

Gardens we produce over 60,000 flats of plants in the spring representing approximately a two times turnover rate of all available greenhouse space. About 3,000 seed flats are sown to provide the transplants for this operation. Our usually dark weather in western Washington increases the possibility of grower error in cultural techniques and creates problems with stretching of seedlings. To alleviate these difficulties the idea of a growing room was proposed.

In the corner of our service building we have a 20 × 20 foot insulated room with a drain in the floor and a refrigeration unit hung from the ceiling in one corner. It was originally designed for the storage of cut flowers. Since we no longer grow these the room had become a non-productive storage area. It seemed an ideal place for a growing room.

*Our primary objective in designing this room was to pro*duce a high quality seedling that does well after transplanting, and to do so with a minimum of time and effort. Since we are a young and growing company we attempted to maximize both the capacity and the flexibility of the room in anticipation of greater future neds and alternative uses.

Design and construction was a joint effort on the part of our staff. Valuable information was received from Duane Thompson and Dick Chamberlain who have written of similar projects in their own bedding plant operations, and from Dr. Robert Norton of the Western Washington Research and Experiment Station in Mount Vernon.

Using this information we decided to provide 1,000 footcandles of light intensity at soil level using cool-white flouresscent lights. This sets the distance between the tube and the soil at 10 inches. With ceiling mounted light fixtures we have 6 tubes for each shelf holding 16 flats, or a total of 96 flats over an area 8′ long and 45″ wide. By placing the flats on moveable carts the room can accommodate 7 carts making its total capacity 672 flats on 400 sq. feet.

Welded angle iron forms the framework of the carts and 4 × 8 foot sheets of plywood trimmed to 45″ width are used for the shelves. The dimensions are 45½″ wide by 96¾″ long by 81″ high. All parts of the room are painted white as this is the best reflective surface for flourescent light. Low profile casters permit an increased capacity of the room by allowing the carts to be placed adjacent to each other and moved for accessibility.

All wiring is enclosed in conduit and mounted on the ceiling. The carts plug into the ceiling and are grounded through the floor with cords long enough to permit the carts to move a couple of feet in any direction.

We are currently using Sylvania Lifeline F96T12 Cool-White High Output 8′ flourescent lights with high output rapid start ballasts. High output fixtures were chosen because they are more energy efficient than standard fixtures. They represent a 10 percent higher initial cost, but deliver 25 percent more light with the same current draw.

Entire fixtures were purchased as the cost of the ballasts, if bought separately, would have been more. The sheet metal was discarded and the ballasts are mounted separately, 3 on the end of each shelf. This reduces heat around the seed flats, eliminates the need for insulation and decreases the distances between shelves. The sockets are mounted on the metal framework. The ballasts are shielded on the inside of the shelf with a 2 × 6 and on the outside with a strip of sheet metal salvaged from the discarded fixtures. This contains the radiant heat from the ballasts which then merely warm the air.

Figure 1. Seed germination units in growing room.

Two exhaust fans are mounted in the ceiling to remove heat. In the corner where the refrigeration unit hangs, two galvanized steel holding tanks raise the temperature of the water to approximately the ambient room temperature, providing tepid water to water the seedlings thus eliminating the need for a water heater.

Thermostats are strategically mounted in the room to provide automatic control of the exhaust fans in the ceiling, a

louvered fan to provide fresh air from outside, a circulation fan in the refrigeration unit, and to control heat alarms. Extra outlets above each cart increase the options of the room by allowing the use of such devices as timers and fans, if desired. Individual switches for each shelf provide daylength control and, of course, mean that the lights may be turned off when not in use.

At Skagit Gardens we used standard 11″ × 22″ plastic flats run off on a flat filler using our regular potting soil. Most seed is broadcast over pressed moistened soil. A 5 ppm boron drench is applied which seats the seed in the soil and counteracts boron deficiencies that we have encountered in the past, particularly in the crucifer crops. Milled sphagnum moss is then sprinkled over the surface and moistened with a fine mist nozzle. This moss serves to hold moisture around the seed for best germination. It also lets some light through which enhances germination of many seeds and it also has a reputation for decreasing the incidence of damping-off. Very fine seed such as begonia is broadcast on the top of the premoistened moss. Sheets of glass are then placed over these flats for the duration of the germination process to ensure high moisture around the exposed seed.

Watering is done by hand with a hose coming from the holding tanks and feeding is done with a Hozon proportioner having a 5 gallon concentrate bucket using Peter's 20-20-20 at 200 ppm nitrogen.

Nearly all seedlings are raised under 24 hours of illumination. If day-length control is desired the lights can be turned off and a black plastic curtain hung around a shelf or a whole cart to block out light from adjacent carts. Seedlings are taken to the greenhouses when ready to transplant and arranged on the floor along the north end for easy access.

When the room is in use there is a distinct temperature gradient from ceiling to floor. The top shelf maintains a steady 80°F. soil and air temperature and the bottom shelf a steady 60°F. By proper shelf selection the ideal temperature for germination can be provided for all plants that we grow from seed. Plants thought of as requiring darkness for germination were often found to germinate quite well on a lighted shelf. If not, they were placed on a shelf with the lights turned off, or any appropriate dark place until germination, and then grown on under light.

Light readings on the shelves vary from about 1200 foot-candles in the center to about 750 foot-candles on the edge. Plant growth is a response to the intensity of the light times the duration of exposure. At a certain point light saturation sets in.

This condition is characterized by foliar chlorosis thought to be the result of photosynthate production exceeding the ability of the plant to metalbolize it. It is corrected by decreasing either the intensity or duration of exposure. Petunias, for example, light-saturate at 14 days from sowing under continuous lighting, tomatoes at 21 days, and lobelia at about 4 weeks. Some plants, such as peppers and celosia, were never observed to show any symptoms of saturation. Salvia germinated very well in the room, but developed poorly afterwards and subsequent sowings were removed to the greenhouse before being ready to transplant. Nearly all other items are raised to transplant size in the growing room. Marigolds are not done in the room as the long days delay flowering. Tuberous begonias in nurse flats from early sowings, which need supplemental illumination to develop properly, achieve rapid growth with a 16 hour light regime.

The most striking effect of the growing room is the extremely rapid growth that seedlings make. This necessitated many changes in sowing dates. Plants also show increased pigmentation and seeds sown as mixes stand out immediately after germination. An advantagous effect of using this room is the decreased stretching of seedlings. This can be a major factor in our often dark western Washington climate. Tomatoes are a prime example. They are germinated on the top shelf and at 14 days have 2-3 true leaves and are ready for transplant. If, for some reason, they can not be transplanted by 21 days they are moved from the top shelf to the bottom and put on 16 hour days. They can then be held without stretching for a period of several weeks. This could not be done if the seedlings were being raised in the greenhouse.

We expected that somewhat tender seedlings would emerge from the room and possibly need a hardening off period before transplanting. We found quite the opposite to be the case. The seedlings were stockier and more vigorous than those we were able to produce in the greenhouse.

There are some problems encountered with our growing room. The light intensity and sometimes soil temperature are too high in the center of the shelf for some plants, such as coleus. Possible solutions to this include the removal of the two center tubes, the re-spacing of the tubes, and the replacement of only the outer pairs of tubes when they begin to dim. This would only need to be done on a few shelves to accommodate low light plants. Rapid drying of the surface of the seed flats has occasionally hurt germination, but probably also inhibits damping-off which ony rarely occurs.

A major advantage of the growing room has been a radical

decrease in the labor required to raise the seedlings. With occasional use of a helper during heavy sowing weeks I was able to easily produce all the seed flats for the season. The time saved in running around looking after seedlings was used to better supervise the cutting operation. The result was an increase in both quality and quantity of material with a decrease in the number of people required to get the job done.

Our growing room cost over $16,000 to build and will take years to pay for itself. It is difficult to place dollar values on improvements in quality and savings in time by a salaried grower. All plants, except salvia, grown in this room showed a distinct increase in quality so that use of this room has proven highly advantageous to our bedding plant operation. Its 400 sq. ft. are equivalent to 2,000 sq. ft. of greenhouse space. Its artificial environment is unaffected by the time of year or the weather so that the results are more predictable. With the high turnover rate due to rapid seedling development, the room can easily handle an operation twice our size. So as our needs increase the room will become even more valuable to us.

SEED BED PRODUCTION IN RHODE ISLAND

LARRY CARVILLE

Horticultural Associates

Tolland, Connecticut 06084

Production requirements for any seed bed operation must be a determination by top management. This decision should be periodically reviewed and kept current with market demands and production costs. If a production facility can economically purchase seedlings to fill its market needs, it should not consider seedling propagation. Certain specific needs must be considered by each management staff in reaching its decision. Some of the relevant areas are: 1) Propagation needs of the firm; 2) Seasonal planting requirements; and 3) Reliability of delivery capabilities.

The Rhode Island Nurseries, Inc., Newport, Rhode Island has always maintained a seedling production capability to meet both its propagation and production requirements. This policy is reviewed annually to reflect current needs and market trends. Great importance is attached to the needs of the propagation division in having a ready supply of understocks for grafting and for lining out.

Production output of the seedbeds is not intended to produce salable seedlings. However, if surplus quantities are pro-

decrease in the labor required to raise the seedlings. With occasional use of a helper during heavy sowing weeks I was able to easily produce all the seed flats for the season. The time saved in running around looking after seedlings was used to better supervise the cutting operation. The result was an increase in both quality and quantity of material with a decrease in the number of people required to get the job done.

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Production output of the seedbeds is not intended to produce salable seedlings. However, if surplus quantities are pro-

duced from any given crop, these items may be offered to the trade. Seed beds are maintained on a two year program and no seedlings are retained in the seed beds beyond this time.

Seed bed construction and maintenance. All seed beds are prepared during late summer in a reserved portion of the propagation facility. The planting area is first wheel harrowed, dressed with cattle manure, then deeply rototilled with a 100 inch Howard Rotovator. The area is then leveled by hand raking; beds are staked out and the seed beds are constructed. One by three inch edging strips are placed vertically along two perimeters of the seed beds. These strips are held upright by iron hooks which are hammered into the soil. The beds are constructed to measure 68″ between the two edging strips. The length of the beds is determined by available space.

After the strips are in place, the planting area is rolled lightly with a slightly weighted lawn roller. Seed is hand broadcast to the desired density and lightly rolled into place. A covering of ⅓ sand, ⅓ peat and ⅓ perlite is placed over the seed to a thickness of ¼ to 1 inch, depending on the size of the seed.

If the seed bed is sown in the fall, salt or marsh hay is spread over the covering and snow fence panels, 4 feet by 6 feet, are placed over the beds. These panels are supported on both ends by the edging strips and will remain in place over the winter months. The panels keep the mulch in place, keep animals from disturbing the seed beds and define the planting areas for the workers.

In early spring, when seed germination is apparent, the hay mulch is carefully removed but the panels remain in place to provide shade protection for the young seedlings. The above process is repeated for all spring sowing except that the marsh hay is not applied over the seed beds. In both cases, the shade panels remain in place over the beds for the first growing season. As soon as growth exceeds 4″ to 6″, the panels are raised on T-irons to allow the seedlings additional room to develop.

Seed beds are hand weeded on a regular basis with two-person crews, one person working from each side of the 68″ wide bed. Seedlings are thinned as required during the early weeding operations. No herbicides are used in the seed bed areas. Paths between the seed beds are kept clean by rototilling and weed population on the perimeters of the seed bed is kept down by mowing and periodic applications of Paraquat.

Harvesting. Deciduous seedlings to be used as understocks or for lining out are harvested in late fall after the first hard frost. Usually, this occurs in late October in the Newport area. Seedlings may be lifted with a bed lifter or may be hand spaded

from the beds. All seedlings are processed bare root, placed in boxes and stored in a large cooler to await grading and trimming. *Acer palmatum* 'Atropurpureum,' *Fagus sylvatica* and *Cornus kousa* seedlings are graded into two sizes. Number ones will be stored over the winter in peat/perlite and will be potted in 2½" rose pots the following March. Number two seedlings will be stored in a similar manner but will be potted in 2¼" standard pots during March for a lighter grade understock. These understocks will be grown on for one season prior to moving into the greenhouse during November of the second year for grafting.

In many cases, seedlings of *Cornus kousa* make sufficient growth during the first season so that they may be graded and potted immediately after harvesting. They are then moved into the greenhouse in November to be used as understocks during the winter grafting program. Deciduous seedlings such as *Myrica* and *Viburnum* are harvested in the spring from the seed beds, graded and moved directly into the field planting operation.

Picea excelsa and *Cedrus deodora* are harvested from the seed beds in early fall. They are dug bareroot, graded and potted for use as understocks. Number two sizes are potted in 2¼" standard pots and are carried along during the winter in a cool house. They are then moved outside in the spring, grown on and moved into the greenhouse for use as understocks that winter.

Conifer harvesting. Other conifers harvested during the late summer after two growing seasons in the seed beds include *Taxus cuspidata* (Syn. T. *cuspidata* 'Capitata'), *Picea pungens* and *Pinus strobus*. These seedlings are graded, trimmed and transplanted to be grown on for two more growing seasons. At the end of the fourth year, these 2 plus 2 liners will either be transplanted directly to the field for growing on or, in the case of some of the smaller grades of *Pinus strobus*, they will be set aside for understocks. Two year seedlings of *Pinus thunbergiana* are harvested directly from the seed bed in early spring and after grading, are transplanted directly to the field.

Seed sources. One of the most important ingredients in any successful seed bed production program is a constant and reliable seed source. These sources should provide information with the seed order, such as year of harvesting seed, elevation of seed source, name of strain (if applicable) and how long the seed has remained in storage. Accurate record keeping of this information is essential and when a seed source no longer proves to be reliable, these records will provide the propagator with information upon which to base his decision. An unreli-

able seed source is an unjustifiable luxury. Certain species of seeds may be available locally and, where practicable, they should be harvested. Some of the species which we picked at Rhode Island Nurseries included *Acer palmatum, Myrica pensylvanica, Cornus kousa, Pinus thunbergiana, Fagus sylvatica* and *Viburnum carlesii*.

The final element essential to seed bed production is cost of production record keeping. This system should be closely monitored and annually reviewed. When cost figures indicate that seedlings may be purchased more economically from an outside source, management will have the necessary information upon which to base a decision.

Tube production. Recent controlled experiments with seedling production in Styroblocks or plastic tubes has proven very praticable. This method is particularly applicable to the grower who wishes to produce limited quantities of several species. Seedlings are removed from the blocks or tubes after one growing season and may be potted or bedded out for growing on. Cost of maintaining seed stands is reduced to a minimum by using this method.

Seed treatment. With the exception of *Taxus* seed, all seed is stored in a large cooler until required for planting. Temperature is controlled at a range of 34 to 40°F. Large seed lots are first mixed with clean sand and are stored in wooden boxes. Small lots of seed are mixed whith shredded sphagnum peat and stored in plastic bags. *Taxus* seed is usually received from an overseas source in mid-January. This cleaned seed is mixed with equal parts of clean sharp sand, placed in wooden boxes and stored outside in the elements for stratification. Seed received in the winter of 1978 will be planted in the fall of 1980.

Table of harvesting and seeding.

Fall harvest:
- *Acer palmatum* 'Atropurpureum'
- *Fagus sylvatica*
- *Cornus kousa*
- *Taxus cuspidata* (T. cuspidata 'Capitata')
- *Picea excelsa, P. pungens, P. glauca* 'Densata'
- *Cedrus deodora*

Fall seed
- *Acer palmatum* 'Atropurpureum'
- *Fagus sylvatica*
- *Cornus kousa*
- *Taxus cuspidata*
- *Myrica pensylvanica*
- *Viburnum carlesii*

Spring harvest:
- *Pinus thunbergiana*
- *Myrica pennsylvanica*
- *Viburnum carlesii*

Spring seed:
- *Picea excelsa, P. pungens, P. glauca* 'Densata'
- *Pinus strobus, P. mugo*
- *Cedrus deodora*
- *Taxus cuspidata*

ROOTING CERTAIN BROAD-LEAF EVERGREEN CUTTINGS BY IMMERSION IN A HORMONE-FUNGICIDE SOLUTION

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Since manufacture of indolebutyric acid and Dip-and-Grow rooting aids were banned in 1978 by the Environmental Protection Agency it was imperative that we save our dwindling supply of these compounds and go back to using naphthaleneacetic acid. Oregon plant propagators did a lot of squirming and screaming; as a result we have some good news and some bad news. IBA has been released in Oregon for five years; that is the good news. The bad news is — most of the supply of this material in this country was sent to Europe.

Cuttings can be treated by dipping the base in a hormone power, or in a concentrated solution or by total immersion. I will address my remarks to the latter method. This is a report on the use of naphthaleneacetic acid (NAA) as the active ingredient.

There are four logical reasons for its use:

1. Faster sticking of cuttings, it saves one operation.
2. Cheaper than IBA.
3. IBA may be hard to purchase.
4. More uniform rooting; it probably does not wash off leaf bases.

The procedure for making the solution:

1. Use four gallons of water
2. Add four tablespoons of Captan
3. Add two teaspoons Benlate
4. Add two teaspoons NAA from a bottle of Alpha 800 Holly Dip. This is the same material holly branches are dipped in for leaf retention.

We see no evidence of damage to plants regardless of how strong Captan is applied. Benlate may have to be discontinued because it has five problems which are under investigation: 1. may be carcinogenic; 2. may be phytotoxic; 3. may be spermatogenic; 4. may cause fish kill; 5. may kill earthworms.

On some original research in using IBA and NAA, I found some basic differences between them. IBA caused greater callus formation than NAA while NAA seemed to activate the plant to form xylem or wood tissue. This led me to the use of the im-

mersion treatment, reasoning that I wanted action from the top downward.

Species that responded by giving rapid and uniform rooting include the following: *Viburnum davidii;* English Ivy; Laurel (3 species); Cotoneaster *dammeri, C. dammeri* 'Lowfast' and *C. microphylla US*; All cultivars of heather; *Berberis thunbergii* 'Red Pygmy' (summer cuttings only); azaleas; Skimmia *japonica; Aucuba japonica.*

If red spider or aphids are present a tablespoon of Clorox per gallon of solution is added.

Even though the above plants are considered easy to propagate, the use of this treatment gives uniformity of rooting and reduces rooting time by about ⅓.

We are now testing harder-to-root broadleaf evergreens by using our immersion method first and then dipping the base in Hormodin #3 or Hormex 8 or 16.

Preliminary trials in 1978 with pyramidal arborvitae using immersion treatment plus Hormodin #3 resulted in nearly 100% rooting if taken after January 1st.

Tam junipers also rooted well with this double treatment. *Juniperus horizontalis* cultivars were damaged and rooted best with Hormodin #3 only.

One note of caution: NAA is a bud repressant. A slight overdose may cause buds to remain dormant, especially in *Viburnum davidii*.

SUMMARY

Many broad-leaf evergreens root uniformly and faster when treated by total immersion in a solution containing NAA

Addition of IBA in powder form at the base of hard-to-root broadleaf and coniferous cuttings show promise for further experimentation.

Surface insect control with Clorox added to the solution seemed to cause no apparent decrease in the rooting response.

Increasing NAA dosage may inhibit new growth.

RHODODENDRON STOCK PLANTS — CARE AND MANAGEMENT

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Maintaining a block of rhododendron stock plants for production of cutting wood requires more thought and attention than some of us believed was necessary. Certainly, this was the case with our firm.

We produce container-grown rhododendrons. In earlier years we relied on our stock of container plants to provide cutting wood for all of our needs. But as demand for finished plants increased we realized that more thought and planning would be required if we were to be successful in providing a good grade of cutting wood for our operations.

Our initial problems concerned the removal of wood from plants we planned to sell. We were constantly making compromises on either the quality of cutting wood or the quality of the plants we were shipping. While we were able to live with these problems we soon learned that not all of the cultivars of rhododendrons we wanted to grow responded favorably to container culture. Some had very weak roots in containers. Others were very sensitive to cultural procedures such as fertilizing and watering and generally were not healthy plants. After several years of attempting to overcome these problems we recognized that we were not doing a good job of managing the production of cutting wood. We were being forced to take leftover material, that is wood from plants not particularly saleable and wood from the survivors of plants not growing well in containers. So we set about developing a field-grown stock block of approximately two acres.

We anticipated that plants growing in the ground would have more uniform growth because of more regular watering and fertilizing and would develop better quality wood in contrast to occasional stresses caused by dryness of container stock. This decision was hastened after we had determined that our inability to satisfactorily root certain cultivars was directly associated with the quality of cutting wood and not necessarily due to our propagation techniques or facilities.

Following very simple soil preparation we commenced field planting, using available material, nothing especially selected. Our most significant observation of this phase of establishing a stock block is that the individual plants do not become productive until their new rootlets become established in the native soil. It is actually possible to destroy a plant by re-

moving the cutting wood to soon, that is before the roots are established in the new soil. Our practice, at present, is to wait at least one year before we commence removal of cutting wood from a newly acquired cultivar.

Watering is by overhead impulse sprinklers. Initially, we cultivated the field to keep out weeds, etc., but this proved unsatisfactory. the combination of overhead water and much walking about the fields compacted the soil. So we allowed the grass and weeds to grow and now rely on a power mower for weed control.

Prior to mowing we considered chemical controls and actually proceeded with separate applications of Treflan and Casoron on a limited area. This was a serious mistake. While both materials accomplished the mission of controlling weeds, we found that the long range effect of the materials on those stock plants we tested was devastating. Three and four years later we are able to detect effects of the chemicals by misshappen foliage and poor ability to root. The chemicals apparantly linger in the plant longer than they do in the soil, for after we removed most of the damaged plants, cultivated the soil and replanted, new plants grew normally. My observation of this phase of management of a stock block is to rely on mechanical weed control and to not introduce chemicals into the stock area.

While we rely nearly 100% on our stock block for cutting wood, we still make forays into our container area and remove selected wood. It is a very valuable and convenient source of material. But this past year we were reminded again that if we are going to continue to use wood from our containers, they too, just like the field-grown mother block, must receive special attention, otherwise one can easily suffer damaging results by following perfectly normal cultural practices. I am referring to pest control procedures and fertilizing. In the case of fertilizing, one has to be careful not to feed too often or too heavily those plants from which cuttings are to be taken. With container plants in an artificial bark mix this is a special problem. The best looking container plants, ones that are the greenest and the plumpest, are not always the best source for propagating wood. So fertilizing of those plants should be carefully considered.

The other problem is pest control. We are not quite sure of the direct cause of problems we experienced this past year, but we do know that the use of a combination of systemic materials will affect rooting. We did spray both indoors and out-of-doors plant material that was both in the process of rooting or was already rooted and awaiting transplanting. The material used was Orthene and Benlate with spreader added. Briefly, following spray application, certain of the material died. Some that sur-

vived did not make initial growth from the tip of the cutting, but rather from the root system. We feel that if some of these systemic materials, insecticides and fungicides, will affect cuttings, then some effect must also be sustained by wood not yet removed from the parent but sprayed prior to the taking of cuttings. Our observation is that it is good management to be extremely cautious with the use of systemic materials on plants to be used for cuttings.

We have soil tests made of our stock fields and apply fertilizer as required in the late fall. Too much plant food will cause the cuttings to become increasingly darker green after being stuck in the artificially heated medium. This greening effect will continue until the cutting commences to decay and is destroyed.

The method of removing cutting wood is as varied as there are propagators. Some take all of the wood every year; others take all of the wood every other year. We compromise by taking most of the wood every year, but always allow uncut leaders to remain on each limb. We have heard stories of growers who no longer can root cuttings from some of their once most dependable stock plants though the appearance of wood has not really changed.

We are not sure of the answer to this problem but suspect it is related the nutrition associated with the removal of all of the wood each year and the lack of development of new rootlets on the mother plant. Perhaps old mother plants should be discarded after a number of years. Certainly, if wood from the plant is not productive, make a replacement rather than attempt to nurse an old plant back to health.

With propagation innovations such as tissue culture, information concerning the care and maintenance of a field of stock plants might become as pertinent as the care and feeding of mules used for cultivating. But for countless small growers, such as ourselves, the suggestions I have offered based on experiences at our nursery should be helpful if only to lead growers to recognize that the quality of the cutting wood they use is vitally important and it is best preserved in old-fashioned common sense ways. Poor quality wood will not be improved by ingenious mechanical propagating devices. The simplest way to improve one's percentage of rooted cuttings is to improve one's procedures for caring for his stock plants.

RHODODENDRON SPECIES PROPAGATION AND EXPERIENCES RELATED TO DORMANCY

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The inadequacies of rhododendron species propagation thoughout much of the past century created the situation which necessitated the formation of the Rhododendron Species Foundation (RSF). The 6 or 7 hundred different species of rhododendrons is a diverse group of wild plants — inhabiting regions from the North Polar land areas to tropical equatorial New Guinea, comprising plants ranging in size from mere ground creepers to trees over 50 feet tall, with leaf size from ½ inch to over 30 inches, and with flowers in all colors except blue. While the diversity, charm, and natural beauty of species rhododendrons increased demand, the supply of these plants remained limited and, too often, unreliable. Natural reproduction from seed, by which most wild rhododendrons have been introduced into cultivation, yields a varied progeny-especially seed collected from garden plants which often have been fertilized with pollen from a different species or hybrid. Vegetative propagation, which reproduces the qualities and characters observed in the original plant, has been difficult by rooting cuttings and expensive, together with complications by using grafting.

In 1964 the Rhododendron Species Foundation was established to collect, preserve, and distribute species rhododendrons. Scions of verified and, where possible, superior forms have been obtained from British gardens that contain extensive collections of plants grown from seed collected in the Himalayas and western China, the center of rhododendron distribution in the wild. These scions are grafted or, if of the more readily rooted smaller leaved types, are rooted and grown on to form the nucleus of the collection. With these imports and selections from American gardens and wild collected material from Japan, Korea, Taiwan, Europe, and North America the RSF has established a collection of some 430 species and a total of over 20,000 plants. These are now located at its permanent home and garden site at Federal Way, Washington.

Aside from gathering all of this material, the Foundation obviously has needed to improve upon past propagation practices in order to realize its goal. It has been necessary to extend to the field of wild rhododendrons, the advances made in the commercial hybrid rhododendron realm which, through rooted cuttings, can supply large quantities of reasonably priced and

popularly acceptable plants. The vegetative propagation of species rhododendrons is not radically different from that of hybrid rhododendrons. The success in increasing the production of species at the RSF is the result of varying existing methods rather than innovating greatly different ones. In fact, the greatest benefit of general value from a review of the RSF experience comes from the demonstration of the potential of carefully tailoring general practices to the specific requirements of individuals plants.

The steps in standard rhododendron propagation from rooted cuttings practiced at the RSF include the following:

1.) Cuttings taken are of the current season's (less than one-year old) growth.
2.) Leaves exceeding two inches in length are trimmed to about that length to maintain more uniform bench spacing.
3.) Cuttings are submerged in a benomyl solution for a minimum 5 minute soak.
4.) Cutting length is shortened to 3 inches for average size (½" to ¼" diameter) cuttings and proportionately shorter to 1½ inches for the smallest cuttings.
5.) The lower ½ to 1 inch of the stem is wounded to a depth just below the cambium to expose two lines of cambium tissue.
6.) Cuttings are dipped, to the extent of the wound, in a powder or liquid rooting hormone preparation — with IBA content ranging from 0.1% to 1.6%.
7.) Cuttings are placed in greenhouse benches with 4 inches of a ½ coarse peat and ½ perlite medium, with bottom heat maintained just above 70°F, and with misting governed by an electric leaf device.
8.) When root development has progressed to form a 1½ to 2 inch diameter root ball, cuttings are transplanted to greenhouse benches with a ½ sawdust and ½ peat (with fertilizer) medium.
9.) Rooted cuttings are encouraged to grow through the late winter and spring in the greenhouse benches with a minimum air temperature of 58°F, supplemental light and periodic liquid fertilizer application.
10.) Young plants are moved out, mostly to a lath house, in June to adjust to outside conditions and to harden off for the winter.

Adjustments and alterations to these procedures have been necessitated by characteristics found in many species which

either are not present or are not critical in commercial hybrid production — a diversity hardly surprising in view of the fact that barely one dozen species figure in the parentage of the great majority of standard hybrids. Lacking hybrid vigor, the wild plants can not be expected to so easily adjust to any slighting of their requirements, so more precise treatment is required. Further, many commercial hybrids were selected, in part, because of the ease with which they would root from cuttings.

Perhaps the least mentioned, yet potentially most limiting, factor affecting species rhododendron propagation success is dormacy. The dormancy traits of a species, the condition of the stock plant relative to dormancy at the time cuttings are taken, the response of the cuttings to propagating, especially the greenhouse environment, whether to encourage, discourage, or inhibit the initiation or satisfaction of dormancy, the conditions necessary to satisfy or overcome dormancy, and the relationship of dormancy to root growth and to initiation are all possible factors in propagation and are mostly undocumented. What we have observed is that the nature of dormancy varies greatly among rhododendron species, and that problems with the propagation of some species have been overcome by altering methods in a way to avoid dormancy as a negative factor.

One frequently encountered dormancy-caused problem is the inability or slowness of cuttings to make new growth after rooting. These cuttings have gone into a state of dormancy, and not being subjected to the period of winter cold which would naturally satisfy dormancy breaking requirements, will not renew growth under greenhouse conditons, or will do so only after being maintained under optimum growing conditions for an extended period. This problem has been encountered most widely in the propagation of deciduous rhododendrons, and particularly the deciduous azalea species (included within the genus) and the popular Knaphill-Exbury hybrids. A dormancy habit, so elaborate as to include the shedding of all foliage, is not likely to be easily reversed once begun. So it is important that the propagator work with material that is not dormant or is not placed under conditions where it will tend to go dormant.

With many deciduous azalea species, particularly the American natives, such as *Rhododendron calendulaceum* (Michx.) Torr., our experience shows that it is particularly important to take cuttings early, beginning in May, as soon as growth has fully extended, and to encourage rapid rooting with bottom heat near 73°F. An early rooting cutting will have more long summer days in which to produce top growth before decreasing day length can trigger the onset of dormancy. After being induced to make this first flush of growth, most cuttings

will increase in vigor and produce succeeding flushes in the greenhouse throughout the winter and early spring, even though under conditions of decreased light in which the later rooting cuttings will not initiate growth.

While avoiding the onset of the dormant state is the usual procedure in propagating some rhododendron species, others are successfully increased using cuttings which are at the end of the dormant period. The group of deciduous azalea species centered around *R. schlippenbachii* Maxim., can be propagated from leafless cuttings of nearly 1-year-old wood, taken in early April just as the vegetative buds swell and the flower buds are showing color. With dormancy satisfied, growth inhibitors have ceased to govern and the buds need only warmth to extend into full growth. The naked cutting produces its new leaves soon after being placed in the propagating bench, then initiates roots, and will be ready for transplanting in the normal length of time. A new flush of growth follows transplanting, after which the plant is best left to experience normal dormancy and mild winter cold. Besides other deciduous rhododendrons, such as *R. semibarbatum* Maxim. and *R. mucronulatum* Turcz., which have been propagated by late winter cuttings, some evergreen species also may be produced from cuttings taken at the end of dormancy. Cuttings of *R. fargesii* Franch. and some forms of *R. wardii* W.W.Sm. seem to be at peak physiological condition to root, grow, and survive when taken in late February.

The propagation of all deciduous rhododendrons is not so hampered by dormancy. The so-called "three-leaved" Japanese azaleas, represented by *R. reticulatum* D. Don ex G. Don, can be propagated from firm cuttings of vigorous growth taken from August to November. Apparently their dormancy is not so profound and leaf drop is a more casual affair. Thus, vigor readily overcomes the tendency to cease growth towards fall.

On the other hand, many evergreen species (Table 1) have failed to grow after rooting or after being grafted. This problem is most frequent in cuttings taken in July and August and transplanted in October and November. Cuttings taken at the same time, but transplanted in late January or February, will often commence growth sooner, as will cuttings of the same species taken in October and transplanted in February. Apparently, the early transplants, being removed from under the mist while daylength is still decreasing, continue to produce dormancy-inducing growth inhibitors, which the mist leaches from cuttings in the rooting bench. The later transplants are removed from mist at a time when increasing daylength is apt to overcome dormant tendencies and new growth is more easily stimulated. The fall cuttings, though well into a state of dormancy,

may be leached of the inhibiting compounds while under mist, and again emerge at a time of increasing daylength. Much research is needed to verify this hypothesis, but the problem is best minimized by timing the removal from mist after the middle of January. In grafting, the failure of late summer and fall grafts to produce growth is best avoided by waiting until February, after natural cold requirements are met, to begin propagating troublesome species. An alternative method, when the timing of availability of cuttings is beyond the propagator's control, is to graft in the fall. Then, after mending and air-hardening is completed, the plants are placed in a greenhouse with a minimum temperature near 32°F to allow an amount of cold that often will be sufficient to overcome dormancy. This treatment may also succeed with grafts that have failed to grow during their entire first year.

Table 1. Evergreen rhododendron species difficult to bring into new growth.

A. Most difficult — R. *basilicum* Balf. f. & W.W. Sm., R. *clementinae* Forrest, R. *coriaceum* Franch., R. *giganteum* Forrest ex Tagg, R. *hylaeum* Balf.f. & Farrer, R. *longesquamatum* Schneider, R. *mallotum* Balf.f. & Ward, R. *praestans* Balf.f. & W.W.Sm., R. *sidereum* Balf.f., R. *taliense* Franch., and R. *watsonii* Hemsl. & E.H. Wils.

B. Moderately difficult — *R. argyrophyllum* Franch., *R. barbatum* Wallich, *R. cerasinum* Tagg, *R. crinigerum* Franch., *R. cyanocarpum* (Franch.) W.W.Sm., *R. eclecteum* Balf.f. & Forrest, *R. falconeri* Hook.f., *R. fictolacteum* Balf.f., *R. hodgsonii* Hook. f., *R. insigne* Hemsl. & E.H. Wils., *R. macabeanum* G. Watt. ex Balf.f., R. strigillosum Franch., *R.* succothii Davidian, R. *uvarifolium* Diels., and *R. wightii* Hook.f.

A different problem appears to be related not so much to dormancy as to the need for certain species to follow natural annual growth cycles. Continuous forcing of flushes of growth under artificially maintained optimum conditions yields increasingly distorted growth. Leaves may be fewer in number but larger in size and misshapen, often puckered and with wavy edges. Stems and petioles are frequently enlarged. Such growth is often produced from lateral buds. In some other species, the apical buds develop, but the new shoots lack lateral buds. If the newly shoot's lone bud at the apex develops into a flower bud,

Table 2. Species of rhododendron for which a normal rest period is vital.

A. Those which, when forced excessively, produce distorted growth — *R. albrechtii* Maxim., *R. callimorphum* Balf.f. & W.W.Sm., *R. campanulatum* D.Don, *R. eximium* Nutt., *R. lacteum* Fanch., *R. schlippenbachii* Maxim., and *R. viscidifolium* Davidian.

B. Those which, when forced excessively, produce "blind" shoots — *R. anthopogon* D.Don, *R. collettianum* Aitch. & Hemsl., *R. lyi* Levl., *R. manipurense* Balf.f. & G. Watt, *R. roxieanum* Forrest, *R. souliei* Franch., *R. viscidifolium* Davidian, and *R. wardii* W.W.Sm. (some forms).

the end result is a barren growth. Simply allowing the plants a normal rest period and forcing no more than one or, at the most, two flushes of growth annually avoids these unwanted results.

There is much more to be learned about dormancy, how it is triggered, how it operates, and how it can be overcome or taken advantage of in the propagation of species rhododendrons. But the propagator who adjusts his timing or treatment of cuttings in consideration of dormancy is likely to experience success in producing these plants.

MYCORRHIZAE IN RELATION TO ROOTING CUTTINGS

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It has been stated by Zahner (1965), and probably by others before, that "In the natural environment, there exists no organism that lives like a hermit." Ponder that statement for a moment, and then let's consider plants and their associations with other organisms as a example. Certainly no plant in nature lives alone, but instead is surrounded, both above and below ground, by a myriad of microorganisms covering their roots, branches, leaves, and flowers. Some live in close association with the plants becauses of the chemical exudations from roots and leaves that support the microbe's life processes. Consider if you will, however, the intimate association that exists between plant roots and mycorrhizal fungi. Such associations are nearly universal, such that mycorrhizal associations are the rule not the exception. Healthy rootlets of most vascular plants growing in natural soil are inhabited by these beneficial fungi in a state of symbiosis. We are just now beginning to understand the nature of these fascinating associations, and what some of the implications are to the propagation, growth and survival of plants.

It is important to understand that there are two main types of mycorrhizae: ectomycorrhizae and endomycorrhizae. The key differences between these two types are that ectomycorrhizae generally form a thick mantle of fungal hyphae on the outside of the root tips, and the hyphae penetrate between the root cortical cells. (3).

These fungi are most often mushroom-type fungi (Basidiomycetes) that can be grown in culture. When they colonize roots, they often induce extensive proliferation of roots,

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greatly increasing the root surface area. In addition, the fungal hyphae extend outward from the root into the nooks and crannies of the soil, absorbing water and nutrients that are translocated back to the host root.

In contrast, the endomycorrhizae, mainly vesicular-arbuscular (VA) mycorrhizae, form no outer mantle and penetrate and completely fill up the root cortical cells. The VA mycorrhizae are obligate symbionts that cannot be grown in axenic culture. They must be grown in association with living plant roots. The last stage in their life cycle is to produce large, thick-walled spores on hyphae that extend into the soil from mycorrhizal roots. The VA mycorrhizae induce little or no change in the morphology or appearance of the roots and can only be detected by clearing the root and staining the fungal structures inside the root.

Ectomycorrhizae occur mainly on members of the Pinaceae, Betulaceae, and Fagaceae; the same fungi can form mycorrhizae with members of the Ericaceae, although the morphology of the association is somewhat different, i.e. they are called ectendomycorrhizae because they form only a loose outer mantle but penetrate and fill up the outer root cortical cells. Most of the other higher plant groups form VA mycorrhizae.

We know that the plant derives a number of key benefits from the mycorrhizal associations such as increased uptake of water and nutrients. We can also observe that ectomycorrhizae exhibit a greatly changed morphology (compared to non-mycorrhizal roots) in response to growth-promoting substances produced by the fungal symbiont. One could readily hypothesize that such substances might influence the physiological process of root initiation during cutting propagation. This thought was the basis for our first experiments on mycorrhizae in relation to rooting of cuttings (2).

Rooting of cuttings of some plants is relatively easy, especially if a rooting hormone is applied at the proper time. Other plants such as bearberry (*Arctostaphylos uva-ursi* (L) K. Spreng., are not so easily propagated by cuttings and were thus chosen as test species. The hypothesis was that ectomycorrhizal inoculum grown in the laboratory and added to the rooting medium would produce growth-promoting substances that would influence the rooting process. Two months after we had added the ectomycorrhizal inoculum to flats of rooting medium and had stuck cuttings, the benefits became apparent. Cuttings of 4 cultivars of bearberry in the uninoculated rooting medium were nearly all dead, as evidenced by the lack of roots and the presence of necrotic leaves. In contrast, cuttings in the inoculated medium were green, buds had broken, and growth was

proceeding. Most had significant root systems. We visually rated the root ball size of those cuttings that had roots. It was obvious that more cuttings had rooted and root systems were larger on cuttings stuck in medium containing the ectomycorrhizal inoculum. An examination of the roots revealed, however, that in most cases the bearberry roots were not actually infected with the mycorrhizal fungi, i.e. mycorrhizae had not formed. This observation suggested that the rooting response was induced by one or more entities produced by these fungi in the medium. Further, the response was not the same for each of the four bearberry cultivars tested, i.e. one fungus-cultivar combination resulted in enhanced rooting while the same fungus with another cultivar gave no rooting enhancement.

A graduate student, C.A. Call, joined me on this project at this point to examine the phenomenon more closely. He confirmed that the response was real, using as many as 13 fungi on still a fifth bearberry cultivar, as well as on huckleberry (*Vaccinium ovatum* Pursh.). Using three fungi he found that he could dilute the inoculum 10-fold and still enhance rooting. A culture filtrate of the ectomycorrhizal fungi also enhanced rooting, but to a lesser degree than the living fungi. Inoculation of the rooting medium was most beneficial during the non-optimal period for rooting. December, than during any other time of the year including the time considered to be optimum by propagators (October). He also noted that rooting was enhanced more in well-aerated medium than in water-logged medium near the mist nozzle. When rooted cuttings were transplanted into pots, he observed a striking growth enhancement of cuttings rooted in mycorrhizal inoculum compared to uninoculated control cuttings. Some mycorrhizal inoculum was carried along with the root ball and mycorrhizae did form, a response which would account for the dramatic growth response.

Our results thus far and those reports in the literature led us to consider several possible mechanisms responsible for the rooting enhancement phenomenon. It is possible that the mycorrhizal inoculum somehow changed the physical, chemical, and/or biological composition or structure of the medium in such a way as to enhance rooting, but we have not explored those possibilities enough to comment on their involvement. Rather, we have focused on the idea that mycorrhizal fungi release certain growth factors into the medium that interact with endogenous growth substances in the cutting. It is known (4) that some ectomycorrhizal fungi can produce growth regulators such as auxins, cytokinins, gibberellins, and B vitamins *in vitro*, but none of these substances is produced by all the fungi we tested. We felt it was possible, however, that all of the fungi

might produce other materials such as ethylene and/or auxin synergists.

Another graduate student, James Graham, has demonstrated that most of the ectomycorrhizal fungi he has tested can produce variable amounts of ethylene *in vitro* if provided with the right precursor, such as the amino acid methionine. At very low concentrations, ethylene has been shown to stimulate root initiation, although other reports are contradictory (1).

We are most aligned with the idea that auxin synergists or rooting co-factors (1) are produced by these fungi. Auxin synergists are polyphenolic compounds that can control the hormone balance in plants; they can help maintain high levels of endogenous auxin in the cutting; they are known to be involved in the host infection process; and they may form auxin-phenol complexes that may predispose tissue to initiate root primordia. We are presently testing our fungi to see if they can, indeed, produce such materials. If so, we will perform experiments to demonstrate their role in the rooting enhancement phenomenon.

Among the many things we still don't know about this rooting phenomenon is how widespread it occurs, i.e. how many hosts might respond and how many fungi may be capable of inducing this response. Several cooperators have been testing inoculum of one fungus, *Pisolithus tinctorius*, on a wider host range. Dr. Wilbur Anderson of Mt. Vernon, Washington, has rooted tissue culture rhododendron cuttings in *P. tinctorius* inoculum and obtained slightly better survival, percentage rooting, and fresh weight of cuttings stuck in inoculated medium than cuttings stuck in uninoculated control medium. A commercial concern in Chicago, Illionis has been exploring this phenonmenon using mainly endomycorrhizal (VA) hosts stuck in a medium inoculated with *P. tinctorius*. In some tests they observed enhanced rooting of hosts like chrysanthemum, although there appeared to be a cultivar response similar to that which we observed for bearberry. In one case, *P. tinctorius* plus rooting hormone gave what appeared to be an additive effect on the root ball size (R.J. Steinkamp, personal communication), a response which could support the rooting co-factor idea expressed earlier. The significance of these findings, if confirmed, would be that the growth factors produced by these ectomycorrhizal fungi may influence rooting of non-ectomycorrhizal hosts (i.e. endomycorrhizal hosts) and thus broaden their potential use to propagation of many more host plants.

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THE USE OF MYCORRHIZAE IN THE PROPAGATION OF ARCTOSTAPHYLOS UVA-URSI

VERL L. HOLDEN

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Mycorrhizae have long been known to influence the growth of plants. The fruiting body of this interesting family of fungi has also been known to Europeans as truffles. I first became interested in the use of mycorrhizae when Dr. James Trappe of Oregon State University presented a lecture on the use of mycorrhizae at an Oregon State University Ornamental Short Course. He suggested that mycorrhizae fungi exist on most plants when they are growing out-of-doors in native soils. He also showed some very convincing slides that illustrated what happened to plants that did not have the benefit of the mycorrhizae fungi.

Taking the hint, I dug up a kinnikinnick (*Arctostaphylos uva-ursi*) plant from one of my mother blocks and took the soil and roots and put them in a small cement mixer, added water and let it run for about an hour. Then I strained the muddy water through a window screen sized sieve and sprayed the diluted solution over 50,000 rooted cuttings of kinnikinnick which had recently been potted into 2¼ in. pots. I know I took a chance, but the results were phenomenal. The growth at the end of the year was almost double of what I had been obtaining and the plants were in an extremely healthy condition. I showed the plants to Dr. Robert Linderman of the U.S.D.A. Ornamental Plant Laboratory at Corvallis, Oregon, and he confirmed that I did indeed have mycorrhizae fungi growing on the roots of nearly every plant examined. Unfortunately, this particular mycorrhizae grows partly on the inside and partly on the outside of the roots and there has been no success in propagating it when it is not associated with live roots.

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I have been successful, however, in inoculating large groups of plants by cutting the mycorrhizal roots from growing plants, putting them in a kitchen blender for a few minutes and spraying the resulting liquid on plants I wished to inoculate. At this time I am inoculating cuttings in the cutting bench after they have been stuck and are starting to root. You can see mycorrhizal roots on the rooted cuttings when they are lifted from the bench about 2 months later. These mycorrhizal roots (Figure 1) are on the plants for as long as I keep them and perhaps for the life of the plants. I have noticed no detrimental effects as a result of mycorrhizal inoculation. The plants appear to grow faster, are much more healthy, and have much better transplanting percentages than uninoculated plants. I am sure that we are just on the edge of great discoveries about the use of mycorrhizae in the growing of plants.

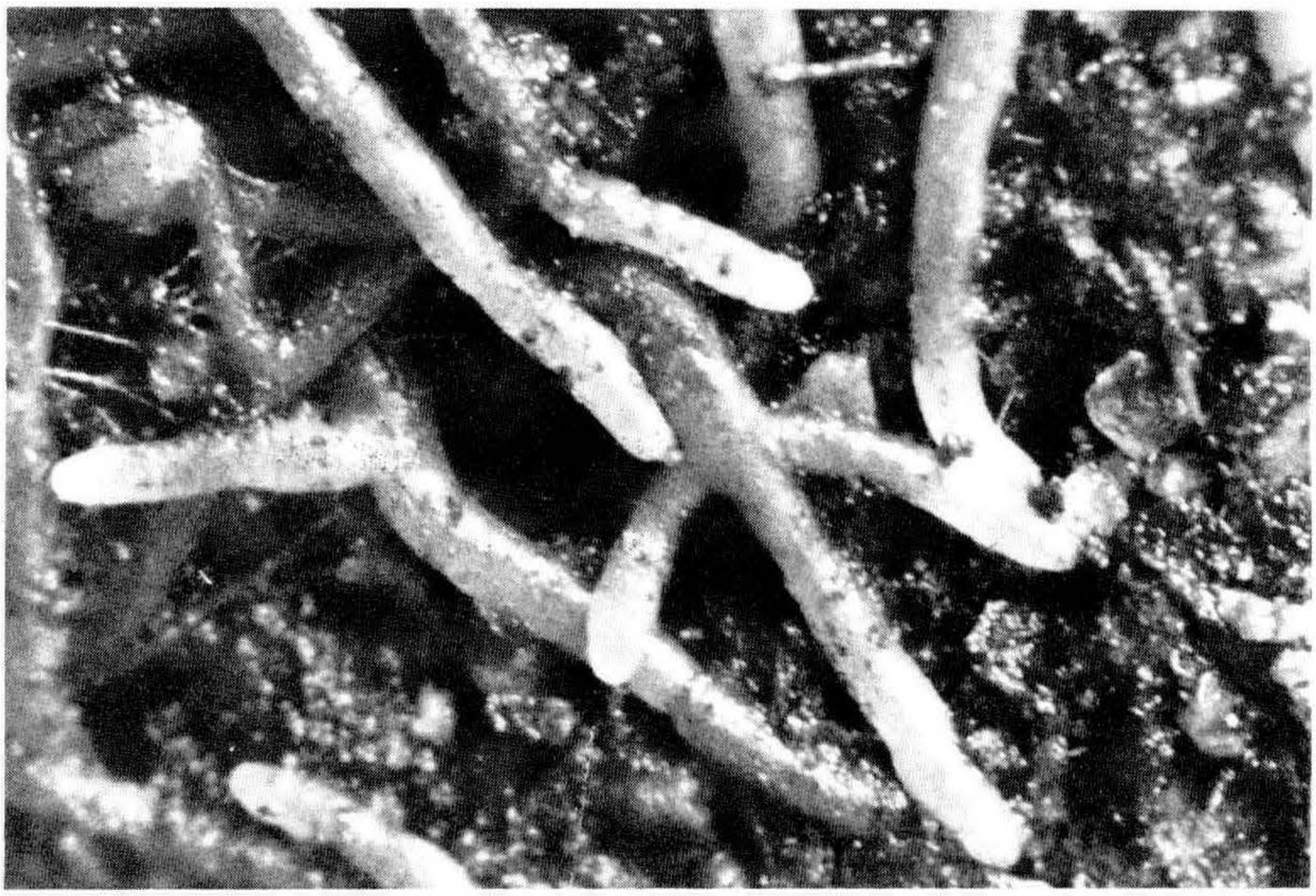

Figure 1. Mycorrhizal roots of *Arctostaphylos uva-ursa*. X 180. Photo by Wm. Snyder.

PROPAGATION OF KALMIA

JOHN E. EICHELSER

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Collected plants of *Kalmia latifolia*, sometimes known as mountain laurel, have been used as ornamentals for many years, yet, little has been done to propagate selected cultivars in nur-

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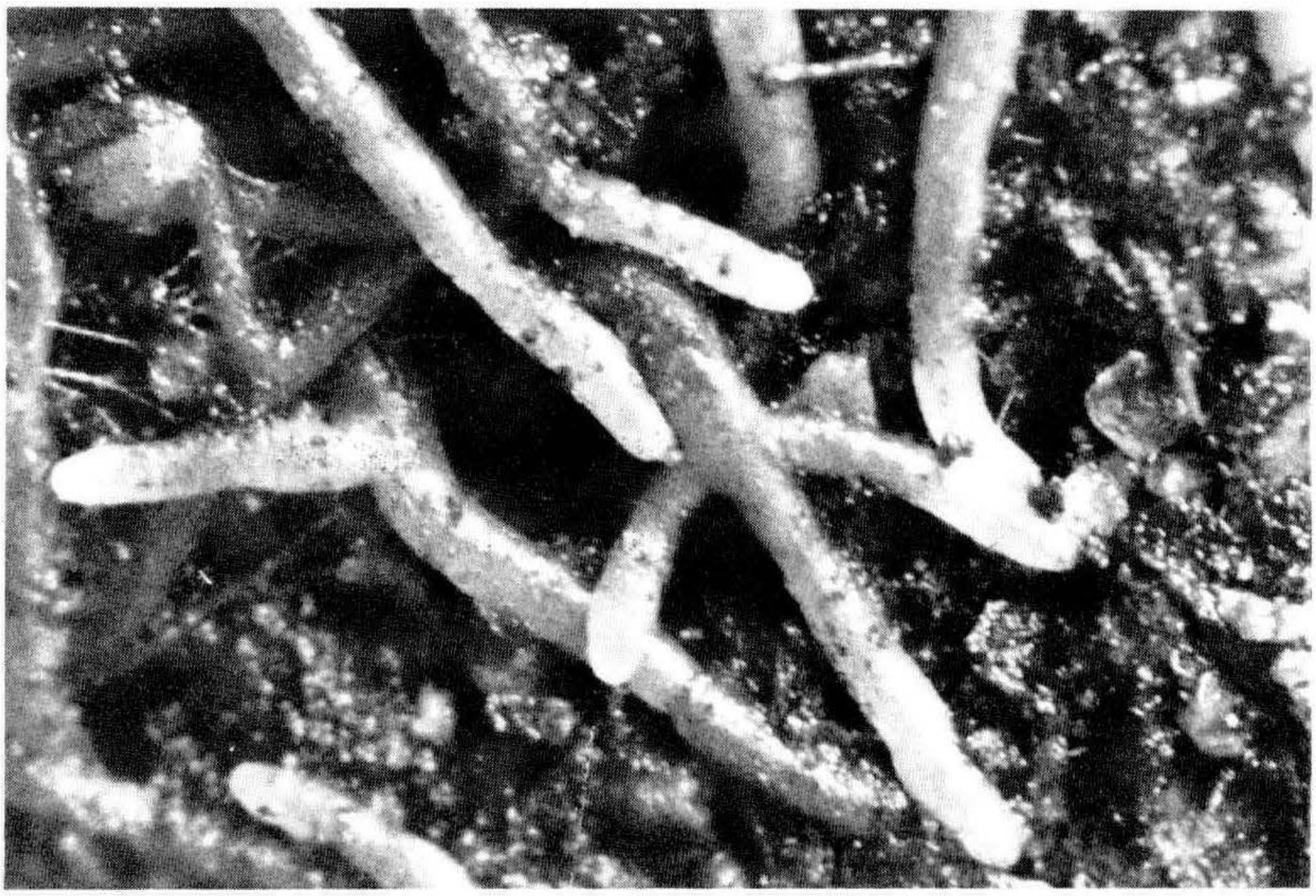

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Collected plants of *Kalmia latifolia*, sometimes known as mountain laurel, have been used as ornamentals for many years, yet, little has been done to propagate selected cultivars in nur-

series until recently. Even now most kalmias grown in nurseries are propagated from seed since their cuttings are believed by many to be nearly impossible to root.

After working with kalmia for many years we have improved our method to the point where we can produce cuttings of kalmia cultivars in quantity and can expect an acceptable percentage of rooting, usually 60% to 75%.

In our attempts to root kalmia we have used many different rooting media, including sand, peat moss, perlite, pumice sand, decomposed sawdust and fresh sawdust, both of cedar and Douglas fir. We tried every commercial rooting hormone available and even took a try at mixing our own. We have tried rooting cuttings nearly every month of the year. Some cuttings are taken in late October, but most of them are taken in January at which time they root most rapidly for us.

The methods we now use are the result of the experience we have gained from many years of searching.

Bottom heat at 73° to 75°F is supplied by electric cables in greenhouse benches that are six inches deep. Our cuttings are all taken from young plants. Juvenility seems to be very important as our percentage of rooting from young plants is nearly twice as high as that for cuttings from older stock plants. The cuttings are dipped in a Benlate solution and allowed to drain. A double wound is used followed by an "in and out" dip in liquid hormone. Currently we are using FAST ROOT which contains 0.5% 3-indolebutyric acid, 0.5% a-naphthalene acetic acid, and 0.0175% boron. This material is used at the rate of 5000 ppm. Mist is used ten seconds every ten minutes during daylight hours. The rooting medium is composed of 40% fir sawdust, 40% cedar sawdust, 10% perlite, and 10% peat moss. The sawdust should be thoroughly leached before cuttings are stuck.

Our percentage of rooting and the size of the root ball is superior in this medium over another combination we have used.

By the time we are ready to root kalmia our benches have already been used to root rhododendrons. We have tried removing the old medium and putting in fresh medium, as well as sticking our kalmia cuttings in the medium from which the rhododendrons were removed. The results have been noticeably better when we stick them in the medium that has already been used once, and this practice has not seemed to cause us any disease problems. We wonder if this could be the result of the action of mycorrhizae fungi?

We transplant our kalmia in June. Kalmia cuttings root

slowly and we find that when we transplant, a few have callused but have no roots. These are restuck in flats and caried on under mist, but with no bottom heat. By fall most of these will have rooted.

If the above methods are used, and with patience to wait about 5 months for roots to appear, one should be able to root kalmia cuttings with very acceptable percentages.

ROOTING OF TISSUE CULTURED RHODODENDRONS

WILBUR C. ANDERSON

Northwestern Washington Research and Extension Unit
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Abstract. Rooting of tissue cultured rhododendrons directly from stage 2 can be successful, however, small changes in the growing environment cause variable survival rates. Uneven crop growth also has been a problem. My research has been redirected towards a stage 3 rooting step in culture in an effort to increase rooting percentages and reduce plant growth variations observed.

INTRODUCTION

The steps in tissue culture propagation involve 3 conceptual stages (3). Stage 1 describes the necessary procedures in establishing plant propagules in the culture environment. The important factors in stage 1 include the selection of the appropriate source of explants; choice of the approprate methods of disinfesting all pathogens from the explants, and determining the appropriate chemical and physical environment for growth and establishment of the culture. Stage 2 is the time when the plant propagules are multiplied. The important considerations of this stage are finding the appropriate growth regulator combinations for propagule multiplication (i.e. shoots for rhododendrons, crowns for strawberries, and bulbs for lilies). The number of times propagules are recycled in stage 2 depends on the genetic stability of the crop and the amount of propagation required. Stage 3 is the term used to describe transition period from the multiplication of propagules and establishing them in the soil environment. After stage 3, the plants can be handled in a similar manner used for growing seedlings.

The stage 1 and stage 2 requirements for propagating rhododendrons have been previously reported (1,2) including revision of the inorganic formula. At the present time about 50 rhododendron cultivars have been established in culture. Other

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crops in the heath family that have been successfully established include bearberry, azalea, and kalmia.

During this last year my laboratory has emphasized experimental tests to determine if the in-culture stage 3 could be eliminated in the propagation of a wide variety of crops. The motivation to eliminate the in-culture stage 3 was based on reducing tissue culture costs since each handling after the last multiplication step requires individual handling of each plant. Therefore, using stage 3 prior to establishing tissue cultured plants in soil becomes a labor intensive step. Establishing rhododendron shoots directly into the soil environment was one of several crops intensively studied.

MATERIALS AND METHODS

A cooperative agreement was worked out with Briggs Nursery, Olympia, Washington, and Clay's Nursery, Langley, B.C. Canada, to root tissue-cultured rhododendron shoots directly from stage 2 and then to report back their results.

Research Unit. The planting procedure for the first experiment was to plant the shoots directly into unitized cells that were filled with 50:50 peat/perlite. The planted trays were placed in a closed box made from 1″ × 8″ boards for the box sides and were covered with 7 mil mylar over the top. A wet felt pad was placed under the trays to increase the humidity. The light source was from cool white fluorescent tubes with 16 hrs of ca 400 fc of light. Temperature was maintained at 70-75°F. The plantlets were maintained in the closed box for 5 weeks and then moved to the greenhouse under 40% shade.

Briggs Nursery. The planting mix used was 50:50 sand-peat and several kinds of planting containers were used. The plantlets were placed in a fog chamber with light coming from a combination of natural and supplemental light.

Clay's Nursery. Several different soil mixes were tested including a) peat; b) Jiffy 7's; c) 33% sand, 33% perlite; and d) 67% peat, 67% perlite. The trays of plantlets were placed on a bottom bench with most of the natural daylight shaded. The light source was from cool white fluorescent lights. The trays of plantlets were placed in styrafoam boxes and covered with glass. Temperature was maintained at 70-72°F. The plantlets were kept in this environment for 6 weeks and then placed under a propagation mist system.

RESULTS AND DISCUSSION

Research Unit. Early observation noted that plantlets planted directly into cells take up too much space in a growth room environment because rooting and initial growth of

rhododendrons is slow. There is about a 2-month lag in growth before the rapid plant growth phase begins. The planting mix must be porous to prevent water-logging conditions. Approximately 20% of the plantlets were lost in the laboratory and 20% when moved to the greenhouse, probably indicating that time in the light room should be increased to 6-7 weeks.

Briggs Nursery. A fogging device was used to mist the plantlets. There was a positive correlation of survival with the fog pattern emission.

Another interesting observation made at Briggs Nursery was that a thin layer of sphagnum moss placed on the surface of the planting mix improved survival and rooting.

Clay's Nursery. During the first experiment it was found that the 67% peat, 16% sand and 16% perlite was the best soil mix tested. During the second experiment best result was with 72% peat, 18% perlite and 9% sand and 1 pound of 18-6-12 Osmocote (8-9 mo.) per cubic yard. In all the previous studies no fertilizer had been added to the soil mix. The improved general health and survival of the plantlets indicates that a fertilizer program in the early stages of rooting will be helpful.

The combined results of the experiments show that all the culivars tested can be successfully rooted. There are several cases of variations in cultivar survival ranking between test sites and also between experiments at each site which indicates that both the general condition of shoots from the stage 2 cultures and the propagule rooting environment are important factors in plant survival.

Two major problems became apparent through these rooting experiments: the average survival rates were lower than hoped for, and the uniformity of the crops was variable at all 3 locations. Both of these problems can be aggravated by non-uniform shoots that come directly from stage 2. Some of the shoots are spindly and long and some have a translucent appearance from growing in direct contact with the culture medium.

An alternative method to reduce the problem is to grow the shoots in a stage 3 culture medium for one month. Here the shoots become uniform in appearance, taller, stockier, the base of the shoot becomes callused. Only a small percentage of the shoots produce roots in the stage 3 media. The individual plantlets are then transplanted into individual cells and are established as plants under a normal propagation mist system.

Using the alternative stage 3 in-culture step does not require any more handlings of the plants than planting directly from stage 2 into the soil. It may have advantages of greater

survival and greater crop uniformity. Any method that improves the percentage of usable plants without sigificantly increasing cost will likely be an advantage.

The length of time required in the small cells is about 3 months to reach sufficient size for transplanting into gallon cans.

Table 1. Survival and Growth of Tissue Cultured Rhododendron Shoots Planted Directly From the Shoot Multiplication Medium at 3 Locations.

Experiment 1. (Cuttings planted 4/1/78; survival observations 6/1/78)

	Research Unit		Briggs		Clay's	
Cultivar	Shoots planted	% survived	Shoots planted	% survived	Shoots planted	% survived
Blue Pacific	70	67	120	95	186	96
Pracox	73	89	432	91	241	79
Vulcan	73	88	103	69	199	90
Impeditum	73	64	102	72	210	95
PJM	73	71	120	69	194	88
Cynthia	64	38	204	91	173	90
Rose Elf	73	64	120	86	214	65
Hurricane	73	63	60	90	199	61
Cunningham white	73	64	120	53	183	77
Unique	73	11	120	65	184	58
Total shoots planted	718		1501		1983	
Mean % survival		62		79		80

Experiment 2. (Cuttings planted 6/27/78; survival observations 9/15/78)

	Research Unit		Clay's	
Cultivar	Shoots planted	% survived	Shoots planted	% survived
PJM	150	79	447	90
Hurricane	150	73	301	81
Vulcan	150	73	301	81
Emasculum	150	77	246	76
Jean Marie de Montague	150	60	128	74
Total shoots planted	750		1565	
Mean % survival		72		84

In conclusion, the stages of propagation are schematically shown in Figure 1. Softwood shoot cuttings are surface sterilized and planted on the culture medium in stage 1. Once the new flush of shoots has grown 1-2 cm, these are cut off in stage 2, cycle 1. Small clumps of shoots arise from adventitious buds on the stem and leaves. Stage 2, cycle 2 begins with removing these small clumps and planting them on fresh culture media. Once these are successfully started, normal multiplication rates can be readily achieved of 20-40 shoots/culture in a 10 week culture period. These cultures are continually recycled until the crop requirements are met. The shoots then are transferred to stage 3 either in culture or to a soil environment for about 1 month. The plantlets are then planted into individual

plant cells to grow for approximately 3 months. Then the rhododendrons are ready to be planted into gallon cans.

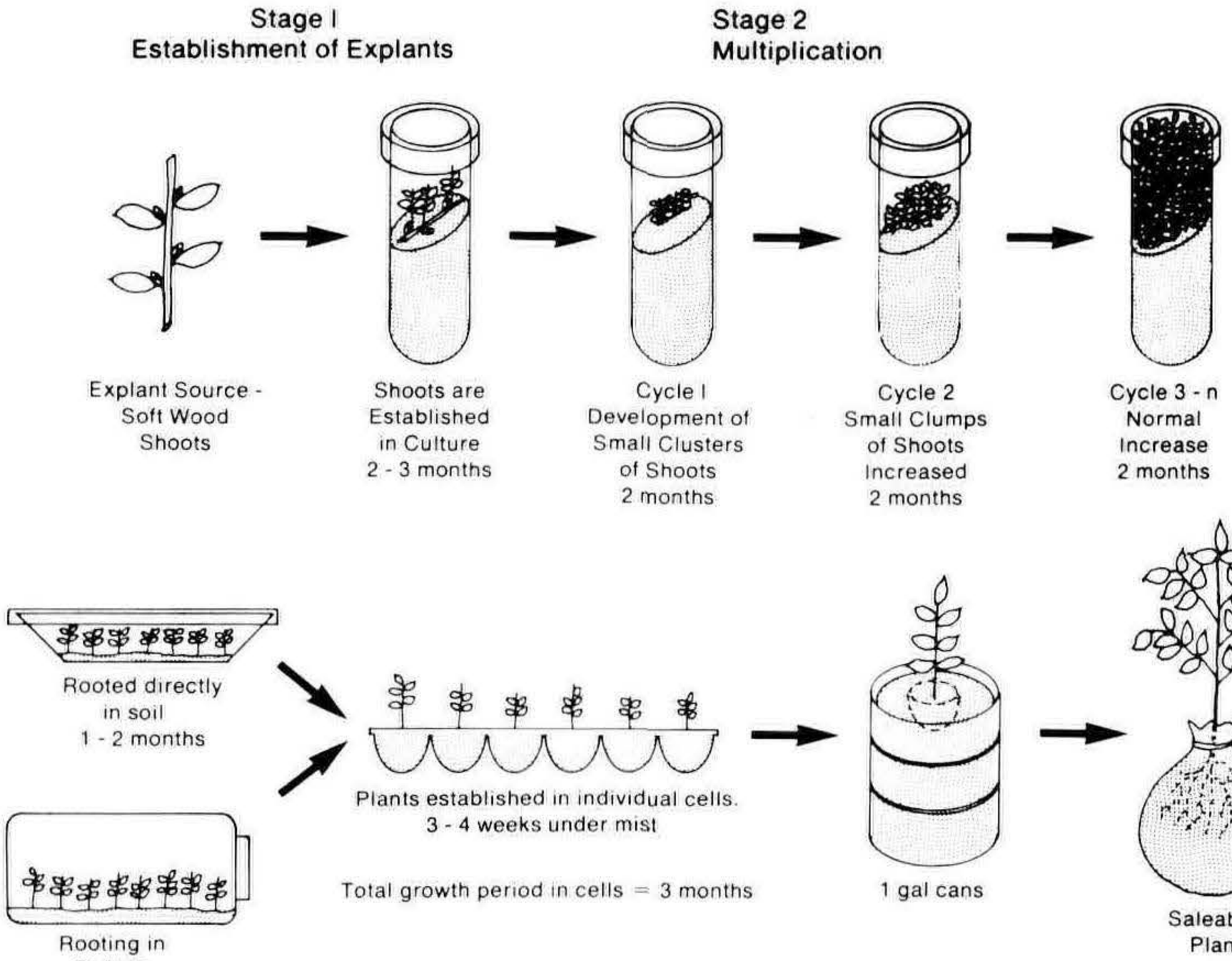

Figure 1. Steps in tissue culture propagation of rhododendron.

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CLONAL PROPAGATION OF WOODY PLANT SPECIES THROUGH TISSUE CULTURE TECHNIQUES

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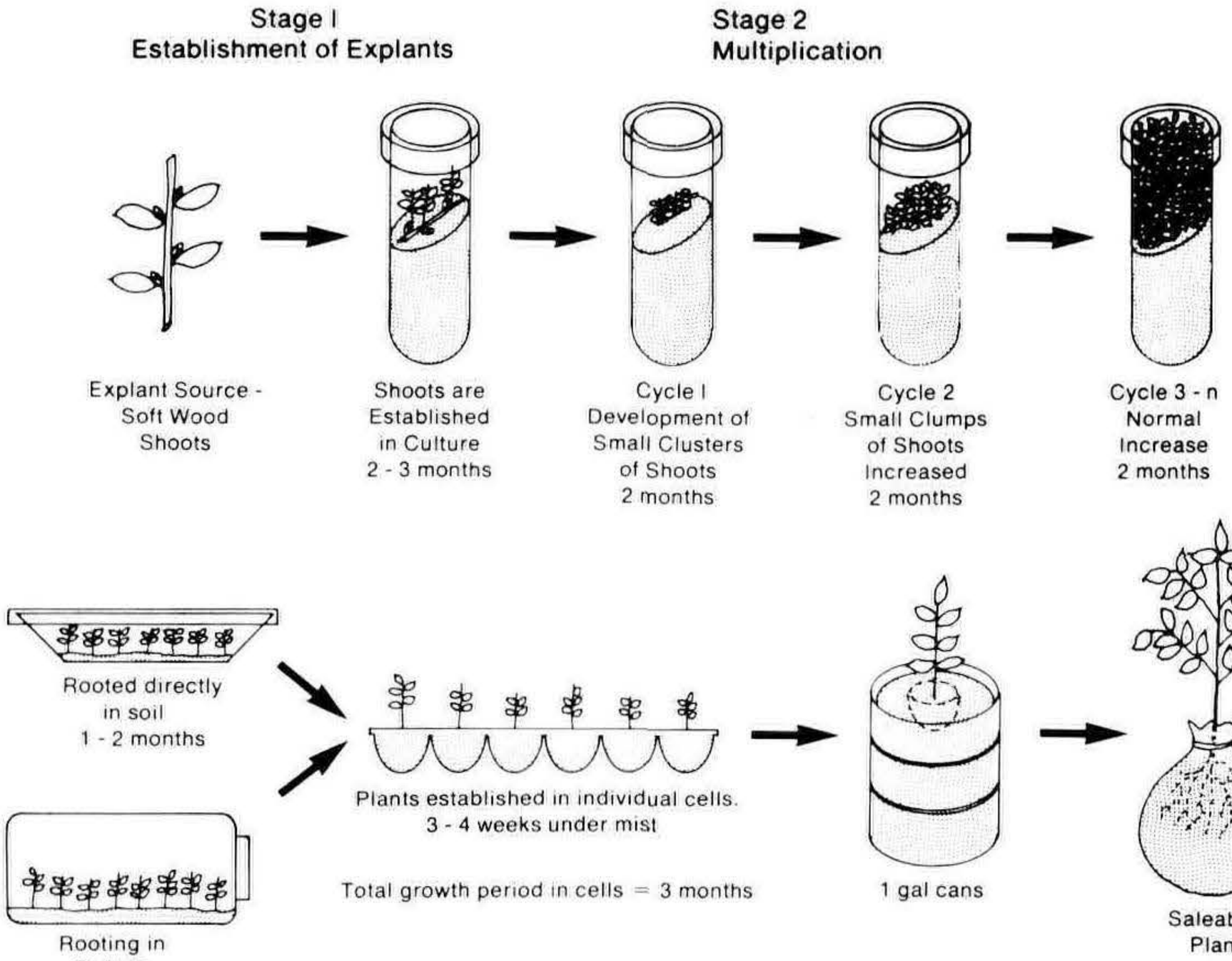

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Abstract. Significant progress has been made in development of tissue culture techniques to meet the requirements for mass clonal propagation of

selected woody species. Regeneration of plantlets from Douglas fir cotyledons has been accomplished under defined conditions. Differentiation originated from cells residing in the hypodermal layer. Biochemical studies have shown that newly synthesized proteins with molecular weights ranging from 16,000 to 20,000 daltons are associated with developmental events. A workable Douglas fir protoplast system has been established for obtaining calluses from protoplasts isolated from cotyledon. In studies with deciduous species, *in vitro* requirements for mass clonal propagation on a scale of more than one million plantlets per year has been accomplished for pear rootstock, 'Old Home × Farmingdale 51', plum rootstocks, 'Pixy' and 'St. Julien X' and ornamental *Prunus cerasifera* 'Newport.' Research with apples, cherries and other ornamentals is less advanced but is indicative that high frequency plantlet regeneration will be obtained.

REVIEW OF LITERATURE

The potential use of *in vitro* techniques in forest tree improvement programs has been described (4,5,12,20,31,34). Morphogenesis in culture of coniferous tree species has been reported for *Sequoia sempervirens* (3), *Platyeladus orientalis* (syn. *Biota orientalis*) (29,39), *Pinus gerardiana* (39), *Cryptomeria japonica* (24), *Picea glauca* (7,8), *Pinus palustris* (35), *Pseudotsuga menziesii* (Mirb.) Franco (11,14,15,36,41,42), *Tsuga heterophylla* (13), *Thuja plicata* (18) *Pinus taeda* (12,16,33), *Pinus contorta* and *Picea sitchensis* (40), and other species (38).

With regard to the development of tissue culture techniques for mass clonal propagation of deciduous woody species, various degrees of success has been reported for fruit trees — apples (1,16,21,25,26,27), almonds (32,37), almond-peach hybrid (37) and cherry (16) — and for the ornamental species *Ilex aquifolium* (23), forsythia (19), rhododendron (2) and bougainvillea (9).

In this article, we report the current status of our research toward development of tissue culture techniques for mass clonal propagation of selected woody species including conifers, fruit trees and ornamentals. We have made significant progress and our successes lead us to believe that economic, large scale propagation of woody species is not far away.

MATERIALS AND METHODS

Sources of plant materials and methods for their preparation. For conifers, our principal experimental material has been cotyledons of Douglas fir [*Pseudotsuga menziesii*]. Other conifers included in this study are listed in Table 1. In addition to using cotyledons as initial explants, plant materials from different plant parts and different ages have also been used. Seeds were obtained from various sources: (a) Douglas fir (*Pseudotsuga menziesii)*, western hemlock (*Tsuga heterophylla*), loblolly pine (*Pinus taeda*), and Caribbean pine (*Pinus caribaea*) from

the Western Forestry Research Center, Weyerhaeuser Co., Centralia, Washington; (b) *Cryptomeria japonica* from the Government Forestry Experimental Station, Tokyo, Japan; and (c) other species from the commercial suppliers, Herbst Brothers (Brewster, N.Y.), F.W. Schumacher Co. (Sandwich, Mass.), and Roy Carter (Sylmar, Calif.). Juvenile Douglas fir of approximately 6 to 7 years of age was obtained from Alfred Teufel Nursery (Portland, Oregon). Plant materials from adult Douglas fir were collected from the vicinity of the Oregon Graduate Center.

Table 1. Conifer species for which the potential for clonal propagation through tissue culture techniques has been established.

Species	Adventitious Shoot Formation	Adventitious Root Formation	Plantlet Regeneration
1. *Cryptomeria japonica*	+	+	+
2. *Cupressus arizonica*	+	+	+
3. *Picea abies*	+	+	+
4. *Picea sitchensis*	+	+	+
5. *Picea caribaea*	+	+	+
6. *Pinus elliottii*	+		
7. *Pinus ponderosa*	+		
8. *Pinus taeda*	+	+	+
9. *Pseudotsuga menziesii*	+	+	+
10. *Tsuga Heterophylla*	+	+	+

Sources and ages of tissue explants used:
(a) Excised mature embryos: 5,7,8 and 9.
(b) Cotyledons (up to 3 months): 1,2,3,4,5,6,8,9 and 10.
(c) Hypocotyls (up to 3 months): 9.
(d) Needles (up to 2 years): 9.
(e) Stems (up to 2 years): 9 and 10.
(f) Stems (adult trees): 9.

For deciduous woody species, actively growing herbaceous shoots obtained from clonal stock plants maintained in a greenhouse were used as experimental materials. These stock plants, fruit tree rootstocks and ornamentals, were provided by A. McGill & Son Nursery (Fairview, Oregon), Oregon Rootstock, Inc. (Gervais, Oregon), Stark Bro's Nurseries and Orchards Co. (Louisiana, Mo.), and Willow Drive Nursery (Toledo, Wash.).

To obtain aseptic tissues to be used in culture establishment, plant materials, after washing thoroughly with running tap water, were sterilized by submerging with slight agitation in 6 to 20% Clorox (5.25% sodium hypochlorite, NaOCl, the Clorox Co., Oakland, Calif.) for a period of 8 to 20 min., depending on the condition and source of tissue, and then rinsed several times with sterile, deionized water until free of Clorox. Prior to the establishment of tissues in culture, a preconditioning treatment was applied to all Clorox sterilized plant materials by placing them for about a week on an agar solidified nut-

rient medium with no supplement of plant growth regulators. This preconditioning step enables the selection of vigorously growing tissues for use in culture establishment and allows the elimination of contaminated and injured tissues. The aseptic tissues were sliced into 3 to 10 mm pieces which were subsequently cultured on appropriate media.

Culture media and systems. The basal medium contains, per liter, (a) inorganic compounds: 825 mg NH_4NO_3, 950 mg KNO_3, 220 mg $CaCl_2 \cdot 2H_2O$, 185 mg $MgSO_4 \cdot 7H_2O$, 85 mg KH_2PO_4, 6 mg $FeSO_4 \cdot 7H_20$, 7.2 mg Na_2EDTA, 3.1 mg H_3BO_3, 11.2 mg $MnSO_4 \cdot 4H_2O$,. 5.3 mg $ZnSO_4 \cdot 7H_2O$, 0.4 mg KI, 0.2 Mg $NaMoO_4$, 0.01 mg $CuSO_4 \cdot 5H_2O$, and 0.01 mg $CoCl_2 \cdot 6H_2O$; and (b) organic substances: 250 mg myo-inositol, 2.5 mg thiamine·HCl, and 30 g sucrose. In general, the basal medium was used at full strength. However, if retardation of tissue growth was observed, 2- or 4- fold diluted basal medium was used. The plant growth regulators added to the basal medium were as follows, (a) auxins: indole-3-acetic acid (IAA), indole-3-butyric acid (IBA), 2-naphthaleneacetic acid (NAA), and 2,4-dichlorophenoxyacetic acid (2,4-D); and (b) cytokinins: N_6-benzylaminopurine (BAP), 6-(3-methyl-2-butenylamino) purine (2iP), and kinetin. The final pH of the nutrient medium was adjusted to 5.5. The heat labile compounds, after adjusting the pH to 5.5, were sterilized separately by filtering through 0.20μ Nalgene Filter Units (Nalgene Sybron Corp., Rochester, N.Y.), and then added to the autoclaved nutrient media.

Two types of culture systems, agar solidified solid system and fabric tissue support liquid system, were employed in culturing various tissues. For preparing solid medium, 0.6 to 1.0% Bacto-agar (Difco Lab., Detroit, Mich.) added to the nutrient medium was autoclaved and subsequently poured into either 60 × 15 mm or 100 × 20 mm plastic petri dishes (Falcon Plastics, Oxnard, Calif.). The fabric tissue support liquid system consisted of a culture vessel containing 100% polyester fleece saturated with an appropriate liquid nutrient medium. Replacing the solidified agar with a fabric material for tissue support allows the nutrient to flow in a liquid state and, thus, facilitate the process of supplying tissue explants with appropriate nutrients required for each developmental stage without transfer of cultured tissues. Owing to its flexibility and simplicity, this system exhibits the potential for industrial application in mass clonal propagation (15).

RESULTS AND DISCUSSION

CONIFEROUS SPECIES

In this laboratory, significant advances have been made in

development of tissue culture techniques to attain the goal of mass clonal propagation of forest tree species. Initiation of multiple shoots and roots, and regeneration of plantlets have been accomplished to various degrees for several species of gymnosperms (Table 1). Practically, all coniferous species studied, Japanese cedar, Arizona cypress, Norway spruce, Sitka spruce, Caribbean pine, slash pine, ponderosa pine, loblolly pine, Douglas fir, and western hemlock, have exhibited morphogenetic responses. Furthermore, tissues from different plant parts and from different ages of plants respond to tissue culture treatment. For example, various Douglas fir tissues, excised mature embryos, cotyledons, needles, and stems of juvenile and adult trees produced adventitious buds (Figure 1).

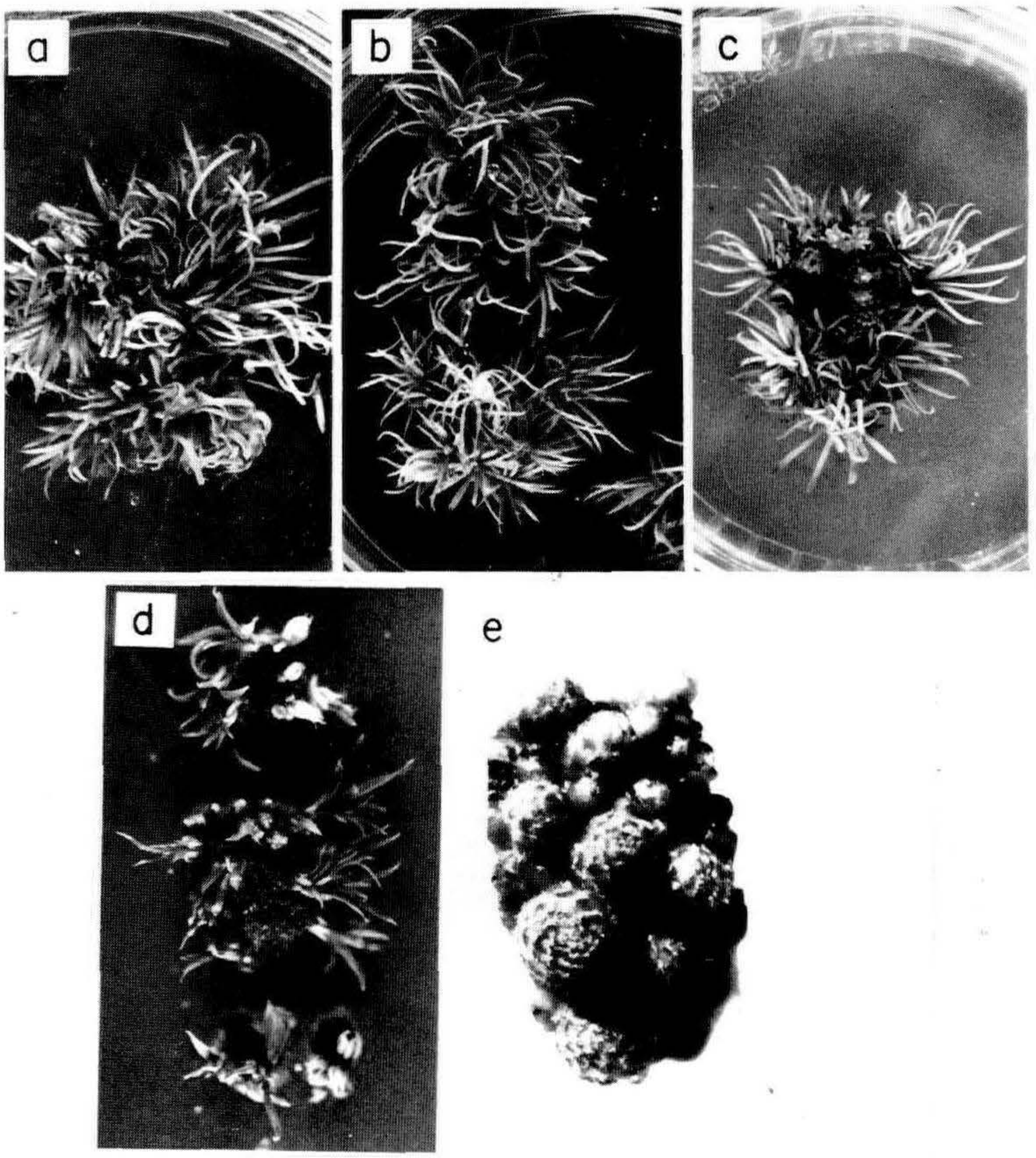

Figure 1. Multiple adventitious shoot formation in culture from various Douglas fir tissues. Plant materials used were: (a) excised mature embryo, (b) cotyledon explants from young seedlings, (c) needle explants from young seedlings, (d) stem explants from juvenile trees, and (e) stem explants from adult trees.

In order to better define various factors controlling differentiation *in vitro*, Douglas fir cotyledons were chosen as a model system for an in-depth study of (a) tissue culture requirements for each developmental stage leading to plantlet regeneration (11-17), (b) the histological sequence of adventitious bud development (10), (c) the elucidation of biochemical mechanisms controlling differentiation (22,43), and (d) requirements for a workable protoplast system (28). The progress we have made in each of these various areas of research are reported here.

Factors influencing adventitious bud formation. For stimulation of adventitious bud formation in culture, a relatively high concentration of cytokinin with respect to that of auxin is required (Figures 2a and b). The extent and nature of morphogenetic responses expressed by tissue explants depends on the genomic composition and physiological condition of the plant material. The diversity of morphogenetic responses was more apparent when natural auxins (i.e. IAA and IBA), instead of synthetic auxins (i.e. NAA and 2,4-D) were used. Using the identical nutrient medium supplemented with natural auxin, different morphogenetic responses occurred for Douglas fir cotyledon explants derived from different regions of the same seedlings or from the same regions of different seedlings. The most likely interpretation of these differences is due to the existence of different amounts of auxin-degrading enzymes among a heterogeneous seedling population. As a consequence of these differences, even applying the same amount of exogeneous natural auxin to all tissue samples, the actual functional auxin concentrations among these explants differed significantly.

Synthetic auxins have low susceptibility to enzymatic degradation, thus addition of low concentration of either NAA or 2,4-D to nutrient medium provided a uniform stimulation of adventitious bud formation. Among the most commonly used cytokinins (i.e. BAP, kinetin, and 2iP), BAP was most effective in stimulating adventitious bud formation; 2iP was the least effective. To date, the most effective concentrations of plant growth regulators for stimulating Douglas fir cotyledons to produce adventitious buds are 5μM BAP plus 0.5 to 5.0 nM NAA, or 5μM BAP plus 0.25 to 5.0 μM IAA or IBA,

A histological analysis of adventitious bud formation in culture of Douglas fir cotyledon showed that the organized structure originated from hypodermal cells of cotyledon and that its development sequence advanced through four anatomically distinguishable structures: (1) meristemoid, (2) bud primordia, (3) shoot apex with needle primordia, and (4) adventitious bud. Bud primordia were well-defined after 21 days in

culture. The anatomical structures of adventitious buds were similar to those formed on intact plants. Beneath the shoot apex, the stem consisted of a well-differentiated pith and vascular bundle. This vascular system extended from stem axis acropetally into the needles.

Biochemical mechanisms involved in adventitious bud formation of the Douglas fir cotyledon system were studied by analyzing double labeled (^{14}C, ^{3}H) newly synthesized cytoplasmic soluble proteins by SDS polyacrylamide gel electrophoresis. Increase of a low molecular weight protein fraction ranging from 16,000 to 20,000 daltons (i.e. bud protein fraction) was observed for cotyledon culture capable of producing adventitious buds (i.e. bud culture). An increase of bud protein fraction was detected after 2 days in culture and reached a maximum level at day four. Association of the bud protein fraction with adventitious bud formation was supported by results obtained from comparing bud culture with that of other morphologically distinct types of cultures in that bud culture always contained a higher amount of this protein fraction. Furthermore, when bud culture was transferred from bud medium to callus medium, suppression of bud protein synthesis occurred. Partial purification of the bud protein fraction was achieved by solubilizing proteins with 60% ammonium sulfate solution. Preliminary results obtained from fractionation of proteins with DNA-cellulose column showed that a bud protein exhibited a strong binding affinity with DNA. Further elucidation of the bud protein fraction is necessary if the nature and function of these proteins are to be understood. Meanwhile, this characteristic protein marker can be used as a probe in design and evaluation of tissue culture experiments.

Regeneration of plantlets. Regeneration of Douglas fir plantlets under defined culture conditions has been accomplished (Figure 2c). Excised tissue-culture-produced shoots were subjected to root initiation by placing them on an agar solidified rooting medium. In addition to an appropriate concentration of auxin (NAA), a concentration of sucrose lower than that used for shoot initiation was beneficial for root initiation. For stimulation of root formation, concentrations of NAA and sucrose at 0.25 μM and 0.5% respectively were required; under these conditions about 80% of tissue culture-produced shoots formed roots. The incubation temperature also had a profound influence on the regeneration frequency of plantlets and on their anatomical structure. For example, at 24°C only a few plantlets were produced and friable callus which formed at the transition region between stem and root caused a discontinuity in the anatomical structure of the plantlets. In contrast, at 19°C

a high frequency regeneration of plantlets showing a normal morphological appearance was obtained.

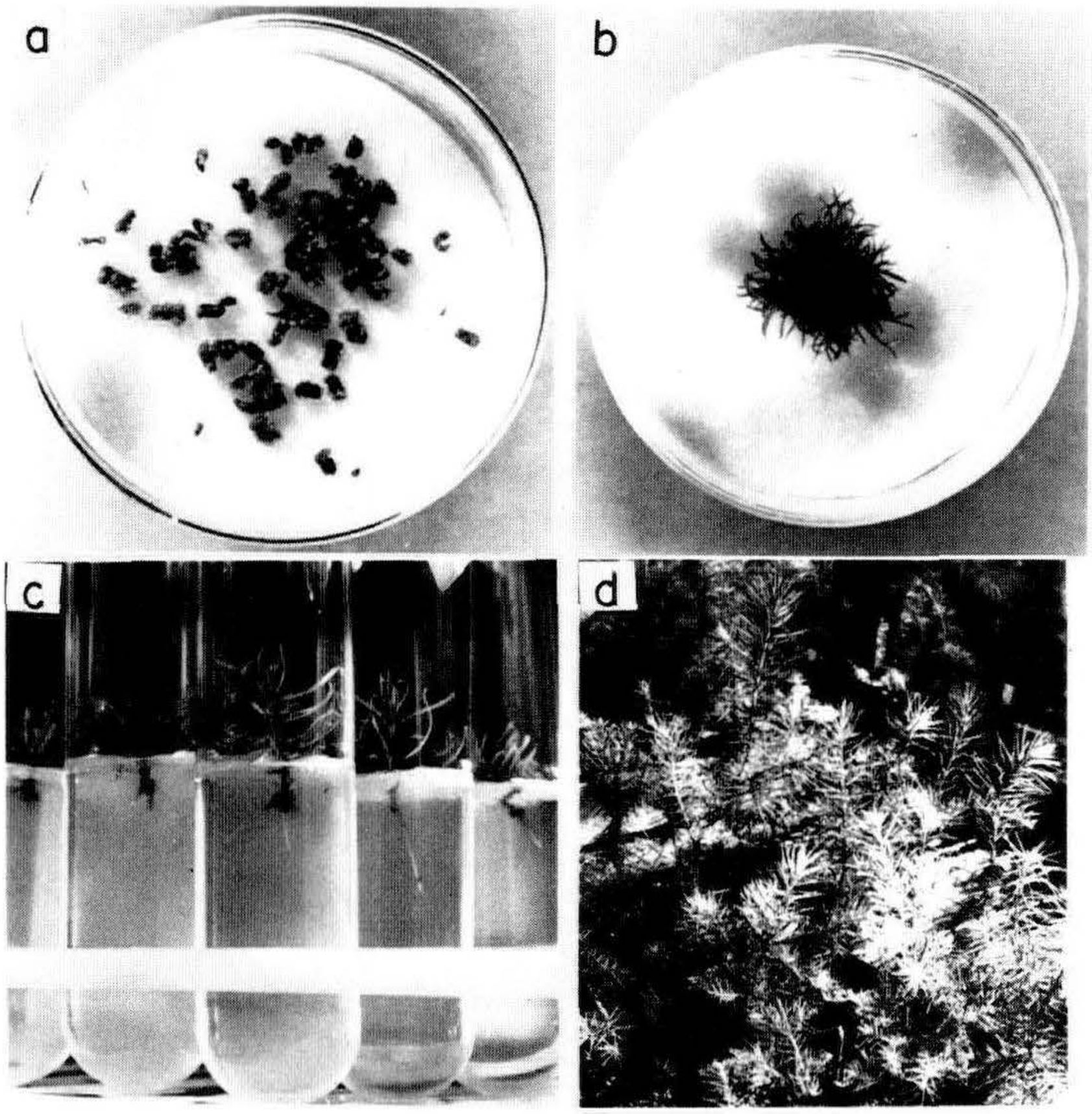

Figure 2. Sequential development in culture of plantlets from Douglas fir cotyledons. (a) Initiation of adventitious buds, (b) Development of multiple shoots, (c) Regeneration of plantlets, (d) Plantlets grown in greenhouse.

For establishing tissue culture produced plantlets in soil, it is essential that the humidity surrounding plantlets be reduced gradually from the high humidity condition of culture to the lower humidity of the greenhouse; a drastic change in humidity causes dehydration of plantlets and results in a reduction of their survival rate. Douglas fir plantlets grown in a greenhouse appear to be normal (Figure 2d). Long-term observations of the growth behavior of these plantlets are necessary to evaluate their performance.

Douglas fir protoplast system. A potential of in vitro techniques, other than that for mass clonal propagation, is to provide an effective method for introducing desirable new strains through genetic engineering at a cellular level. By using protop-

lasts or single cells asexual hybrids, mutants and cells containing foreign organells or molecules might be produced. A prerequisite for somatic cell genetic manipulation is the establishment of a workable protoplast system with respect to 1) methods of protoplast isolation, 2) culture conditions capable of supporting protoplasts to resynthesize new cell walls, and 3) culture conditions capable of supporting active proliferation of regenerated cells. In this laboratory, we have demonstrated, using the Douglas fir system, the first successful results in culturing protoplasts of Gymnosperms (28).

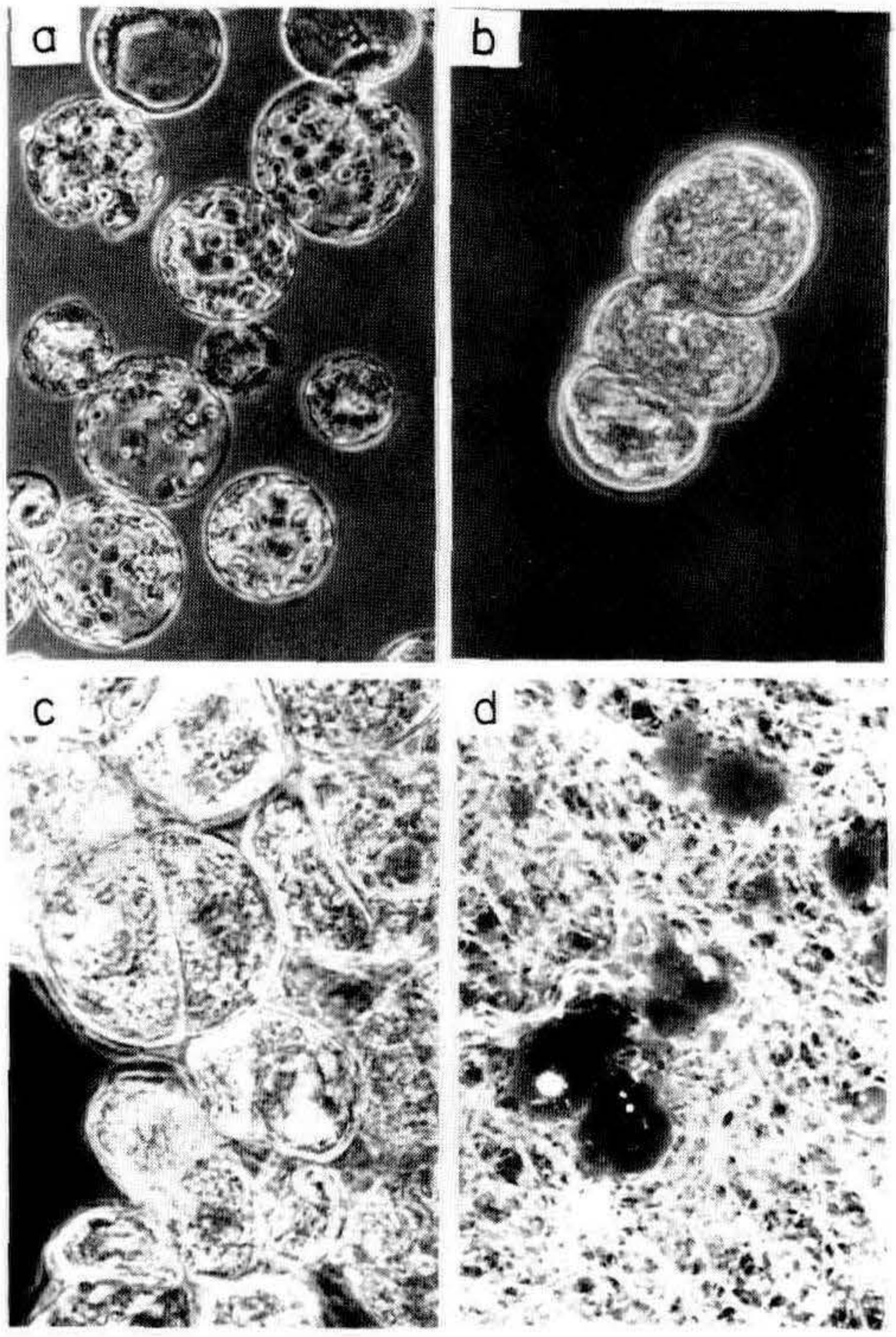

Figure 3. Callus formation from protoplasts isolated from Douglas fir cotyledons. (a) Freshly isolated protoplasts. Protoplasts, after resynthesizing new cell walls, underwent cell division showing (b) 4-cell stage, (c) colony formation, and (d) callus formation.

Douglas fir cotyledons obtained from 2-4 week old seedlings were used for protoplast isolation. The yield of protoplasts was significantly increased by subjecting cotyledons, prior to protoplast isolation, to a preconditioning treatment for 8 days in the presence of 15μM BAP and 0.5μM NAA. The most effective protoplast isolation mixtures consisted of Cellulysin, Macerase and sorbitol at concentrations of a) 4%, 1% and 0.4M and b)

2%, 0.5% and 0.6M, respectively; in both cases, isolation of approximately 5.5 × 10^4 protoplasts from 100 mg of tissue was achieved at the end of 3 hours incubation. Freshly prepared protoplasts were relatively free of cell debris and were extremely viable (Figure 3a). For culturing protoplasts, a fabric tissue support saturated with an appropriate liquid nutrient medium was used. Most of the protoplasts were capable of resynthesizing new cell walls after culturing for 72 hours in a nutrient medium containing 5μM BAP and 15μM NAA. Addition of a high concentration of glutamine (10 mM) to the culture medium was required for proliferation of regenerated cells derived from protoplasts. However, in addition to an appropriate culture medium, the method of protoplast culture was also important. For example, if the droplet method was used, regenerated cells failed to proliferate beyond the 20 cell stage. However, when a fabric tissue support, saturated with an appropriate liquid medium was used, regenerated cells proliferated actively (Figures 3b and c) leading to callus formation (Figure 3d). This combination of a fabric tissue support and culture medium supplemented with a higher glutamine concentration provides an effective way for culturing Douglas fir protoplasts.

DECIDUOUS SPECIES

Significant progress has been made during the past eight months toward development of tissue culture techniques for mass clonal propagation of selected deciduous species including apple rootstocks, cherry rootstocks, pear rootstocks, plum rootstocks, apple cultivars, and ornamentals. Results obtained from evaluation of tissue culture responsiveness of these deciduous species with respect to multiple shoot formation, root formation and plantlet regeneration are summarized in Table 2. Plantlet regeneration in culture is accomplished by a two step method: 1) stimulation of stem explants to produce multiple shoots, and 2) root initiation of tissue-culture-produced shoots. A reproducible, high frequency regeneration of plantlets which meets the specifications for commercial scale production has been obtained for four clonal plants: pear rootstock 'Old Home × Farmingdale 51,' plum rootstocks 'Pixy' and 'St. Julien X,' and ornamental *Prunus cerasifera* 'Newport.'

Multiple shoot formation. The basal nutrient medium used for culturing deciduous tissues was similar to that used for conifer tissues. A nutrient medium supplemented with 5μM BAP plus 0.5 to 5.0 μM IBA stimulated a variety of deciduous species to produce multiple shoots (see Table 2). After approximately six weeks in culture, formation of 10-100 shoots per tissue explant was observed. Variations observed in shoot multiplication rate and shoot development (stem elongation and leaf

Table 2. Status in development of tissue culture techniques for clonal propagation of selected deciduous cultivars

Cultivars	Multiple Shoot Formation	Adventitious Root Formation	Plantlet Formation (%)
I. Apple Rootstocks			
1. Antonovka KA313	+	+	+ (>50%)
2. EMLA-7	+	+	+ (>70%)
3. EMLA-9	+	+	+ (>60%)
4. EMLA-27	+		
5. MAC-9	+	+	+ (>70%)
6. Seedlings	+	+	+
II. Cherry Rootstocks			
1. Colt	+	+	+ (>80%)
2. Mahaleb X Mazzard 14	+	+	+ (>80%)
III. Pear Rootstocks			
1. Old Home × Farmingdale 51	+	+	+ (>90%)
IV. Plum Rootstocks			
1. Pixy	+	+	+ (>85%)
2. St. Julien X	+	+	+ (>85%)
V. Apple Scion Cultivars			
1. Stark Jumbo	+	+	+
VI. Ornamentals			
1. *Acer platanoides* 'Crimson Sentry'	+	+	+
2. *Prunus cerasifera* 'Newport'	+	+	+ (>78%)
3. *Pyrus calleryana* 'Bradford'	+		
4. *Pyrus faurei*	+		

expansion) seem to be caused by differences in the physiological conditions and genomic characteristics of particular plant species. The morphological appearance of multiple shoots produced in culture of some fruit tree rootstocks (shown in Figure 4) is normal. Based on the shoot multiplication rate obtained to date for various deciduous species, three groups can be identified: 1) those producing more than 30 shoots per explant, pear rootstock 'Old Home × Farmingdale 51,' plum rootstocks 'Pixy' and 'St. Julien X', and ornamental *Prunus cerasifera* 'Newport'; 2) those producing about 10 shoots per explant: apple rootstocks 'Antonovka KA 313', 'EMLA-7', 'EMLA-9' and 'MAC-9', and ornamental *Pyrus calleryana* 'Bradford'; and 3) those producing less than 10 shoots per explant: apple rootstock 'EMLA-27', apple scion cultivar 'Stark Jumbo,' and ornamentals *Acer plantanoides* 'Crimson Sentry' and *Pyrus fauriei*. These results indicate that the shoot-forming medium for species in the second two groups is currently suboptimal and continued experimentation in optimization of medium is required. Judging from the *in vitro* growth behavior of these species, high shoot multiplication rates probably will require only a slight adjust-

ment of the existing shoot-forming medium. In some cases, such as some apple rootstocks and cherry rootstock 'Mahaleb × Mazzard 14,' tissue-culture-produced shoots are quite succulent and the medium composition needs to be modified further in order to produce shoots with better characteristics.

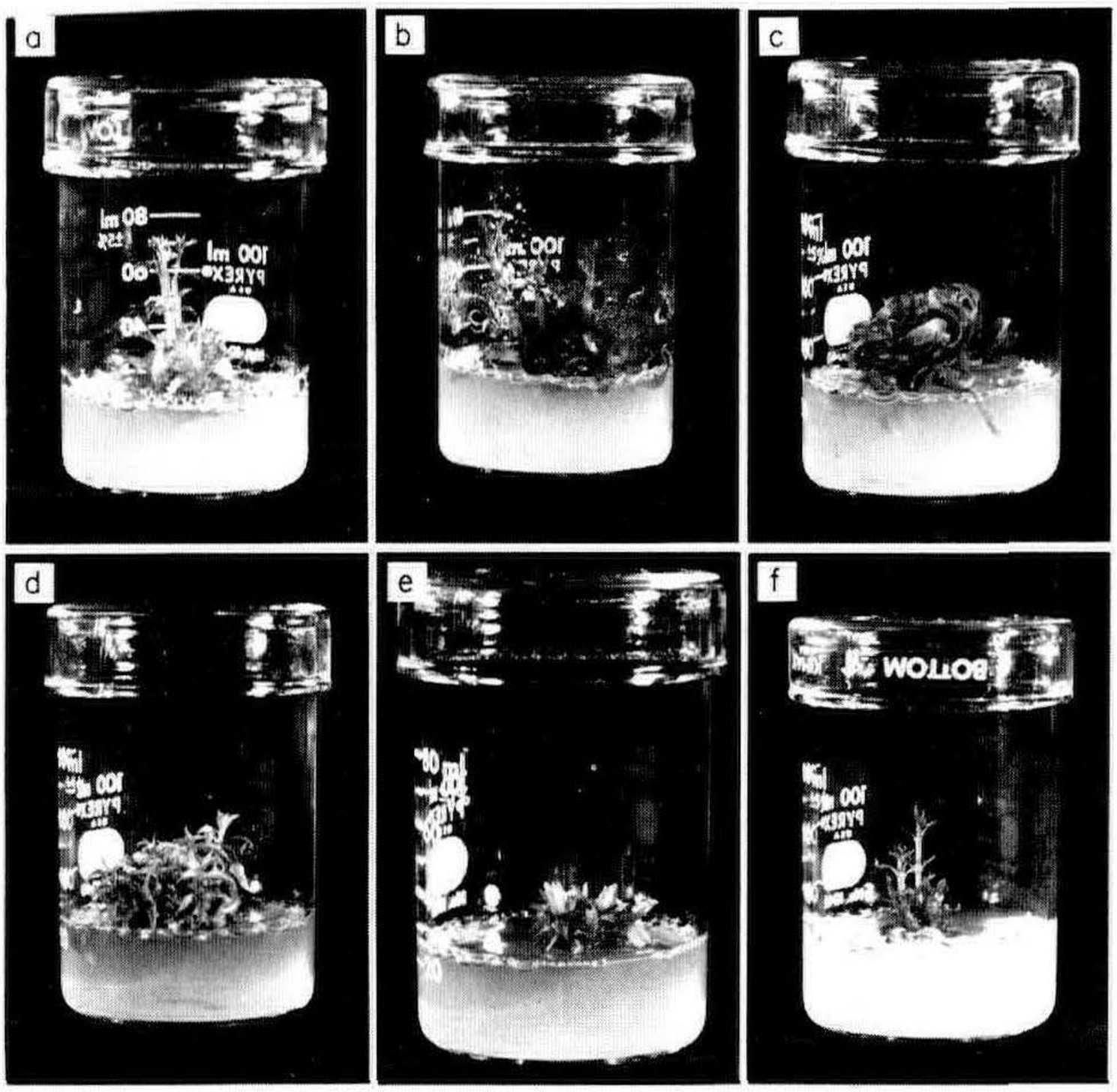

Figure 4. Formation of multiple shoots in culture from selected clonal fruit tree rootstocks. Apple rootstocks: (a) Antonovka KA 313 and (b) MAC-9. Cherry rootstock: (c) Mahaleb × Mazzard 14. Plum rootstocks: (d) St. Julien X and (e) Pixy. Pear rootstock: (f) Old Home × Farmingdale 51.

Regeneration of plantlets. Plantlets were regenerated by subjecting tissue-culture-produced shoots to a rooting medium. Rooting responses varied using rooting medium supplemented with auxin at concentrations of 0.5 to 5.0 μM IBA (Table 3 and Figure 5). For those deciduous species exhibiting a high shoot multiplication rate, in the presence of 2.5 and 5.0 μM IBA, roots started to appear after one week in culture from more than 60% of shoots and from more than 80% at the end of 3 weeks. Shoots of plum rootstocks 'Pixy' and 'St. Julien X,' produced with different types of auxin (either IBA or 2,4-D), required different rooting conditions. Shoots produced with 2,4-D rooted readily on basal medium without supplement of IBA because the residual 2,4-D existing in shoots was more than sufficient to stimulate root formation; however, shoots produced with IBA required additional IBA for root initiation. For *Prunus cerasifera* 'Newport,' rooting efficiency is controlled by the anthocyanin

content of shoots; a high concentration inhibited root formation whereas a low concentration did not. Plantlets regenerated from some fruit tree rootstocks are shown in Figure 5. These plantlets grew vigorously in the rooting medium showing both rapid shoot and root elongation.

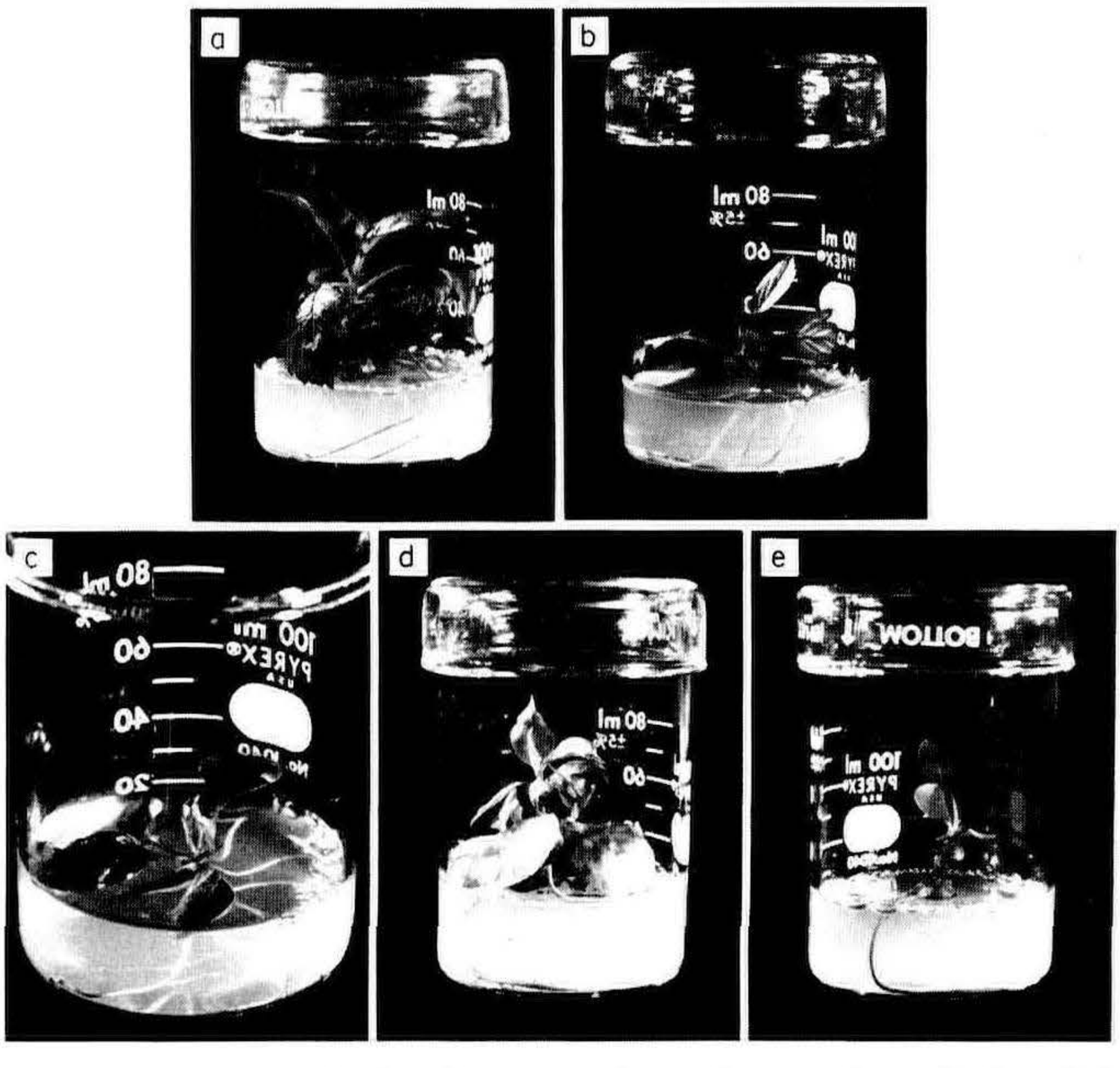

Figure 5. Regeneration of plantlets in culture from selected clonal fruit tree rootstocks. Plantlets were regenerated by rooting tissue culture produced shoots. Apple rootstocks: (a) MAC-9 and (b) EMLA-7. Cherry rootstock: (c) Mahaleb × Mazzard 14. Plum rootstock: (d) St. Julien X. Pear rootstock: (e) Old Home × Farmingdale 51.

Table 3. Rootability of tissue culture produced shoots of selected deciduous species

Cultivars	IBA Concentration μM	Total No. of Shoots	No. of Rooted Shoots	[1]Frequency of Rooting (%)
I. Pear Rootstocks				
1. Old Home ×	5.0	70	64	91
Farmingdale 51	2.5	30	28	93
II. Plum Rootstocks				
1. Pixy	5.0	52	46	89
	2.5	48	47	98
2. St. Julien X	5.0	84	73	87
	2.5	82	77	94
III. Ornamentals				
1. Prunus cerasifera	5.0	25	20	80
'Newport'	2.5	51	43	84

[1] Rooting frequency was estimated after subjecting tissue culture produced shoots to rooting medium for 3 weeks.

Establishment of regenerated plantlets in soil. The potting mixture used consists of soil: peat moss: perlite: sand (1:1:1:1) and mist propagation techniques were used in transferring sterile plantlets to soil. Potted plantlets were immediately placed in a mist chamber equipped with an intermittent-mist water spray and an electric bottom-heat cable. The temperature of the chamber was maintained at 25°C. The frequency of water spraying was adjusted such that plantlets were always covered with a thin layer of water. After one week, the frequency of water spraying was reduced to allow plantlets to harden-off for placement on a greenhouse bench. Hoagland nutrient solution was administered to plantlets at 2 to 4 week intervals. Plantlets grew vigorously under greenhouse conditions; apple plantlets grew to about 6 feet in 6 months and plum rootstock 'St. Julien X' and *Prunus cerasifera* 'Newport' plantlets grew about 2 feet in 3 months. We have tested various systems for transplanting deciduous plantlets to soil and find this described system to be the most effective way (Table 4).

Table 4. Survival rate of plantlets of selected deciduous cultivars grown under greenhouse conditions[1]

Cultivars	Experiment	Total No. Plantlets	No. of Plantlets Survived	Survival (%)
I. Pear Rootstocks				
1. Old Home ×	1	46	43	93
Farmingdale 51	2	51	43	84
II. Plum Rootstocks				
1. Pixy	1	49	41	84
2. St. Julien X	1	47	43	92
	2	45	44	98
	3	52	44	85
	4	91	74	81
III. Ornamentals				
1. *Prunus cerasifera*	1	45	41	91
'Newport'	2	62	55	89

[1] Plantlets, after transplanting from aseptic conditions into potted soil, were immediately placed inside a high humidity moist chamber for approximately one week followed by gradually decreasing the humidity by prolonging the water spray intervals. At the end of 2 weeks, potted plantlets were placed on greenhouse bench.

At present, we have approximately 400 plantlets of 'St. Julien X,' 200 each of 'Pixy' and *Prunus cerasifera* 'Newport', and 100 of 'Old Home × Farmingdale 51' growing in the greenhouse. The morphological appearance of these plantlets is uniform (Figure 6). We intend to outplant these plantlets for subsequent use as understock for appropriate fruit tree cultivars so that we can evaluate their performance. The anatomical structures and chromosomal complements of these plantlets

will also be analyzed in order to assure that tissue culture techniques we have developed produced true-to-type plantlets.

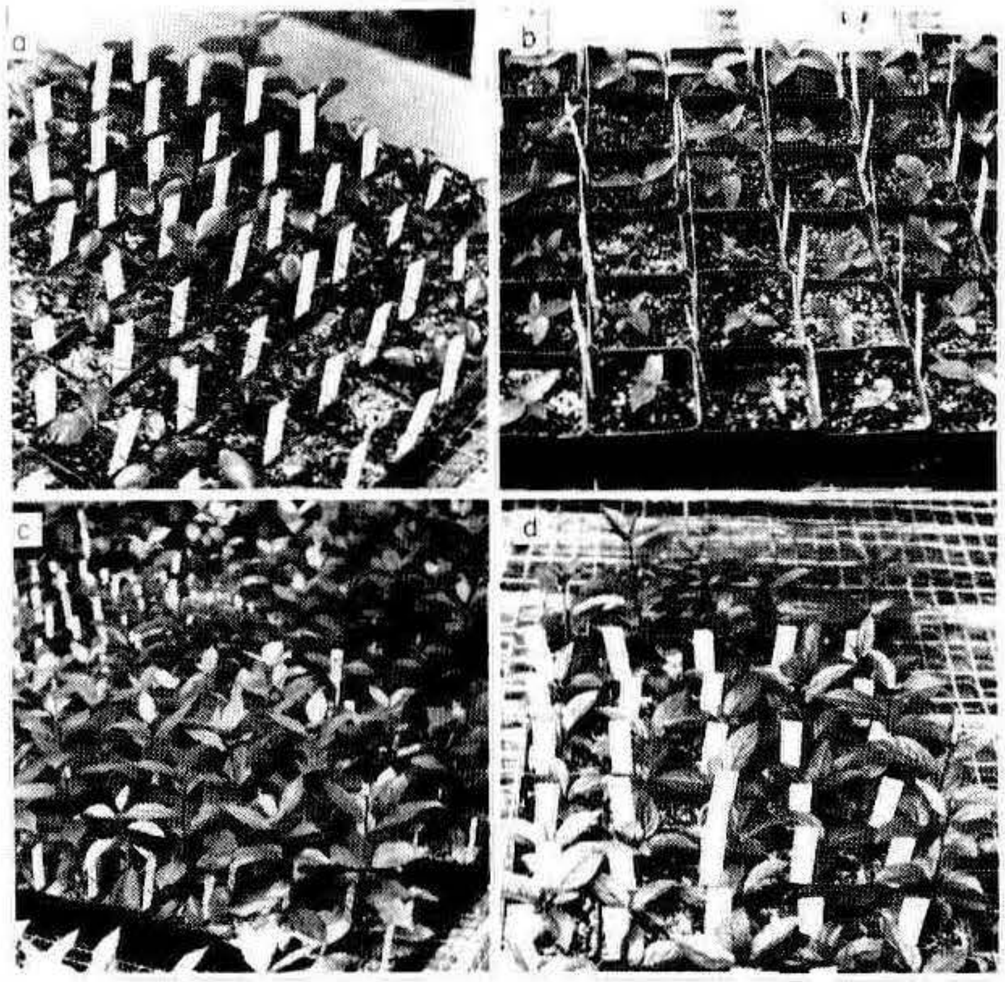

Figure 6. Fruit tree plantlets grown under greenhouse conditions. Pear rootstock: (a) Old Home × Farmingdale 51. Plum rootstocks: (b) Pixy and (c) St. Julien X. Ornamental: (d) *Prunus cerasifera* 'Newport.'

Mass clonal propagation of plantlets on a scale of one million plants annually can be accomplished for pear rootstock 'Old Home × Farmingdale 51,' plum rootstocks 'Pixy' and 'St. Julien ×,' and ornamental *Prunus cerasifera* 'Newport' if appropriate tissue culture facilities and personnel are provided. A significant contribution of this work is that it provides methods which allow the rapid introduction of new rootstocks such as 'Pixy' to the market and for highly reliable rooting of plants such as 'Old Home × Farmingdale', 'St. Julien' and *Prunus cerasifera* 'Newport' which are relatively hard to root by conventional cutting techniques. Our results show that woody species respond as readily as herbaceous species to tissue culture treatment for mass plantlet production.

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AFTERCARE PROCEDURES REQUIRED FOR FIELD SURVIVAL OF TISSUE CULTURE PROPAGATED *ACACIA KOA*

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Abstract. A system of treatments was developed which permitted frequent rooting of *Acacia koa* shoots grown aseptically from shoot tip callus, successful transplanting of the plantlets from aseptic to normal growing conditions, and eventual field establishment of the tissue-culture propagated plants. Rooting was promoted by removing the shoots from a source of benzyladenine for a month or more before providing them a rooting stimulant. To induce roots to become functional, rooted plantlets were grown in a hydroponic medium (Hoagland's solution) for a month or more after their removal from an agar-gelled medium. To date, 82 plants of one clone have been established in the field.

Acacia koa Gray is a large forest tree of Hawaii that has become increasingly valuable as a source of cabinet wood, but like other valued timber species it is becoming short in supply. There is a need to increase the population of straight, well-formed trees of the type best suited for veneer and lumber production. Toward this end, a tree improvement program has been undertaken with the species that includes clonal propagation of superior trees among its aims. Normal techniques of vegetative propagation have proven difficult with this species, but one of the techniques with which we have had some success has been aseptic callus culture of shoot tip tissue. We have grown and field-planted 82 plants produced from the tissue of one shoot tip. The tissue culture technique by which plantlets were first obtained was described earlier (10). This paper reports the results of research that have enabled us to readily root the shoots produced, remove the tissue-culture propagated plantlets from their flasks, cause the root system to become functional, and eventually successfully field-plant the young trees.

REVIEW OF LITERATURE

Although a large amount of literature has been devoted to studies of propagation of forest trees by tissue culture, few of these studies have been aimed at establishing the tissue-culture propagules in the field (3,8). Populus is the only genus for which considerable success in field establishment has been reported (6). Many researchers (1,2,9,11) specifically mention serious rooting difficulties with tissue-culture propagated shoots. In our work with one clone of *Acacia koa*, we have achieved 60 percent success in rooting and 80 percent survival

of the plantlets produced after removal from aseptic culture. This success required considerable experimentation.

MATERIALS AND METHODS

Shoots were grown from callus derived from a seedling shoot apex by methods already described (10) but summarized below. The basal nutrient medium of Murashige and Skoog (7) gelled with 0.8 g/l agar and containing various hormone additions was used for all aseptic growth and rooting experiments. Rooted plantlets were potted in both aseptic and non-sterile Hoagland's solution (4) and in a potting mix of peatmoss, vermiculite, and perlite.

Continuous light at photon flux densities of 50 to 120 u mol $m^{-2}sec^{-1}$ of photosynthetically active radiation was used in the experiments.[3] A constant temperature of 25°C was maintained. The growth of regulators used in the experiments were coconut water, benzyladenine, naphthaleneacetic acid, and indolebutyric acid. The coconut water was derived from green nuts and kept frozen until used. Plantlets growing in one liter containers of potting mix were fertilized once a month with 25 ml of a 20:20:20 liquid fertilizer. Plants were grown in a nursery and then planted in the forest at three locations similar in elevation to that of the tree that provided the seed from which they were all grown.

RESULTS

Shoot formation and growth. Shoot meristems formed in a subculture of callus derived 1 year earlier from a seedling shoot tip. The solid medium on which they formed contained 10 mg/l of benzyladenine. The callus, with shoot meristems, was then transferred to a medium with 1 mg/l benzyladenine for 1 month and then to one containing 10 percent coconut water for another month. Then it was transferred back to a 1 mg/l benzyladenine medium for another month and again followed by transfer to the 10 percent coconut water medium. These sequential transfers caused the meristems to proliferate and begin shoot elongation. Following these transfers, the shoots were maintained and multiplied on a 1 mg/l benzyladenine medium by dividing and subculturing the callus and shoots at approximate monthly intervals.

Initiation of roots. Rooting experiments were undertaken as soon as shoots had produced two or more leaves. We placed the shoots, some with callus and others without, onto media containing 0.2, 0.3, 1.0 mg/l indolebutyric acid and 0.5 and 1.0 mg/l naphthaleneacetic acid. No roots formed in any of these exper-

[3] Light terminology and measurements follow those of Incoll et al. (5).

iments, so after about 3 months, several of the shoots were transferred to a nutrient medium without growth regulators in an attempt to "dilute" the amount of auxin they had taken up.

Some of these shoots, together with basal callus, were placed on a medium containing 0.2 mg/l indolebutyric acid after having been on the regulator-free medium for about 1 month. Two of these rooted. This suggested to us that after having been grown on a medium containing benzyladenine, the shoots had to be grown for a time without growth regulators to "clear" or dilute the benzyladenine. Furthermore, they would only root from that portion of the stem surrounded by callus tissue, so callus surrounding the stem base was essential.

Actually, several empirical experiments were needed to demonstrate that these were indeed the answers to success in rooting koa shoots. These experiments demonstrated that a period of at least 3 weeks on regulator-free medium was required in order to overcome the inhibitory effect of the 1 mg/l benzyladenine treatment. A concentration of 0.3 mg/l indolebutyric acid produced better root growth than did a concentration of 0.2 mg/l, or than 0.5 mg/l naphthaleneacetic acid. Shoots without basal callus invariably died. Using a period of 1 month in regulator-free medium and 0.3 mg/l indolebutyric acid in the rooting medium, we achieved approximately 60 percent success in rooting.

Initiation of autotrophic growth. The first six rooted plantlets removed from aseptic media and transplanted to a rooting medium rapidly desiccated and died. Microscopic examination showed a good connection between the stem and root vascular systems, but the plants appeared to die of moisture stress.

A second group of six plants was potted and placed under intermittent mist. These survived until they were removed from the mist. They then all died of apparent moisture stress.

A series of experiments were then made to seek a conditioning method that would result in survival of the plantlets after removal from the aseptic rooting medium. Several of these tests required continued aseptic growth to improve root systems, while others involved immediate transfer from aseptic to non-sterile media.

The aseptic treatments consisted of growing the plantlets in erlenmeyer flasks containing distilled water; agar-gelled water; agar-gelled basal medium without sucrose and growth regulators; without growth regulators; the three media darkened with activated charcoal or by mixing with peatmoss and vermiculite; full-strength Hoagland's solution in agar-gelled form; and moist peatmoss-vermiculite without a nutrient solution added.

The non-sterile methods were: placing the roots in Hoagland's solution with the tops open to the air or enclosed in polyethylene bags; transplanting to water, perlite, or peatmoss-vermiculite; and keeping the plantlets under intermittent mist or in polyethylene bags. The Hoagland's solution and water experiments included tests with light excluded from the roots.

Of these experiments, only two had promising results, the aseptic medium without growth regulators and the non-sterile Hoagland's solution treatments. Roots grew more extensively in the basal medium without growth regulators, but did not grow well in the minus sucrose, or darkened basal medium. The other treatments that produced good root growth were the non-sterile Hoagland's solution trials. The roots grown in flasks of solution from which light was excluded were larger than those open to light. Plantlets in the Hoagland's solution quickly desiccated and died unless kept covered with polyethylene bags.

All the plantlets that survived the various treatments and retained their vigor were transplanted to peatmoss-vermiculite-perlite and kept under polyethylene except, of course, those that were already in this medium under intermittent mist. These were simply removed from the mist. Soon after they were transplanted, all the plantlets died except those from the non-sterile Hoagland's solution treatments. All of these survived and gradually began to grow autotrophically.

In examining roots grown in agar-gelled media and those grown in Hoagland's solution, we found that the roots from the liquid medium had root hairs while those from agar did not (Figure 1). Also, roots grown in agar frequently lacked a fully developed vascular system while those from Hoagland's solution always had such a system.

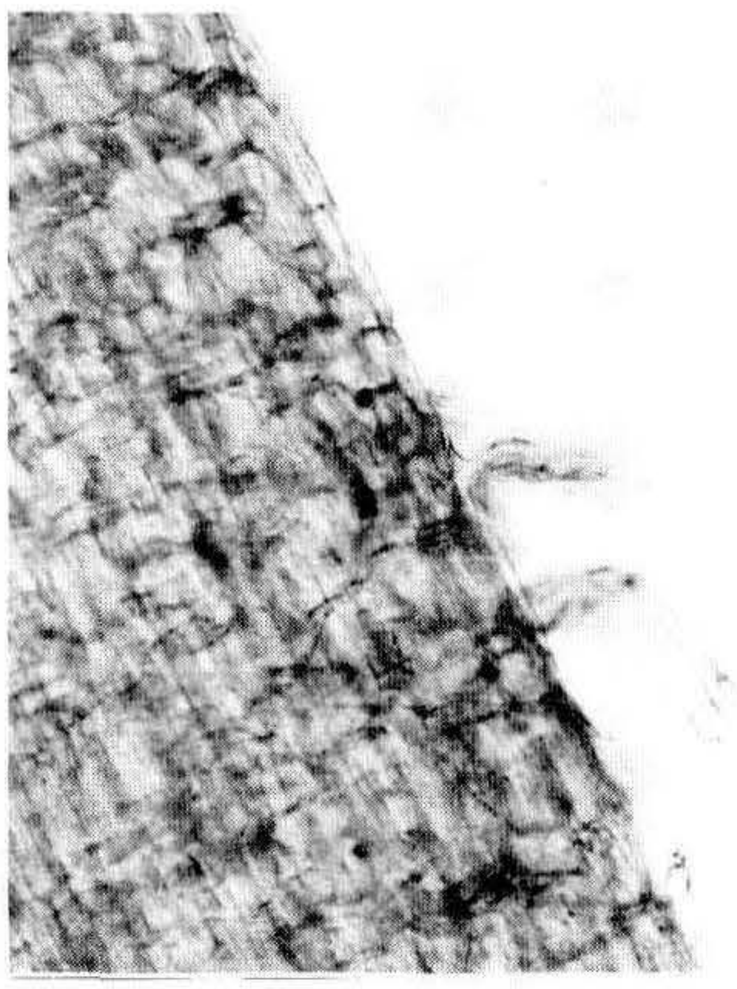

Figure 1. Root hairs on a root after growth in Hoagland's solution.

Once the method of growing plantlets in Hoagland's solution was worked out, a system was perfected in which the roots were suspended in 50 ml flasks of solution, covered from light with aluminum foil, and the entire plantlets surrounded by polyethylene bags for 1 month. The well-rooted plantlets were then transplanted to potting mix. Survival of the plantlets moved from agar to Hoagland's solution was 83 percent. Those that failed generally had short (2-3 cm) rather than normal size (5-8 cm) root systems.

Hardening for field planting. The plantlets were potted in a mixture of peatmoss, perlite, and vermiculite and fertilized once a month with 25 ml of a 20:20:20 liquid fertilizer per one liter container of potting mix. It was found necessary to cover them with polyethylene for 4 to 6 weeks after transplanting to reduce transpiration.

Empirical trials of light requirements indicated that rapid growth required photon flux densities more than 100 u mol m^{-2} sec^{-1}. Plants supplied only 60-80 u mol m^{-2} sec^{-1} grew very slowly. Best growth was achieved with continuous light at 120 u mol m^{-2} sec^{-1} supplied by Gro-lux (Westinghouse) lamps.

Buds became enlarged, indicating rapid root growth after 2 to 3 months in the laboratory. At this stage they were moved to a greenhouse for further growth in stronger light (70% of ambient sunlight) and higher temperature. Survival of the plantlets moved from Hoagland's solution to potting mix was 77 percent.

The elevated temperature of the greenhouse (30-40°C) frequently induced the early formation of phyllodes, the mature leaf form of the species (Figure 2).

Figure 2. Phyllodes formed on tissue-culture propagated plants when grown in a very warm greenhouse.

The first field planting was made with 16 plants taken di-

rectly from the greenhouse. Nine of these 16 died within a week of planting. Soon after this, a group of 35 plants was shipped to the island where they would be planted and spilled out of their pots in shipment. Sixteen of the 35 were in satisfactory condition and were immediately planted; the other 19 were placed on an outdoor nursery bench to recover from the damage in shipping. Six of the 16 plants planted directly after shipment died soon after planting. All 19 of the plants that had been stored outdoors survived planting when they were planted 3 months later.

Since then, we have found that the plants require a period of growth of at least 2 months in full sunlight before field planting. Otherwise, their leaves are bleached and fall off. This occurs with both true leaves and phyllodes.

Although none of these plants has been inoculated with rhizobial bacteria, 16 of the 82 that have been planted were observed to be nodulated at the time of planting (Figure 3). The nodulation occurred during growth in the greenhouse or outdoor nursery.

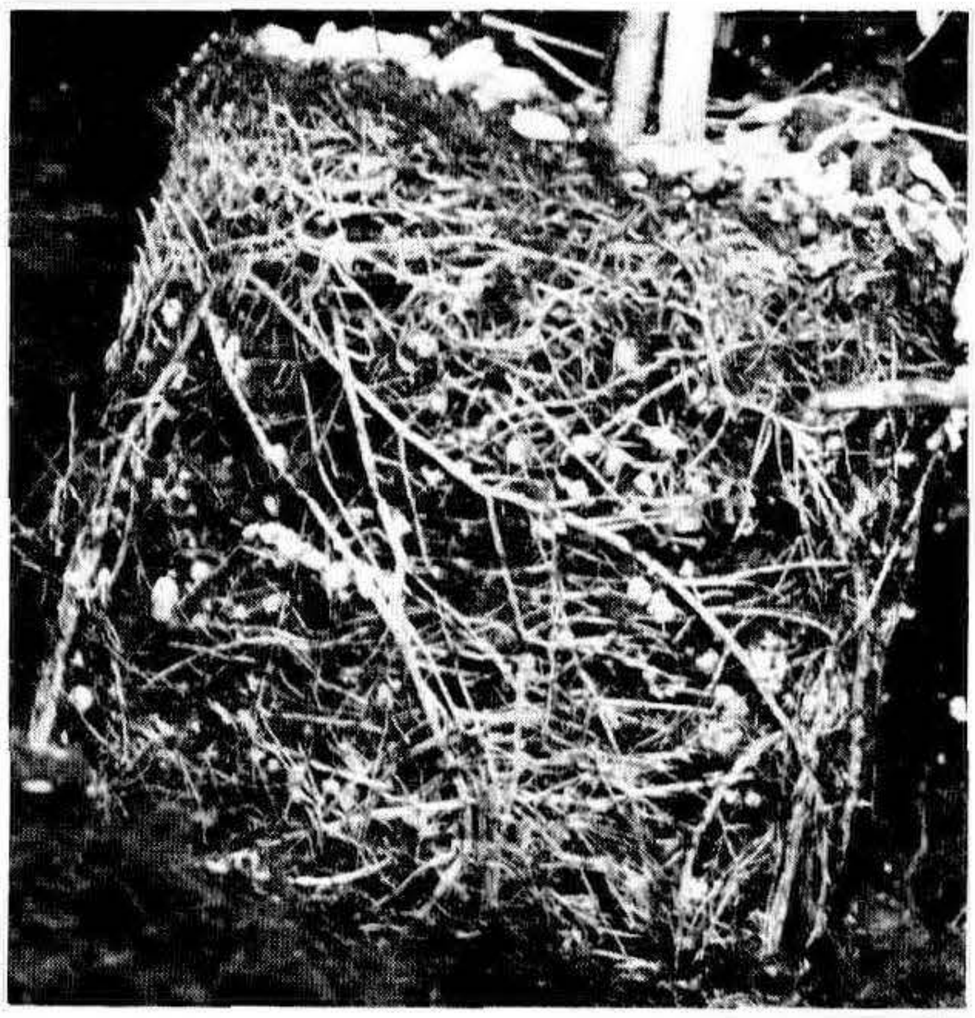

Figure 3. Nodules formed on the root systems of some of the tissue-culture propagated trees.

Trees of the oldest plantings — now 16 months old — are growing normally, although not as rapidly as nearby natural seedlings (Figure 4). They exhibit a normal form for the species, but so far lack the uniformity that should occur in a single clone.

DISCUSSION

The procedure we have developed to produce plantable trees from shoot tip callus consisted of 14 steps (Table 1). About 16 months are required to carry the process from meristem in

Figure 4. Tissue-culture propagated tree (arrow) has grown normally, but more slowly than nearby natural seedlings about 6 months after planting.

callus to planted tree in the forest, but the process is a continuous pipeline once started.

Table 1. Sequential treatments required to grow *Acacia koa* plants from callus cultures.

Step	Condition	Culture time	Treatment
1	Seedling shoot tip callus	1-2 months	10 mg/l benzyladenine
2	Shoot meristems in callus	1	1 mg/l benzyladenine
3	Shoot meristem in callus	1	10% coconut water
4	Shoot meristems elongating	1	1 mg/l benzyladenine
5	Shoot meristems proliferating	1	10% coconut water
6	Shoot meristems elongating	1	1 mg/l benzyladenine
7	Shoots proliferating, callus growing	1	1 mg/l benzyladenine
8	Leafy shoots + callus	1	No growth regulators
9	Leafy shoots + callus	2-3	0.3 mg/l Indolebutyric acid
10	Rooted plantlets	1	Hoagland's solution
11	Functional roots	2-3	Potting mix
12	Rapid growth	1-2	Greenhouse
13	Plantable seedling	2	Outdoor nursery
14	Plant in field		

The key parts of the procedure are step 8, during which benzyladenine is depleted and step 10 during which nonfunctional roots become functional. We attribute the enhanced

rooting after a period of growth on a regulator-free medium to the absence of the auxin-inhibition of the cytokinin benzyladenine. How the benzyladenine is altered during the period of growth on the regulator-free medium is not known. It may simply be diluted by greater dispersion due to continued cell division.

The formation of root hairs and root vascular systems in the liquid medium which made the roots functional may be a physical rather than chemical effect resulting from the absence of agar. The evidence to support this conclusion is that none of our agar-gelled Hoagland's solution cultures formed functional roots. The gelled media may have mechanically inhibited root hair development. The greater gas exchange that was possible in the non-sterile treatment may also have improved root development.

The growth of the plants in an outdoor nursery, proved essential (Step 13). *Acacia koa* is a species that grows best in the field if exposed to full sunlight immediately on emergence from the soil. The leaves formed in reduced light bleach in bright light so a period of hardening in bright sunlight greatly increased the survival of the propagules.

It is interesting that the genetic programming required for phyllode formation as a result of high temperature, and for nodulation in response to rhizobial bacteria was retained through the callus culture process. The temperature control of phyllode formation in the species has been observed repeatedly in seedlings grown in the same greenhouse.

We believe that our techniques for improving rooting by "diluting" the cytokinin and improving root functioning by a period of hydroponic growth may be useful to other tissue culturists experiencing these common rooting problems.

Although we have only produced plants from one clone so far, the system developed shows promise. After more than 3 years, shoots continue to proliferate without signs of diminishing. If most of the shoots and callus had not been sacrificed for other experiments, many more than the 82 trees now planted would have been produced.

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PROPAGATION OF TROPICAL FOLIAGE PLANTS

W. STEPHEN SVEDIN
R. & S. Nursery
Hillsboro, Oregon 97123

Most foliage house plants come from the tropics. These plants require a temperature around 60 to 70° F to grow; they will stop growing at 50° F and will be badly damaged at 45° F. Other species come from the temperate zone and can tolerate temperatures to almost freezing and, if hardened off, can survive being frozen.

Our customers learn about the different foliage plants through a magazine or a book or advertisement where they see a perfect plant — no broken leaves, no leaf spots, and the plant has perfect shape. So, of course, that is what they want to buy.

There is our challenge, or half of it, to produce a perfect plant. The other half of our challenge is to grow those perfect plants and make a profit for the company even with the price of pots going up all the time and wages for our employees going up. This all means that of the 100 plants you start you had better sell 100 or you will not make it. There are several things that help. As you think about the kinds of house plants that are popular today you will notice two things:

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1) they are a little harder for Mrs. Housewife to kill than usual, and

2) their cuttings will root fast and easily if treated right.

In the production program at R & S Nursery we use several different methods to start the plants; which one we use depends on the plant, its size, the time of year, and the weather.

For our environment control we use either a mist with bottom heat, or no mist and no bottom heat. All of our cuttings are stuck in the pots to be rooted whereas our seed is germinated in flats and the plants transplanted into pots.

In determining how to root the different species of plants, I try to notice what the ideal growing conditions are. It seems that with the plants I work with the condition which gives the best growth is also the condition in which they will root best.

Some examples of the methods I use are: The succulents, which are started out of the mist. Jade cuttings are put into a warm area and the soil kept DRY until they start to root; then they are kept lightly moistened. The peperomias are started in slightly moist soil until rooted then, to prevent disease, they are allowed to dry between watering. I use tip cuttings with these species, although leaf-bud cuttings and even a leaf cutting will produce a new plant but it takes too long to be economical.

The ivys (*Hedera helix*) are also started out of the mist; with these I use sections of plant 2 or 3 nodes long with the leaves attached; they are stuck 2 to a pot in moist soil and kept in a cool greenhouse.

There are several plants in the *Plectranthus* genus that I start out of the mist. These are kept in moist soil. They are rooted in one week and are ready to sell in two more weeks. It is too bad everything couldn't be turned out that fast.

Plants that I start under mist include the genus *Pilea*; these are a group of plants that come from Southeast Asia. If these plants are not rooted under a mist the leaves burn and the older ones drop. This will leave a plant that is not good enough to sell. It is only useful to move up to larger pots and that is a waste of time.

Other plants that are started under a mist are the velvet plant (*Gynura aurantiaca*), the piggyback plant (*Tolmiea menziesii*), the spider plant, *Chlorophytum capense* (syn.: *C. elatum*), *Iresine*, and *Maranta spp*. These are all done as tip cuttings; the smaller ones go two to a pot, and the bigger ones one to a pot. For piggyback or spider plant I use a well developed plantlet.

When using the mist system it is important to remember to

take the plants off the mist as soon as they are rooted because, as rapidly as they grow, it is important to harden them off before selling them. Also, if left in the mist and heat they will grown extremely fast. This makes the new growth soft and very susceptible to disease and insect attack.

We propagate 7 different species by seed: schefflera, dwarf schefflera, green nephtysis, *Philodendron selloum*, coffee, *Dizygotheca elegantissima* (Syn.: *Aralia elegantissima*), and Fatsia japonica (Syn.: *Aralia seboldii*). These are planted two or three to a pot after the first true leaf forms.

Seeds of all of these germinate best at warm temperatures (about 80° F) and except for *Fatsia japonica*, temperatures around 60 to 70° to grow. *F. japonica* plants grow best at a cooler temperature (55 to 50° F).

I have in the past propagated some of the variegated *nephthytis*; this is done by stripping all the leaves from the vine and cutting at each node to leave an inch of stem. These are stuck in soil so that the bud is at the surface of the soil. They are kept barely moist and warm and should be rooted and starting to grow in about one month.

An important part of our program is the size of the cuttings we use. In the past I have seen plants from large cuttings that have been rooted and sold. To me this is not right; these plants are soft and, depending on where they come from on the mother plant, they will not be very well adjusted to the light intensity. We try to make our cuttings a little smaller. This allows the plant to grow to saleable size, which is at least as high or as wide as the pot. These plants will be hardier and better adjusted; they will not deteriorate on our customers shelves before they are sold. And, just maybe, they will last a little longer on Mrs. Housewife's window sill.

COMMERCIAL PROPAGATION OF LILIES

EDWARD A. McRAE

Oregon Bulb Farms,
Sandy, Oregon 97055

The past 15 years has seen a revolution in lily cultivation; this is especially true in Holland where the acreage has increased dramatically from 600 to over 3,000 acres annually. The propagation of these plants is achieved through both sexual and asexual methods and these procedures will continue to hold their place in crop production as both have their distinct advantages, depending on the market served.

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SEED PROPAGATION

The main advantage of seed propagation is that the virus diseases, which plague commercial stocks, are not seed transmissable. We can use this method to continually produce healthy, vigorous and disease free stocks and propagate them annually from seed; using this method virus disease can be kept under control. The older stocks are discarded, thus health and vigor are kept at a high level, and the highest quality material possible is offered for sale. Lilies produced from seed can be strains of the true species or strains of a hybrid group.

Species. The selection of superior individuals within the species and using them as parents ensures a high standard of material not only with regard to health and vigor but also in having the special characteristics desired. The parents can be selected for vigor, disease resistance, stature, foliar characteristics and flower form, placement and substance.

The select individuals are used to produce seed and plants are naturally highly fertile within the species. A number of special clones can also be selected from the species and propagated asexually; these are tested for disease resistance, virus tolerance, propagation qualities, and adaptability. The finest of these are then tested as parents and the parental combination producing the finest and most uniform offspring are used to produce the seed. This is termed an F_1 strain within the species and the cross can be repeated at will as long as the parent clones are maintained. The species of significant importance commercially are *L. regale* (Regal lily), *L. leucanthum* var, *centifolium* 'Black Dragon Strain', *L. candidum* 'Cascade Strain', *L. auratum* var. *platyphyllum* (gold band lily), *L. speciosum* var. *rubrum* 'Supernova'.

Hybrid F_1 Strain. The procedures described previously are again followed; superior forms are selected within a hybrid group especially with regard to color, flower form, season and stature. The selections are again cloned and tested for vigor, disease resistance and finally as parents. The parents producing the greatest vigor and uniformity in the seedling population are chosen for seed production. It should be noted that reciprocal crosses are not identical in hybrid groups, one parent may be more fertile and produce larger quantities of seed, another may have superior pollen; continued vigor of seedling populations is not guaranteed if the roles of the parents is reversed. One parent, therefore, always adopts the role of the seed parent and the other the pollen parent. Hybrid F_1 strains grown commercially include 'Burgundy' and 'Citronella' in the pendant asiatic lilies, 'Copper King', 'Golden Splendor', 'Pink Perfection', and 'Hearts Desire' in the trumpets and aurelians and 'Imperial Crimson',

'Imperial Gold', 'Imperial Pink', 'Imperial Silver', and 'Jamboree' in the exotic orientals.

Seed Storage, Germination and Growth.

1. Lily seed can be stored at 0° F. and remain viable for many years.

2. There are two distinct types of seed germination in lilies which greatly influence the treatment of the seed.

Epigeal Germination This is usually termed the "above ground" germination; the tip elongates rapidly, appears above ground, along with the cotyledon, which takes on the functions of a leaf; true leaves follow and will continue to be produced throughout the growing season.

Hypogeal Germination This is termed "below ground" germination; the tip elongates but does not emerge above the ground; the food supply in the endosperm is transferred to a small bulblet. The bulblet must go through a cold period before the first true leaf appears from the center.

Seed Sowing and Growth. The epigeal seed can be sown directly in outdoor beds in early spring and the seed will usually sprout in four to six weeks if temperatures and moisture levels are favourable; the seed is covered lightly and moisture levels are maintained throughout the season. The seedlings can be lifted late in the year, packed in boxes for winter storage and planted out in rows the following spring. The larger bulbs will attain commercial size in one more year, the smaller will require two. Asiatic, trumpet, and aurelian lilies belong to the epigeal group.

The hypogeal seed is sown in June using a mixture of vermiculite and milled sphagnum moss, the medium must be moist and not saturated. The seed is thoroughly mixed with the medium which is placed in plastic sacks, a small opening is left for air exchange. The sacks are placed at an incubation temperature of 65 to 70° F. and they will germinate and form bulblets in 8 to 14 weeks depending on the variety. The sacks are removed from the incubator when the bulbs are well formed and placed at cool temperatures until spring. They are then sown in outdoor beds using the same procedures as the previous group. This group usually requires two years in the seedbed followed by one or two years in rows before commercial size is attained. The oriental lilies belong to this group.

Lily seed can also be sown under greenhouse conditions where growth will be rapid due to total control of the environment.

CLONAL PROPAGATION

Natural Propagation. The majority of lilies propagate natu-

rally through bulb division and with the formation of bulblets and bulbils. Bulb division is not important commercially and cultivars with this inherited characteristic are undesirable in most markets.

Bulblets are formed on the underground parts of the stem and these are simply collected during harvest. They are washed, treated with a suitable fungicide and planted in rows to produce future commercial crops. The smaller bulblets will require two seasons growth before reaching commercial size. It is important to collect bulblets from large plants only; this insures that vigor is maintained and that the bulblets were produced that season; this would not be guaranteed if bulblets were collected from small bulbs planted the previous year.

Bulbils. A few lilies produce bulbils in the axils of the leaves and these can be used for propagation. The bulbils are collected in late summer and planted in beds, covering lightly. The following year they are lifted and require planting in rows for a further season before reaching commercial size.

Scale Propagation. This method is used extensively in the propagation of hybrid lily clones; it induces vigor and by propagating from carefully selected mother blocks stock quality is maintained at a high level. The mother blocks are planted separately and are rigidly scrutinized throughout the season for any symptoms of disease, lack of vigor and trueness to type. The bulbs are lifted in the fall, washed carefully and scaled (large bulbs can yield from 30 to 100 scales per bulb). The scales are placed in clean plastic trays and dipped in a fungicide solution for twenty minutes. They are then packed in layers in moist vermiculite using sturdy boxes lined with plastic. The boxes are placed in an incubator at a temperature of 60 to 80° F. depending on personal preference. The scales will form bulblets in 6 to 12 weeks depending on the cultivar. The cooler temperatures tend to encourage root development which is very desirable.

Following incubation the scales are placed in cold temperatures over winter and are planted in rows outdoors the following spring. They must be covered lightly and will make considerable growth the first year. Soil is added to the rows in late fall and by the following year an excellent quantity of commercial and planting size bulbs are harvested.

Tissue Culture. Shoot tip culture has been used to produce "virus-free" stocks of lily clones very successfully. Cultures of the cultivar 'Enchantment' taken in 1968 is now producing the entire crop which is well over 1,000,000 annually. Tissue culture can also be used to rapidly increase a very promising clone in its early stages of development. It will also continue to be an invaluable tool in maintaining high quality clonal material.

CUTTING PROPAGATION OF ROSES

RALPH S. MOORE

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"Secrecy — about what you have discovered, never prevents the other fellow from making the same discovery." Fred Hoyle. (From Science and Society in Modern Times) as quoted in STONEHENGE, p. 4

This is a basis upon which this Society was founded and it is in that spirit that I wish to share some of my ideas and discoveries in cutting propagation of roses.

For many years I have been interested in the propagation of roses from cuttings. In our nursery we grow thousands of miniature roses from cuttings and I have also proposed that most garden cultivars of roses be commercially grown on their own roots. I have tried to promote the idea to nurserymen, home gardeners, American Rose Society members, etc., whenever and wherever I can get an audience.

The idea is not new but for various reasons the propagation and growing of roses on their own roots has been overlooked, ignored or opposed. In a conversation with Dr. Walter Lammerts, the Dean of American rose hybridizers ('Charlotte Armstrong', 'Queen Elizabeth' and others) some ten years ago, he said "I agree that the idea is good but how do you convince the commercial growers"?

Going back further, it was not too many years ago that most, if not all, roses were grown from cuttings, divisions, or suckers. In fact, the Howard Rose Company of Hemet, California (discontinued as of 1978) for many years — up until the 1930's — had as their slogan, "Howard's Own-Root Desert Climate-Grown Roses".

When I was a boy many nurseries grew and sold own-root rose plants. In those days plants were usually grown in the open field from hardwood cuttings or were started under glass from softwood leafy cuttings. These rooted softwood cuttings were then:

(1) transplanted to the field to grow on and be sold as one- or two-year-old dormant plants; or

(2) the rooted greenhouse cuttings were shifted into small clay rose pots to be grown on and sold by mail order. Such plants also were used as premiums by magazines and other plant merchants.

Own-root roses have been used for greenhouse cut flower production. In a recent newsletter of the Rose Hybridizers Association, Mr. Charles Dawson of Finchville, Kentucky wrote that

while he was propagation supervisor for the firm of A. Rasmussen & Son, Inc., New Albany, Indiana, they were propagating some 200,000 plants annually from cuttings (1925 and into the 1930's). The year 'Briarcliff' (Pierson, 1926) came on the market, Mr. Rasmussen purchased 10,000 rooted cuttings for stock plants. The following season Mr. Dawson rooted and sold over 250,000 'Briarcliff' plants for cut flower production.

Going back even further, many a gardener grew his or her own plants from the stems of roses in a bouquet. The stem (minus the flower) was inserted into moist soil and a Mason fruit jar set over the cutting or group of cuttings until rooting occurred.

Many of the old roses (now collector's items) such as the moss roses, centifolias, damask, rugosa, hybrid perpetual, etc., could be grown from suckers or by divisions. It is because of the stooling or suckering habit that many of the old roses have survived in such places as abandoned farmsteads, old mining camps, etc.

Somewhere around the turn of this century the practice of budding came on the scene. There were some good reasons that the propagation of roses commercially by budding became popular. Among the reasons:

(1) While many, if not most, of the older roses prior to the 1900's were propagated on their own roots by cuttings, the breeding of roses and the resulting popularity of new strains of roses made recourse to budding necessary.

(2) Because it was customary up to the 1920's to propagate most roses from cuttings (either hard or soft wood) the cultivars then grown were selected partly because they would do well on their own roots.

(3) Several understocks have been used in various times and places, but the once famous garden cultivar, 'Gloire des Rosomans' (Vibert, 1825) found its way into Southern California where it became familiar as a yard and hedge rose. But it was the ease of rooting from hardwood cuttings, the abundant root system and the ease of budding that transformed a common rose into the famous 'Ragged Robin' understock — and with this root the budded rose industry of Southern California was born.

(4) In 1900 the rose 'Soleil d'Or' was created by the great French rose hybridizer, Pernet-Ducher. This cross of a garden rose, 'Antoine Ducher', (H.P.) × *Rosa foetida* 'Persiana' produced the parent strain for our orange, yellow and bi-color roses of today. With it came many problems, including the lack

of easy rooting. So budding was the answer — and has been all these many years.

(5) Later, in the 1930's another garden rose, the vigorous climber, 'Dr. Huey', got into the act almost by accident when someone noticed some plants in a field of 'Ragged Robin', which were somewhat similar but more vigorous. Trials were made with this new improved 'Ragged Robin' (from Shafter, Calif.), which was later identified as 'Dr. Huey'. 'Dr. Huey' quickly became the favorite understock in the growing fields of California and Arizona. For many years some 25 million bushes per year have been budded on 'Dr. Huey' understock.

In other areas of the U.S. and overseas various understocks have found favor. In Texas, the favorite understock is and has been some form of the species, *Rosa multiflora*. Certain selection of *R. multiflora*, propagated from cuttings, have been used in Oregon, New Zealand, Australia, and South Africa. In some areas seed-propagated *R. multiflora* is favored as an understock. For florist roses, 'Manettii' stock is often used.

It is the author's opinion that there are certain advantages to cutting propagation; among them we suggest the following:

1. There is no "sucker" problem, as any shoots originating on the plant will be the cultivar originally obtained (barring a bud sport or mutation).

2. In areas where winter damage may kill the plant top, any new shoots originating from the root area will be the true cultivar, not an understock sucker.

3. There is much less chance that the plant will be infected with virus (provided the cutting is taken from a virus-free mother plant).

4. The propagation of cuttings can be almost a year round operation and thus the need for "instant" labor at a given peak time is avoided. This could help minimize the vulnerability of the industry to union pressure.

5. Production (propagation and growing) could become more decentralized than at present, thus favoring the production of rose nursery stock more in the geographical area of use. This could bring cultivars to the customers which are better adapted and aclimated.

6. Propagation of roses from cuttings would lend itself admirably to the modern practice of container growing.

7. With ever increasing freight cost, more localized or area distribution would have advantages. There is also the possibility of large scale production of liners in light weight media to be shipped to greenhouses and other growers for finishing off in larger (1, 2, or 4 gallon) containers.

To help in this transformation of the rose industry we have at our disposal several methods and techniques not available to the old time own-root rose growers. Some of these are:

1. Rooting hormones
2. Mist propagation
3. Light weight soil mixes
4. Plastic containers
5. Plastic growing houses
6. Chemical fertilizers - liquid, slow-release and others.

To these aides in production I would add certain others:

One of the most important, in my estimation, is intensive breeding efforts — to not only produce good plants with flowers of desirable forms and colors but cultivars which would root easily and in the shortest time.

The often heard objection that a budded plant will mature in the garden quicker than one grown from a cutting may not be entirely valid. In the first place, most gardeners forget that the budded plant is usually two years old (sometimes 3) and they may be comparing it to a one-year cutting-grown plant. But given a good strong, well-rooted cutting-grown plant placed alongside a similar budded plant, the garden satisfaction can be equal, with often some pluses in favor of the own-root cutting-grown plant.

At least the container-grown own-root plant will be delivered in a live, often actively growing condition with 100% of its own roots intact, ready to take off in the customer's garden. I firmly believe that rose breeders, with the materials available today, could change the rose industry within ten years. There are now a number of cultivars which root and grow well. These can be the launching pad for the roses of tomorrow. While I have devoted much of my working life to the breeding and development of miniature roses, I have now added to my rose breeding program the quest for other types of garden roses which can be as easily and successfully grown from cuttings as are my miniatures.

Another area of investigation in the search for methods to make cutting propagation of roses practical appears to be the actual selection and preparation of the cutting material itself. To this end I have followed out some ideas and I have learned a lot.

In January, 1977, the idea occurred to me that some of the canes of our miniature roses were too large in diameter to root easily and that, especially with new cultivars, where propagation materials were in short supply anyway, we might induce

single bud cuttings to make plants. Thus, we used some cuttings not over 1 in. long. I knew that cuttings usually root most quickly if cut right below the node, as rooting does not have to wait for the base of the cutting to callus but may send out roots from undifferentiated tissue at the bud.

The idea is to make what I call a "slice cut," starting ¼ in. or more below the bud, slicing as to remove a shield bud, but cutting deeper into the wood and continuing up under the bud (but not removing the bud). The theory was that this cut (wound) would induce rooting around the bud and in the cut area, with the single bud developing into a well balanced plant, much like an original seedling (Figure 1).

Figure 1. *Left.* Cutting out single bud cutting with knife.
Center top. Appearance of two single bud cuttings with leaves attached.
Right. Appearance of two single bud cuttings after rooting.
Cuttings made July 31, 1978. Dug and photographed September 18, 1978. (climbing 'Cecile Brunner')

Based on my suggestion, this type cutting was tried by a New Zealand nursery on 'Mermaid' rose with far greater success than they had experienced previously. To carry the idea further, we have, in the 1978 season, made a number of experiments, duplicating each trial several times, even though with relatively small numbers. These experiments are continuing.

Using the cultivars, climbing 'Cecil Brunner' and 'Golden Glow' (a yellow-flowered climber) we tried various cuts, size of

cuttings, 1 and 2 node cuttings and trials of various rooting media.

The original slice cut worked well and gave rooting considerably better than did conventional cuttings. But there were two surprises with modifications of the slice cut. One was what I call a "slant cut", in which the base of the cutting is cut at an angle to expose an area from ¾ to 1 in. in length. This worked even better if the base of the cut ended just below the back of the basal node. The other surprise was in using a single-bud cutting made like a shield bud but longer and with more wood. The shield was cut out approximately 1¼ to 1½ in. length. Rooting was phenomenal. All cuttings were made with leaves; the bases, including all cut surfaces, were dipped in Hormex powder. In one lot we included cuttings without leaves; these failed entirely.

In addition to the two cultivars used in the experiment mentioned above we also included two lots of cuttings of 'Little Darling' and 'Queen Elizabeth'. Results were similar.

To further test the idea, cuttings of the miniature rose 'Avandel' (easy to root) and 'Scarlet Gem' (slow and more difficult) were included in the first trials. Only the slice cut was used but there was a marked difference in the rooting of 'Scarlet Gem'.

No bottom heat was used; all samples were rooted outdoors under mist in our regular growing mix (⅓ fir bark, ⅓ peat, ⅓ perlite) unless noted otherwise.

NOTE: In our operation at Visalia, California, we grow between 600,000 and 700,000 miniature rose plants each year.

CO_2 AS AN AID TO ROOTING

S.E. SORENSON

Homestead Nurseries Ltd.
Clayburn, B.C., Canada

We are pleased with the use of CO_2 in our softwood cutting propagation program. For two seasons we have sent CO_2 through our mist lines to assist in rooting. Efficient rooting practices are necessary for us since this is a relatively large part of our business. Leaching and *Botrytis* infection were but a few of the problems that cut down our productivity in spite of our many sanitary practices.

In early 1977, while revising our propagation program, we discovered an article in the 1968 I.P.P.S. Proceedings entitled, "Carbonized Mist in Plant Propagation" by J.M. Molnar and

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W.A. Cummings, C.D. of A. Research Station, Morden, Manitoba, Canada. This showed that CO_2 promoted rooting when sent through mist lines. Using this article as a model, we replumbed our mist lines in a poly propagation house. The results were striking. We did not have replicated trials so we cannot prove this statement by detailed measurements and rooting times, but we can attest to the results by visual means. There was less *Botrytis* on *Cornus alba* 'Elegantissma Variegata' leaves and much healthier *Prunus cistena* cuttings. In general, there was less leaching, cleaner foliage and faster rooting on all cultivars in the polyhouse.

With this initial success in our polyhouse we changed over our outdoor propagating frame in 1978 to the use of CO_2 to assist the softwood cutting propagation. Here again we are satisfied that CO_2 improved rooting.

Our softwood cutting propagation season was hardly over when *The Plant Propagator, Vol. 23 No. 3*, September 1978, arrived carrying an article — "Effects of refrigeration, CO_2, and photoperiod on the initial and subsequent growth of root cuttings of *Ilex Cornuta* 'Burfordii', by Adolph J. Laiche, Jr. of Mississippi State University," which corroborates our results with CO_2.

For the future we plan to make some mechanical improvements in our CO_2 systems. Time clocks to cut off the CO_2 around 11 A.M. when winds or ventilation systems usually start up are being considered. Possibly injectors could be used to more accurately induce CO_2 into the lines instead of using electric valves.

These are but a few ideas that we have in mind to cut down the waste, to more accurately measure CO_2 and, finally, to allow for a more trouble-free maintenance program.

We have been rooting semi-soft *Pinus mugo* cuttings for the past four years with fair success. Timing is critical in this case, for when the cuttings are too hard, they are difficult to root; conversely, when on the soft side, they fail. We feel that by using CO_2 on "soft" *P. mugo* cuttings they would survive. This could be a new horizon in softwood cutting propagation since "soft" (immature) softwood cuttings could be used for many hard-to-root cultivars.

TRANSPLANTING THE DOUGLAS FIR PLUG

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INTRODUCTION

Container production of reforestation stock in the U.S. Pacific Northwest is a relatively new technique that has been undergoing exponential growth during the first half of this decade, yet has diminished somewhat during the second half. In 1970, about 90 thousand plugs were produced in Oregon and Washington and by 1976 nearly 54 million were grown (1). After 1976, the enthusiastic growth for container production has actually decreased to 44 million seedlings. In relation to the bare-root tree production of 170 million, the container trees represent about 20% of the total production of reforestation stock in the Pacific Northwest.

The decline of container production in the Northwest is partly due to some reforestation failures on difficult sites where plugs had been used. These difficult sites are frequently areas with brush competition and mammal browsing. Small plugs have little chance of surviving, let alone growing, when brush forms an overstory above the seedling and provides habitat for browsing by mountain beaver, rabbit, and deer.

Due to these failures, many foresters have tried to plant a larger tree, such as a 2-1 transplant or a 3 year-old seedling. This type of tree would have enough height to be less affected by brush and weed competition and also would possess more lateral branches so that if animals remove some of the foliage, there would still be enough remaining to keep the tree growing. These trees would take 3 years of nursery care before they could be outplanted and are more expensive compared to the plug or 2-0 bare root.

Two years ago, our nursery was approached by a few timber companies which possessed some of these difficult sites and also operated their one plug nurseries. It was felt that the plug seedling could be transplanted in a nursery growing area and within 2 years reach the needed size for outplanting, rather than the typical 3 years with bare-root stock. In addition, the container nursery could double it's production by producing plugs for late summer transplanting in August and, also, produce a crop of plugs for winter planting in the woods. Our main concern was the ability of the plug to develop a suitable root system that could support a large top upon outplanting. After producing 500,000 of these in 1977, we felt confident enough in the tree that we transplanted an additional 2 million

in the spring and 2 million in the fall of 1978. The plug transplant has unique properties in it's morphological character that make it a valuable addition to the variety of stock available for the forester to choose among when selecting the type of tree most suited for his site.

We will discuss the cultural techniques that are used in the production of the plug transplant and show a cost comparison between this and other reforestation types.

CULTURAL TECHNIQUES

We prepare our ground as soon as we can work up the soil. Usually this entails plowing, discing, and rototilling. The ground is fumigated under tarp with 380 lbs. of 66% methyl bromide and 33% chloropicrin. After removal of the tarp the ground is again disced and harrowed.

The transplanting is done with a mechanical transplanter planting six lines, eight inches apart, and with three inches between trees in a line. We use two machines and have the capacity to plant up to 160 thousand trees per day. Each transplanting crew consists of 11 members: 1 foreman, 1 tractor driver, 6 planters, 2 trailers, and 1 loader. The foreman is responsible for insuring that the trees are planted upright with a straight root system and firmly-packed base. The two trailers fill in any skips in the beds by handplanting trees so we can maximize production per acre. About 140 thousand trees can be planted per acre. Special racks were built to handle plugs coming to us in Styroblock containers. The containers slide down in front of each person who is planting; he can extract the trees directly from the block and feed them into the planting wheel. Plugs that arrive to us already extracted at the greenhouse are just laid in a tray in front of each planter. Transplanting plugs results in fewer "J"-root problems than occurs with bare-root stock. The root system is in a "plug" shape and allows the tree to be firmly anchored in the soil by the packing wheels of the planter. With bare-root stock, we have had problems with one tree binding the next in a tangle of roots and, in so doing, drags it into a sharp angle in the soil.

A serious problem that many transplant nurseries face is the quality of the stock on arrival at the nursery. This is particularly a problem during the spring when trees have been held in cold storage for transplanting. Some trees may be in storage for 1 to 4 months before being transplanted into the field. Hemlock, in particular, is susceptible to damage if stored for over two months and we prefer these trees to be transplanted in the fall.

A great advantage of the plug over a bare-root seedling is that it can be transplanted in late summer with no intermittant

period of storage. Plugs that are held through the winter can become root-bound in the Styroblock or cell. Early bud break can also occur since the container nursery must continue to fertilize the plug while at the greenhouse to keep it from becoming chlorotic. If the plug is extracted during the winter and held in storage, it can have many of the same problems as barefoot stock with disease and lost vigor.

Sometimes the container nursery must transplant the plugs in the spring. In this case, we recommend that plugs be extracted from the container when the seedling is fully dormant and then put into cold storage. A plastic wrap with an open end, forming a bundle of 50 plugs, has usually been satisfactory. The bundles can then be placed in a box or bag and stored under refrigeration.

The highest quality plug for transplanting is one that has been cultured at the greenhouse for the specific purpose of a late summer transplanting. In order for these trees to become ready, they must be sown earlier in the greenhouse, such as the first part of December, and must be "hardened-off" with firm buds by early August. A plug that is transplanted in late summer will be about 10 cm larger than a spring-transplanted plug. It's caliper is usually over 8 mm and the root system is much more developed than that of a spring transplant, since the tree has gone through two additional periods of active root growth in the fall and early spring.

Our disease control program is mainly preventative maintenance. This begins with sterilizing the soil with a fumigant such as methyl bromide/chloropicrin and proceeding with cultural practices that will minimize reinoculation by pathogens.

Tilling equipment that is used in a suspected area should be cleaned of all residual soil and sterilized with an antibacterial detergent before using in newly-fumigated ground. A common source of disease is infected stock brought in from another nursery or field. We require all stock coming to us for transplanting to be inspected for disease. This usually entails an agar culture treatment of seedling sections and identifying the disease growth through a microscope. Any seedlings showing high potential risk can either be refused for transplanting or accepted, but restricted to a certain area removed from our healthy trees.

The trees are inspected daily for the appearance of unusual color or growth. If a symptom can be recognized in its earliest stages there is a much better chance of arresting or preventing future damage with the use of certain fungicides. In analyzing disease problems, the visual symptoms should not be the only means of determining the identification of the disease. Visual

symptoms mainly indicate that a problem exists but is not a confirmation of what the specific disease is.

The agar plate technique can be very useful in determining the effectiveness of various fungicides on the disease by incorporating the funigicides in the agar medium and viewing it's control. Once the disease has been identified, we can apply the desired fungicide on the field by either tractor or airplane.

We use about ten different herbicides on our transplant fields according to the time of year, weed species present, and physiological state of the trees. These herbicides include atrazine, simizine, prometryne, glyphosate, dicamba, Dacthal, Enide, bifenox, 2,4-D, and 2,4,5-T ester. Our major weed problems are subclover, dog fennel, horsetail, mustard, and sheep sorrel. With the use of these herbicides and fumigation we have seen a steady decline in the number and proficiency of weeds in the field. However, even with the use of herbicides, we still have a need for handweeding at various times during the growing season.

We can get a good understanding of our nutrient status from soil lab reports and incorporate the proper amount of nutrients into the soil before transplanting. Not all of our fields have the same soil type and therefore we have to independently sample stratified areas. The levels of nutrients which we feel are sufficient for our fields are given in Table 1.

Table 1. Levels of Nutrients

pH	: 5.2 to 5.6		
organic matter: 3 to 4%			
CEC	: 15 to 20 meq/100g		
NO_3	: 150 to 200 ppm	Cu	: 1.0 to 1.5 ppm
NH_4	: 50 to 100 ppm	Zn	: 1.5 to 2.0 ppm
PO_4	: 50 to 100 ppm	Mn	: 5 to 10 ppm
K	: 250 to 350 ppm	Fe	: 10 to 15 ppm
Ca	: 9.0 to 13.0 meq/100g	B	: 3.5 to 4.0 ppm
Mg	: 2.0 to 3.0 meq/100g		

Not all lab tests use the same method of extraction and might give a wide range of figures. We try to have our soils tested by only one lab so that soil fertility levels may be easily correlated each year to former tests. Soil type and it's cation exchange capacity also influence the nutrient availability of the soil. Each nursery should determine its own sufficient levels.

Once we have incorporated the proper fertilizers before transplanting to reach an optimum level, we continue a fertilizer program during the growing season to accelerate growth and development. We check our nutrient levels at various times during the growing season with a soil test kit and pH meter. A

late summer transplant does not receive any additional fertilizer until early spring when we apply a complete fertilizer (20-20-20) at about 100 lbs/acre to enhance bud break, root development, and shoot growth. During late spring and early summer we concentrate on nitrogen applications such as ammonium sulfate at 80 lbs/acre. Nitrogen is necessary for continued shoot elongation and diminishes from the soil quickly due to irrigation during this period. In early August, we apply a phosphate-potassium fertilizer to initiate the "hardening-off" process and influence root elongation. This is our last fertilizer application for the year so that second-flushing from early fall rains will not occur and result in frost damage by late fall. We prefer to apply small amounts of fertilizer frequently so that the transplant receives a uniform amount of nutrients throughout the growing season.

The soil texture can influence the growth of the plug to a great extent. In sandy soils, the plug root system will put out many lateral roots so that the 'plug' shape becomes almost indistinguishable from a 2-1 bare root after a year in the transplant beds. On the other hand, clay type soils will keep the plug shape intact and very few lateral roots will extend through the soil. Most of the root growth in clay soils is in a downward direction and the tree is not balanced in its root:shoot ratio due to this poor root development.

Proper irrigation is important to the growth and development of the plug transplant yet it is difficult to determine how much water should be applied and when to apply it. We not only depend on water to encourage growth and induce dormancy, but also for it's function in disease control by reducing soil temperatures. We have tried the "farmer's approach" and irrigated when we thought we should. However, with a relatively new nursery and new personnel, this approach was less than optimal. During the past growing season we have used the pressure bomb as developed by Waring and Cleary (2). With this tool one can determine the water stress of the tree at that period of time. By relating the stress readings to research data one can determine whether to irrigate or not. This instrument becomes very important to us during the late summer when we want to hold back the water to induce dormancy but not so much that the vigor of the tree is threatened.

Before lifting the trees from the beds some clients prefer to have their trees sprayed with a mammal repellent. We apply these chemicals with a spray tank but have been considering the use of an airplane or helicopter. The repellents have been successful in some areas to a certain degree, but do not provide total control. Nor do they have a long period of activity, only

about 3 to 4 weeks. Unless the trees are resprayed in the woods the new foliage from subsequent bud burst is unprotected and can be browsed.

The trees are lifted starting about December 1 and continuing through late February. This is the period when the trees are in their deepest dormancy and can withstand the shock of being removed from the soil. During this operation the roots must be protected from exposure to drying conditions. The trees are either lifted by machine completely out of the ground or the ground is agitated sufficiently to allow hand pulling without damage to the roots. We load the trees into large boxes on trailers and bring them to the packing shed as soon as possible. There the trees get rinsed down to remove any dirt on the foliage and to re-moisten the roots. The trees are then stacked into a cold room kept at 33-34°F and 90% humidity for further processing.

The trees are graded and root-pruned if the client desires. Trees that are culled would be those of poor root or shoot growth, damaged, or diseased. The graded trees are counted, bundled and sent down the conveyor belt to a person who packs them in either bags or boxes. Packing material is sometimes requested as shingletoe, peat moss, or tree moss. Our experience receiving trees from other nurseries indicates that bags with no packing material have generally contained the freshest trees. Once packaged, the trees go back into the cold storage room to await shipment.

OUTPLANTING

It is much too early to form a definite picture as to how plug transplants will perform in the woods since we have only one crop out on the sites. However, the preliminary surveys are encouraging. In 1978, 500,000 plug transplants were sent to 3 locations in the Coastal Range of Southern Oregon. Each of these locations were considered difficult areas for regeneration due to heavy weed encroachment and severe mammal browsing. Past experiences using either the plug or 2-0 bare root usually resulted in low survival figures or very limited growth. The 2-1 bare root transplants were tried and because the trees were larger with more lateral buds, the survival is high, as is the capability for continued growth of these trees despite the browsing.

The plug transplant seems to show an additional improvement over the 2-1 due to it's vigorous growth. Upon browsing, a 2-1 would usually not resume considerable shoot elongation but wait until the following spring before pushing up new growth. The plug transplant, however, seems to have the ability to con-

tinue pushing out new growth despite the browsing. This additional vigor may be due to the more developed root system it has compared to the 2-1 bare root.

A comparison study between the plug and plug transplant was done near Gold Beach, Oregon by Champion Timberland foresters. The trees were planted in the same watershed in the spring of 1978. Both types had 90% or better survival, but 35% of the plugs had been browsed so heavily that survival in the near future was questionable. On the other hand, the plug transplant had 0% in the "questionable" category and all seemed firmly established on the site (personal communication).

Table 2. Cost Comparisons Among Types of Reforestation Stock.

	2-0	2-1	plug	plug-1
Trees planted/acre	680	550	680	550
Establishment percentage	70%	90%	55%	92%
Number of trees est./acre	476	495	347	506
Number of trees to replant/acre	24	5	126	—
Site prep. costs/acre	$190	$190	$190	$190
Stock costs/acre	$41	$66	$51	$66
Planting cost/acre	$52	$61	$45	$61
Respray cost/acre	—	—	$14	—
Replant cost/acre	—	—	$10	—
Establishment cost/acre	$283	$317	$310	$317

From the regeneration cost data we received from the Gold Beach operation, there appears to be little difference among the 2-1, plug, and plug transplant establishment costs. The 2-0 type was a little lower (Table 2). However, these costs do not show the relative advantages that the plug transplant has over the other types of stock. These advantages are:

1. The plug transplant represents a two year regeneration plan whereas a 2-1 takes three years before the tree is brought to the woods.

2. A plug transplant is usually a more consistent tree than the bare root 2-1, or the 2-0 in height, root system, and caliper.

3. The plug transplant is larger than the 2-1 when it has been fall-transplanted and much larger than a 2-0 or a plug.

4. Plugs can be transplanted in late summer with no storage transition between the seedling beds and transplant beds. Bare root transplants usually have a period of storage which declines vigor.

5. A container nursery has much more control over the seedling's environment than a bare root nursery and, therefore, it becomes a much safer, consistent area to grow seedlings. As seed costs rise and expensive, genetically improved, seed be-

comes more available the most efficient use of that seed will probably be within the container greenhouse rather than open fields. The plug transplant will allow these container trees to achieve some of the advantages that bare root transplants have in size and increase their success in the woods.

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PLANNING AND ESTABLISHING A NURSERY IN THE WESTERN HIGHLANDS OF SCOTLAND

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Two years ago after a tour of the Scottish nursery stock market I decided to start a container unit producing trees and shrubs in the Western Highlands. The decision was momentous. It led to a complete transition in my own life and that of my family; it brought a diversification to a traditional family run hill farm producing sheep and cattle for the store market; and it marked the first full commitment by the development agency in the Highland region to the development of nursery stock in the Western Highlands of Scotland.

My story begins and ends with Kinsealy Research Centre, Dublin, Ireland. Not only did I find the encouragement which eventually led to the establishment of Barguillean Nurseries but also at Kinsealy the ingredients of what was to be, two years later, my own business.

Though relatively small as a research station the work that has been produced from the Institute is well known throughout the world of horticulture. Considering the scarce resources and manpower the pioneering is considerable. Kinsealy for a "drop-out" like myself was perhaps the best possible place I could have spent my first six months. For it was there that my mind was opened up to the great range of technical possibilities facing the industry. I was baptised in innovation and from that point on and during spells at various other institutions and nurseries I kept returning to the basics which had been digested at Kinsealy.

I made my way to Denmark and Holland where I spent a year working principally on Arne Jensen's nursery at Orting near Arhus in Jutland. After the academic atmosphere of the research station it was time to tackle other people's commercial disciplines. During the next eight months I worked my way through the apprenticeship of being a nurseryman and it was there that I learnt a great deal about the discipline of commercial life and the need to establish high standards in all aspects of the work. One begins to catch the details of the work itself and the respect with which it is tackled in Denmark and Holland.

I returned in October, 1976, to my native Scotland. During the months in Denmark I had opened correspondence with a number of key people in Scotland about the prospects for a new nursery there. Isn't it surprising, looking back, how few people

had anything relevant to say in those early days of planning? I polled opinions from every point of view in those summer months in 1976 before my return and got only the vaguest suggestions about the commercial viability of large scale nursery development in Scotland. In some ways it was disappointing to find so few people enthusiastic but, in other ways, it was good for it threw me back on my own resources and fueled my determination to return and get stuck in even if it were against the odds.

During the course of the summer months my correspondence with the Highlands and Islands Development Board — *HIDB* — produced a very favourable response. My timing was perfect. The HIDB had just wound up a successful five year pioneer project at Ormsary in Argyll to establish the possibility of creating a commercial nursery stock development in the West of Scotland. My initial approach to the Board was received with cautious enthusiasm and over the next few months before my return the general principles of my venture were established and explored in correspondence.

So on my return to Scotland in October the first step was to look at the market here. What I found confirmed my suspicions. Despite a long tradition of nursery stock production in Scotland, and the existence of many famous nursery families in the North East of the country, production in the last few years has lagged badly. The shift to containerised shrubs and trees has accelerated at tremendous paces in the rest of the UK. In Scotland this hasn't produced much of a revolution in production methods. To this day the bulk of production is open ground and the thrust of marketing directed principally towards the traditional local authority market. However, in the intervening years there has been an enormous upsurge in garden centre interest and these outlets are spreading fast throughout the country here north of the Border. These retail outlets now account for a very considerable turnover and the garden centres are obliged to look to England, Holland, and Denmark for an alarmingly high proportion of their needs. A two week tour of Scotland during that first month of my return showed that in the Glasgow and Edinburgh corridor, garden centres were stocking their beds with container plants grown largely in England and that, when approached for a reason, the answer was always the same: "but where can we find continuity of supply at the right quality here in Scotland? Whom can we rely on to deliver when we need the stock? There are only a few scattered specialists and we haven't the time to shop around. We must be able to trade with a company that can fulfill all our needs and make planning our purchases trouble free."

The first economic model we produced for a nursery would have called for an investment of £120,000. Money like that wasn't available and so we pared away the capital equipment and devoted all available resources to stock purchase and working capital. A figure of £60,000 was arrived at, incorporating an initial £15,000 of investment capital, with the remainder being devoted towards creating a fast build up of cash flow to facilitate the development of the nursery.

The model was accepted in the next few weeks by the Highland Board and after a series of meetings between myself and them the decision to get going was given in January, a bare three months after the formal approach. It goes without saying that I have been very considerably impressed with the amount of help I received from the HIDB and have nothing but praise for the enthusiasm and support they have given to the venture since it was conceived.

In March, 1977, the bulldozers roared onto a most unlikely location for a nursery stock unit. A four acre site with a 9 meter drop from one end to the other was gouged and terraced until the site was ready for building.

A great deal of preparation had been put into the design of the nursery not only to make it easy to service but with as much attention as possible being given to the aesthetic virtues of the site itself, which is in the midst of some of the most spectacular mountain scenery in the world. Some initial landscaping was done in the first year to soften the scars left by the bulldozers. Since then the initial site has reached full capacity and, seen from above, where the road passes the site, the nursery creates its own landscaping with the variety of colours and textures of the plants. Phase two, which brings in another three acres in autumn, 1978, will be accompanied by the creation of large stock plant areas on the high banks surrounding the nursery.

Barguillean Nurseries has every right to be branded a Kinsealy nursery since from the beginning I have incorporated a number of systems pioneered at the Institute. I think I am right in saying that Barguillean is the first nursery in the UK to incorporate automatic capillary beds throughout the development and it is about these beds that most of my talk at Bristol this year was directed.

Barguillean has now worked with capillary beds more than 40 metres long and 10 metres wide, for almost two years and I am convinced that this system should be better understood and more widely applied. It involves the nursery in an irrigation system for containerized plants that is trouble free, efficient,

labour saving, cheap to build and maintain, and brings versatility to the design of the nursery.

Each bed is basically a basin with concrete shuttered 4 inch sides six inches deep constructed on *absolutely level* ground. The inside of the bed has two 12 inch trenches dug out equidistant down the centre of the bed. The bed is then lined with a strong lining material like Typar upon which is then spread a polythene lining material to be waterproof. The lining material below protects the polythene and prevents it from being torn by stones or gravel, resulting in leaks which make the bed inoperable. The bed, once fully lined, is then filled with four inches of sand trodden down firmly by a gang of men as the bed is filled. Once filled the bed is flooded with water to ascertain where high and low spots lie. High spots are raked off to fill low 'puddled' areas and supplementary sand added where necessary to finish off the bed. Left to dry off for a few days without the addition of further water, the trenches for seepage pipes are now carefully dug along the line of the original 12 inch trench described at the beginning of the paragraph. The trench is easy to dig out a spade width at a time from the firm moist sand. It looks very neat when completed and it is into these two trenches that a 90 mm slotted draining pipe is installed from one end of the bed to the other. The pipe should be surrounded with fine grade gravel and then topped off with sand. Around one end of the pipe a small tank large enough to accommodate a ball cock and valve is excavated from the sand and lined with concrete by the means of shuttering boards. From this tank the pipe leads out and down through the bed. The ball cock and valve, when fitted, can be adjusted to ensure the right level for water in the bed which should be adjusted to about one inch beneath the surface of the bed. The bed will now operate automatically and you can send the staff home for the weekend without fear for your stock (Figure 1).

A new nursery doesn't just arrive on the scene without a struggle to gain recognition. No matter how professional your approach, no matter how strict your grading and quality, it takes time to get going. Alas, banks and lending agencies prove impatient, financial resources are thin at the end of the first twelve months, and you have a lot of bills to pay, and less and less time to be given second and third chances. You must, as we discovered at Barguillean, get the whole conception right at the beginning. You must get the figures right and not be strapped for working capital before you have even got half off the ground, for momentum must not only be kept up in the first year, it must drive on solidly in year two so that your customers feel your confidence.

I arrived on the scene in Scotland barely two years ago and

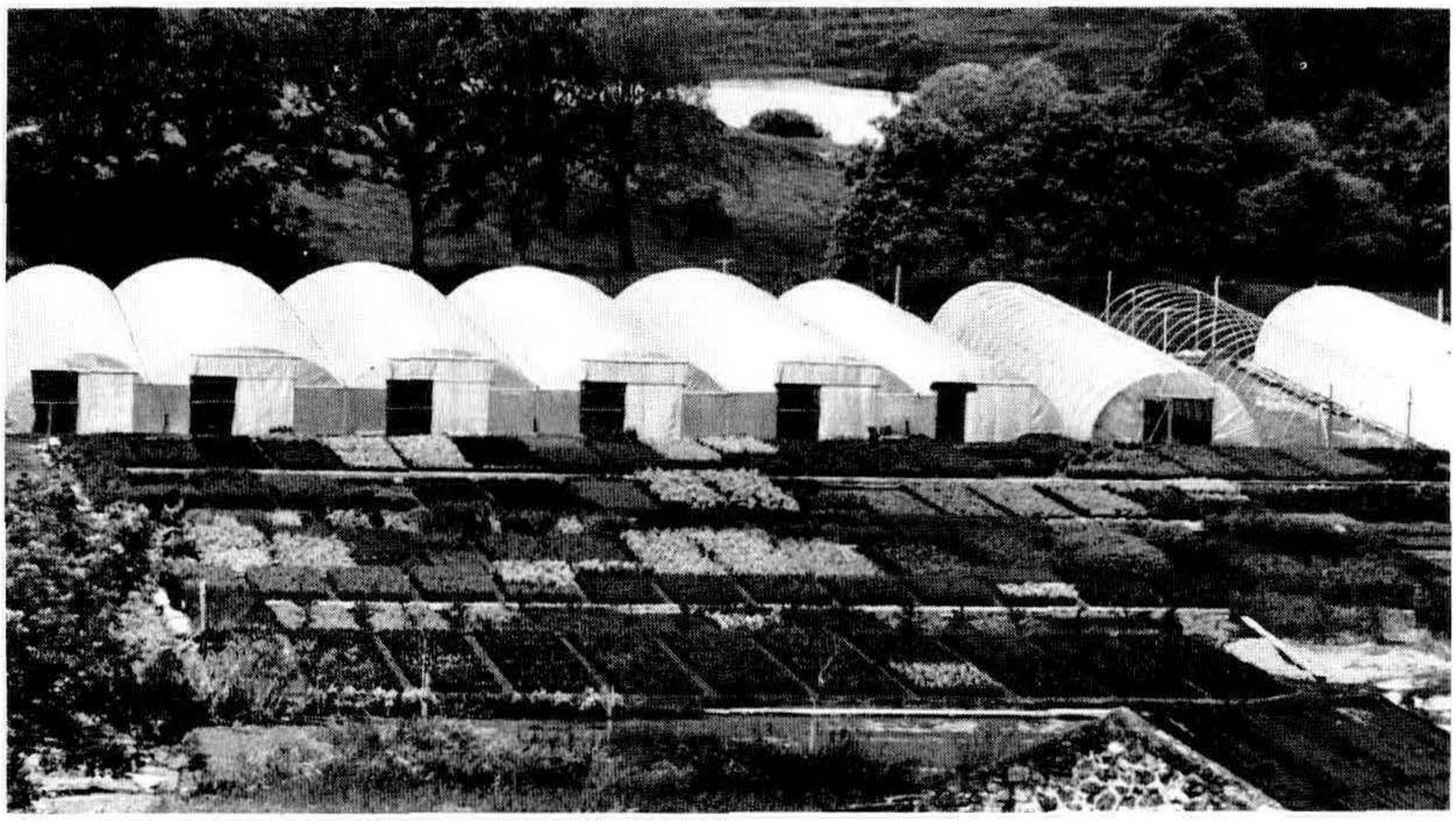

Figure 1. Plastic Houses and Capillary Beds at Barguillean Nurseries Ltd.

by September, 1977, I had to get moving on the sale of my first year's efforts. By Christmas, 1977, we had sold only £5,000 of stock and the going was uphill. But perseverance pays, and over the next six months the thousands of miles of driving I did bringing samples to people, making contacts, sweating out orders, using my instincts where they were necessary and screwing up my courage when my morale dropped, paid off. Garden centres in Scotland and the North of England began to realize the scale we were attempting and have initial confidence in our ability to deliver a grade and quality of plants up to and, in some cases, above the standard they were used to.

Year one, which ended in March, 1978, produced sales of only £14,000 but already this year Barguillean sales are touching £50,000 with a great deal of our own stock coming forward for sale in the coming months. An analysis of the sales produces an interesting picture. Average sale is £350. So during these first 18 months sales have been built up almost exclusively on sample orders. It is an indication of the confidence being felt in the trade at the present time that a new nursery like my own can produce sales figures of this magnitude 18 months after the nursery was built. But the quality has to be right, and you must never give up the discipline of grading out religiously and delivering orders that are uniform in shape and size. For it is here that your reputation will be built.

In developing my nursery I acknowledge the great assistance received from J. G. D. Lamb and J. C. Kelly of the Kinsealy Research Centre and from the managerial expertise of J. J. Costin.

STRATIFICATION — A DETAIL OF TECHNIQUE

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These notes are concerned with only the initial part of the stratification process. Stratification involves the chilling of a seed and this involves two factors — cold and moisture. Before the cold temperature treatment can have any effect the seed must be fully imbibed. Thus the medium with which the seeds are to be extended must hold sufficient moisture to allow the full imbibition of the seed and maintain the moist environment to prevent any subsequent water loss. The chilling effect will not begin until this stage is reached and I suspect that many of the variations in chilling time fail to take account of this fact. In practice dry seeds are put into the cold treatment and the first period is taken up with imbibition — not with the action of the cold, so attenuating the apparent chilling time.

In addition, the extending medium must maintain the aeration of the seeds as the chemical changes appear to require a fairly high level of respiratory activity. Thus the stratifying medium must balance the moisture content and aeration if successful chilling is to be achieved.

The following constitutes a technique which has proved successful under practical conditions. The stratifying medium is based on Irish sphagnum peat moss — medium grade. The peat, as dry, from the bale is sieved through a ¼″ or ⅜″ sieve and the tailings are discarded. This peat is now moistened until the stage when a handful of damp peat is gently squeezed and a drop of water is exuded: at this stage the moisture content is sufficient and aeration is maintained. Experience has shown that this stage will be achieved by mixing 4 volumes of dry, sifted peat with 1 volume of water.

This medium is now used to extend the seed lot; however, the quantity involved also needs to be standardised. Sufficient medium must be provided so that sufficient water for imbibition is available and yet aeration is maintained. Experience has shown that, as a rule of thumb, 1 volume of seed should be mixed with 4 volumes of damp peat. The seed and damp peat are thoroughly mixed and the mixture is then placed in a polythene bag together with a label. The bag is then tied to prevent water loss and a tie-on label is attached externally. The bag containing the seeds is now left in a warm environment for the seeds to imbibe; this will probably take 10 to 14 days.

The seeds are now ready to be chilled and can be transfer-

red to a cold room or refrigerator at a temperature of 38°F (3°C) or below (but above freezing). The bags should be turned and shaken at least once a week to maintain an even temperature effect and to prevent settling, with a consequent reduction in aeration.

If this procedure is adopted it will be found that chilling times are far less variable than might be anticipated from the available literature and any chilling time for a particular seed lot can be assessed accurately and with confidence.

CLONAL VARIATION IN ROOTING OF SOFTWOOD CUTTINGS OF WOODY PERENNIALS OCCURRING NATURALLY ON DERELICT LAND

JOHN E. G. GOOD[1], J. A. BELLIS[1], AND R. C. MUNRO[2]

Abstract. The Institute is investigating many aspects of inter- and intra-specific variation in woody plants, including that enabling individuals to grow successfully on derelict and reclaimed land. Clonal stocks are being assembled by rooting cuttings of a wide range of species whose subsequent performances are compared with those of unselected stock in glasshouse experiments and field trials on difficult sites throughout Britain. All four criteria (i) proportion of cuttings which root, (ii) time taken to root, (iii) time of year when rooting is maximal and (iv) survival of rooted plants after potting, have been found to vary considerably both between species and between clones within a species — a feature that influences their possible commercial use. Average rooting of elder: *Sambucus nigra* L. throughout the season exceeded 90% for all clones tested whereas in goat willow: *Salix caprea* L. rooting varied with clone from only 19% to 83% and in silver birch: *Betula pendula* Roth. from 9% to 68%. In silver birch all clones rooted best in July but whereas one clone never dropped below 45% rooting, another gave nil rooting in June.

REVIEW OF LITERATURE

Trees and shrubs propagated commercially are, because they have not been intensively selected, more variable than most agricultural and horticultural crops (11). Excepting a few ornamental cultivars, mostly of exotic origin, there is no equivalent of the true-breeding cultivars of wheat or tomato. Seeds from a single birch tree are likely to produce a varied batch of seedlings, many distinctly different from the mother plant (4). This variation poses considerable problems for tree research, treatment effects often being ill defined unless many replicates are used. Variation can also be problematic for the practising forester and aboriculturist because only a proportion of his

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seedlings will possess the desired qualities to enable them to succeed. This problem is particularly acute on difficult sites such as restored opencast (strip mine) land, wastes from industrial processes, motorway embankments (3,6,8), sites characterized by poor nutrition, inadequate soil aeration, unsatisfactory soil moisture regimes, physical instability and toxicities from several causes. However, despite these difficulties, given time and an adequate supply of seed, colonization occurs naturally with goat willow, sallow (*Salix cinerea* var. *oleifolia* Macreight, Syn.: *S. atrocinerea* Brot.) elder, silver birch, hairy birch (*Betula pubescens* J. F. Ehrh.), being among the first woody plants to establish themselves. Although few quantitative assessments have been made it seems that trees able to establish themselves represent a minute fraction of the total available seed — they could possibly have features fitting them for establishment and survival in adverse conditions (1,5,12). This hypothesis is being tested by clonal propagation and subsequent testing in the field of individual plants collected from many different derelict sites. If some have advantages over the 'unselected' plants currently being used in reclamation work it might be worthwhile to consider their commercial propagation.

Cuttings taken from neighbouring trees of the same species and age often differ greatly in their abilities to root (2,7,9,), differences ascribable to the physiological condition of the cuttings, notably their endogenous auxin concentrations (7,13,15). Clones with large concentrations of endogenous auxin are more likely to root than those with smaller amounts which, as a result, might be expected to be more responsive to exogenous applications of auxins. Irrespective of clone the ability to root fluctuates seasonally. Rooting of *Populus nigra* L. softwood cuttings under mist is directly related to amounts of endogenous auxin (13). The auxin appears to promote rooting by stimulating hydrolytic enzyme activity thus mobilizing starch into soluble sugars which are needed as an energy source for the meristematic activity leading to root production. Rooting is best in spring and late summer when ample stored starch is available, and least successful in mid-season when active shoot growth consumes all available energy supplies. Similar seasonal fluctuations, also related to auxins, were found in sallow. In this instance Vieitez and Pena (15) suggested that the balance between auxins and inhibitory compounds controlled the ability to form roots so determining the seasonal rooting responses.

This report records some of the problems encountered when rooting selected 'tolerant' clones of woody perennials from sites of dereliction.

MATERIALS AND METHODS

Stem cuttings from young containerised plants, collected from spoil tips mostly in Scotland, were taken at intervals of about two weeks from early spring until September. They were dipped in distilled water and then in a commercial rooting powder containing 0.1% 1-napthylacetic acid (NAA) and 2% Captan fungicide. Thereafter cuttings were inserted to a depth of 50 mm in coarse silica sand in plastic trays buried to their rims in a raised shingle bed. Bed temperatures in an unshaded glasshouse were maintained at 24°C ± 3°C. At intervals cuttings, kept moist beneath a misting unit controlled by an electronic leaf, were examined, the "minimum" period to rooting being the period from insertion to the development of vigorous branched roots. At this time rooted cuttings were transferred into 3" plastic pots with sterilized compost consisting of 2 parts coarse sand; 2 parts moss peat; 1 part loam; 6.45 kg of slow release fertilizer (Osmocote 18:11:10) and 3.89 kg John Innes base fertilizer were added to each cubic metre. Potted cuttings were placed on a "weaner" bench which was misted less frequently than during propagation. One week later they were put in an unheated glasshouse where they remained, being potted as required in the above mixture until they were sufficiently established to be put outside in their final 12.5 cm (5") containers.

Many species were rooted in the period 1973-1977 (Table 1). Some rooted relatively easily whereas others — hawthorn (*Crataegus monogyna* Jacq.), mountain ash (*Sorbus aucuparia* L.), and common (European) ash (*Fraxinus excelsior* L.) were generally more difficult. Where attempts were made with only one or two clones, success or failure may have been due to chance selections of good or bad "rooters"; the outcome should not be considered as providing a guide to the response of the species in question.

Among species characteristically colonizing derelict land — goat willow (SC), sallow (SA), hairy birch (BPu), silver birch (BPe), elder (SN) — it was found that rooting ability differed (Table 2). Elder was consistently easy to root, with an average of over 90% of cuttings of all six clones tested rooting whereas percentages varied considerably in species of willow and birch. Only 19% of goat willow clone SC 42 rooted compared with 83% of clone SC 50. Nine percent of silver birch clone BPe 48 rooted compared with 68% of clone BPe 73. Sallow clone SA 90 roots easily as would be expected of plants with a known ability to layer, a character which could be of value in stabilizing mobile reclaimed soils.

Although these average figures give an indication of the overall rooting capability of different species and clones they disguise appreciable seasonal fluctuations (Figure 1.). Birch

Table 1. Tree and shrub species found on sites of dereliction that have been rooted as softwood cuttings.

Species	Comments
Broadleaved plants	
Acer pseudoplatanus	Difficult, few cuttings produced on stock plants.
Alnus glutinosa and *A. incana*	Generally fairly easy but some clones difficult.
Betula pendula	Generally fairly easy from young stock plants but some clones difficult.
Betula pubescens	Markedly easier than *B. pendula* in the clones tried.
Crataegus monogyna	Considerable clonal variation. Vigorous material from young plants required.
Fagus sylvatica	Very difficult.
Fraxinus excelsior	Difficult, few cuttings produced on stock plants.
Malus sylvestris	Only one clone tested, easy.
Prunus avium	Only one clone tested, easy.
Quercus robur	Considerable clonal variation. Growth of rooted cuttings very slow.
Salix caprea	Considerable clonal variation but most are reasonably easy and some very.
Salix atrocinerea	Clones tested easier than *S. caprea*.
Sambucus nigra	Very easy, even from old plants.
Sorbus aucuparia	Fairly difficult, very few cuttings produced on stock plants.
Ulmus glabra	Considerable clonal variation. Many cuttings die after rooting.
Conifers	
Juniperus communis	Easy but slow.
Larix decidua	Very difficult.
Pinus sylvestris	Considerable clonal variation, rooting very slow.

clones rooted maximally at the end of July, with clones BPe 28, BPu 47 and BPu 86 reaching 100%. Whereas the rooting of the latter two hairy birch clones never dropped below 45% and 30% respectively, silver birch clone 28 failed to root in late June and the percentage for clone 48 of the same species never exceeded 20%. In addition to the July peak, earlier but smaller peaks were detected when rooting clone BPe 28 and BPu 86, this secondary peak occurring in early May and early June respectively.

The same pattern of rooting was found in goat willow with peaks in April/May and again in July. Clones SC 29 and SC 51 rooted more readily than clone SC 42.

Cutting production and their subsequent rooting represent the first stages of plant production. Subsequent losses can be severe. In the period from rooting to being put outside (wean-

Table 2. The rooting percentages of softwood cuttings taken from selected clones of 5 species of woody perennials found growing on industrial waste.

Species and Clone	No. of cuttings put into propagation bed	No. of cuttings rooted	Percent rooting
Salix caprea			
SC 29	220	159	72
SC 42	163	31	19
SC 50	193	160	83
SC 51	229	154	67
SC 76	242	145	60
Salix atrocinerea			
SA 12	559	384	69
SA 90	54	49	91
Sambucus nigra			
SN 20	147	141	96
SN 40	79	71	90
SN 49	184	147	80
SN 63	142	140	99
SN 77	145	137	94
SN 89	19	19	100
Betula pendula			
BPe 28	122	70	57
BPe 34	655	122	19
BPe 48	177	16	9
BPe 64	199	81	68
BPe 73	119	81	68
BPe 92	38	6	16
Betula pubescens			
BPu 47	189	134	71
BPu 86	87	48	55

ing) losses tended to be greatest in clones which were difficult to root, e.g. clones SA 12, SC 42, SN 49, BPe 34, BPe 48 (Table 3). There were, however, exceptions, e.g. clones BPu 86 and BPe 92 with high rates of survival although difficult to root and clones SC 51 and BPe 64 where the situation was reversed. Other observations suggested that survival during weaning paralleled differences in rates of rooting with quick rooting clones having high rates of survival (Table 4).

Like rooting percentages, rates of rooting differed seasonally (Figure 2), with fluctuations greater in birch than in willow. In both species early season cuttings rooted quickly regardless of clone, thereafter the rates tended to be slower. However in birch clones BPe 28 and BPu 47 of hairy birch with large rooting percentages rooted rapidly, silver birch clone 48 with a small rooting percentage, rooted slowly. Goat willow clone SC 29 rooting percentages were subject to major seasonal changes, but rates of rooting remained more or less constant. Although

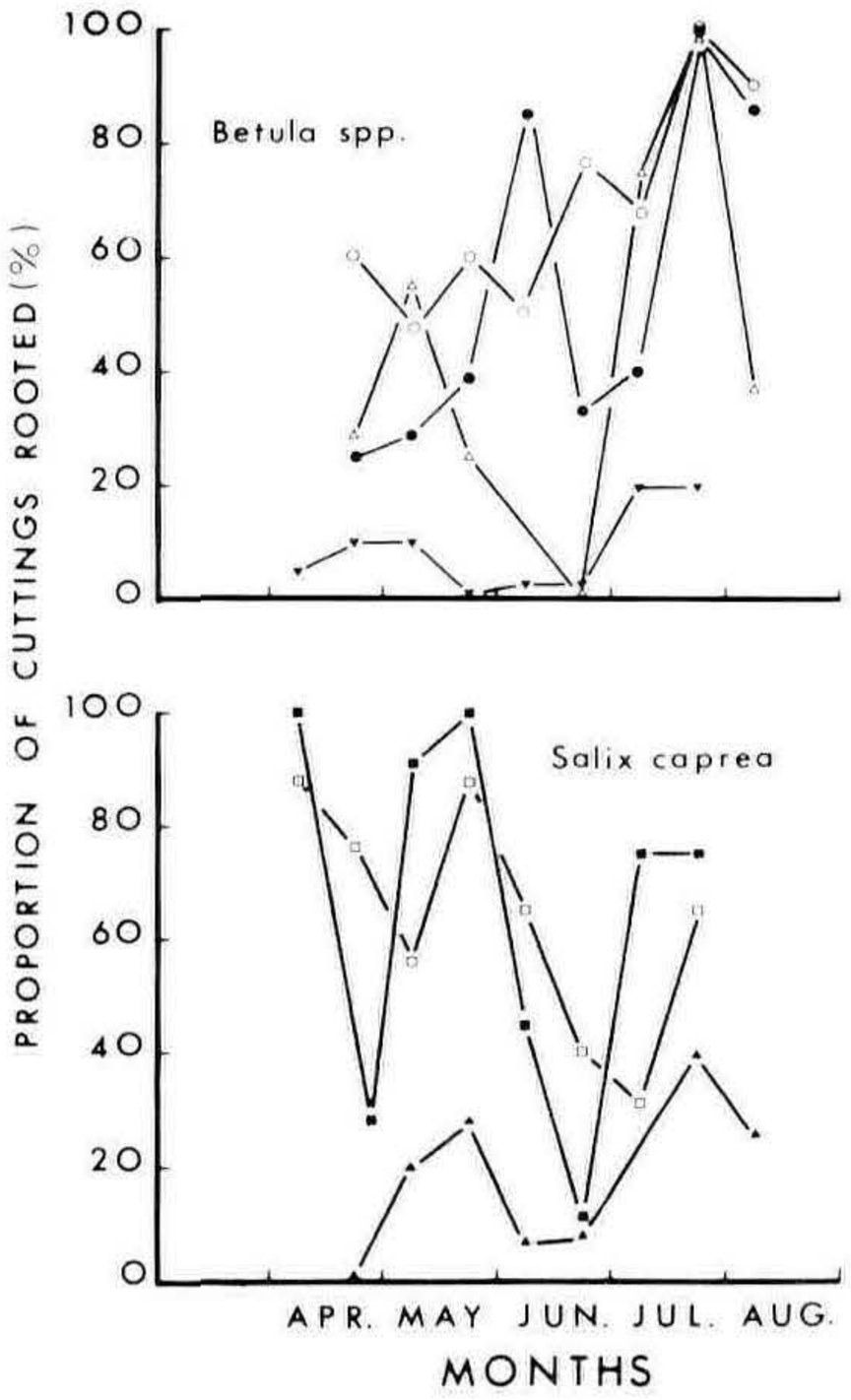

Figure 1. Rooting of cuttings taken at different times of the growing season from selected clones of birch (*Betula pubescens* and *B. pendula*) ○ — ○ BPu 47; ● — ● BPu 86; — BPe 28; ▼ — ▼ BPe 48; and goat willow: (*Salix caprea*) □ — □ SC 29; ▲ — ▲ SC 42; ■ — ■ SC 51.

few cuttings of SC 42 rooted, their rates of rooting were no slower than those of easy to root clone SC 51.

DISCUSSION

Programmes aimed at developing cultivars of woody plants for amenity horticulture and arboriculture, are likely to become involved with the selection of individuals with preferred characteristics, be they of form, foliage colour, flowering habit or, as in the present study, tolerance of infertile and inhospitable sites. So that the suitability of the chosen individuals may be exploited experimentally and, thereafter, commercially, they must be amenable to vegetative propagation — hence the present interest in inherent differences of rooting response. If a clone cannot be rooted it may be difficult or impossible to take advantage of other characteristics.

Using young stock plants, softwood cuttings of a wide range of species have been rooted including some previously regarded as difficult, e.g. sycamore (*Acer pseudoplatanus* L.), common (European) alder (*Alnus incana* (L.) Moench.), European larch (*Larix decidua* Mill), Scots pine (*Pinus sylvestris* L). However, interest was subsequently focussed on producing

Table 3. Rooting Percentages and Survival During Weaning of Softwood Cuttings Taken from Selected Clones of 5 Species of Woody Perennials Found Growing on Industrial Waste.

Species and Clone	No of cuttings put into propagation	No. and percent of cuttings rooted		No. and percent of plants surviving at the end of the period of weaning	
Salix caprea			%		%
SC 29	163	104	(64)	89	(86)
SC 42	133	24	(18)	12	(50)
SC 50	14	10	(71)	8	(80)
SC 51	87	57	(65)	37	(65)
SC 76	242	145	(60)	119	(82)
Salix atrocinerea					
SA 12	446	281	(63)	207	(74)
SA 90	54	49	(91)	47	(96)
Sambucus nigra					
SN 20	60	58	(97)	46	(79)
SN 40	43	39	(91)	38	(97)
SN 49	107	83	(77)	74	(89)
SN 63	79	77	(97)	72	(93)
SN 77	114	108	(95)	100	(92)
SN 89	19	19	(100)	15	(79)
Betula pendula					
BPe 28	58	27	(46)	22	(81)
BPe 34	337	61	(18)	35	(57)
BPe 48	177	16	(9)	3	(19)
BPe 64	129	58	(45)	22	(38)
BPe 73	36	13	(36)	4	(31)
BPe 92	38	6	(16)	5	(83)
Betula pubescens					
BPu 47	117	81	(69)	49	(60)
BPu 86	87	48	(55)	25	(52)

stocks of a wide range of "tolerant" clones of species which occur commonly as colonizers of bare ground, including coal and other spoil tips. Elder, a much underrated woody perennial for use in difficult situations (10), including those subject to vandalism has, as expected, proved easy to root in the period from April to August. Willows and birches have proved less amenable, rates and numbers of rooting cuttings differing seasonally and from clone to clone. In general, the present results confirm that there are spring and late summer peaks in rooting capacity (13,15). However, the timing of the peaks and troughs differed from clone to clone, possibly reflecting differences in the physiological condition of the respective mother plants, although they were handled similarly.

Regardless of the mechanisms involved, undoubtedly related to endogenous auxin levels, it is essential to know the optimal time to obtain rootable cuttings. Thus clone BPu 86 might have been rejected if only the batch of cuttings inserted in late June had been considered because at this time none rooted. One

Table 4. Periods To Root And Survival During Weaning Of Softwood Cuttings Taken From Selected Clones Of 5 Species Of Woody Perennials Found Growing On Industrial Waste.

Species and Clone	Mean period to rooting (days)	Percent survival of potted plants
Salix caprea		
SC 29	18	86
SC 42	25	48
SC 50	23	75
SC 51	32	65
SC 76	21	82
Salix atrocinerea		
SA 12	20	74
SA 90	17	96
Sambucus nigra		
SN 20	20	79
SN 40	19	96
SN 49	18	98
SN 63	16	94
SN 77	16	93
SN 89	20	79
Betula pendula		
BPe 28	34	83
BPe 34	45	58
BPe 48	48	23
BPe 64	47	38
BPe 73	47	31
BPe 92	31	83
Betula pubescens		
BPu 47	29	60
BPu 86	29	51

month later, however, cuttings from the same mother plants gave 100% success. But, of course, periods of optimum rooting may differ from year to year as a result of climatic fluctuation. In the authors' experience these differences are not likely to seriously affect propagation programmes and may be minimized by varying hormone treatments, bed temperatures, and light regimes. Attempts could also be made to root single node sections in aseptic conditions, a technique which has proved successful with a range of birch clones (14). Aseptic culture is especially suited to investigating the precise conditions required for rooting in differing clones since environmental factors can be changed individually or in combination, a matter not easily achieved in standard propagating houses.

The direct relationship between the time for cuttings to root and their subsequent survival during weaning is of considerable importance in maximizing plant output, possibly reflecting their nutrient status. Applying nutrients in mist has favoured rooting of some species but not of others (16). Partly to minimize the growth of algae, mosses and liverworts on propagation beds, the authors favour foliar feeding of potted cuttings using a

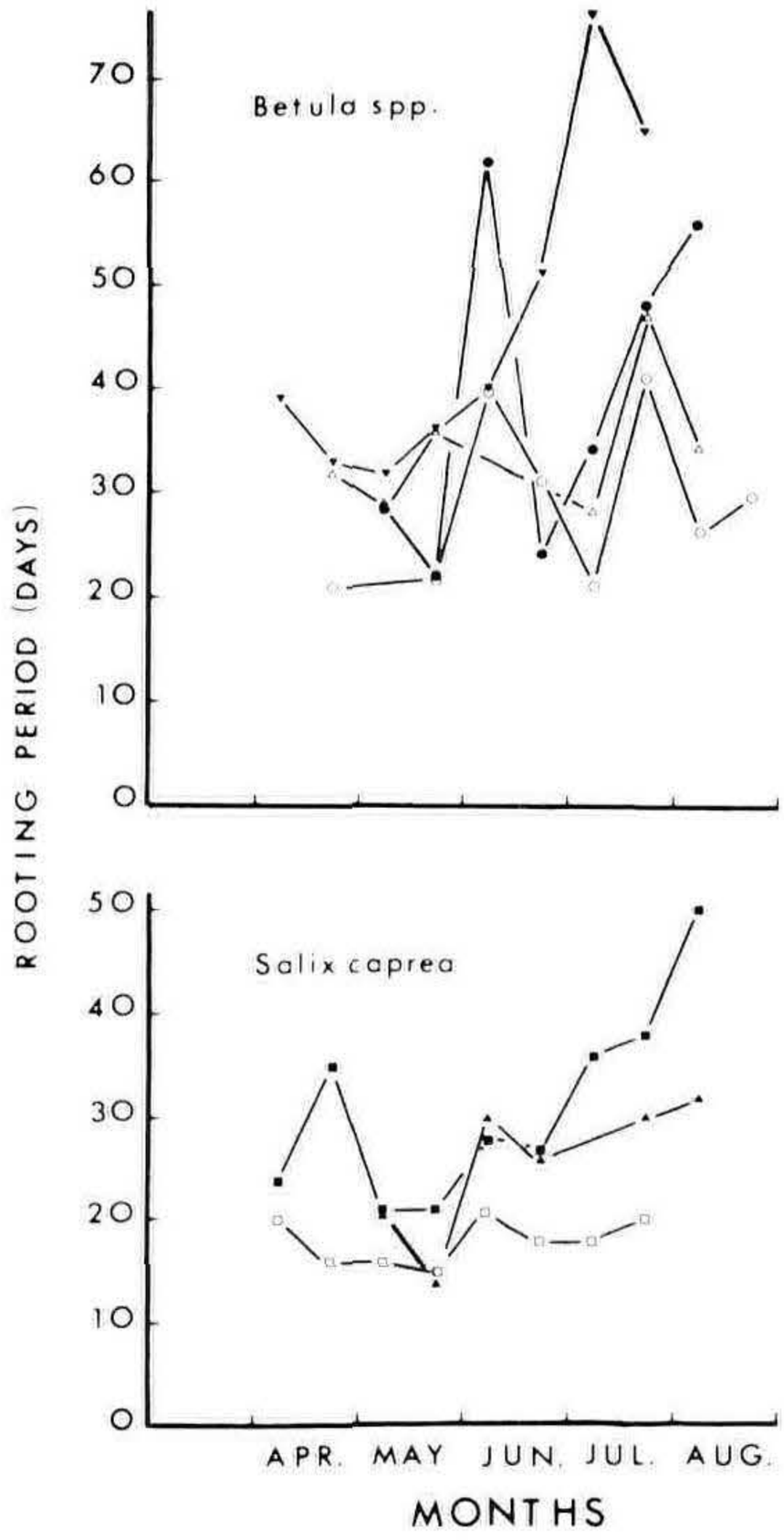

Figure 2. Changes in the minimum period for root development when cuttings were taken at different times of the growing season from birch (*Betula pubescens* and B. *pendula*) ○ — ○ BPu 47; ● — ● BPu 86; — BPe 28; ▼ — ▼ BPe 48, and goat willow: (*Salix caprea*) □ — □ SC 29; ▲ — ▲ SC 42; ■ — ■ SC 51.

pressure sprayer until signs of vigorous new shoot growth are apparent.

Finally, in a paper dealing with the rooting of cuttings it must be emphasized that their quality reflects the management of mother plants which should be kept well fed, free of pests and pathogens, and systematically pruned to encourage the production of numerous strong young shoots.

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THE WORK ON ASSORTMENTS AT THE TREE RESEARCH STATION, BOSKOOP, HOLLAND

H. J. VAN DE LAAR

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Research Station for Arboriculture,
Boskoop, Holland

At the Research Station for Arboriculture at Boskoop is a trial ground where research work is being undertaken regularly on nursery stock, for example, collections and trials with new cultivars. Quite a lot of shrubs are brought together here to examine their use in gardens and plantations.

The judging committee of the Royal Boskoop Growers Association criticises plants at shows (for example Flora Nova). These plants may be awarded a prize of a gold or a silver

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The judging committee of the Royal Boskoop Growers Association criticises plants at shows (for example Flora Nova). These plants may be awarded a prize of a gold or a silver

medal. New selections have been planted at the owners' nursery, or at the trial ground. They will be criticized several times and eventually awarded with an Award of Merit or a First Class Certificate.

Another type of judging work is that of plant collections as complete as possible. These plants will be criticised several times and provided with merit stars as follows: — *** = excellent;** = very good; * = good; s = for special purposes; o o = can be eliminated. This type of judging work is the most valuable one. (See Table 1).

Some of the criticised genera in the last few years are: *Berberis, Betula, Buddleia, Calluna* and *Erica* (yellow-leaved cultivars), *Cytisus* and *Genista, Fagus, Hydrangea, Ilex, Mahonia, Rhododendron repens* hybrids, *Robinia,* and *Spiraea.*

During the judgment of these collections attention is paid to their growth, flowering, resistance to diseases, winter hardiness, etc. Moreover, attention is paid to the reduction of the number of species and cultivars. This is important as well. There is no sense in growing very extensive collections. Too many cultivars resemble another one.

Table 1. Results of Judging in a Recent Trial.

Genus	Total	***	**	*	s	?	o
Berberis	95	7	17	22	2	9	38
Buddleia	34	1	6	6	1	3	17
Cytisus hybrids	38	8	8	9	—	—	13
Hibiscus syriacus	31	3	8	7	—	—	13
Hosta	35	2	6	7	3	—	17
Hydrangea	23	3	6	7	1	—	6
Mahonia	23	4	3	2	1	8	5
Malus	98	5	19	19	3	6	64
Potentilla fruticosa	30	4	3	6	2	1	14
Pyracantha	19	3	1	1	3	1	10
Rhododendron hybrids	197	14	27	50	1	—	105
Rhododendron mollis hybrids	77	12	17	16	—	—	32
Spiraea	45	4	8	11	7	—	15
Total	745	70	120	154	24	28	349

At the moment, Dutch growers are producing around 500 different species and cultivars of *Calluna* and *Erica.* This is an unacceptably large number for most people. On that account an advisory body of 10 persons, all members of the Dutch Heather Society "Ericultura", compiled a list of recommendations. This list is classified in 5 groups. Groups A, B and C (together 190 cultivars) include all valuable ones. Group D contains 170 species and cultivars of less value. The committee asks that these heathers be not propagated any longer. They are very similar to other cultivars, or they are less hardy under Dutch

climatical conditions. The remainding part of 130 heathers are put into group E. These are mainly new cultivars or less known and they will be judged on their usefulness and ornamental value in the coming years.

It looks as though in this group there will be novelties, and improvements on the older cultivars which can put them into groups A, B and C.

It stands to reason when a comprehensive assortment of a genus is cultivated, confusion is to be expected. In the past 10 to 15 years the correct naming of callunas and ericas on many nurseries in Holland has been checked. In several nurseries and also in collections, the naming of these plans was incorrect. It is of frequent occurrence that a cultivar has been grown under different names; for example, *Erica cinerea* 'C.D. Eason' has been found under 15 different names in Dutch nurseries. One of the Dutch well-known heather growers grew this cultivar under 6 different names, as: 'C.E. Pearson', 'Splendens', 'Fulgens', 'Rosabella', 'Rosea', 'David Eason', etc.

Another example: In 1964 the naming of the hostas on Dutch nurseries was checked. In those days they grew 25 different species and cultivars. Many were incorrectly named:

Hosta — On labels in 28 nurseries (171 lots) in 1964

Correctly named	Synonyms	Wrongly named and wrong indications of leaf colour, sizes, origin etc.	Unknown (no names)
11	71	63	26

In the coming years we will do research work on the following collections already assembled: *Acer palmatum* (purple-leaved cultivars), *Actinidia, Amelanchier, Cornus* (large flowering types), *Epimedium, Euonymus, Fothergilla, Hamamelis, Hebe, Hedera, Hosta* (new cultivars), *Juniperus* (creeping and low growing forms), *Magnolia, Parthenocissus, Pieris, Potentilla, Pyracantha, Salix* (dwarf forms) and *Skimmia*.

Since 1963 most winters in the Netherlands have been mild to very mild. Some years ago the judging committee decided to plant quite a number of shrubs, which are in fact not hardy under Dutch climatical conditions. These are, for example, the most hardy: *Cistus, Escallonia, Eucalyptus, Fuchsia, Hebe* and *Senecio*. Besides, several plants from the Himalaya were obtained from seed which had been collected by Len Beer, Roy Lancaster and Dave Morris in East Nepal in 1971. These are: *Betula utilis, Hypericum hookeranum, Ilex dipyrena, Sambucus adnata* and *Spiraea arcuata*. In addition, there are the plants which I myself collected in East Nepal in 1973 under Roy Lan-

casters' leadership. These are, among others: *Acer campbellii, Berberis erythroclada, Berberis hookeri, Cotoneaster cavei, Daphne bholua, Juniperus recurva, Lonicera glabrata, Osmanthus suavis, Rhododendron campanulatum, Sarcococca hookerana, Vaccinium nummularia, V. retusum* and *Viburnum grandiflorum*.

During the judgment of plants on their usefulness and ornamental value, first attention is mostly paid to the correct naming. During the last few years quite a lot of research has been done in the genera *Amelanchier* and *Skimmia*. We have imported much material especially of *Amelanchier* from England, America, Canada, Germany, Poland and Sweden.

The Skimmias are also muddled up. We know that we are going to open a "can of worms". In spite of that, we are hopeful to get, after some years, a selected group of valuable and named clones which we will propagate vegetatively and which we will distribute to nurserymen. In this way we are trying to get more uniformity in this genus.

According to dendrological reference books *Skimmia* × *-foremanii* (*S. japonica* 'Foremanii') is a female plant. The plants which Dutch nurserymen grow on a lavish scale under this name, are male plants, namely the valuable plants normally being grown as *Skimma japonica* 'Rubella' in Great Britain. The Boskoop Research Station also verifies the names on tree nurseries in Holland. This is an important aspect in view of the export of nursery products, as is the importation of new cultivars which we propagate and distribute to nurserymen when it appears that they have commerical value. We also supply cuttings and scions of correctly named plant material. For many years the Research Station has distributed a great many scions of awarded *Hibiscus syriacus* cultivars. We examine unknown plants for nurserymen. This work is of frequent occurrence because there are so many nurserymen with only a little knowledge of plants.

In addition to the judging committee of the Royal Boskoop Growers Association, the N.A.K.-B. (General Netherlands Inspection Service) has a separate selection committee for street trees. This official body possess gardens with mother-plants, from which very large quantities of correctly named and healthy propagating material to nurserymen is supplied.

New cultivars have to be, in the first place, an improvement over other older cultivars. They have to be clearly different from these older cultivars. New selections have to be distinguished by:

a. better leaf and/or flower colour
b. better form of the flowers or the flower trusses

c. more floriferous and/or a longer period of flowering
d. better and/or larger fruits
e. more frost resistant
f. resistant to all sorts of diseases
g. other properties (for example ground-covering)
h. easy or better to propagate (important for growers)
i. easy or better to grow (important for growers)

All these qualifications are important factors in the decision whether new selections will be given an award or not.

The results of all this work, including descriptions of new cultivars and plants given awards is published regularly in "Dendroflora", a yearly publication of the Royal Boskoop Growers Association and the Dutch Dendrology Society.

Another aspect of the work is giving instructions to nurserymen in nomenclature. The Information Service of the Ministry of Agriculture has distributed a folder on a large scale, called: "Naming of Plants". This pamphlet is also used at Horticultural Colleges.

Cultivars, raised and awarded in Holland since 1958

Acer negundo 'Flamingo'
Berberis × *frikartii* 'Amstelveen'
Berberis × *media* 'Red Jewel'
Berberis thunbergii 'Bagatelle'
Berberis thunbergii 'Helmond Pillar'
Buddleia × *weyerana* 'Sungold'
Calluna vulgaris 'Allegro'
Calluna vulgaris 'Carmen'
Cedrus deodars 'Golden Horizon'
Chamaecyparis lawsoniana 'Alumigold'
Chamaecyparis lawsoniana 'Blue Surprise'
Chamaecyparis lawsoniana 'Golden Wonder'
Chamaecyparis lawsoniana 'Pixie'
Chamaecyparis lawsoniana 'Stardust'
C. obtusa 'Fontana'
Clematis montana 'Tetrarose'
Cotinus coggygria 'Red Beauty'
Cytisus 'Dukaat'
C. 'Frisia'
C. × *praecox* 'Allgold'
Daphne mezereum 'Ruby Glow'
Elaeagnus pungens 'Goldrim'
Escallonia 'Red Elf'
Forsythia ovata 'Tetragold'
Genista tinctoria 'Golden Plate'
Hamamelis mollis 'Sunburst'
Ilex aquifolium 'Golden van Tol'
Ilex aquifolium 'Silver van Tol'
Juniperus squamata 'Blue Carpet'
Juniperus squamata 'Blue Star'
Mahonia aquifolium 'Apollo'
Paeonia lactiflora 'Pink Giant'
Pernettya mucronata 'Crimsonia'
Pernettya mucronata 'Lilian'

Pernettya mucronata 'Parelmoer'
Pernettya mucronata 'Rosalind'
Pernettya mucronata 'Signal'
Pernettya mucronata 'Sneeuwwitje'
Pernettya mucronata 'Wintertime'
Picea abies 'Little Gem'
P. glauca 'Alberta Globe'
P. pungens 'Blue Trinket'
P. pungens 'Hoto'
Pinus heldreichii 'Satellit'
P. mugo 'Ophir'
Platyeladus orientalis (syn.: Thuja orientalis) 'Golden Surprise'
Rhododendron 'April Glow'
Rhododendron 'Baron van Dedem'
Rhododendron 'Concorde'
Rhododendron 'Directeur Dorsman'
Rhododendron 'Dr. Tjebbes'
Rhododendron 'Ingenieur Harmsen'
Rhododendron 'Karin'
Rhododendron 'Linda'
Rhododendron 'Manderley'
Rhododendron 'Primeur'
Rhododendron 'Sacko'
Rhododendron (azalea, Japanese) 'Jan Wellen'
Rhododendren (azalea, Japanese) 'Lily Marleen'
Rhododendron (azalea, Japanese) 'Mahler'
Rhododendron (azalea, Japanese) 'Silvester'
Rhododendron (azalea, Japanese) 'Wintertime'
Rhododendron (Knap Hill-Exbury hybrid) 'Golden Flare'
Rhododendron (Mollis hybrid) 'Dinie Metselaar'
Rhododendron (*viscoas* hybrid) 'Arpège'
Rhododendron (*viscosa* hybrid) 'Carat'
Rhododendron (*viscosa* hybrid) 'Diorama'
Rhododendron (*viscosa* hybrid) 'Jolie Madame'
Rhododendron (*viscosa* hybrid) 'Rosata'
Symphoricarpos × *chenaultii* 'Elégance'
Taxus baccata 'Raket'
Taxus baccata 'Summergold'
T. cuspidata 'Rustique'
Vaccinium vitis-idaea 'Koralle''
Viburnum plicatum 'Cascade'
Weigela 'Ballet'
Weigela 'Eva Supreme'
Weigela 'Fiesta'
Weigela 'Rosabella'

Plants imported from other countries, awarded in Holland.

Acer palmatum 'Burgundy Lace'
Acer palmatum 'Butterfly'
Acer palmatum 'Crimson Queen'
Acer palmatum Red Pygmy'
Acer palmatum 'Seiryu'
Caryopteris × *clandonensis* 'Kew Blue'
Chamaecyparis nootkatensis 'Tatra'*
Chamaecyparis obtusa 'Green Diamond'*
Clematis 'Rouge Cardinal'
Clematis 'Voluceau'

Cotoneaster (*dammeri* hybrid) 'Eichholz'
Hamamelis × *intermedia* 'Diane'
Hamamelis × *intermedia* 'Winter Beauty'
Ilex 'Washington'*
Juniperus chinensis 'Mint Julep'
Juniperus chinensis 'Robusta Green'
Picea abies 'Frohburg'
P. × *mariorika* 'Machala'*
Pinus parviflora 'Negishi'
Potentilla *fruticosa* 'Red Ace'
Rhododendron 'Anna Rose Whitney'
Rhododendron (azalea, Japanese) 'Campfire'
Rhododendron (*repens* hybrid) *Monica**
Rhododendron 'Rêve Rose'
Rhododendron (*will.* hybrid) 'Bremen'
Sambucus racemosa 'Sutherland'
Taxus × *media* 'Parade'

*Named in the Netherlands

Other new Dutch cultivars

Acer palmatum 'Trompenburg'
Actinidia chinensis 'Buitenpost'
Alnus × *cordinca* 'Sipkes'
Arctostaphylos uva-ursi 'Rax'
Berberis = *ottawensis* 'Forescate'
B. thunbergii 'Dart's Red Lady'
B. thunbergii 'Pink Queen'
Calluna vulgaris 'Boskoop'
Calluna vulgaris 'Dart's Gold'
Calluna vulgaris 'Dirry'
Calluna vulgaris 'Marleen'
Calluna vulgaris 'Roland Haagen'
Campsis radicans 'Florida'
Colutea × *media* 'Copper Beauty'
Cytisus purgans 'Aleida'
Daboecia cantabrica 'Cinderella'
Erica cinerea 'Providence'
E. tetralix 'Ardy'
Fagus sylvatica 'Purple Fountain'
Genista pilosa 'Goldilocks'
Hydrangea aspera 'Mauvette'
H. paniculata 'Kyushu'
Lonicera periclymenum 'Belgica Select'
Physocarpus opulifolius 'Dart's Gold'
Pinus mugo 'Allgäu'
Potentilla fruticosa 'Dart's Golddigger'
Potentilla fruticosa 'Dart's Nugget'
Prunus maackii 'Amber Beauty'
Prunus nipponica 'Spring Joy'
P. nigra 'Mahogany Lustre'
Rhododendron (*Azaleodendron*) 'Ria Hardijzer'
Spiraea × bumalda 'Dart's Red'
S. *nipponica* 'June Bride'
Ulmus 'Dodoens'
Ulmus 'Lobel'
Ulmus Plantijn'
Viburnum × *rhytidophylloides* 'Dart's Duke'
Vitis 'Boskoop's Glory'

New cultivars from abroad, except Great Britain

Acer platanoides 'Royal Red'
Berberis × *ottawensis* 'Auricoma'
Calluna vulgaris 'Carl Röders'
Calluna vulgaris 'Schurig's Sensation'
Chaenomeles × *superba* 'Jet Trail'
Cornus sericea (syn.: *c. stolonifera*) 'Kelsey'
Cytisus 'Luna'
Cytisus 'Palette'
Cytisus 'Roter Favorit'
Euonymus fortunei 'Gold Tip'
Forsythia ovata 'Ottawa'
Hibiscus syriacus 'Russian Violet'
Hydrangea arborescens 'Annabelle'
Hydrangea paniculata 'Tardiva'
Ilex × *meserveae* 'Blue Angel'
Ilex × *meserveae* 'Blue Girl'
Ilex × *meserveae* 'Blue Princess'
Juniperus × *media* 'Gold Coast'
Kalmia latifolia 'Ostbo Red'
Magnolia 'George Henry Kern'
Mahonia japonica 'Hivernant'
Philadelphus 'Frosty Morn'
Pieris japonica 'Purity'
Pieris japonica 'Valley Rose'
Pieris japonica 'White Cascade'
Populus × *canescens* 'Bunderbos'
Potentilla fruticosa 'Goldstar'
Potentilla fruticosa 'Sommerflor'
Prunus laurocerasus 'Rudolf Billeter'
P. virginiana 'Shubert'
Pyracantha 'Mohave' (*P. Koidzumii* × *P. coccinea*)
Pyracantha 'Soleil d'Or' ('Sungold')
Rhododendron 'Scintillation'
Robinia 'Casque Rouge'
Salix 'Hakuro'
Spiraea japonica 'Shirobana'
S. nipponica 'Halward Silver'
Taxus baccata 'Melfard'
Thuja occidentalis 'Danica'
Thuja occidentalis 'Smaragd' ('Emeraude')
Tsuga canadensis 'Jeddeloh'
Viburnum 'Pragense'
V. × *rhytidophylloides* 'Alleghany'
V. sargentii 'Onondaga'
V. sargenti 'Susquehanna'
Wisteria × *formosa* 'Issai'

PROPAGATION OF BULBOUS AND BULBOUS-LIKE PLANTS

LORD SKELMERSDALE

Broadleigh Gardens
Barr House, Bishops Hull, Taunton, Somerset

The plants we are concerned with fall into clearly defined groups. These are:

1) *Bulbs*, which are modified swollen leaves, usually but not always containing the shoots, made up of the compressed flower stem and bud; e.g. narcissus.

2) *Corms*, which are modified stems, with buds externally at the bottom; e.g. crocus.

3) *Stem tubers*, which are modified stems, with buds or eyes at the top; e.g. cyclamen.

4) *Rhizomes*, which are modified stems growing horizontally, either on the surface of or underneath the soil; e.g. some irises.

5) *Stolons*, which are again modified stems growing horizontally, but which have the shoots appearing at the ends and not at the upper surface; e.g. *Scilla adlamii*.

Bulbs are the easiest of all to propagate and do so naturally with usually a year between each stage. The sequence is *offset; single nose; double nose; double nose with offsets*, one — occasionally two; *mother bulb*, i.e. a single nose bulb (occasionally absent) with numerous offsets clinging loosely together and eventually breaking apart to start the cycle again.

Obviously this is a fairly slow method of increase and it is possible to hasten it by the process known as twin scaling. Here one cuts through the bulb with a sharp knife, dividing it into portions containing a pair of leaf scales and, most important, a section of the base plate. These are put in a polythene bag with damp vermiculite (12 parts vermiculite to one of water) and kept at 70°F. After 3-4 weeks adventitious shoots arise around the edges and in between the leaf scales and, in many instances, roots as well. At this stage they are potted up normally in our standard nursery compost of ½ John Innes No. 2 and ½ sedge peat. This process sometimes occurs naturally where the centre of the bulb has been eaten away by the grubs of the Daffodil Fly.

It is important to keep everything free of dirt and disease at all times and it has been recommended (Ticknor - Daffodils 1974) to soak the scales in Benlate at the rate of 1 oz. to 1½ gallons of water for one hour. I have not done this but I do dip

the knife into methylated spirits between cutting up each complete bulb.

There are several ways of producing adventitious bulbs on hyacinths, which I have not practised. These are by removing the whole central portion of the bulb vertically, with an apple corer, when up to 10 bulbils are produced of a comparatively large size, maturing in 2 to 3 years; by cross-cutting a star shape on the base of the bulb, giving about 25 bulbils which mature in 3 to 4 years; and by scooping out the centre of the base plate to the depth of ½" leaving a small ring to hold the bulb together, giving 25 to 50 bulbils maturing in 4 to 6 years. All these operations are usually done in August in a propagating chamber, with high humidity and a controlled temperature of 70-90°F and the bulbils are produced 2 to 3 months later. The whole bulb is planted out in November or December in the usual way and, on lifting the second June, the bulbils are separated and grown on until they are large enough for sale.

Corms are subjects which naturally produce so many offsets that I don't bother to propagate them artificially. Also they usually flower when very small and, given sufficient high potash fertilizer, will quickly come to a saleable size. In nature they are also propagated by seed (see below).

Stem Tubers may also propagate by seed in nature. However this is not always satisfactory, especially when it is not produced in sufficient quantities. Cyclamen and potatoes are tubers (although the former is traditionally but wrongly referred to as a corm). Cyclamen can be propagated in two ways. Firstly by cutting them to pieces, each with an eye. This is not normally done as the eyes are often indistinguishable. They do not require any heat. Secondly, many cyclamen produce stalks on top of the tubers and these may be cut off when dormant and treated as hardwood cuttings in gentle bottom heat. For many years this was the only way of propagating *Cyclamen rohlfsianum*.

Dr. D. Meikle, senior botanist at Kew Gardens, reported that the seedleaf of cyclamen seedlings can be removed and treated as a softwood cutting. Cyclamen seedlings apparently have a second immature seedleaf which does not develop unless the first one is damaged. (Ref. Cyclamen Society Conference Sept. 1978; to be published spring, 1979).

Rhizomes are easily propagated by the method used for root cuttings. They reproduce best by just cutting off the current season's growth at the node; they will produce shoots both from the new and the old portions. However, it is not always realised that by cutting at each node along the rhizome each portion will grow in time. Heat is not required.

Stolons are a most unusual form of natural corm reproduction. Indeed I can only think of three examples — *Crocus nudiflorus, Scilla adlamii* and *Erythronium americanum*. These produce stolons from the base of the parent corm and, after a year, the tips form corms of their own, sever themselves from the parent bulb, usually by rotting, and the process starts again. This *can* be hastened by removing the stolon before the new corm is formed but it often takes as long for the new corm to arrive at flowering size as it would do naturally, so I do not bother.

All the foregoing is, of course, on the methods of vegetative propagation. Last, but not least, we must consider sexual reproduction. Seed is our chosen method of propagating as many of the subjects that we grow as possible. It is, however, only applicable to species and to a very few "fixed" hybrids. Until recently almost all our seed sowing was done using 2¼" deep plastic seed boxes with our standard nursery compost already referred to. All the seed was covered by sieved compost to a depth of ¼". The boxes were kept in a cold glasshouse. We are now sowing more and more seed in drills in sleeper-edged beds which can be covered with shading material or Dutch lights as necessary.

Depending on the subject, the seedlings mature in 2 to 10 years which can make for a very expensive bulb. Trillium seeds, for example, exhibit double dormancy; I have had some success in mixing the seeds with damp vermiculite and putting them for six weeks in a domestic freezer box, followed by six weeks in the airing cupboard, then back in the freezer for six weeks and then finally sowing them. It has been suggested to me, however, that the second period of freezing should be delayed until the spring, as Trilliums put down their first root after the first freezing and will not produce cotyledons until after the root has been frozen. I am intending to put this to the test this autumn (1978).

Question. Many cyclamen, e.g. *C. coum*, do not produce "trunks" — are they then propagated by seed?

Answer. Yes, but most cyclamen will produce "trunks" if planted deeply enough (this is seen by recent collections from the wild, including C. coum.

Question. I have read about a method of producing adventitious buds on plants of *Trillium* species by cutting away a broad band at the base of the bud. Have you done this?

Answer. No, but I, too, have read of this and will have to experiment with it.

PROPAGATION OF PLANTS IMPORTED FROM NEW ZEALAND

PETER CATT

Liss Forest Nursery,
Petersfield Road, Greatham, Hampshire

I first bought liner stock from New Zealand in 1974. The plants arrived at London Airport on Sunday, were cleared by customs on Monday, and I collected them on Tuesday morning. That same afternoon they were potted.

This was only a small order consisting of: 25 *Abelia grandiflora* 'Francis Mason'; 25 *Yucca filimentosa* 'Variegata'; 10 *Pieris japonica* 'Pink Delight'; 10 *Pieris japonica* 'Scarlet O'Hara'; 10 *Pieris japonica* 'White Caps'; and 10 *Pieris japonica* 'White Cascade'.

It was the *Pieris* that most interested me at that time as I was specialising in ericaceous subjects. I bought the other plants out of interest. In fact, since that time, I have widened my field of production, and annually increase my production of *Abelia* and *Yucca* as they are beautiful plants and sell very well.

Abelia grandiflora 'Francis Mason' has a green and gold variegated foliage and should be grown in full sun to bring out the best colour.

We take cuttings in May or June using a peat/grit mix. They root in about 4 weeks and are then potted into 3½" pots and stood in a polythene tunnel to grow on. We pot from 3½" pots to 6¼" containers.

Yucca filamentosa 'Variegata' has a creamy yellow variegation with, at times, a pink edge. These we propagate by removing the small toes around the base of the plants we are potting from 3½" pots to 6¼" containers in the spring. The young bits are boxed up and kept shaded in a frost-free glasshouse until they show signs of activity when they are put outside to grow on. In the spring they are potted into 3½" for another year.

The *Pieris* cultivars are propagated mainly in the autumn under mist. No hormone is used as we get a good take without it. No problems were experienced with the establishment of this first batch of plants which were all potted into 3½" pots and placed in a glasshouse with some shade, where they stayed for the rest of that year and into the spring of 1975. The house we kept frost free.

The following year I bought *Cortaderia selloana* 'Aureolineata'; *Phormium cookianum* 'Tricolor'; *Phormium tenex* 'Bronze Baby'; *Phormium tenex* 'Radiance'; and *Yucca filamen-*

tosa 'Variegata'. These arrived on 21st July 1975 and all grew away well.

The Phormium were large plants and were potted into 6¼" containers. Unfortunately, a wet spell followed by a heavy frost killed many. The worst to suffer being *Phormium tenex* 'Bronze Baby'. I have never bought any more of this plant but one that did survive was divided up this year and made 13 nice plants. I think that *Phormiums* should be over wintered the first year after importation in a glasshouse or polythene tunnel. Home produced plants from seed are definitely tougher. I raise quite a few from seed each year and have no trouble.

Cortaderia selloana 'Aureo-lineata' is propagated by division in May or early June when we experience no problems.

In 1976 I received one consignment in March which consisted of: *Cordyline australis* 'Purpurea' (*C. australis* 'Atropurpurea'?); *Pittosporum tenuifolium* 'Irene Patterson'; *Pittosporum tenuifolium* 'James Stirling'; *Camellia sasanqua* cultivars; *Citrus limon* 'Meyer'; and *Aucuba japonica* 'Picturata'.

No problems were experienced with any of these plants, though the camellias took another season before they grew well.

Cutting of *Pittosporum tenuifolium* 'Irene Patterson' proved very difficult to root. We took the cuttings in the autumn, as we do with our other *Pittosporum* cultivars, but of 350 cuttings taken only 35 rooted. Cuttings of *Pittosporum tenuifolium* 'James Stirling' root like weeds and grow nearly as fast.

In September, 1976, I received *Cortaderia* 'Aureo-lineata' and these have been grown in two different ways. We potted them into 5" pots to carry them through the winter. All the young plants grew well but the old splits never grew and eventually died. This *Cortaderia* is a beautiful plant with gold variegation.

I also had some *Pieris japonica* 'Flamingo' which I had to look after very carefully during the following winter. This *Pieris* didn't flower properly until this year. It is an outstanding introduction having deep pink flowers.

Magnolias were the next subject I imported; these arrived in early June. This was the first deciduous plant that I had imported but no problems were experienced. They were potted into 3½" pots and put into a polythene tunnel which was shaded because of the heat of that summer. They came into leaf a few weeks later and grew well, making plants which were potted the following spring into 6¼" and 8¼" containers and were ready for sale the autumn of 1977.

The cultivars were: *Magnolia soulangeana* 'San Jose' which has large, fragrant, rose pink flowers; *M. Kobus var stellata*

'King Rose' which has pink buds opening blush pink; *M. kobus var. stellata* 'Royal Star' which has pure white flowers and is later than other cultivars; and *M. kobus var. stellata* 'Water lily', with it's fragrant white star-shaped flowers.

Plants of *Pyracantha coccinea* 'Harlequin' did not travel well, and more than half of them rotted. They are, however, very easy to propagate by cuttings taken in October and placed under mist.

Because of a demand for *Photinia* × *fraseri* 'Red Robin', I bought in liners in April 1977, which we potted into 3½" pots and later the same year into 6¼" containers. Again, they grew well and all made saleable plants by autumn. This is another line that is easy to root, so once we have sufficient stock plants of our own there will be no need to import.

This year I received some *Magnolia grandiflora* 'Russet' having white flowers and bright russet on the underside of the leaf, and *M. grandiflora* 'Samuel Sommer' which has large creamy-white fragrant flowers, and produces flowers at an early age. These arrived in early April. They were potted into 6¼" containers and stood in a frost-free glasshouse. Plants of *Magnolia* 'Russet' are very tall, up to 2 ft. and so I cut them back to about 1 ft. So far (3 months later) they haven't grown any, but there is good root development. They were moved outside at the beginning of July. Plants of *Magnolia* 'Samuel Sommer' were not stopped, but they have not started growth yet either.

Because I experienced problems with rooting *Pittesporum* 'Irene Patterson' cuttings, I bought in another batch this spring. This has a very pretty mottled leaf, sometimes almost white. They were large plants for liners and I didn't like the look of the roots, which had, of course, been washed clean. We lost 200 of the 250 ordered.

The *Pieris*, too, arrived in a very poor condition and most of these died. The reason apparently was the very hot autumn (our spring) in New Zealand which caused the plants to grow very soft. Along with my June consignment was *Parrotia persica* which arrived with their autumn foliage. These were potted into 6¼" containers and stood outside where they are now breaking well and I think will make saleable plants by the autumn.

Another new line for me is *Wisteria sinensis*. These arrived in June, were potted into 6¼" containers and stood outside. So far they have not broken dormancy.

To sum up, I am very pleased with the plant material I have imported from New Zealand. It is beautifully packed, documentation is minimal, it is sent C.I.F. — Carriage/Insurance/

Freight to London Airport and the supplier always treats complaints sympathetically. There is duty to be paid which is between 1/5 and 1/6 of the quoted price, and there is delivery and dispersement from the airport to you. I always collect at the airport, however, as I then know there is a minimum delay before the plants are obtained.

PROPAGATION OF CONIFERS BY CUTTINGS AND GRAFTING

ANTON THOMSEN
Thomsens Planteskole
9200 Aalborg SV
Denmark

PROPAGATION BY CUTTINGS

Propagation of conifers by cuttings is the most common method used, but there are usually several different ways of treating cuttings of the same cultivar. More than once I have seen another nursery propagating a cultivar which we find difficult; they tell me how they do it, I go home and do exactly what they told me using the same peat, same hormones, at the same time and everything, but still I don't achieve the results as they do.

We have almost all our cuttings in our propagating glasshouse which is 20 × 61 m and made of aluminum. All the cuttings are inserted in plastic flats 30 × 60 cm with holes in the bottom so the compost can be in direct contact with the sand on the floor of the glasshouse. That way the capillary system can work so the compost does not get too wet. This also means that the flats are the furthest practical distance from the mistlines so the mist can cover the cuttings with the required minimum of water, in just a few seconds.

Almost all cuttings are inserted in a layer of sand with a low pH, about 1½ cm thick, upon a layer of peat mixed with a little sand in order to make it easier to separate the cuttings when they are lifted. A few years ago we used pure peat much more, but we feel that our results justify the greater effort of putting 2 separate media in the same flat; now we only use pure peat for a few cultivars.

We have plastic pipes 25 cm underground and 50 cm apart to heat the soil to 22°C in the summer and down to 12°C in the winter. During the winter we try to keep the temperature of the air at about 5°C. We have automatic shading controlled by a

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photocell which also turns the shades on at night which saves energy.

Almost all cuttings are dipped in a rooting hormone, usually Floramon C which contains 0.4% naptacid and 10% captan in a 50:50 ratio. If the same plant is propagated both summer and winter, we use only ½ strength hormone in the summer. Quite a few of the cuttings also root well under a plastic tent with bottom heat. This is, of course, a cheaper set-up and by working with cuttings for several years we seem to have found out which cultivars do best under mist, which do best under plastic tunnels, and those which root well in either one. We also get good results with plastic tunnels in the open.

Once a week all the cuttings are sprayed with benomyl or Euparen, the latter especially at low temperatures.

We have tried taking cuttings in November, keeping them in coldstore at −4°C and inserting them in the flats in March. One year the results were as good as those obtained with fresh cuttings; another year the results were not so good, though this might be accounted for by the fact that the temperature rose to +4°C for about 14 days on account of poor inspection.

I consider it of great importance to have top quality stock plants; and we have almost 2 hectare of different stockplants. These must be carefully selected for that purpose, must be regularly replaced, especially as some grow poorly after being cut back every year; they must be in a good healthy condition and well fed.

After rooting has begun, the cuttings are watered every week with liquid fertilizer, usually with the Hornum mixture which contains both major and minor nutrients, at a strength of ½ ppm.

Below are a few comments on the timing and the media we use for the different species:

Chamaecyparis: Cuttings are made in August and September, although good results can be obtained at almost any time of the year. Sand is the medium we use for all of them and all are treated with Floramon rooting hormone.

Juniperus: These are propagated from July until November, starting with *Juniperus horizontalis* cultivars which we do not treat with hormone, then *Juniperus chinensis*, *Juniperus virginiana*, and finally *Juniperus communis* cultivars. All are treated with Floramon and inserted in sand, except *Juniperus scopolorum* "Blue Pyramid" for which we use peat.

Picea: *Picea glauca* 'Conica' and *Picea abies* 'Nidiformis' are taken in early July and inserted in sand in plastic tunnels outside, without being treated with hormones.

Taxus: These cuttings are made from September to December and we now use only peat with a layer of sand for almost all of them, but peat and perlite, which we formerly used, also gave very fine results. This year we tried some of the rockwool Grodan blocks and the results have been pretty good though not better than in sand. Maybe they will grow faster after being potted; that remains to be seen.

Thuja: Cuttings of *Thuja occidentalis* cultivars are almost all made in the spring, though good results have been obtained from all except *Thuja occidentalis* 'Pyramidalis' taken in July and August. Floramon is applied and sand and peat layers are the medium used.

PROPAGATION BY GRAFTING

I am supposed to be a specialist on grafting, and I have had quite a number of years of practice, but it seems to be more and more difficult to decide which is the best method of grafting for the different cultivars of plants. I must admit that I was much better at it 30 years ago.

We only graft plants that we are not able to propagate satisfactorily any other way as this is the most expensive type of propagation. In some cases we graft cultivars which, although they take easily enough from cuttings, do not grow fast enough. For instance, *Chamaecyparis obtusa* 'Nana Gracilis' from cuttings grows very slowly and seems to continue to do so for the rest of its life and, for this reason, is usually grafted.

. It is very important, when you graft, that all the factors under your control are right; the understock must be carefully selected and potted or heeled in at the right time; the scion must be in fine condition when taken and not allowed to dry out at any moment; the grafter must keep his knife sharp and clean; the temperature during aftercare must be correct, etc. . . . I have found that even if the grafter is not too careful about the way he fits and ties the scion to the understock, the results may be fine given the correct aftercare. For instance, when grafting *Chamaecyparis*, *Juniperus* and *Betula* there is little difference between the results of different grafters; however, *Picea* cultivars are exceptions where a skilled grafter is needed.

As skilled nurserymen become more and more scarce and the working hours get shorter and shorter, it becomes increasingly necessary to let automatic gadgets take over the job of supervising. Our results improved considerably after we had automatic shading, ventilation, basal and air heating installed. Some of the things we know little about is what the influence of weather conditions during the summer and winter before have on the scionwood. I have heard that one should only take

the scions when the temperature is above 0°C, but, if this were the case, we would be unable to do any grafting some years as we do all our grafting between December and March and in some years we have below freezing temperatures for maybe 2 months, yet these years we can still get fine results. Other years, such as the winter of 1977-78, where we had fairly warm weather until late February, we had poor results on some of the cultivars we consider easy, even though all the factors seemed to be perfect, yet we had good results on one of our most difficult plants, the Thomsen Blue Spruce. We graft during the winter for at this time we have available the necessary skilled labour, whereas we are always short during the summer.

We use a rubber band specially made for grafting by MEYER in Germany for tying and we use a bow-type knot that comes undone easily when you pull one end.

Aftercare of the grafts is of utmost importance, and particularly so during the first 6 weeks. We keep the grafts either under a plastic tent heeled in sphagnum peat with the union uncovered. This must be done carefully, for if any part with needles is covered, and this applies especially to *Picea*, the scion usually dies. After about 5 to 8 weeks we start to cut the understock back, usually in 2 stages about 4 weeks apart. On all grafts the rootstock top is completely removed one month before we pot them on into one or one-and-a-half litre plastic pots after the new shoots have matured, although on all *Picea* we leave a small part of the understock with a few branches, which are to be cut off the following spring. This seems to give better results. After being heeled-in all the grafts are sprayed with Benlate once a week and, a few weeks after grafting, the plants are also given liquid fertilizer once a week at ½ ppm.

I cannot say that we always have fine results. I am ashamed to say that it often seems when I talk to colleagues from other nurseries, that they always have results of at least 90% each time, while I am satisfied with 60-90% saleable plants; that is a percentage taken 6 months after grafting. A result of less than 50% is unsatisfactory.

There are many ways you can graft a certain cultivar depending on where you live, the way the business is run, time and labour managed, whether you have greenhouse or outdoor facilities, etc. . . .

I shall briefly describe below how we graft the different genera.

Abies: We graft quite a range of *Abies* and consider it an easy plant to graft and usually get fine results. We use *Abies alba* as understock, 3-year-olds for *Abies koreana* and other dwarf cultivars, and 4-year-olds for plants with thicker scions,

e.g. *Abies lasiocarpa* 'Argentea'. In November we heel the bare-rooted rootstocks in peat under glass keeping the soil temperature between 10° and 12°C, raising it to 14°C in January. We graft the plants in January-February when the new white roots are visible. The grafts are heeled-in in peat with the wounds uncovered under a plastic tent and the soil temperature is raised to 16°C in February.

Cedrus atlantica 'Glauca' is grafted onto *Cedrus deodara* and treated in the same way as *Abies*, but here we still have a rather valuable plant even if the graft fails.

Chamaecyparis: the only cultivar we graft here is *Chamaecyparis obtusa* 'Nana Gracilis', as our climate is too harsh for the more sensitive cultivars. We propagate quite a few cultivars by cuttings that were previously always grafted, e.g. *Chamaecyparis lawsoniana* 'Hollandia', *Chamaecyparis lawsoniana* 'Lanei', *Chamaecyparis lawsoniana* 'Aurea Kelleriis', ('Kelleriis Luteà') the hardiest of the yellow types, *Chamaecyparis lawsoniana* 'Stewartii', etc. . . . *Chamaecyparis* can be grafted in December and are, therefore, the first to be grafted. We use a side-graft leaving a flap from the understock to cover the scion, and treat the grafts similar to *Abies*.

Juniperus: We do not graft many cultivars today as we can propagate almost all of them by cuttings. We only graft *Juniperus chinensis* 'Blaauw', as this method gives a saleable plant much quicker, and *Juniperus scopolorum* 'Blue Heaven' because our results from cuttings are too poor and we also get rather a nice plant within a few years. We use *Juniperus chinensis* 'Hetzii' as understock; they are potted up and can be grafted any time between December and April. We like to leave a small opening in the bottom of the flap of approx. ½ mm which will be filled with callus within a few days.

Picea: Most cultivars are grafted onto *Picea abies* and, if possible, we like to use 2 to 3 year old rootstocks, and we certainly do this with cultivars with very thin scions, like *Picea omorika* 'Nana'. But for plants with thicker scions we have to use 4-year-old understock. These are potted up during October and November in the greenhouse; they will have rooted and be ready for grafting in late January. We use a side-graft. The grafted plants are inserted in pure sand in an open bench in the glasshouse and the unions very carefully covered with sand.

We prefer to use 1-year-old scionwood for blue spruce but for the different dwarf types we have to use 2-year-old scionwood. Removing the needles from the scions of *Pinus* and *Picea* without harming the bark can be rather difficult. The method varies from one cultivar to another; some you can cut or scrape off with a knife, but for others you can pull or rub them off.

Formerly we used to wax spruces and quite a few other plants, placing them in open benches, but we find the method described here more successful. We have tried taking the scions in November-December and keeping them in plastic bags in coldstore at 4° Celsius and grafting them in March. Even if the scions looked a bit dry the results were just as good as with newly cut scions. The reason for this experiment was to avoid winter damage and also, in the case of prostrate evergreens, it can sometimes be hard to find cuttings and scions in winters where there is a lot of snow, although this has not been a problem in recent years.

Pinus: We use *Pinus mugo* as understock for all *Pinus*, including the five-needled types. The understocks are potted up in August and moved to the glasshouse in December to be ready for grafting in February. They are usually treated like *Picea* and inserted in sand, but inserting them in peat under a plastic tent with the unions uncovered has also been successful.

Pseudotsuga: These are treated exactly the same as *Pinus*.

Taxus: We graft *Taxus baccata* 'Fastigiata Aurea' and usually use *Taxus media* 'Hicksii' as the understock. They are treated in the same way as *Juniperus*, and they turn out fine when grafted in December. We also grow this cultivar by cuttings but the growth is then slower than when we graft.

IMPROVEMENT OF HARDY NURSERY STOCKS

J. B. SWEET, R. ANNE GOODALL and A. I. CAMPBELL

Long Ashton Research Station
Bristol, Somerset

Selection of plants with improved or new ornamental characters of horticultural value has been a feature of the nursery trade for many years. Nurserymen have been aware of the variation which occurs in plant material and have selected, propagated, named and sold improved cultivars and clones. However, the major attributes considered by propagators are ease of rooting and rapid growth, much less attention being paid to the eventual appearance of the plant. In consequence it is, e.g., the easiest rooting × *Cupressocyparis leylandii* clone, or the more rapid growing *Cornus alba* 'Gouchaltii' cultivar, that is chosen rather than the cultivars with the best appearance when mature.

Recently a more scientific approach to the selection of nursery stocks, coupled with an investigation of their virus diseases, has been initiated in several countries. At Long Ashton propagating material of several common trees and shrubs has

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Selection of plants with improved or new ornamental characters of horticultural value has been a feature of the nursery trade for many years. Nurserymen have been aware of the variation which occurs in plant material and have selected, propagated, named and sold improved cultivars and clones. However, the major attributes considered by propagators are ease of rooting and rapid growth, much less attention being paid to the eventual appearance of the plant. In consequence it is, e.g., the easiest rooting × *Cupressocyparis leylandii* clone, or the more rapid growing *Cornus alba* 'Gouchaltii' cultivar, that is chosen rather than the cultivars with the best appearance when mature.

Recently a more scientific approach to the selection of nursery stocks, coupled with an investigation of their virus diseases, has been initiated in several countries. At Long Ashton propagating material of several common trees and shrubs has

been obtained from twelve commercial nurseries and grown under standard conditions. Examination of the material revealed several causes for their variability. There was considerable misnaming of certain cultivars. For example, most nurseries were growing *Cornus alba* 'Gouchaltii' labelled as *C.alba* 'Spaethii' (Ed. note: *C. alba* 'Spaethii' = C. alba 'Aurea'). In addition there was confusion over the nomenclature of certain *Forsythia*, *Crataegus* and *Ceanothus* cultivars. There was considerable variation in the rooting of some cultivars, e.g. *Daphne* × *burkwoodii* 'Somerset,' *Syringa vulgaris* 'Souvenir de Louis Spaeth' and *Prunus cerasifera* 'Atropurpurea' (*P. pissardii*), and in the bud-take of *Acer platanoides* 'Crimson King' and *Crataegus* × *prunifolia*. In the *Acer*, *Crataegus* and *Syringa* cultivars these differences were possibly due to genetic variability within the cultivars, possibly mutations, and/or the variability of their respective seedling rootstocks.

Examination of the commonly used rootstocks has revealed tremendous variability in the seedling material, particularly in *Acer platanoides*, *Tilia platyphylla*, *Fraxinus excelsior* and *Crataegus oxyacantha* (*C. laevigata*). Not only are these variable in form and vigour but also in their degree of compatibility with the commonly propagated cultivars. Thus there is a great need for sources of more uniform seedlings or compatible clonal rootstocks that will produce the uniform runs of trees one is now accustomed to seeing in fruit tree nurseries.

Some of the subjects studied, e.g. *Sorbus aria* 'Lutescens' (*S. aria* 'Lutetiana'?) Salix *alba* 'Tristis' (Syn.: *S. vitellina* 'Pendula'), *Prunus serrulata* 'Kanzan' (= *P. serrulata* 'Kwanzan') and *Spiraea bumalda*' Anthony Waterer' appeared to be very uniform, varying little in form, vigour and ease of propagation.

VIRUS INFECTIONS

The role of viruses in reducing the quality, vigour and ease of propagation of nursery stocks is also being assessed.

Poor rooting of some *Daphne* 'Somerset' and *Prunus cerasifera* 'Atropurpurea' was directly associated with virus infection, as was the poor bud take of certain *Malus floribunda* and *Prunus serrulata* 'Kanzan' ('Kwanzan') clones. Virus tested (VT) material of these two latter species has been available to the nursery trade through the EMLA scheme (1,3) for several years. However, it is obvious that nurserymen are not using this material or are propagating VT material on infected rootstocks. A study of *Prunus avium* seedling rootstocks has revealed that up to 25% may be infected with prune dwarf virus, which causes bud failure, incompatibility and poor growth of many

ornamental *Prunus* species. It is, therefore, most important that VT scions are always propagated on VT rootstocks.

Surveys of nursery plants and soils have shown that nematode-borne viruses, particularly arabis mosaic virus, were prevalent, causing debilitating diseases in a few species, but often occurring as latent infections (2). However, symptomless infections of certain ash and lilac cultivars have been shown to significantly reduce the vigour of these plants.

Studies of the isolates of arabis mosaic virus from different hardy ornamentals have shown that they were very similar, so it seems likely that the nematode vector is capable of transmitting this virus between a wide range of plant species.

Virus infections in Rosaceous ornamentals have been examined in detail, and three fruit tree viruses, prunus necrotic ringspot (PNRSV), prune dwarf (PDV) and apple chlorotic leafspot (CLSV) have been found in several genera (4,5). CLSV is not thought to be important in species other than ornamental *Malus* (1) whereas PNRSV and PDV appear seriously to affect the propagation and growth of several *Prunus* species, and the apple mosaic strain of PNRSV has been associated with a brilliant yellow mosaic disease of *Aesculus* spp. (6). CLSV, PDV and PNRSV occur in a proportion of hedgerow hawthorn and blackthorn plants, and the significance of these plants in the epidemiology of these viruses is being assessed. PDV was found to be seed-transmitted in *Prunus avium*, and several clones from the material of *P. serrulata* and *P. cerasifera* 'Atropurpurea' (*P. pissardii*) from the nurseries examined were infected.

Plants free from readily detectable viruses could often be selected after virus-testing. However, some cultivars were wholly infected, so other methods of virus elimination were examined. Poplar, for example, was freed from poplar mosaic virus by heat therapy at 38°C, followed by excision and rooting of 1 to 2 cm shoot tips (4). Similarly *Rosa* and *Daphne* spp. were freed from rose mosaic and cucumber mosaic viruses, respectively.

More heat-stable viruses, particularly nematode-borne viruses, could not be eliminated from *Daphne* by this procedure. However, meristem excision and *in vitro* culture, preceded by heat therapy was found to be effective (5).

Experiments to determine the rate at which virus-tested material becomes infected are in progress, but preliminary results suggest that reinfection of trees and shrubs with nematode-borne viruses is slow, often taking several years in soil containing appreciable numbers of viruliferous nematodes.

Woody plants, unlike many herbaceous plants, generally do

not seem to become rapidly infected with viruses introduced by their natural vectors. Thus under normal conditions little infection is likely to occur during the short period that plants are grown on nurseries and hence nurserymen will generally benefit from the use of VT material. However, reinfection of the mother plants is likely to occur eventually so special precautions of soil sterilisation, isolation, regular testing and, if necessary, replacement are needed.

Experience so far has shown that, in general, VT material is likely to propagate better, grow more vigorously, survive transplantation and establish well. A strong, well established tree is more able to withstand the rigours of drought, waterlogging and disease and thus the benefits of VT material may well extend beyond the nursery.

The best of the clones of trees and shrubs obtained from the 12 nurseries are being virus-tested, so that the genetically superior material is also free from known viruses.

Discussions are now under way with the nurserymen and representatives from the horticultural colleges and the Ministry of Agriculture to determine the most appropriate method for making the virus-tested material of the selected clones and shrubs available to the industry.

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PERLITE FOR PROPAGATION

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There is one fact to remember, and that is — that the roots of plants absorb many times their volume of air. In addition to this, one of the plant growth regulators is biosynthesised, in part, in the roots and then translocated up the plant to the leaves. This being so, it is obvious that a good root system is very important to the well being of the plant.

There has been a lot said in the press, and by various people involved in the commercial aspects of compost manufacture, about the characteristics of the additives recommended. Many of the claims made for particular groups of additives have been exagerrated and I cannot help but feel that the horticultural industry and also the amateur grower, have been exposed to gimmickry.

GRITS

All additives used in the compost industry can be classified by their particle size and also by their surface contours. These two characteristics affect their water holding capacity, the level of aeration contributed to the compost, as well as the drainage characteristics of the compost. There are many grits on the market varying from the smooth contoured quartz or silver sand to the rough surfaced coarse granite sold in Guernsey as "Growrite." The thickness of the film of water around the surface of the grits, at similar particle size, is about the same. The water holding capacity of the grits is, therefore, dependent on the roughness or smoothness of the surface. The water holding capacity of the silver sand we tested was about 100 kg. of water per cubic metre, but the water holding capacity of the very rough surfaced "Growrite" was about 300 kg. of water per cubic metre. This difference in water holding capacity was due entirely to the surface contours. The particle size range under test was passing a ¼ inch mesh and retained on a 10 mesh BSS (−6mm+1.7mm).

A further factor which affects significantly the water holding capacity is the particle size. As the particle size decreases, the volume of the film of water in relation to the volume of the grit increases and, therefore, the water holding capacity increases. When the particle size is less than about 60 mesh BSS (250 micron), the film of water around a grit particle coalesces, and a state of waterlogging is reached. It is possible to achieve a very wide range of water holding capacity for a given grit by

merely varying the particle range of the material. As a generalization the drainage characteristics of a grit of given particle size increases with the surface roughness of the material.

POLYSTYRENE

Polystyrene chips and spheres have been used for potting composts. Because of its honey-combed cellular structure polystyrene is a most effective heat insulator and the material, therefore, has advantages over grit for root development. Unfortunately, with regard to water holding capacity, the water holding capacity of the spheres and chips cannot be calculated from the particle size because the surface tends to repel water. The water holding capacity of spheres passing a ¼ inch mesh and retained on a 10 mesh BSS (−6 + 1.7mm) is only about 20 kg. of water per cubic metre. This low water holding capacity coupled with its low density presents problems of mixing with peat.

PERLITE

Formation. Perlite has a similar cellular structure to polystyrene but it can be wetted readily with water. It also has a higher density. Unlike polystyrene it can be mixed readily with peat. I first came across perlite when we attended the IPPS Conference at St. Paul, Minnesota, U.S.A., a few years ago. We were taken to many large nurseries in different parts of America and, as a layman, one of the surprising features was the large quantities of perlite used, especially by the propagator. As a result of this trip I decided to learn more of this material.

Perlite is quarried from old volcanic lava beds. During the early stages of cooling, water entrapped in the lava evaporates leaving a crust of a highly porous pumice-like material. Below this crust there are a number of layers of cooled minerals containing variable amounts of entrapped water. The perlite ore is quarried from one such layer or strata. The high density rock is then crushed, graded, and then heated to about 1,000°C. The entrapped water vaporises, and the heated granule expands. The particle formed has a glass-like skin, covering what is in effect a glass foam. About 98% of the volume of the particle is air entrapped in a closed cellular structure. The surface of the particle is rough and similar in contour to "Growrite" granite grit. The water holding capacity of a perlite particle is similar to that of "Growrite" of similar particle size.

Properties. When the perlite skin has been fragmented by crushing, the cellular structure is exposed. The water holding capacity of the fragmented particle can be as high as 850 kg. of water per cubic metre. One of the interesting characteristics of fragmented perlite is that it facilitates moisture movement of

water into partly dried peat fibre. There is an advantage in incorporating a small proportion of fine perlite into a perlite used for the production of peat-perlite composts. For propagation composts, the perlite used should be substantially free from fines. We have now made available a fines-reduced coarse perlite. One of the most important properties of perlite as an additive for propagation composts is the thermal insulation characteristics of the material. Because of the high air content of the particle its insulation characteristics are similar to those of the urea-formaldehyde foams used in cavity walls to insulate a house. There is evidence that the root hairs of plant subjects are attracted to the surface of the Perlite granule. The perlite appears to bond on to the roots and this perlite-root relationship appears to promote massive secondary root growth. Peat-perlite mixtures have now been used very successfully as propagation composts; it has been shown by many propagators, both in the U.K. and in the United States, that cuttings of many plant subjects can be rooted more successfully and quicker in such mixes than in peat-grit composts. We attribute this success to the aeration and heat insulation properties of the perlite particle. Perlite also appears to stabilise or help in the stabilisation, of the compost temperature, and evidence has accrued which indicates that the bottom heat required by many cuttings can be reduced by the incorporation of perlite into the propagation compost.

APPLICATIONS

FUCHSIAS. In a simple comparative trial the cultivar 'Flirtation Waltz', was half rooted in a proprietary peat/sand compost, and the other half in a mix of five parts of perlite to one part of peat, both with bottom heat of 65°F and an ambient night temperature of 50°F. The cuttings were evaluated after one month, and those in the perlite mix all had improved root systems and 60% of them were "massive", in comparison with the peat/sand compost cuttings.

A further trial at a local college was undertaken to determine the effect of peat to perlite ratio in the rooting and potting-on of fuchsia cuttings. Mixtures of perlite and a proprietary peat-based seed/cutting compost were used as follows: 100/0, 75/25, 50/50, 25/25, 0/100. Briefly the conclusions on best and worst growth were as follows:

Characteristic	Best Mix	Worst Mix	Comments
Cutting root development	100% perlite	100% Compost	50/50 Performed well
Potting root development	50/50	100% perlite	
		100% Compost	
Plant height	50/50		
No. of leaves	100% Compost	100% perlite	
Weight of plant	25/75	100% perlite	

The conclusions were that 100% perlite is the best rooting medium if plants are potted on as soon as rooted, but the 50/50 mix is best if they are left to grow on for any length of time. There is some evidence that the final potting compost benefits from a 25% perlite incorporation.

CARNATIONS. The British National Carnation Society recommends one part of peat to two parts of perlite (33/67) for rooting cuttings, and a 50/50 mix for potting on.

GERANIUMS & PELARGONIUMS. Some recent trials by the President of the British and European Geranium Society have shown that for rooting cuttings, a 50/50 mix of perlite with a proprietary peat-based compost reduced rooting time from 21 days to 14 days — with bottom heat at 65°F under plastic covers. A repeat trial in warmer weather showed a reduction in rooting time from 18 days to 11 days with the addition of perlite. Further benefits were observed from the addition of perlite to the potting-on compost at a rate of one part of perlite to six parts of a proprietary peat/sand compost.

CHRYSANTHEMUMS. The propagation of chrysanthemum cuttings for AYR flower production is probably the best known application of perlite in U.K. horticulture. One recently published book on chrysanthemum growing recommends a rooting medium of 40% peat and 60% perlite, but other growers use varying mixes between 25% peat/75% perlite, and 50/50. Chrysanthemum growers use large rooting benches continuously cycled every 12 to 13 weeks with steam sterilization between each crop. For this application it is important to minimise the fines content in the perlite to avoid the formation of an anerobic layer in the bottom of the rooting bench.

ERICAS. Some leading commercial heather growers are now using 50/50 peat/perlite instead of peat/grit for rooting cuttings in trays. They report generally better root growth in the peat/perlite mixes in approximately half the time previously taken with peat/grit. Alternatively they were able to switch off the bottom heating cables and achieve rooting in the same time in cold peat/perlite, compared with hot peat/grit. A further advantage is that the rooted cuttings are much lighter to despatch by road or rail.

RHODODENDRONS AND AZALEAS. A 50/50 peat/perlite mix has been shown to be satisfactory for rooting under U.K. conditions. For potting-on an 85/15 peat/perlite mix is recommended.

CONIFERS. *Cupressocyparis leylandii* 'Castlewellan' cuttings were rooted in 50/50, peat/perlite in polystyrene trays. With bench warming to 21°C under mist the cuttings which were struck on the 4th of July had visible root growth after 7 weeks, and were potted on after 12 weeks. Identical cuttings alongside in peat/sand mix showed no signs of rooting until over 10 weeks. Under these particular conditions the use of perlite gave a reduction in rooting time of approximately one third, it also gave a stronger root system which was more easily transplanted without damage to the hair root system.

FOLIAGE PLANTS. A wide range of foliage plants and ornamental shrubs are being rooted in 60/40 peat/perlite, with a reduction in rooting time and improvement in percentage take. For example, *Dieffenbachia* cuttings have been rooted in four weeks compared with six weeks in a peat-based compost.

HANGING BASKETS & PLANTERS. Perlite is being incorporated as a 1/1/1 soil/peat/perlite compost to give lightness, moisture retention, aeration and drainage while reducing the frequency of maintenance required with outdoor civic decorations.

ORCHIDS. Orchids are now widely propagated by meristem culture and the resulting plantlets are grown on in perlite/bark composts.

CONCLUSION

The main benefit of perlite is that it can be used by the grower in many different ways to control the rooting environment in order to match the requirements of different plant sub-

jects in terms of: aeration, insulation, moisture retention, and drainage.

SOME ASPECTS OF THE PROPAGATION OF RHODODENDRON, MAHONIA, AND ILEX BY CUTTINGS

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RHODODENDRONS

Most textbooks advise using relatively thin growths, preferably without a flower bud and, indeed, for the more difficult to root cultivars this is sound advice. However, for easier rooting cultivars, such as 'Pink Pearl' 'Sappho', 'Tortoiseshell Scarlet' and 'Cunningham's White', we deliberately choose strong vigorous shoots because we find we can still obtain a high percentage of success with this type of cutting and, of course, we get a much stronger one-year-old plant for lining out. Incidentally, this is a philosophy which we use with all plants where enough material is available. The terminal bud, whether vegetative or flower, is removed to encourage bushy growth. A wound is made on each side of the base of the cutting and about four leaves are left on. In the case of large-leaved cultivars, or those which have a spreading habit, these are trimmed by as much as ½ to prevent overlapping and consequent decay in the cutting bench. A start is usually made on making cuttings during the second week of October and the job is completed about a month later.

One of the problems frequently encountered with rhododendron cuttings after insertion is deterioration of the base, even with easy rooting cultivars. In my experience, once this sets in it will usually extend all the way up the stem and the cutting is lost. There are several possible causes:

a) The main one is undoubtedly poor aeration at the base of the stem, to which rhododendrons seem particularly susceptible. This is, of course, related to the rooting medium and the air/water ratio within it. We have experimented with various combinations, such as mixtures of peat and sand, peat and grit, and peat and expanded polystyrene, but have reached the conclusion that the most satisfactory medium is pure sphagnum peat (fine grade). However, it is important that the peat should be correctly prepared; I prefer it to be fairly light and dry when the cuttings are inserted. To increase aeration at the base of the

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cutting we have even gone as far as to place a false bottom in the bench of wire netting, providing an adequate number of holes are bored in the base of the bench to facilitate drainage and the upward passage of air into the bench. After insertion, the cuttings are heavily sprinkled and then covered with a sheet of 150g clear polythene film. Moisture condenses on the under-surface of the polythene which, being in direct contact with the leaves, prevents their drying out. I consider this to be a more satisfactory system than mist because less water is involved and, therefore, problems with poor aeration due to over-wet compost are less likely to occur. The polythene is removed once a week and is left off overnight to give the cuttings a good airing. Before the polythene is replaced the cuttings are sprayed lightly with water. By the time rooting commences, moisture from the condensation has worked its way down into the peat and no major watering is given until rooting is fairly well advanced when the peat is given a thorough soaking.

b) Other causes of stem deterioration are related to hormone and temperature levels, either individually or combined. We use various strengths of IBA in talc, usually mixed with an equal volume of captan dust. Thus a mixture of equal volumes of 4% IBA and 50% captan dust will produce an effective rate of 2% IBA. Too high a strength of hormone may cause damage to the base of the stem and subsequent breakdown, especially when combined with too high a temperature at the base of the cutting. We have suffered losses in the past which I am sure have been caused by these factors and we now take great care to see that our thermostats are functioning correctly before we start. We try to maintain a temperature of 65/68° F (20° C), no higher.

c) Another factor which may be involved is light intensity. As we all know, light intensity, temperature, and moisture levels are all inter-connected. An experience we had several years ago is worth recalling. That year the glasshouse which we use to root rhododendrons had been used for another purpose during the summer months and shading had been applied to the glass. This was not removed when the cuttings were inserted and on inspection about two weeks after insertion the whole batch of 5,000 cuttings was discovered to have begun deteriorating from the base. These were removed and so was the shading, and a further batch of cuttings taken, all other conditions and treatment remaining the same. This time rooting proceeded normally. Ever since we have taken great care to clean the glass before taking our cuttings and fortunately we have not suffered any similar disasters.

Hardening off and Bedding out. The cuttings remain in the

rooting benches until the end of March by which time most will be strongly rooted. About a month earlier the undersoil temperature is reduced and the polythene is left off for longer periods at each weekly uncovering. A little ventilation is given on suitable days until the cuttings are thoroughly hardened off. They are then lifted and lined out approximately 5″ × 5″ in cold frames in a mixture of peat and leaf mold. Prior to planting an application of aldrin dust is worked into the compost as a precaution against vine weevil which can be a serious pest in this crop. After lining out, the rooted cuttings are thoroughly watered in and covered with shaded glass until growth commences.

We consider that removal from the propagation house to the cold frame is essential at this time while there is still a certain amount of cold weather to come, for the following reason. When we first began rooting rhododendrons cuttings, instead of the system I have just described, we potted the rooted cuttings and then stood them in a slightly heated glasshouse where the temperature was not allowed to fall below 40°F. We noticed that the first flush of growth was then very uneven, some cuttings not breaking at all, some making only very short growths and some breaking very late in the season. When the cuttings were removed to the coldframe about the end of March, however, flushing is strong and even. We have, therefore, concluded that a certain amount of low temperature is needed to promote normal growth. Of course, this only applies to cuttings taken in late autumn and which remain in the rooting bench throughout the winter; it is interesting to note that where cuttings are taken earlier and potted or lined out in coldframes before the end of December (as is often the case in the U.S.A.) the problem does not arise.

Subsequent Treatment in the Cold Frame. Once growth commences, ventilation is gradually increased and the lights finally removed. As soon as the first flush of growth is complete or just before, the tips are removed to encourage a further flush which will produce a fine bushy plant for lining out. In some years, with certain cultivars, it is possible to obtain three flushes of growth in one season by frequent stopping. An application of a balanced liquid fertilizer is given after each stopping.

Lining Out in the Nursery. Lining out in the nursery generally takes place in early autumn so that the frames are empty and ready to receive next year's crop the following March. Most cultivars will produce a saleable plant 18″ to 24″ high in two years from planting out, thus giving us a three year production cycle altogether.

MAHONIA JAPONICA

The problem with mahonias, as far as we are concerned, is always lack of material due to the naturally slow growth of plants in this genus. Apart from *Mahonia japonica* which, of course, can also be raised from seed, we are concerned with bulking up of some of the fine new hybrids of *M. japonica* and *M. lomariifolia*, *M. media 'Charity'*, its sister seedling *'Winter Sun'* and possibly the best of them all *M.* × *media 'Lionel Fortescue'*.

In order to make the most of the material we have we use leaf bud cuttings. These are taken during December/January. A single wound is given and the cuttings are then treated with 2% IBA in talc. They are then inserted singly into 2″ clay pots in pure sphagnum peat and plunged up to the rim into a heated glasshouse bench filled with peat and covered with polythene as already described for rhododendrons. A high rooting percentage is usually obtained and the rooted cuttings, after hardening off, are knocked out and potted on into 4½″ pots in which they are grown on for the rest of the season. Early the following season they are potted on into 7½″ whalehide pots and a saleable plant about 18″ high can be produced in two years.

ILEX AQUIFOLIUM

The propagation of hollies by cuttings is not a difficult operation and I do not propose to go into it any great depth. We usually take cuttings in late November or December using, where possible, strong terminal growth 15 cm long. These are rooted under similar conditions as already described for rhododendrons and mahonias, i.e. under polythene film and using a medium of straight sphagnum peat. We have also used mist in which case a more porous compost of peat and grit is used to cope with the extra moisture. Besides a wide range of cultivars of *Ilex aquifolium* and *I.* × *altaclarensis* it may be of interest that we also propagate the common *I. aquifolium* by cuttings. Although usually raised from seed, it may be 3 to 4 years before young plants 30 to 45cm are produced. By careful selection of strong vigorous cutting material, it is possible to produce well-branched liners of this size in only one season and with the added advantage of being much more even than seed-raised plants.

Because of pressure of work in the last two years we have taken our cuttings as late as January and early February; it has been interesting to note that results are equally as good as when cuttings are taken in November. They seem to root remarkably

rapidly at this time and are usually strongly-rooted one month from the date of insertion.

Once rooted the cuttings are hardened off; we like to lift and pot just as the terminal bud begins to show signs of movement. They are then placed in coldframes under shaded glass until established, when the glass is removed. At the end of the first flush of growth the plants are stopped to encourage side branch. As with rhododendrons, vine weevil can be a serious problem in the pots and aldrin is used as a control.

LIGHT INTERLUDE — PHOTOPERIODISM

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The title of this talk is taken from the chapter heading of a book that I have just written but which has not, I am afraid, yet found a publisher. The book deals with *inventors;* not so much what they invent but the manner in which their minds work and how they come to have their inspirations. One of the points I try to make is that the inventor's mind is quite unlike that of, say, a designer or a research worker. A designer may be a very clever fellow indeed, as also are research workers such as biologists and chemists, but they suffer from one great fault which absolutely precludes them from being inventors . . . they cannot see the wood for the trees! Examples are given below to illustrate this allegation and it so happens that they are all about photoperiodism, hence the title.

Since photoperiodism was discovered in 1911, thousands of researchers have studied the effect in detail, making painstaking observations on hundreds of thousands (if not millions) of plants to determine whether they are long-day plants or short-day plants, or to study the effects of night breaks, etc. I have recently read two very erudite books on the subject, both by English authors; Harry Smith (Phytochrome and Photomorphogenesis, — McGraw-Hill, 1975) and Daphne Vince-Prue (Photoperiodism in Plants, — McGraw-Hill, 1975). They both quote about 500 references and Harry Smith actually draws attention to the fact that there were some 2,000 papers on the subject, so it can hardly be said to be an uncharted sea. It would appear that very clever people have now isolated the actual element responsible for performing the act of photoperiodism, — a molecule called *phytochrome.* Like other complex organic molecules, such as *chlorophyll* and the *hormones*, there is every

[1] Horticultural Engineer

rapidly at this time and are usually strongly-rooted one month from the date of insertion.

Once rooted the cuttings are hardened off; we like to lift and pot just as the terminal bud begins to show signs of movement. They are then placed in coldframes under shaded glass until established, when the glass is removed. At the end of the first flush of growth the plants are stopped to encourage side branch. As with rhododendrons, vine weevil can be a serious problem in the pots and aldrin is used as a control.

LIGHT INTERLUDE — PHOTOPERIODISM

F. CHARLES BROOKER, C.ENG., F.I.E.E.[1]

Lodsworth, Petworth, Sussex

The title of this talk is taken from the chapter heading of a book that I have just written but which has not, I am afraid, yet found a publisher. The book deals with *inventors;* not so much what they invent but the manner in which their minds work and how they come to have their inspirations. One of the points I try to make is that the inventor's mind is quite unlike that of, say, a designer or a research worker. A designer may be a very clever fellow indeed, as also are research workers such as biologists and chemists, but they suffer from one great fault which absolutely precludes them from being inventors . . . they cannot see the wood for the trees! Examples are given below to illustrate this allegation and it so happens that they are all about photoperiodism, hence the title.

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chance of being able to synthesise it artificially, although I'm not sure what good this will be to anybody.

Now, the main point about phytochrome is that the molecule can take two forms: it "flip-flops" from one form to the other under the influence of particular narrow wavebands of light; "far-red" makes it take one form and "red" makes it take the other. One mode *initiates* certain biological responses and the other mode *inhibits* biological responses; i.e., it acts as a switch. There is no "in between" state; it has to be one or the other. Naturally, the researchers have done countless experiments to prove that this is so, subjecting different plants to sequences of far-red and red lights, finding the exact wavelengths to which they are sensitive and observing the subsequent biological responses, not only of bud initiation but other things like dormancy of seeds, leaf fall, etiolation, etc. All are dependent on the mode of the phytochrome, i.e., whether it is P_r or P_{fr}.

This is most exciting and fills in most of the detail of what was known in the general sense about short-day and long-day plants but nobody seems to have asked the question: how *long* is a day . . . or night? That is not strictly true; Dr. Vince-Prue got near to asking the question when she headed a sub-section, "How dark is dark?" but it turned out to be a dissertation on whether passing clouds had an effect on day-length or whether moonlight reduced the effective length of the night. In other words, she was concerned with the *intensity* of the light source and it didn't seem to worry (or even surprise) her that the plant didn't appear to notice variations in intensity . . . it made up its own mind when day began and ended!

So when *does* day begin and end? You can look it up "officially" in Whittaker's Almanac, of course, but the plant hasn't got this advantage. Also, the transition from day to night, and vice versa, varies enormously in different latitudes. At the equator, it is very rapid, lasting only a few minutes. As we move towards either Pole, the "twilight" period gets longer until, at the Poles, there *is* no 24-hour day . . . their "day" lasts for 6 months, followed by a 6-month "night." Apart from this extreme, plants seem able to cope with twilights ranging from minutes to hours and, as our blinkered researchers have pointed out, it is not a question of light intensity. The plant behaves exactly as though the daylight were switched on and off . . . just like an electric light.

It is at this point that the difference between an inventor and a researcher begins to show! I am an electrical engineer and the moment the switching of an electrical circuit is mentioned, I cannot help but visualise the switch itself. I won't go into technical reasons but the fact is that the "make-and-break" ac-

tion of a switch has to be very fast, however slowly you move the operating lever, or knob. It is known as a "toggle" action and there are many ways of achieving it; the type you find in a thermostat is probably familiar to you but the simplest is any spring that is in an unstable position. It doesn't matter how slowly one moves the operating lever, the spring can only occupy one of two positions . . . it cannot rest "in between." And that is precisely the behaviour of our phytochrome molecule . . . it can be P_r or P_{fr}, but nothing else.

Putting the sun in the place of the operating lever, we can see that it moves fast (in terms of change of intensity) at the equator but more slowly at latitudes towards the Poles but it is *not* the intensity that causes the switching action. What, then, is it? You have to get up pretty early in the morning to discover the secret; yes, it is the beautiful red *dawn* (or red *sunset*, if you're the lazy type). As the sun's rays appear at the horizon, they start by having to pass through a very great depth of the earth's atmosphere and this has the maximum filtering effect on the shorter wavelengths, leaving only the *far-red* band of light. As the earth rotates (i.e., the sun "rises"), the rays have less depth of atmosphere to penetrate and the far-red gives way to ordinary *red*. This is the trick; the *change*, in that order, from a predominance of *far-red* to a predominance of *red* in the spectrum. Nothing to do with intensity. The reverse happens at sunset, of course; the *red* burst precedes the *far-red*, causing the phytochrome molecule to switch from P_r to P_{fr}, where it remains until morning. Thus, the plant has measured daylength whether it has a twilight lasting a few minutes or several hours.

Lastly, let us take a look at what clever man has done with his brilliant knowledge of photoperiodicity. To those whose interest is in horticulture, the obvious use is his manipulation of daylength to produce all-year-round flowers and fruit, i.e., "out of season." Personally, I can think of no more depressing sight than acres of absolutely uniform blooms at the "wrong" time of the year. The real wonder of this world is the infinite *variety* of plant life, brought about by the variations of environment over the world's surface and the ever-changing seasons. Does it not seem strange that man should use his cleverness to obliterate this glorious diversity and achieve dull uniformity?

CURRENT TRENDS IN RESEARCH ON WILLOWS AT LONG ASHTON

K. G. STOTT

Long Ashton Research Station
Bristol, Somerset

The post of Willows Officer was created in 1922 to conduct research and give advice on basket willow growing and was located at Long Ashton to be near the main basket willow growing area in Somerset. In the 1930s, H. P. Hutchinson also began to study cricket bat willows. I inherited both interests on appointment in 1949 and from the mid 1950s became more interested in the use of tree willows for paper pulp, windbreaks and land reclamation. Until recently the amenity value of this large and fascinating genus was relatively neglected. Now willows are being used increasingly for all kinds of amenity planting and it is important that those associated with propagation and the nursery trade should be aware of future requirements for propagating material, rooted plants and standard trees, and particularly of the Long Ashton Willows Collection as a source of reliable propagating material.

LONG ASHTON WILLOW COLLECTION

In the 1930s collecting began in order to establish a comprehensive selection of basket willows from all the European centres of production. Hence cultivars of *Salix triandra*, *S. purpurea* and *S. viminalis* predominate. Clones of cricket bat willow (*S. alba* var. *calva*, syn.: *S. alba* 'Coerulea') were acquired to support investigations on cricket bat willow culture and timber quality. From 1955, tree willows, selections of naturally occurring clones or hybrids of *S. alba* (white willow), have been acquired from Europe and New Zealand to supplement our native selections. Whilst all sections will be enlarged, the main aim now is to increase our holding of ornamental willows.

The collection was last replanted in 1971 and was regrouped into species beds. The 250 kinds and their location are listed in an article in the Long Ashton Report for that year. We now have over 300 different willows; 12 stools of each kind are maintained and coppiced annually.

The collection is valuable for scientific reference and allows the comparison of a range of characteristics within a single genus. For example, it has been used to study variations in leaf shape, the distribution of particular plant constituents, or the preferences of individual pests and diseases. It is also a unique source of propagating material and increasingly meets demands for willows suitable for a range of purposes. Selec-

tions have been supplied to some 25 nurseries so that in future, most requests can be met from trade sources.

TRENDS IN THE USE OF WILLOWS

Basket willow growing in Britain declined from 1967 following the import of cheap willows and baskets but recently interest in the home production of both products has increased, allied to similar trends in many craft industries. Cricket bat willow growing remained steady but now as the game is growing in popularity worldwide, demand exceeds supply and new plantings are being made in most areas of lowland England in addition to East Anglia, the traditional centre. However, the increase in the number of plants required for basket or cricket bats is small compared with the demand for willow for amenity planting — where orders for 10,000 plants are common.

The requirement is for trees that are cheap to produce, easy to establish, hardy, quick growing, relatively vandal proof, and capable of growing in a range of indifferent environments. Willows are well suited to meet these requirements, being easily propagated vegetatively. Their growth is rapid and as willow shoots are very difficult to break, vandals soon get discouraged. The existence of a wide range of species, hybrids and clones ensures that a willow suited to most soils can be found that will produce a shrub or a bush, or a large tree with one or more interesting features.

Three new situations where willows have much to offer are described below with an indication of a few of the most appropriate kinds.

1. Ornamental willows for general landscape and amenity planting

a) *Winter Bark Colour*

One of the best contributions willows can make in amenity planting is to enhance winter colour. If coppiced on a three-year rotation the shoots of many willows are strikingly coloured. The bark can be yellow, orange, red, chestnut brown, black or, as in *S. daphnoides*, a blue waxy bloom gives the stems a purple or turquoise appearance. Much more could be made of these hardy trees for large scale ornamental plantings.

b) *Catkins*

Many willows have showy male or female catkins. Those of *S. caprea* — goat willow and its hybrids are often very large. *S. daphnoides* and its allies flower early and have long silvery hairs which glisten in the January sunshine. There are smaller, shrubby willows like *S. hastata* 'Wehrhanii' (Syn.: *S. wehrhanii*), *S. aegyptiaca (S. medemii)* and *S. fargesii* which only grow to 1 m and have especially attractive catkins.

c) *Summer Foliage*

The cricket bat willows and other selections of *S. alba* have shimmering silvery foliage; others like *S. lapponum* are even more densely clothed in hairs and therefore appear silvery white. *S. pentandra* has glossy shiny leaves and those of *S. eleagnos (S. incana)* look like lavender.

d) *Habit*

The most common ornamental tree sold is the golden weeping willow *S. alba* var. *tristis*, but *Salix matsudana* 'Tortuosa' has a most unusual twisted habit, and grows into a medium sized tree. The *S. triandra* hybrids, 'Rouge D'Orleans' and *S. triandra* × *S. purpurea* 'Kerksii' both make spreading bushes with fine feathery foliage.

2. Difficult environments — reclamation and amelioration

A new development is the use of willows for the reclamation or amelioration of difficult environments — such as motorways, spoil tips, etc. Here willows are acting as pioneers either to improve the environment by their abundant leaf fall and extensive root system or to protect and shelter other, more delicate species. On these difficult sites with a high failure rate the cheapness of willows is a great advantage.

Increasing attention is being paid by local government authorities to reclaiming spoil tips and other eyesores. These schemes usually involve an element of levelling and hence considerable movement of earth. Since the tips are usually relatively infertile, the resulting compacted terrain is often an exceedingly inhospitable medium for plants and this has forced an interest in pioneer species that can at least grow, if not thrive, in these difficult situations.

Experiments have shown that hybrids of *S. purpurea* and of *S. daphnoides* are notably successful, producing a thicket in which eventually other species can be established.

Willows are suitable trees for motorway planting, especially in areas where pollution is high and where soils may be compacted and poorly drained. Several thousand cuttings supplied to the Forestry Commission in the mid-60s are now a noticeable feature along part of the Cheshire/Lancashire section of the M6. The best willows for these situations are vigorous bushy hybrids of *S. caprea*, (goat willow), *S. viminalis* (common osier) and *S. cinerea* (sallow). *S. daphnoides* is useful on sandier soils and *S. purpurea* on heavy clays.

Planting conditions in urban developments and new towns after the builders have left are often little better than motorway embankments, but the risk of vandalism is higher in urban

areas. The bushy willows, often with attractive catkins and bark colour, have much to offer in these difficult situations.

Willows have proved successful in other difficult environments. For example, untrimmed hedges have been used to provide shelter from salt laden winds in Cornwall, and in the Hebrides where *S. caprea* and *S. daphnoides* were established as front line shelter behind which taller growing pines could be established.

3. Windbreaks

With our horticultural interests we, at Long Ashton, have been very much aware in recent years of the value of windbreaks for fruit, vegetables, glasshouses and nursery stock. Usually a windbreak shelters an area downwind to a distance ten times its height, and so it is useful to characterise windbreaks according to height. On top fruit farms the perimeter windbreaks are allowed to grow as high as possible — they may reach 25 m. But within modern intensive orchards it is advisable to have windbreaks at repeated intervals across the holdings trimmed to a top height of 9 m. For vegetables and soft fruit 4 to 5 m will usually suffice. Willows have the advantage that they are cheap, easy to establish, and can survive mechanical trimming (mutilation by flail cutter would be more truly descriptive) and by selecting the right kind, willows can be found that grow naturally to about the required heights. For perimeter windbreaks of 25 m, many of the Dutch selections of *S. alba* and *S. fragilis* are very suitable. 'Liempde' is frequently used in Holland and though 'Tinaarlo' and 'Vries' both grow very fast (1 m/year) we have found that the slightly less fastigiate, but more feathery 'Drakenberg' or the cricket bat willow make a more efficient windbreak.

These willows will thrive at a closer spacing than poplars and so produce an effective windbreak more quickly. They do not throw troublesome root suckers and some find their shimmering silver foliage more pleasing than the sombre green of poplars.

The shrub willows, which naturally rarely exceed 9 m, are showing promise for quickly established moderately tall windbreaks where the intention is to lop mechanically up to 9 m. Hybrids of *S. caprea* (goat willow), *S. cinerea* (sallow) and *S. viminalis* (common osier) are suitable. 'Bowles Hybrid,' which is a fastigiate selection of *S. viminalis*, is finding increasing favour on the silt soils of the Fens for internal windbreaks among fruit trees, where alders do not seem to thrive.

In addition to the uses described above, willows are used for the protection of riverbanks and revetments; they are very suitable for the production of paper pulp and particle board,

and with the concern for energy supplies we may even find coppiced willows grown for fuel and industrial feed stocks. However, at present the greatest need is for production of specialist nursery material of ornamental willows, willows for reclamation and for windbreaks.

CONCLUSIONS

1) The range of habit, catkins, summer leaf and winter bark exhibited by willows has hardly been exploited for ornamental uses in parks and gardens.

2) There is considerable scope for fast growing cheap, vandal proof bush willows for the rougher type of amenity planting associated with new towns, motorways and other difficult environments where pioneer species are required.

3) Willows are eminently suited for windbreaks required by fruit and vegetable growers.

4) At Long Ashton we have a unique collection of willows which are available in small quantities for trials, for educational purposes and to nurseries who wish to produce new lines in a commercial quantity.

INSTALLING A WARM WATER PROPAGATION FACILITY

DAVID HUTCHINSON[1]
Adas, Hampshire

Objective. To install facilities to propagate 50,000 cuttings with relatively low running cost and moderate capital investment. The system to be on high working efficiency with some flexibility to improve the design if necessary at a later date. Cutting basal temperature required: 70°F.

Design. An oil-fired boiler installation was chosen as the source of heat, as 35 second oil is cheaper than electricity by a factor of 2. A polythene tunnel 100′ × 17′ was already erected on the nursery to a high standard. To accommodate 50,000 cuttings an area of over 1,000 sq. ft. of warmed bed is required. Normally the energy requirement for soil-warmed beds is calculated on the basis of 15 watts of electrical loading per square foot. This is equivalent to 50 BTUs per square foot.

A second-hand 60,000 BTU boiler and a 600-gallon oil tank was purchased cheaply due to the fact that numerous domestic consumers were changing over from oil to natural gas.

Warm water at a temperature of 104°F was fed by a cir-

[1]Horticultural Advisory Officer

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culator pump to flow via a header from the boiler to the far end of the bed through 20 half-inch diameter polythene class C BS1972 tube. The warm water was collected by a header and returned to the boiler at a temperature of 95°F by means of a 1½ inch diameter polythene class C BS1972 pipe.

The boiler thermostat was initially set at 105°F; however, when working it was found that the thermostat could be set at 160°F with no problems. Temperature control was by a one probe Nobel controller connected to the circulating pump. The probe was placed at the basal region of the cuttings. A 5-gallon header tank was erected in the ridge of the polythene tunnel. The boiler was lagged with fibre-glass.

Construction. The polythene tunnel was raked level across the width of the tunnel and a 6″ rise was noted from the boiler end to the far end. A sheet of black polythene 500 gauge was laid on the surface of the soil. This was covered by 2″ of sand. A perimeter of two concrete blocks laid on their sides was bedded into the sand to give a height of 8″. The internal measurements were 94′ × 11′.

A header pipe was anchored at each end of the bed. These were made on the nursery and each header pipe had inserted and welded twenty spigots. Each spigot was ½″ in diameter (outside measurement) and 6″ long. The spigots were positioned at 6″ intervals with ¾″ of the spigot protruding inside the 2½″ diameter header pipe. Bleed valves for air release in the system were welded in near the blank ends of the header pipes.

The twenty polythene pipes running down the polythene tunnel were connected to the spigots by heating and expanding the ends of the polythene pipe in boiling water (using a kettle on an extension lead) and securing the pipe in position while still warm with a jubilee clip.

The return pipe of 1½″ diameter class C polythene pipe was installed in the centre of the bed, with two gate valves so that either bed could be switched off from the head source if desired.

A concrete slab (2′ × 1′) access path was laid on top of the sand in the centre of the bed. Four lines of lay flat irrigation tube was laid on the surface of the sand to dampen the sand periodically by means of hand controls.

Installation costs and specification.

Second-hand 60,000 BTU boiler 600 gallon oil tank	£ 80.00
Concrete blocks, 300 @ 18″ × 9″ χ 4″	65.00
Sand/grit, 50 cu yd	156.00

Circulating Pump — Grundfoss 2 speed	17.00
Header Pipe 2½″ dia × 26′ @ 22p foot	5.72
Spigots — ⅜″ internal med gal Blue Band	
Steel Tube 40 × 6″	5.00
Polythene Pipe ½″ Class C	
4 coil of 150 m	92.00
Nobel Controller — 1 probe	53.24
Black Polythene 500g	27.70
Path 2′ × 1′ × 2″ slabs	25.71
Chimney — 10′ × 6″ flue Header Tank — 5 gallon Taps — two — 1½″ Return from Pipe 1½″ dia Polythene Class C Welding Rods	98.58
Electrical Work — Installation	7.00
13 amp twin outlet	3.00
Misc Fittings	26.04
Aluminium for Chimney	14.62
Labour — Installation 100 hours	170.00
	£846.61

Additional costs.

Insulation — 48 sheets 1″ Polystyrene 8′ × 4′ sheets	62.40
— Polythene Wrap	50.00
— Labour — 30 hours?	45.00
	£157.40
Total	£1004.01

Performance. A CO_2 flue gas check was made during the operating period and gave an efficiency factor of 83% combustion. The burner nozzle was rated at just under ½ gallon of 35 second low sulphur oil per hour.

Checks with a 12 probe thermocouple unit showed no temperature difference along the supply header. Across the width of the bed there was a 3°F drop at the sides and a 2°F drop either side of the access path. There was a 5°F temperature gradient down the house from the supply to the return header. The return 1½″ pipe flow dropped 4°F back to the boiler. The Nobel controller was situated near to the return header end of the unit set at a temperature of 65°F at the actual cutting base. (This gave a temperature of 70°F at the top end nearest to the supply header.)

There were 23 nights when the minimum temperature within the polythene tunnel dropped below freezing point. On these occasions the temperature below the polythene film cover over the cuttings dropped to below 50°F and the basal temperature to 60°F recorded at the Nobel probe. During the night with

the extreme low temperatures above the polythene film on the cuttings a large amount of condensation occurred and this saturated the cutting and compost in the imperfectly drained trays.

To overcome cutting and compost saturation on days following frosty nights the polythene film cover was removed from the cuttings from 9 am to 4 pm. On sunny days, providing the polythene film cover was replaced around 4 pm, no increase in the amount of heating was required to maintain 70°F at the base of the cuttings.

Fuel consumption.

Table 1. Fuel Consumption — Average Gallons Per Day

	Dec	Jan	Feb	Mar	Apr	May
Gallons per day	6.8	6.8	6.8	4.5	4.0	2.0

Future improvements in design. If installing the system with hindsight, then insulation would be installed during construction in the base and sides as well as lagging the headers. This would improve thermal efficiency by reducing the heat loss on the perimeter of the bed and adjacent to the path.

To improve the temperature gradient down the tunnel a flow and return system installed side by side would be contemplated. This would call for an additional return header which would be installed alongside the flow at the boiler end. This would mean we could dispense with the 1½″ diameter return under the path.

Cutting trays should be deep with numerous drainage holes. The more plentiful the better providing the compost does not fall through.

The polythene cover over the cuttings could be supported on the hoops or steel or polythene tube so that excess condensation can be returned to the sand base via the edges of the bed and not through the cutting tray.

Conclusion. That a circulated warm water system can be efficient and economical, for soil warming with a high degree of accuracy.

Two questions arise: 1) What are the basal temperature requirements? and 2) Do we need constant heat or can intermittent heat be used successfully to reduce heat inputs?

Acknowledgments. I wish to thank Mr. R. F. Mann, Mr. M. J. Mundy ADAS Mechanisation Advisers, and Mr. M. S. Blunn for their help in designing and accomplishing this work.

MECHANISATION OF POTTING

H. TUTHILL

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Wardington, Nr. Banbury, Oxfordshire

My experience of potting with machines has been gained over the past six years on my own nursery where we use both rigid and polythene bags and also through my contact with other nurserymen who have hired one of the eight machines I have at present available for that use. These are all Javo potting machines.

In the U.K. container production has increased from 19,000,000 plants in 1974 to 31,000,000 in 1977. The number of machines in use is somewhere between 150 and 200.

It is a difficult decision whether to go over to mechanised potting, not least because of the capital outlay (a minimum of £4,000 is required if you are to buy your own machine). This is where the hire service, which I offer, comes in useful as small nurseries, without enough work to justify the high capital outlay, can hire a machine for as little as one day. The big nurseries who have too much work for their existing machinery at peak times can also make use of the machinery over several weeks and sometimes months. The average length of hire is 3 to 4 weeks, sometimes at two or three periods during the season.

There are also the problems which arise from the extra demands the machine makes when in operation. It is not just a matter of switching on and watching potted plants settle into neat rows on standing out ground. A reappraisal of your growing system is necessary if the machine is to be efficiently run and so make real savings in time and work.

I have divided the whole task of potting into five basic operations: 1) Supply of plants; 2) Supply of compost; 3) Potting of plants; 4) Transport of these to container beds; and 5) Standing down.

A potting machine will handle a larger number of plants per day than can be achieved by hand whether using polythene bags or rigid pots. On my nursery we consistently average, over a period of eight weeks, 6,000 — 3½″ poly bags and 14,000 — 3½″ rigid pots in a 6½ hour working day. These rates are achieved with a total staff of seven people, two skilled and the rest unskilled holiday students. This use of unskilled labour leaves my regular staff free for other, more skilled work on the nursery.

Our operation is set out as follows:

Two people remove the cuttings from the seed trays, grade them into three sizes and trim off any excess roots.

On the machine, using polythene bags, four people are needed when potting bare-rooted cuttings. Two people are needed to plant, one to put the bags on and one to take them off, placing them in a plastic tray holding 40 — 3½" plants on a roller conveyor.

With rigid pots we use an automatic pot dispenser and so only need three people, having done away with the person putting the pots on. Only one person is needed for planting when the plants have been grown in some sort of container. One person is used to transport the plants to the standing out area with a fork lift and pallet and one person to set the plants down in the beds.

This season I have improved the efficiency of our potting by having large quantities of plants ready to be potted at one time. Our soil mixing is done in advance and the compost is stored in a purpose built hopper holding two days compost which is fed into the machines at the touch of a button.

Plastic trays are used to transport the plants on pallets to the standing out ground where the fork lift drives down to the bed and drops the pallet close to where the plants are to be set down.

I have described the set-up at Wardington, where I have used the machine almost to maximum output, with all the labour needed to keep the machine going at a good speed and maintain quality potting.

However, the time and work saved is still considerable with only three people, this being the minimum number with which the machine will operate efficiently. The five basic operations must be tackled individually, the plants and compost prepared, the potting carried out on the machine, and then the trays and setting out done when all available trays have been filled.

Potting machines have only been used extensively in recent years and the demand for the machines is increasing every year both for new machines and for our hire service. It is not surprising that the demand is there if one considers that over the last 5 years the capital outlay has gone up from £2,000 to £4,000, a 100% increase, and the cost of labour has gone up by 200 to 300%. Over the past five years potting machines are becoming more sophisticated with recent developments for handling polythene bags, automatic dispensers for rigid pots, the automatic removal from the pot track to the standing down area, and equipment to handle the filling of seed trays.

However, it is still a relatively basic machine requiring a

large number of man-hours. The actual potting of the plant and final quality still relies on a pair of good old "green fingers."

WATER STATUS IN RELATION TO ROOTING HARDWOOD QUINCE CUTTINGS

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Abstract. An antidesiccant polythene wrapping was shown to enhance the rooting of 'Malling Quince A' hardwood cuttings. This increase in rooting was associated with a higher water content in the cuttings. The effect of the antidesiccant was shown to interact with the effect of applied auxin on the rooting of hardwood cuttings.

REVIEW OF LITERATURE

Quince, *Cydonia oblonga*, is used as a pear rootstock and can be propagated by the hardwood cutting technique developed at East Malling Research Station. Using leafless shoot cuttings collected from hedges during the dormant season, this technique depends for its success on the application of synthetic auxin to the cutting bases and the use of a period of basal heat (1).

It is widely recognized that leafy cuttings must be maintained in a turgid condition in order to facilitate rooting. Loach (2) quantified this phenomenon by showing that rooting was suppressed when the water potential of leafy cuttings was low. In a leafy cutting, water stress leads to a closure of stomata and a consequent reduction in photosynthesis; in addition, it is now accepted that water stress itself can cause direct reductions in growth processes and that this generalization applies to the initiation of roots and their subsequent development (2). It was felt that this latter consideration has relevance to the rooting of leafless hardwood cuttings.

METHODS AND RESULTS

The effect of a polythene wrap and basal heat on rooting response. A hardwood cutting may be given an antidesiccant covering by wrapping it with 12.5 mm polythene tape (40 u). In these experiments 40 cm of each 60 cm cutting was wrapped, leaving the basal 20 cm uncovered for planting. In a replicated experiment four treatments were applied to cuttings of 'Malling Quince A' collected in early November, 1977:

(a) control — immediate planting out of doors;

(b) polythene wrapped and immediate planting out-of-doors;
(c) basal heat treatment for two weeks;
(d) polythene wrapped and basal heat treatment for two weeks.

No application of auxin was made to the cuttings. The temperature at the base of the cuttings receiving the basal heat treatment was maintained at 20°C. The mean temperature at the base of the cuttings planted out of doors during the two week period was 4.4°C.

After two weeks all the cuttings were lifted. There was no sign of roots or callus on any of the cuttings which had been planted out-of-doors. Of those given basal heat treatment but no polythene wrap, some callusing had occurred and 3% had rooted. The use of the polythene wrap and basal heat resulted in 80% of the cuttings having roots, many of the roots being longer than 1 cm. At this stage all the cuttings were planted out-of-doors to await suitable conditions for lining out. When the cuttings were again lifted in mid-March, rooting had occurred in approximately one-third of those which had been polythene wrapped but had not received basal heat. The controls were still devoid of roots whilst the degree of rooting in the other two treatments remained unchanged.

The effect of polythene wrap and auxin on rooting response. In a replicated experiment four treatments were applied to cuttings collected in early January, 1978. The treatments were:

(a) control;
(b) auxin application;
(c) polythene wrap;
(d) polythene wrap and auxin application.

The auxin, indolebutyric acid, was applied as a quick dip at 1000 ppm and, after application of the treatments, all the cuttings received basal heat for ten days. At the start of the experiment, and four days later, samples were taken for determination of moisture content. The initial moisture content of the cuttings, expressed on a fresh weight basis, was 44.7%. The results from the second sample are shown in Table 1. The application of auxin and the use of a polythene wrap reduced moisture loss. However, comparing the two auxin treatments the effect of the polythene wrap on moisture content was not statistically significant. If the two polythene treatments are compared, the effect of auxin on moisture content was not significant either.

After ten days of basal heat treatment the cuttings were lifted, and the percentages which had rooted (transformed to angles for statistical purposes) are shown in Figure 1. Consider-

Table 1. The effect of auxin and polythene on the moisture content of 'Malling Quince A' cuttings four days after the commencement of basal heat treatment.

Treatment	Moisture content expressed as a percentage on a fresh weight basis
Control	42.0%
+ Auxin	43.7
+ Polythene	43.4
+ Polythene + Auxin	43.9
Least significant difference at 5% level	1.23

ing the two treatments where the polythene wrap was not applied, there was not a statistically significant effect of auxin on rooting response. In the absence of applied auxin, the polythene wrap enhanced rooting, as was to be expected from the first experiment. In the presence of applied auxin the expected enhancement did not occur and a factorial analysis of these results showed a negative interaction between the polythene wrap and the auxin treatment.

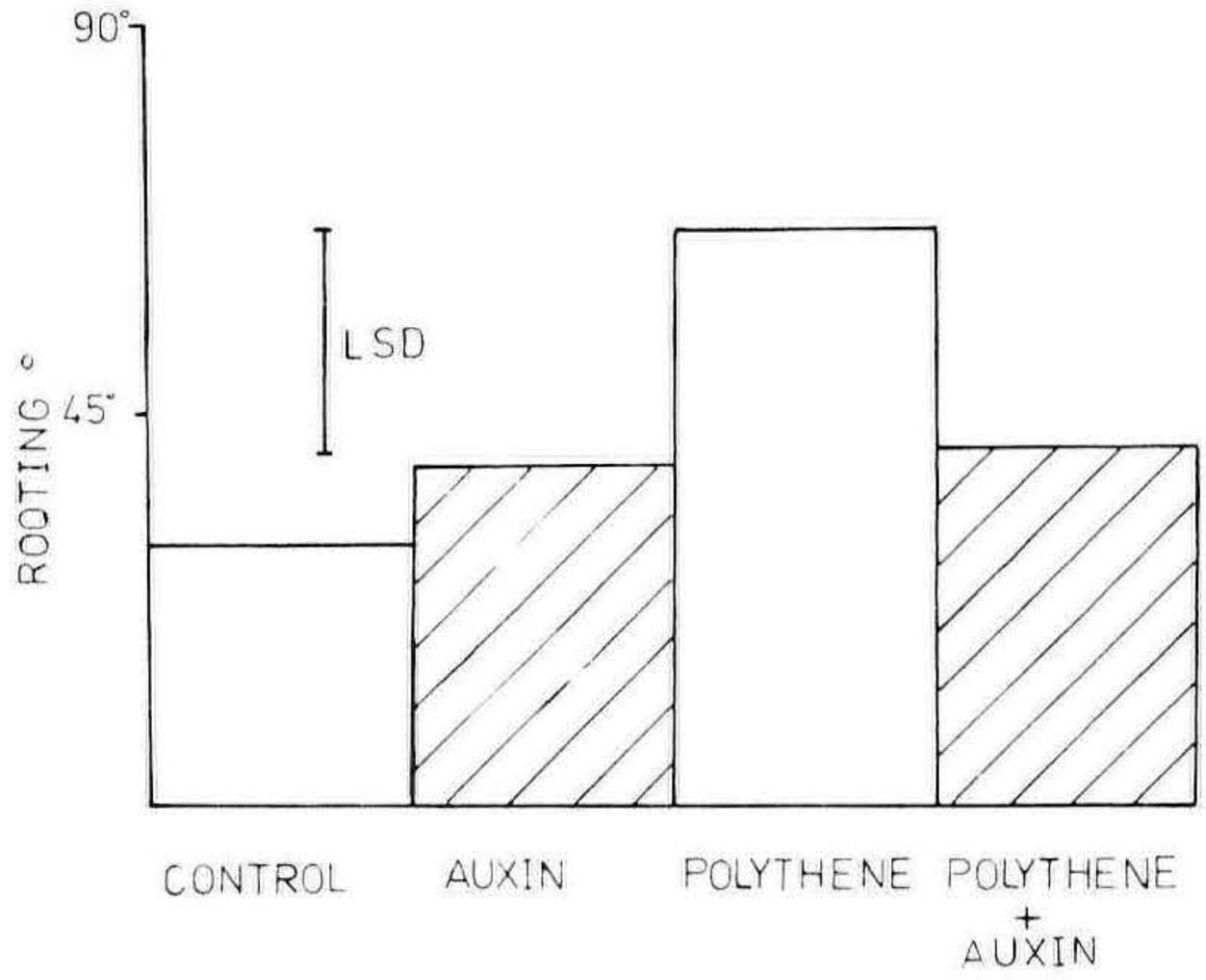

Figure 1. The effect of a polythene wrapping and the application of auxin on rooting of January-harvested cuttings of 'Malling Quince A'.

DISCUSSION

The benefit of polyvinyl resin antidesiccant in the propagation of plums by hardwood cuttings has been demonstrated by Nahlawi (4), and the results of these experiments with quince are in accord with that work. The first experiment showed the beneficial effects of the polythene wrap whilst the second also showed a benefit of the antidesiccant, although only in the absence of applied auxin.

The second experiment showed that the benefit of a polythene wrap was lost when auxin was applied. This can be viewed as an inhibition of rooting by auxin in the presence of the polythene wrap. The effect of polythene alone was to increase rooting and moisture content relative to the control. Auxin-treated cuttings also had a higher moisture content than the control after four days basal heat treatment; this and the lack of rooting response cannot be explained satisfactorily. Interplay between the applied auxin and the antidesiccant has been observed previously in different circumstances (4). The present result serves as a reminder that if antidesiccants were to find more general use in plant propagation the levels of growth regulators used might have to be reviewed.

Thanks are due to East Malling Research Station for the supply of cutting material.

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TESTING POPLARS AND WILLOWS FOR SHELTER BELTS

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The National Plant Materials Centre is part of the Aokautere Science Centre, Ministry of Works and Development, Palmerston North. It is responsible to the National Water and Soil Conservation Organisation for the breeding and selection of plants suitable for erosion control in rural and urban situations. Many plant genera are currently being imported and several of these possess clones or species with characteristics suitable for farm or horticultural shelter. The two genera with which the Centre has had the most experience to date are *Populus* and *Salix*.

POPULUS

Poplars were represented in New Zealand prior to 1973 mainly by the widely planted silver poplar (*P. alba*), cottonwood (*P. deltoides*) and the fastigiate Lombardy poplar (*P. nigra* 'Italica'). Several *P* × *canadensis* (*P.* × *euramericana*) poplars were also planted in an increasing extent for erosion control, and a semi-evergreen mutant of Lombardy poplar, *P. nigra* 'Sempervirens' was widely used for horticultural shelter. The semi-evergreen Lombardy poplar comprised the bulk of shelterbelts in the Tauranga — Te Puke area and a high proportion of shelterbelts in the other horticultural districts.

Since the poplar leaf rust *Melampsora larici-populina* was discovered in New Zealand in 1973 it has overwintered on the semi-evergreen Lombardy poplar and spread rapidly throughout nursery shelterbelts each spring causing premature defoliation.

This has led to reduced growth, dieback of branches, and death of many semi-evergreen Lombardy poplar shelterbelts, as well as providing a source of inoculum for infection of other fully deciduous poplar clones in the vicinity.

The heavy and early rust attacks on poplars planted for soil conservation have been mainly due to the widespread distribution of the semi-evergreen Lombardy poplar; for this reason this Centre continues to recommend the removal of all plants of this clone.

The ordinary Lombardy poplar is also highly susceptible to this leaf rust but has suffered to a lesser extent. The only areas

where the rust is of little importance are the inland areas of Otago and the central South Island, and parts of the Wairarapa where summer rainfall and humidity are low.

The two fastigiate Lombardy poplar clones have been popular because they provided fast efficient shelter when grown from woody unrooted stem cuttings. Their crown is narrow requiring less trimming and occupying less area than most other shelterbelt species and they are mainly free from pests and diseases of fruit tree crops.

In 1976 a new poplar leafspot disease caused by the fungus *Marssonina brunnea* appeared in the Manawatu area. This disease can cause premature defoliation of susceptible poplar clones. Laboratory tests have shown that both kinds of Lombardy poplar are highly susceptible to this disease.

Although *Marssonina* is at present found only in the Manawatu district it may spread further during the next few years. The Lombardy poplar should only be used for horticultural shelter if a regular spray schedule to control *Melampsora* and *Marssonina* can be carried out.

Another fastigiate poplar clone used occasionally for shelterbelts is the rust- and *Marssonina*-resistant 'Bolleana poplar', *P. alba* var. *pyramidalis*. It is slower growing than the Lombardy poplar but free from poplar diseases and pests and may be more tolerant of salt spray. The chief disadvantage of this clone is its tendency to form root suckers. This has been partially overcome in the past by grafting onto *P. yunnanensis* rootstocks. Further work is needed on identifying compatible non-suckering rootstocks before this clone can be recommended for horticultural shelter.

New poplars for horticultural shelter: A rust- and *Marssonina*-resistant *P.* × *canadensis* (*P.* × *euramericana*) clone 'Flevo' was released in 1974/1975 and a rust, *Marssonina* and opossum-resistant clone of *Populus trichocarpa* 'S61741' will be released to commercial nurseries in 1979. Both of these clones should be used only for perimeter shelterbelts around orchards or nurseries since they have large wide-spreading crowns.

The fastigiate Lombardy poplar clones used in New Zealand have widely demonstrated wind resistance and suitability for horticultural shelter.

The fastigiate form of *P. nigra* occurs naturally in the Middle East and, in 1976, a study tour was carried out by C.W.S. van Kraayenoord to locate clones currently used for shelter in western Europe and to select seed sources for importation into New Zealand. As a result of this tour ten seedlots of fastigiate *P. nigra* were imported from Turkey and a total of 33 narrow-

crowned clones of *P. nigra* were imported from Italy, Turkey, France and Yugoslavia. Rust-resistance tests have so far been disappointing since all clones and seedlings have proven susceptible to *Melampsora larici-populina*. Two of these imported clones and 35 of the seedlings have been selected for low to medium susceptibility to rust and are currently undergoing further resistance tests for rust and *Marssonina*. If they do not prove sufficiently resistant then additional seedlots may have to be imported or disease resistance bred into hybrid clones with this form.

Overseas breeding experience indicates that the fastigiate form can be transmitted in varying degrees to a reasonable percentage of hybrid seedlings. Some preliminary hybridisations were made in August, 1978, between rust- and *Marssonina*-resistant *P. deltoides* clones and the rust- and *Marssonina*-susceptible, *P. nigra* 'Italica'. This may provide a range of disease resistant hybrids, some of which may also possess narrow crown forms. The selection of suitable clones from these hybrids will take a minimum of three years in the nursery, followed by three years of field trials.

Poplars for farm shelter. Many less fastigiate poplar clones of a variety of species have been selected for disease resistance at the National Plant Materials Centre and are at present undergoing comparative growth tests at a number of nursery and field locations throughout New Zealand. Many of these clones will be suitable for farm shelterbelts. The first of these clones will become available during the early 1980's

Several disease-resistant clones of *P. trichocarpa* appear particularly promising. These clones were selected from seedlots imported from California in 1974. They possess fine flexible branching over the whole stem and have small leaves which are highly unpalatable to opossums. Their resistance to rust is excellent. Resistance to *Marssonina* is good but further observation is necessary to confirm the level of resistance of each clone.

The first nursery and farm shelterbelt trials of these clones were established in winter, 1978, and additional test plantings are planned for 1979.

Observations of adult trees in California indicate that these clones will have a broad-crowned adult form similar to *P. deltoides* 'Frimley', the common cottonwood clone in New Zealand.

SALIX

Although willows are used extensively in shelter planting in Europe and North America they have not been used much for

this purpose in New Zealand, mainly because the types commonly available were not suitable. The crack willow (*Salix fragilis*) and the weeping willow (*Salix babylonica*) have too broad a crown and are not very wind firm. However, several willows are useful shelter species particularly for wetter sites. As tree willow roots do not spread as far as poplar roots they compete less with crops. Neither do they form suckers from the roots.

The osiers and shrub willows which can be maintained as quite dense shelter by regular trimming are suitable for small to medium-sized shelter. They can be planted in single row shelter belts. These lower growing willows are also suitable fillers in shelterbelts of tall-growing narrow-crowned broadleaved species. However, as they are light-demanding species they must have room to grow upward otherwise they will spread laterally towards the light. They are unsuitable for underplanting with conifers as they will not tolerate shade.

The use of willows in shelterbelts in the past has been restricted to the use of the common pussy willow (*Salix discolor*, or *S. caprea*). These species have disadvantages in that they act as a host for red spider mites and San Jose scale. They are wider spreading and slower growing than Lombardy poplar. The profuse crops of male flowers in spring strongly attract bees and are reputed to result in reduced pollination and fruit set on orchard trees nearest to the shelterbelt. Although these species possess these disadvantages they are still one of the cheapest and most effective shelterbelt trees currently available. The best examples of shelterbelts of these species can be found in Hawkes Bay where they have been widely used.

Several shrub willow hybrids including *S. discolor* hybrids have been established in nursery shelterbelts at the Aokautere Science Centre.

Since 1973, the tree willow, *Salix matsudana* (Peking willow) has been recommended as an interim alternative to Lombardy poplar. It has a very rapid growth rate growing up to 15 meters tall and can give good quick shelter until slower growing species (such as *Cryptomeria japonica*) are sufficiently large for the willow to be removed. It is free from most pests and diseases of fruit trees, but is highly susceptible to silverleaf disease (*Stereum purpureum*). It has not been grown as a trimmed shelterbelt previously and thus it is not known how well the clone will stand up to regular trimming.

Hybrid clones from the cross *S. matsudana* × *S. alba* (white willow) are also under test at present for soil conservation planting. These are extremely vigorous and there are several clones with a narrow growth habit which could be used.

These clones were established in nursery shelterbelts in winter 1977 and require further testing before release.

One hybrid clone, 'NZ 1002' was released in 1978, and can be used in place of *S. matsudana* because it has a greater early growth rate.

All of these tree willow clones are likely to lose their lower branchs and should be underplanted with low-growing willows or shrubs. Alternatively these can be planted in a row in front.

Salix chilensis (Syn: *S. humboldtiana*) var *pyramidalis*, the only willow native to South America, has been used recently for orchard shelter because of its fastigiate, semi-evergreen habit. In shelterbelts at the National Plant Materials Centre, the clone has proved disappointing.

The branches also die back when subjected to frosts or salt-laden winds, and the whole plant may die back when transplanted as a rooted plant. The root system is weak and the plant is subject to toppling on sites with a high water table or shallow soil profile. This clone may be acceptable in warmer areas not subject to frost or salt-laden winds but should only be considered for temporary shelter of up to five years duration.

OTHER SPECIES

A shelterbelt project has been started to look at genera and species suitable for the prevention of wind erosion of topsoil from farmland. It is intended to examine closely species already available in New Zealand and to introduce new plant materials as necessary.

The Aokautere Science Centre has recently established shelterbelts of various species and clones of *Alnus*, *Betula*, *Casuarina*, *Eucalyptus*, *Tamarix*, *Olearia* and Leyland cypress for nursery shelter. It will be several years before these belts have been adequately tested but at present the Leyland cypress clones to not appear very promising due to the occurrance of toppling, and of cypress canker caused by *Monochaetia*. They also have a wide-spreading habit requiring regular trimming.

SUMMARY

The National Plant Materials Centre has selected and released several rust-resistant poplar clones which appear promising for shelter. These clones are, at present, being tested in the Centre's nursery and will be tested in farm shelterbelts from winter, 1978.

Fastigiate forms of *Populus nigra* similar to the Lombardy poplar *P. nigra* cv. Italica have been imported as seed and cuttings and tested for rust-resistance. Several clones are less rust-

susceptible than Lombardy poplar but need further testing for *Marssonina* resistance. The Lombardy poplar is being hybridised with rust-resistant *Populus deltoides* clones in an attempt to combine the fastigiate character with high rust-resistance.

A new tree willow hybrid, *Salix matsudana* × *S. alba* cl. 'NZ 1002', has been released and other tree willow hybrids are being tested in shelterbelts at the Centre.

Hybrids of the common 'pussy willow' *Salix discolor*' and other shrub willows have also been established in shelterbelts at the Centre.

Other genera established for shelter include, *Alnus*, *Betula*, *Casuarina*, *Eucalyptus*, *Tamarix* and *Olearia*. Many more genera are being tested for erosion control and any which appear to have promise for farm or horticultural shelter are retained and tested for this purpose.

RAPID PROPAGATION OF ASPENS AND SILVER POPLARS USING TISSUE CULTURE TECHNIQUES

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In New Zealand poplars are extensively used for soil conservation, farm forestry and for orchard shelter. In 1972 nearly 1 million poplars were planted.

In 1973, however, two species of poplar rust, *Melampsora medusae* and *M. larici-populina* became established in New Zealand. These fungi cause severe premature defoliation, which can result in branch dieback and even in death of the very susceptible poplar clones. Many of the most common poplar clones were affected and their continued cultivation became impossible. As a result poplar planting decreased dramatically in the following years until the first resistant clones selected by the National Plant Materials Centre (now part of the Aokautere Science Centre) became available in 1976.

It also had become apparent that a small number of the existing poplar clones were resistant to the rusts, notably *Populus alba* (silver poplar), *P. tremula* (European aspen), and *P. tremuloides* (American aspen). These poplars, besides being disease resistant, also possess a suckering habit making them valuable in soil conservation planting. However, the aspen pop-

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lars, in particular, have not been widely used as they are difficult to propagate by hardwood cuttings. They can be propagated from root cuttings taken in winter or from softwood tip cuttings under mist in early summer. The number of propagules could be increased more rapidly by placing root cuttings in sphagnum moss in the glasshouse in winter and harvest the young shoots which develop from the preformed shoot initials in the root segments. These young shoots are then rooted under mist. This method was successfully used at the Aokautere Science Centre (2). However this production method was still too slow to satisfy the estimated demand of 200,000 silver and aspen-poplars which can be used annually in soil conservation plantings. Tissue culture methods can considerably speed up the production of these clones.

This paper describes the rapid method of silver and aspen poplar multiplication being used in the tissue culture laboratory at Aokautere Science Centre, Palmerston North. The techniques used here represent the development and practical application of the original work by Whitehead and Giles (6) of the Plant Physiology Division, DSIR.

The process of plant propagation *in-vitro* must proceed through three different steps known simply as stages I, II and III. The various steps in each stage are:

Stage I. In the first stage a sterile living explant is established in culture. Apical and axillary buds are removed from adequately chilled dormant shoots or actively growing shoots in spring through to mid-summer. Excised root sucker shoots have been used to initiate new cultures in autumn.

Buds are prepared for sterilisation by trimming off leaves whilst retaining a small piece of petiole attached to the stem. The buds are rinsed in ethanol prior to a 15 minute surface sterilisation in a solution of 0.15 to 0.3% sodium hypochlorite and 0.05% Tween 80. This is followed with three sterile distilled water rinses. The success of the sterilisation procedure depends in part upon the preculture growing conditions (1). A period of shoot growth in a glasshouse coupled with the application of Bavistan^{R} and Cuprox^{R} sprays prior to culture reduces microbial contamination of most explants to less than 5%. With the aid of a low-power stereo microscope the outer budscales are removed aseptically from the bud in a laminar air-flow hood. Excised buds 1 to 3mm are cultured on a solid agar medium using a modified Murashige-Skoog salts medium (5), plus a cytokinin to stimulate cell division. Refer to Table 1 for individual species media requirements. Alternatively, whole buds may be trimmed and placed onto the same medium as excised buds.

Table 1. The modified Murashige and Skoog medium for in vitro propagation of aspen and silver poplars:

Compound	mg/l	Compound	mg/l
NH_4NO_3	1650	Na_2 $Mo0_4$ $2H_20$	0.25
KNO_3	1900	$CuS0_4$ $5H_2O$	0.025
$CaCl_2$ $2H_2O$	440	$CoCl_2$ $6H_2O$	0.025
$MgSO_4$ $7H_2O$	370	Adenide Sulfate	20.0
KH_2PO_4	170	Nicotinic Acid	0.5
$MnSO_4$ $4H_2O$	22.3	Pyridoxin-HCl	0.5
EDTA	37.3	Thiamine-HCl	0.1
$FeSO_4$ $7H_2O$	27.8	Lysine	100
Zn SO_4	8.6	Inositol	100
H_3BO_3	6.2	Sucrose	20000
KI	0.83	Agar	10000

Hormone requirements (mg/l) of Populus species for in vitro propagation.

Species	Stage I	Stage II	Stage III
P. alba	BA.2	BA.2 NAA.02	IBA.2
P. alba x *glandulosa*	BA.5	BA.5 NAA.02	IBA. 5 NAA.1
P. alba x *tremula*	BA.5, 1	BA.5 NAA.02	IBA.2, .5
		BA.5 NAA.05	
P. canescens	BA.5, 1	BA.5 NAA.02	IBA. 2, .5
P. tremula	BA.5	BA.5	IBA.5 NAA.1
		BA.5 NAA.02	
P. tremuloides	BA.5	BA.5	IBA.5 NAA.1
		BA.5 NAA.02	

BA = benzyl adenine
NAA = naphthaleneacetic acid
IBA = indolebutyric acid

Cultures are incubated at 25°C under fluorescent lights (1 to 3000 lux) with a 16 hour photoperiod. Cultures are regularly checked for microbial contamination, clean explants are transferred to fresh medium after 3-4 days. The growth of bud explants is not uniform, some buds begin growth almost immediately whilst others required 6 to 8 weeks to commence growth. In contrast, shoots from root suckers invariably begin growth immediately.

The hormones in the growing medium control the growth and development of the explant. Basically the types of growth that may develop in this stage depend upon the auxin-cytokinin ratio. With a high auxin-cytokinin ratio in the medium unorganised callus is produced. The organised shoot growth and proliferation promoted by a low auxin to cytokinin ratio, is preferred to the production of undifferentiated callus. Although aspen callus has been differentiated into plantlets by Winton (7), Lester and Berbee in (3) reported irregular shoot production from callus coupled with cytological and morphological variation in plants produced from the same popular callus. Chromosomal abnormalities have been noted in other angiosperm cultures. *Prunus* (8) and *Acer* (4) callus show increasing abnormalities after several subcultures.

The first stage is completed when a sterile explant has commenced growth and possibly some shoot proliferation. When this is accomplished the shoots are transferred to stage II for bulking-up.

Stage II. In stage II, aspen and silver poplar multiplication in vitro is being achieved in two ways:

a) By the production of adventitious shoots from the explant surface in contact with a high cytokinin medium. A large number of small shoots and buds are produced. However, shoot elongation may be retarded, this makes subculturing difficult without the aid of a microscope.

b) Another system for propagule multiplication depends upon the enhanced axillary branching of shoots that can be stimulated by the appropriate combination of medium cytokinin and auxin (See Table 1). This system allows the regular subculturing of shoots 1 to 2 cm long onto fresh medium every 4 to 6 weeks. This proliferation process may be continued almost indefinitely, until the required number of shoots are produced.

An average multiplication rate of 10 shoots per culture per month can be attained, this would suggest more than 10^{10} plantlets per annum could be produced from one original bud. However, in practice, incubation space and nursery facilities could quickly become limiting factors. With the present facilities at Aokautere a daily production of up to 200 plantlets can be achieved. The number of proliferating cultures is kept at constant level by transferring 9/10 of the shoots to Stage III and placing the remaining 1/10 back onto fresh proliferation medium

Stage III. In this stage shoots 1 to 2 cm long are rooted in a simplified agar medium under lights ca 5000 lux. The best root initiation and growth is promoted by using both IBA and NAA in the rooting medium. Callus production in this rooting medium has been reduced by deleting the lysine, inositol and adenine sulphate from the basal medium.

Good root development on 80% of the shoots is obtained in 10 to 14 days, whereafter plantlets can be hardened off. Rooted shoots are then prepared for transfer from agar to a potting medium. To allow for some adaptation to the glasshouse light and temperature regime, plantlets are placed in the glasshouse for two days before being taken out of the agar. Most of the agar is sloughed off plantlet roots prior to potting in a soilless growing medium. Plantlets are sprayed with a systemic fungicide and placed under intermittent mist for 7 to 14 days. During the hardening off period it is particularly important to control water loss by intermittent mist or very humid conditions as plantlets fresh out of culture are unable to remain turgid. Intermittent

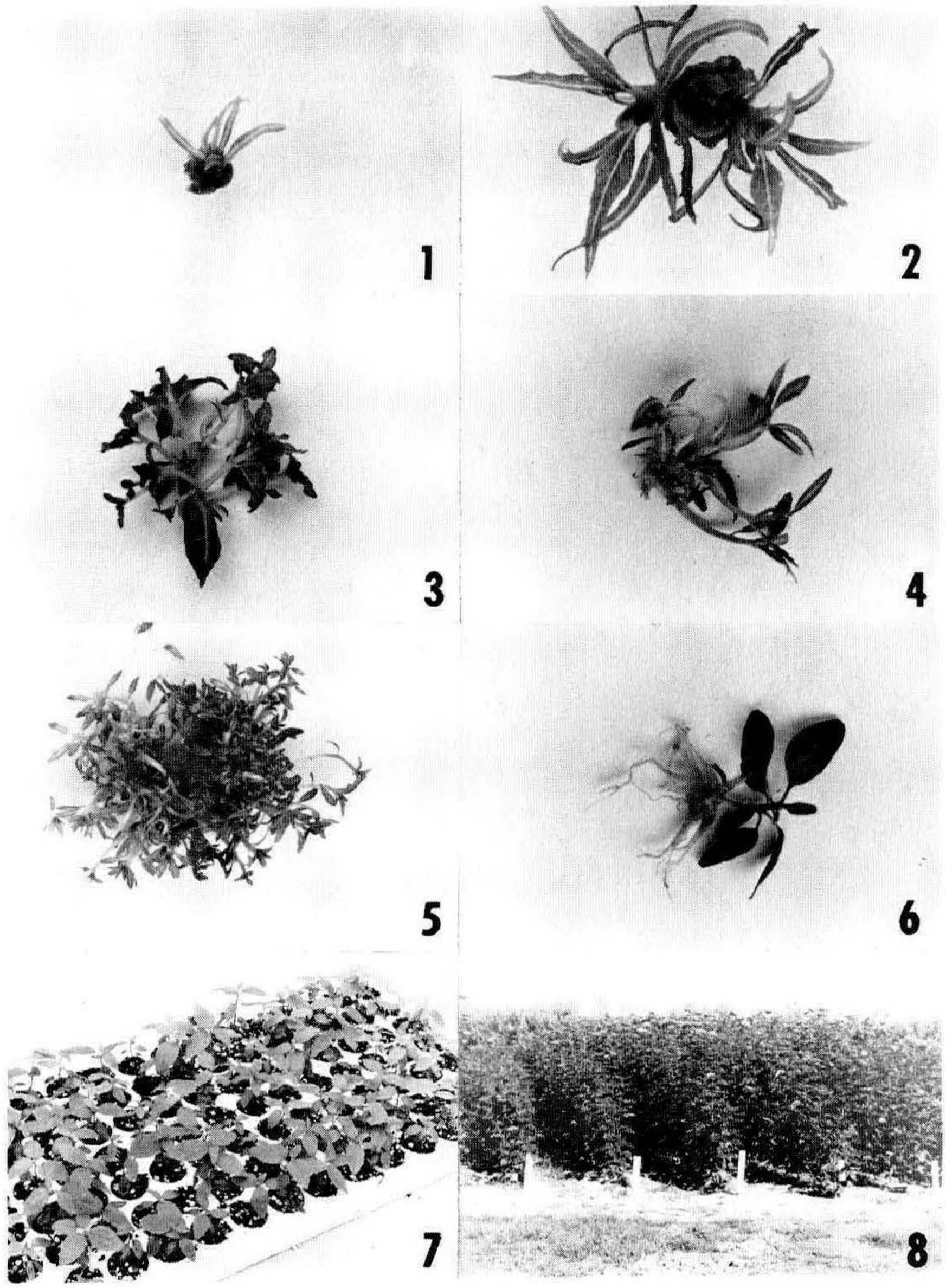

Figure 1. *In vitro* propagation of poplar plantlets and nursery trees from vegetative buds.

1. Growth of *Populus tremula* bud 2 weeks after excision (0.3 cm diam.).
2. Development of axillary buds from *P. alba* × *glandulosea* bud explant after 4-6 weeks (1.5 cm diam.).
3. Enhanced axillary branching of *P. canescens* (2 cm diam.).
4. Adventitious shoot production at the base of *P. tremuloides* shoot (1 cm long).
5. Advanced shoot proliferation of *P. alba* × *nigra* (5 cm diam.).
6. Rooted plantlet of *P. alba* × *glandulos* ready for hardening-off (1.5 cm long).
7. Hardened-off plantlets of *P. alba* × *glandulos* 4 weeks after leaving the laboratory (5-7 cm high).
8. Nursery trees of *P. alba* × *glandulosa* almost 2 m high 4 months after planting out.

mist and photoperiod extension in short days allows 90% of the plantlets to be weaned successfully. The young plants are then held on an unmisted bench for 7 days, during which time extensive root development takes place.

Finally, plants are potted into peat pots and grown-on in the glasshouse until about 10cm high; they are then hardened off outside prior to field planting. They then grow rapidly, attaining 1.5 to 2 meters within 3 months after planting in the field (Figure 1).

SUMMARY AND CONCLUSIONS

The vegetative propagation of difficult-to-propagate poplars has been achieved using tissue culture techniques.

The rapid bulking up of new clones allows quicker introduction of this material into new and existing planting programmes. It is planned to have 20,000 plants of two new *P. alba* x *glandulose* clones available for Catchment Board plantings in 1979. All the plants produced to the present time appear identical to the stock plants.

Besides the in vitro propagation of poplars, the sterile plant cultures have provided a very useful way to import new clones with minimal risk of disease entry. It is envisaged that the international exchange of sterile plant material in this manner will become of increasing importance to plant propagators throughout the world.

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SOILLESS GROWING MEDIA AND MICRONUTRIENT NUTRITION[1]

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The omission of soil from growing media has reduced many management problems and improved plant growth but it has introduced some problems that require further investigation.

When evaluating factors that affect the propagation and growth of plants in soilless growing media, the physical characteristics of the medium are well known (4). However, the chemical activity of the medium is often overlooked or underestimated.

This situation has arisen partly because of the early work with container growing media in California where it was suggested that soilless media components should be of low fertility and not release or fix any plant nutrients (1). Where the growing medium is inert and of nil fertility it should be relatively easy to provide the required level of plant nutrition. If, however, the media components were supplying or withholding some nutrients then it would be difficult to maintain a particular nutritional status, unless the media components were characterised chemically.

It is well known that peats commonly have a strong acid reaction which may be reduced by the use of lime. Peats are also known to bind strongly copper, zinc, iron and manganese in a fairly irreversible manner (7).

Up until recently, perlite and pumice have been taken to be relatively inert, but user experience with these materials has shown that some plants growing in similarly fertilized soilless growing media can show marked differences in the quality of the saleable plant. The foliar symptoms observed often appear like a micronutrient deficiency.

This paper is concerned with the results of two experiments that show micronutrient nutrition of chrysanthemum plants can be influenced by soilless growing media components.

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Experiment I.

METHODS

Rooted cuttings of *Chrysanthemum* 'Nob Hill' were grown for 10 weeks in four different media made from equal parts of either New Zealand peat or Irish peat and either pumice or perlite. The nutrients added to each 10 litres of growing medium are shown in the following table.

Table 1. Standard nutrient supplement per 10 litres of medium

Nutrient	Weight (g)			
	N	P	K	
Osmocote	18	2.6	10	25
Osmocote	14	6	11.6	10
superphosphate				15
dolomite lime				15
agricultural lime				15

At the end of the growing period plant growth was assessed and fully expanded upper leaves were removed for micronutrient analysis by atomic absorption spectroscopy.

RESULTS AND DISCUSSION

After the seventh week of growth, differences in foliar pigmentation were visible. These differences become progressively more obvious by the tenth week.

All plants grown in the perlite-based media, irrespective of the type of peat, showed pronounced interveinal chlorosis in the upper leaves. In contrast, plants grown in the pumice-based medium appeared to be a much healthier green colouration, but a mild interveinal chlorosis was visible in plants grown in the Irish peat-pumice mixture.

It was originally considered that reduced copper availability may be inducing the iron chlorosis symptoms observed in the chrysanthemum leaves (2). Copper deficiency in chrysanthemum is characterised by increased internode length, decreased axillary bud development and chlorosis of the middle leaves. However no differences in internode length, axillary bud development or dry matter production were observed in plants grown in the four media.

The acidity of each medium was determined to ensure micronutrient availability was not being limited by the pH value.

As the optimal pH for organic soil and peats is in the pH range 5.0 to 5.5 (5) it was concluded that pH was not limiting micronutrient availability.

If the media components were unreactive then, given that all other factors were the same, equal nutrient concentrations

Table 2. The initial pH of the growing medium.

Medium	*pH*
N.Z. Peat-Perlite	4.8
N.Z. Peat-Pumice	5.2
I.Peat-Perlite	5.0
I.Peat-Pumice	5.4

could be expected in the leaves of plants grown in the different media.

The levels of iron, manganese, zine and copper are shown in Figure 1.

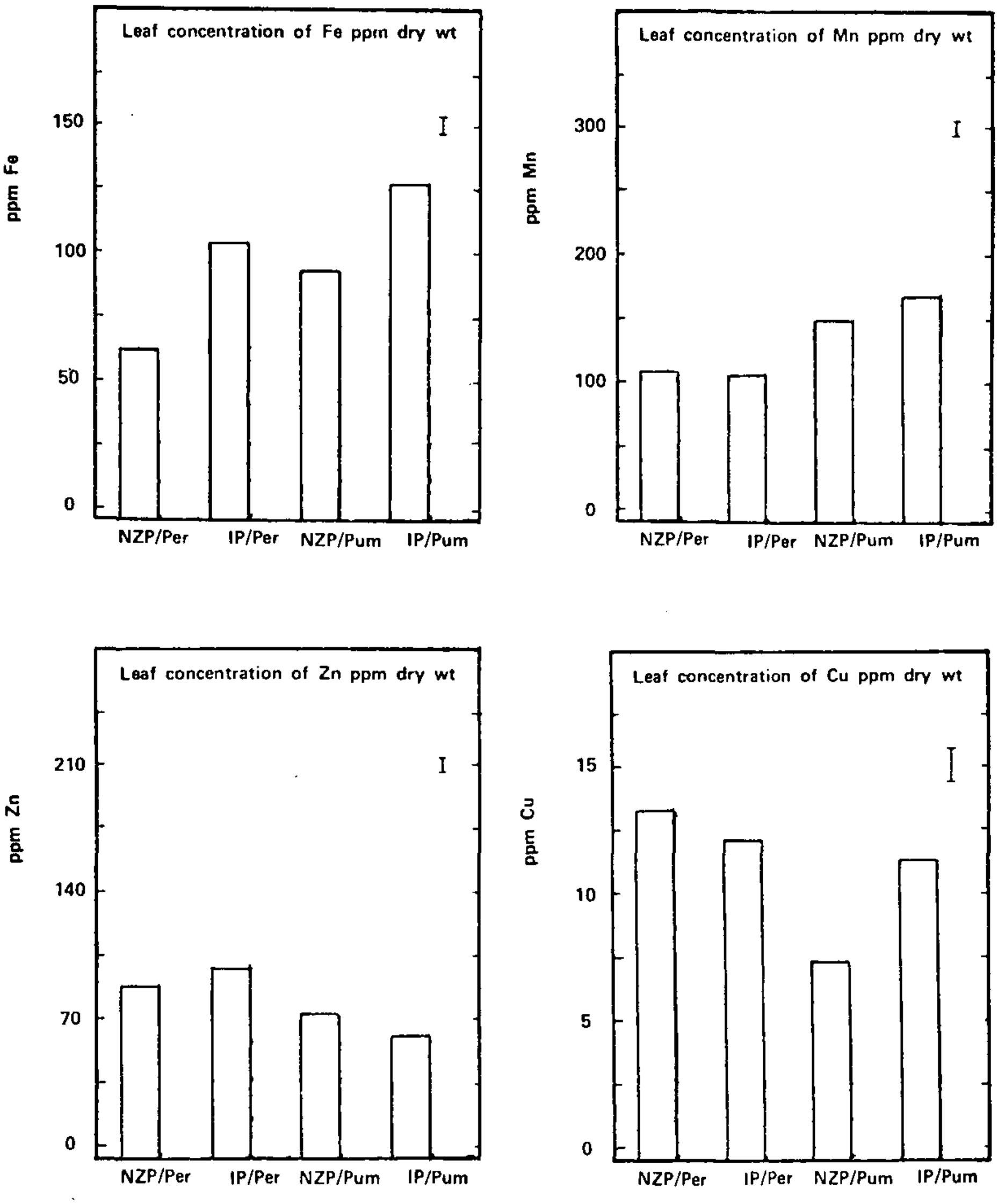

Figure 1. The influence of the growing medium on the foliar micronutrient levels in *Chrysanthemum* 'Nob Hill'. NZP = New Zeland Peat; Per = Perlite; IP = Irish Peat; Pum = Pumice; I = LSD(0.05)

Foliar levels of iron are higher in the pumice based medium compared with perlite, and are higher when Irish peat is used rather than New Zealand peat.

With foliar manganese little difference was detected between the two peats, but manganese levels are higher in leaves from pumice based media compared with perlite.

In contrast, foliar zinc levels were higher in plants grown in perlite compared with pumice. Again only small difference between the two peats were observed.

Foliar copper levels from all treatments were similar, except for foliage from the New Zealand peat-pumice mixture which contained significantly less copper. As the lowest copper level is not associated with the iron chlorosis symptoms, the validity of the original hypothesis is questioned.

However, it is clear that the media components used here show a chemical reactivity that can alter the levels of at least four elements in chrysanthemum leaves. The statistical analysis of the leaf analysis data suggested the two peats had less effect on the foliar micronutrient levels than the perlite and pumice components in the growing medium.

Experiment II.

METHODS

Rooted *Chrysanthemum* 'Nob Hill' cuttings were grown for 10 weeks in perlite or pumice with the same nutrient supply as in experiment I, except the lime rates were halved. Two fritted trace elements, FTE 503 and FTE 36, were applied at the rate of 100g/m^3 of medium and compared with a nil FTE control treatment for iron chlorosis control.

RESULTS AND DISCUSSION

After one month the plants grown in the pumice medium were dark green and apparently healthy. In contrast, the new growth of plants in the perlite medium showed vivid interveinal chlorosis whilst the oldest leaves remained a healthy green.

When sampled after 10 weeks the leaves from all pumice media were non-chlorotic irrespective of the FTE source. The upper leaves from all perlite treatments were highly chlorotic. The most severely affected plants were those grown in the FTE 503 treatment.

Chlorotic expanding leaves greened-up in response to foliar application of 1% w/v Fe EDTA. This indicates an iron deficiency was observed.

The pH of each medium was determined, perlite (6.2) and pumice (6.7). These values are higher than the pH values mea-

sured in the peat based mixtures, but are not considered to be limiting micronutrient availability (5). Plants grown in pumice with the higher medium pH did not show any micronutrient deficiencies.

In Figure 2 large differences in foliar nutrient levels have been detected between plants grown in perlite and pumice. These differences were enhanced by the use of fritted trace elements.

Figure 2. The influence of the growing medium and frit type on the foliar micronutrient levels in *Chrysanthemum* 'Nob Hill'. □ = Perlite; ▨ = Pumice; I = LSD(0.05).

The foliar iron levels in plants grown in pumice tended to be higher than if grown in perlite. Similarly foliar manganese levels were higher in plants grown in pumice rather than perlite. Foliar levels of copper and zinc were higher in plants grown in perlite rather than pumice, particularly where fritted trace elements were added.

Both frits increased the foliar levels of copper, zinc and manganese. Each frit differed in its effect on foliar iron, FTE 36 increased iron levels in perlite-grown plants and FTE 503 decreased iron levels in both perlite and pumice media.

Neither frit prevented or reduced iron chlorosis symptoms in the perlite based medium.

GENERAL DISCUSSION AND CONCLUSION

When the foliar analysis data collected in the experiments are compared with standard critical and optimal nutrient levels (3,6), it is apparent that the micronutrient levels present in these plants should have been high enough to prevent deficiency symptom expression, even without the use of fritted trace elements.

Table 3 Standard values for micronutrient content of chrysanthemum leaves (ppm dry weight)

Level	Copper	Zinc	Manganese	Iron
Optimal	10-50	7.26	195-375	100+
Critical	5	7	25	50-100

source (3, 6)

As the expanding chlorotic leaves responded to iron chelate application, this indicates there is insufficient physiologically active iron present in spite of adequate total iron levels. Either the perlite alone or its combination with the fertilizers has altered the availability of the iron within the chrysanthemum plant.

In summary, it is clear that the components of the growing medium can have an important effect on the nutrition of some plants. The foliar micronutrient levels appear adequate to prevent deficiency symptom expression in both perlite and pumice amended growing media.

Fritted trace elements have not prevented the expression of foliar chlorosis where perlite was used in the growing medium.

Acknowledgement. The assistance and interest of Mr. M. Richards, Massey University during this work is gratefully acknowledged.

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NEW TECHNIQUES FOR PEACH TREE PROPAGATION IN AUSTRALIA

ALLAN WHITE

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Department of Scientific and Industrial Research
Havelock North, New Zealand

With the trend towards higher density planting of peach trees, low cost methods of rapidly producing large numbers of trees are desirable. Earlier this year I visited the Irrigation Research Institute, Tatura, Victoria, Australia, where they have developed two techniques for commercial production of saleable trees from cuttings in one season. Both techniques are simple; however there are several critical requirements which must be fulfilled if they are to be used with success.

Hardwood Cuttings. *Pencil thick basal cuttings 25 to 30* cms long are taken from one-year-old laterals borne on branches that carried fruit the previous summer. The cuttings are typified by short internodes and are only harvested from healthy, vigorous trees less than six years old. Care in selection of cutting material is important to ensure a good strike and rapid growth in the nursery. Cuttings are taken from late June to mid-July (mid-winter).

The cuttings are then treated with the rooting hormone, indolebutyric acid (1000 ppm in 50% alcohol), the base of the cuttings being dipped for 10 seconds then air dried. Treatment must be done within 10 hours of harvesting the cuttings.

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The cuttings are then treated with the rooting hormone, indolebutyric acid (1000 ppm in 50% alcohol), the base of the cuttings being dipped for 10 seconds then air dried. Treatment must be done within 10 hours of harvesting the cuttings.

The cuttings are then rooted in a medium of 4 parts coarse river washed sand and 1 part peat at a bottom heat of 23°C (75°F). Moisture levels at this stage are critical because overwatering can result in death of the callus and roots. Within three to four weeks most peach cultivars begin rooting. When the roots have grown 2 to 3 cms the bottom heat is reduced for a few days then turned off.

Delays in reducing bottom heat can result in root death; also it is important to harden the roots off for planting out or potting on before they become intertwined and impossible to remove from the propagating box without damage.

When the roots have been hardened they are either lined out directly into the nursery or potted into 5 cm peat pots containing a medium of coarse river washed sand and then lined out in the nursery in spring. Care must be taken not to damage the roots which are very brittle or let them dry out. From now on the cuttings are given a balanced liquid fertilizer every second watering.

At the end of the summer the cuttings have grown into rods 1.5 metres high and are suitable for lifting and planting out into orchards. For the Golden Queen cultivar more than 70% of the cuttings produce trees.

Leafy Cuttings. Cuttings may be taken throughout the summer although the best results are achieved using basal cuttings taken in November-December (early summer). The cutting is selected from new growth on fruiting laterals. The soft tip is removed and leaf areas reduced to four half-leaves. Cuttings are about 10 to 15 cm long. Care must be taken to ensure cuttings do not dry out between harvesting them and when they are processed.

Cuttings are given a basal dip of indolebutyric acid (1000 ppm in 50% alcohol) and then inserted into a rooting medium of equal parts vermiculite and perlite. They are rooted under mist at 85% relative humidity and at temperatures below 32.5°C (90°F). No bottom heat is used.

Moisture control in the rooting medium is very critical as overwatering can inhibit rooting or cause root death. Drainage of both the medium and the container needs to be good. Cuttings must also be shaded from full sunlight.

Roots are produced within 35 days and, after a further 14 days hardening off, the cuttings may be lined out in the nursery. Care must be taken not to allow the roots to be damaged or dry out when being planted out. At the end of the summer these cuttings have grown into small trees 60 cm high. For the cultivar Golden Queen, more than 90% of cuttings are successful.

These two techniques offer the nurseryman the possibility of propagating large numbers of peach trees at a low cost and at a one year production cycle compared with the present two year cycle for worked trees with its high labour requirements for budding and heading back.

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PRODUCTION POT-POURRI

ELLABY MARTIN

Martin's Nurseries Ltd.,
Rototuna School Rd.,
R.D. 1, Hamilton, New Zealand

When we started our nursery we grew a moderate range of plants, some in fairly large quantities, and sold a substantial amount of our total production wholesale using the income derived from this to purchase other lines for our retail requirements. As sales in our new garden centre expanded from 1970 we started to experience real difficulties in obtaining sufficient stock in adequate variety for our retail sales. About mid-1974 we decided to change our production process and try to grow the maximum number of cultivars and quantities possible for our own garden centre sales. This policy has proved well worth while for us particularly over the last two years as we have managed to get our re-organised production system functioning in something approaching high gear. We still buy in substantial quantities of some lines but now grow a very large range of several hundred species and cultivars.

This method of running a business works for us with, I believe, real benefits, but I'm not suggesting that our method of operating would have similar benefits for other businesses. We now propagate and grow in containers, and in the field, some 100,000 trees, shrubs, basket plants, climbers, etc., each year. These are propagated in the estimated numbers required in batches throughout the year. For example, if we think we can sell 400 *Ceanothus papillosus* var *roweanus* annually we propagate them in three or four batches several months apart so that we have fresh groups coming into the garden centre throughout the year. Obviously we aim to have the largest group saleable in

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spring, but we do not expect to be selling left-overs late in the year — instead we have a new batch coming forward. The advantages of this method of production are obvious, but there are also a few headaches. Some plants are produced in very small batches, often only 20 at a time. This rather complicated production programme would probably drive an efficiency expert or cost accountant crazy but the benefits for us make it worthwhile.

CUTTINGS

Propagating Benches. These are built of corrugated fibrolite sheets with Pyrotenax cables laid along the depressions and a concrete top poured *in situ*. The cables are thermostatically controlled and kept at approximately 24°C (76°F). Each bench is 4.1 m × 1.5 m with 17.8 cm deep timber sides filled with a rooting medium. Cuttings of some plants are inserted straight into the medium — others are put in boxes or pots of the medium and placed on top of the bench. All but one bench is supplied with time-controlled mist. The bench without mist has a polythene tent built above. On this bench we propagate these plants which do not do well under mist.

Hardening Off. When cuttings are rooted they are potted into tubes or small pots and stood on benches opposite the propagating benches, covered with a polythene tent and, after heavy watering-in, left hot and humid for 2 or 3 weeks. The tent sides are then gradually raised to facilitate hardening off before the young plants are transferred to a tunnel house or frame. Every rooted cutting is potted initially into the same medium which consists of: — 1 part by volume peat; 1 part by volume sand; 1 part by volume sterilised soil; and 1 part by volume sterilised abbatoir mix. *plus*: 1.2 kg. potassium nitrate per m^3; 1.2 kg. dolomite lime per m^3; 100 g. Terrazole per m^3.

Experience has proved that virtually all young rooted cuttings grow well in this mixture. Once established, however, many species must be quickly potted into a more nutritious mix. At that stage we use standard U.C. mixes which we produce ourselves.

Use of Cold Frames. We also propagate a number of cuttings in a type of cold frame 32.5 m long by 1.2 m wide running the length of one outside wall of a glasshouse. Cuttings of easy-to-root plants, such as *Photinia* × *fraseri* 'Red Robin', *Buxus*, most conifer cultivars, including Leyland cypress, are put into a 22 cm deep sand and peat bed in this frame. After heavy watering they are covered directly on top with thin polythene film. The frame top of polythene is then pulled over the structure. Sarlon shade cloth is also used through the sum-

mer. Cuttings are inspected once a week for watering and spraying with fungicide. About 30,000 cuttings are propagated by this very inexpensive method.

GRAFTING

We graft a number of conifers including Koster's blue spruce, *Cedrus atlantica* 'Glauca', *C. deodara* 'Aurea', *Camellia reticulata* cultivars, *Fagus sylvatica* 'Purpurea Pendula', *Wisteria*, and *Gleditsia triacanthos* 'Sunburst'. Usually all grafting is done about mid-August (late winter). We use four main methods of grafting based on past successes; side veneer for *Picea pungens* 'Koster'; tongue veneer for *Cedrus* spp; whip and tongue where the stock and scion sizes match e.g. *Gleditsia*, some camellias, and *Fagus* cvs.; and wedge grafts for camellias.

Before grafting, all potted rootstocks are dried off in a glasshouse for three weeks by withholding water. Scionwood of deciduous plants is cut in mid-July (mid-winter) and stored under a hedge in polythene bags. Coniferous wood is cut 2 to 3 days beforehand and stored in a refrigerator.

After grafting, all plants are sprayed with Wiltproof before going into the grafting pits. These pits are situated inside a larger glasshouse which is kept at approximately 13°C (56°F). They consist of a boarded-in bed filled with untreated sawdust and an 'A' frame structure over which a polythene sheet is draped and, later on, shade cloth. The grafts are plunged into the moist medium up to and over the graft union. Then a 70 mu clear polythene sheet is laid directly on top of the plants trapping condensation and humidity.

For six weeks the grafts are looked at once a week and sprayed with a fungicide, alternating between Maneb, Thiram, Benlate and copper oxychloride. At four weeks the rootstock is reduced by approximately one-third and, six weeks from grafting, the bottom layer of polythene film is removed. Over the next six weeks the grafts are "damped down" 2 to 4 times daily and gradually hardened off by raising the pots free of the sawdust and raising the tent sides, finally leaving only the shade-cloth and reducing the damping down to once daily. Rootstock growth is reduced a further third 6 to 8 weeks after grafting. Three to four months after grafting, the plants are shifted outside to a cool shaded and sheltered area. Five to six months after grafting all stock growth is removed, ties are cut, and plants are staked, or potted on as necessary.

SOME SPECIFIC SPECIES PROPAGATED

Clematis hybrids — We propagate these as early as possible in frequent batches throughout September and October (spring)

taking material off stock plants and the previous year's plants. Cuttings are softwood, nodal and internodal; they are dipped in sodium hypochlorite (NaOCl) and rinsed in water before using Seradix 1. After this they are inserted into pots of sand and put under the mist on bottom heat. These cuttings are potted up in December (early summer) with the crowns buried in U.C. mix straight into 12 cm Ace pots and put under a polythene tent bench in a glasshouse. After four weeks of constant nipping of the shoots (used for further cuttings) the plants are moved outside to our tree shade areas where they establish before the winter. The later batches of cuttings (November-January) are overwintered in the propagation pots and potted up in the spring.

Azaleas — These are propagated in March (autumn). We used to use Rootone hormone powder after a Captan dip but when Rootone became unavailable we used the Captan dip alone with fair success. This led us to compare Captan powder as a basal dip with Seradix 2. Captan proved the better and now we use Captan powder dip for all plants previously treated with Rootone, e.g. *Daphne, Leptospermum* and azaleas.

Proteas — Following a field trip to Owen Gibson's nursery and seeing his success with proteas and leucospermums propagated in clay beds outside, we tried using clay subsoil in boxes for proteas. The cuttings are made 8 to 10 cm long using half-ripe wood and Seradix 3 in July and August (late winter). The cuttings are then put into the clay medium, sprayed with Wiltproof, and put straight outside. A comparison was made with sand as the medium. Results proved that clay was better for rooting, e.g.:

Protea neriifolia in clay ..... 95% rooted.
Protea neriifolia in sand ..... 20% rooted.

All cuttings were dipped in NaOCl solution prepared as follows: *Stock solution:* 0.6 litre concentrate in 4.4 litres water. *Working solution:* 0.6 litre stock solution in 5 litres water. This is made *fresh daily*. All cuttings are dipped in the NaOCl working solution then are rinsed in water before the hormone powder treatment, if this is used.

SOME COMPARISONS BETWEEN PLASTIC AND GLASS GREENHOUSES

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INTRODUCTION

The acceptance of plastic materials for greenhouse construction has been much slower in New Zealand than elsewhere. Worldwide statistics on greenhouses suggest that generally the area of plastic greenhouses is three times the area of glasshouses. The reasons for this lag behind worldwide trends are undoubtedly very complex, but nurserymen and propagators in New Zealand are using a higher ratio of plastics to glass than greenhouse growers generally. The current emphasis on expansion of horticultural production in New Zealand and the general shortage of planting stock is causing many propagators to consider expanding their businesses. This involves difficult decisions on how best to do so. These decisions are not made easier by the wide range of alternative greenhouse covers already offered in New Zealand and the range of new material coming onto the market here and already available overseas (see Table 1).

Table 1. Plastic alternatives to glass for greenhouse use.

	Material	*Trade Names*
(a)	**Currently available in New Zealand**	
	UVI polythene film 125 um thick	GARNITE Greenhouse
	UVI polythene-ethyl vinyl acetate copolymer film 125 um	(NIPPOFLEX (AGPAC Greenhouse PERMAFLEX
	UVI polyvinyl chloride film 300-450 um thick	NYLEX Agricultural PVC
	Polyvinyl chloride rigid sheet	NOVAROOF
	Glass reinforced plastic rigid sheet	DUROLITE fibreglass
(b)	**Available overseas**	
	polyvinyl chloride film 125 um	many brands
	polyvinyl chloride rigid thin sheet	
	UVI double polythene rigid sheet	CORFLUTE
	UVI double acrylic rigid sheet	(ACRYFLUTE (STEGDOPPELPLATEN

The decision on whether to expand plastic or glass greenhouses has to be made objectively from the business point of view on the basis of greenhouse operating costs per unit area and per unit product. The greenhouse operating costs per unit product itself depends on the amount of yield produced under

the various greenhouse covers, but it is possible to compare costs on the assumption that yields are equal with all types of greenhouse.

Estimates of the most important greenhouse operating costs are given in Table 2. Greenhouse operating costs per unit area do not accurately reflect costs per unit production which are dependent on the yields actually obtained. Table 3 shows how the profit margin per unit product can vary by a factor of about three times as a result of variations in greenhouse operating costs and yield using tomatoes as an example.

Table 2. Estimated fixed operating costs for greenhouses. All costs in dollars per sq. meter.

Greenhouse types	Tunnels			Small	Levin	Multibay	Large	
	Single PE[1]	*double PE*	*PVC*[2]	*glasshouse*	*PE*	*Rigid PVC*	*glasshouse*	*GRP*[3]
Capital cost	11	13	12	45	10	16	30	43
depreciation[5]	0.55	0.65	0.60	2.25	0.50	0.80	1.50	2.15
interest[6]	1.10	1.30	1.20	4.50	1.00	1.60	3.00	4.30
recovering	2.00[7]	4.00	0.84[8]	—	1.67[7]	0.50[9]	—	0.63 [9]
maintenance	—	—	—	0.50	—	—	0.50	—
basic operating costs $m2 year	3.65	5.95	2.64	7.75	3.17	2.90	5.00	7.08
heating cost[10]	3.24	2.37	2.57	3.56	1.60	NA	2.85	2.85[11]
ventilating cost[12]	0.63	0.63	0.63	1.00	0.63	NA	1.00	1.00
TOTAL	7.52	8.95	5.84	12.31	5.40	—	8.85	10.93

NOTES:
[1]Polyethylene
[2]Polyvinyl chloride
[3]Fibreglass on steel trusses.
[5]Depreciation over 20 years
[6]Interest on capital at 10%
[7]Annually
[8]Every three years
[9]After fifteen years
[10]Heating costs based on 10,000°C hours below heating set point each year
[11] Heat loss from fibreglass greenhouses under NZ conditions is not known but assumed to be the same as for glasshouses.
[12] Ventilating costs, an arbitrary figure is given dependent on the known variation in fan capacity required for glass and plastic houses.
NB: The use of thermal screens could reduce heating costs by 20 to 30% in all types of greenhouses.

Table 3. Effect of yield and greenhouse operating costs on tomato profit margins.

Yield	Sales	Labour & Variables	Low cost greenhouse			High cost glasshouse		
			Cost	Margins		Cost	Margins	
kg/m²	$/m²	$/m²	$/m²	$/m²	$/kg	$/m²	$/m²	$/kg
15	+30	−20	−5.40	4.60	0.31	−8.85	1.15	0.08
20	+40	−25	−5.40	9.60	0.48	−8.85	6.15	0.31
25	+50	−30	−5.40	14.60	0.58	−8.85	11.15	0.45
30	+60	−35	−5.40	19.60	0.65	−8.85	16.15	0.54

YIELD COMPARISONS

It is difficult to reliably compare yields in plastic and glass greenhouses. Yield in any situation is a result of the environment provided throughout the growing period and the environment itself is greatly modified by different greenhouse types. Some understanding of the physics of the greenhouse environment is required to appreciate the magnitude of the effects of different greenhouse covers and it must be realised that the newer structures all offer the grower a greater opportunity to

control the environment than is available under glass. Plastic and glass greenhouses differ particularly in their effects on light, heat, humidity and air change rates in the greenhouse environment and all these factors affect yields.

Modifications to the light environment. As a general rule fewer structural components are required to support plastic greenhouses than glass roofs and this allows a greater light penetration into the structure. The situation however is confused by the fact that most film plastic greenhouses have curved tunnel roofs rather than traditional even spans and also by the fact that most plastics diffuse light more than glass. Diffusing covers an east-west orientated tunnel greenhouses at high latitudes and low sun angles can result in a light trap situation but the diffusing covers probably do not increase total light intensity in north-south greenhouses or under cloudy conditions and reduce light intensities at high sun angles. I am not aware of any experimental evidence showing whether diffusing or clear greenhouse covers would be best in New Zealand. I suspect that, in general, growers use what is available to them, for example at our latitudes in Japan glass-clear PVC is the most widely used plastic material, but in Europe and North America this material is not available and more diffusing polythene covers are most common. The choice of cover may also affect spectral composition of light within the greenhouse and research is in progress with pigmented films, some of which are claimed to have increased yields under certain conditions.

Condensation, particularly in large drops on plastic greenhouse covers can reduce light transmission considerably but this problem can be avoided by using plastics which wet easily so that condensation forms as a film rather than droplets or by treating the plastics with certain surface active agents. The subject of light intensity in plastic greenhouses is thus very complex but, as a general rule, it is safe to assume light transmission is higher under plastic covers than under glass and should therefore benefit production.

Temperature environment. Plastic greenhouses can be thermally much more efficient than glasshouses particularly when double-skinned. Their thermal characteristics are highly dependent on the plastic material used and particularly on its transparency to long-wave infra-red radiation. All the materials at present in use are more transparent than glass when dry and so lose more radiant heat than glass but they are often covered by condensation which is an efficient infra-red absorber, reducing the radiant losses to levels very similar to that of glass. The greater radiant energy loss is largely offset by lower air change rates through plastics than glass roofs and by the smaller effect of wind in increasing heat loss.

Heat loss from greenhouses is surface area related and hence types of greenhouses such as tunnels which have a large surface to floor area ratio lose much more heat per unit floor area than do multi-bay structures with low surface to floor area ratios. It is also relatively easy to decrease heat loss by using two layers of plastic separated by still air.

Unventilated plastic greenhouses tend to be warmer by day than most glasshouses. When heating is required to maintain ideal thermal environments some plastic greenhouses are more expensive to heat than glasshouses but double skin polythene film houses are much cheaper to heat than glasshouses.

Humidity in the environment. Most growers recognise the effect of aerial humidity on plant disease but it is also important to realise that humidity has effects on yield. Well-built plastic greenhouses should have very much lower air change rates than glasshouses and this results in a far greater proportion of the water evaporated from the crop and soil being retained in the greenhouse. This does not necessarily result in high relative humidities though humidities normally tend to be higher in plastic than glass greenhouses. The relative humidity in a plastic greenhouse without any air change is related to the difference between plant and soil temperatures and skin temperature, which in single skin houses, is normally close to outside air temperature. Warm moist air within the greenhouse is cooled at the inner skin surface to close to skin temperature and hence causes condensation on the skin whenever its wet bulb temperature is above skin temperature. Natural convection maintains continuous air movement within the glasshouse and the wet bulb temperature of the air as a whole thus approaches skin temperature. Relative humidity is proportional to the difference between dry and wet bulb temperatures and so relative humidity in greenhouses is automatically regulated by the difference between greenhouse air temperature and skin or outside temperature. Thus, as a general rule, humidities will be high when inside and outside temperatures are similar and low when there is a large difference betwen inside and outside temperatures. Improving greenhouse insulation by double skinning has the effect of increasing the difference between outside air and skin temperature and hence also has the effect of increasing relative humidity within the greenhouse. Since there is little or no air change in unventilated plastic greenhouses, the moisture lost from the crop is retained as condensation on the skin. Provided that the humidity in the greenhouse is not high enough to cause disease and the condensation remains on the skin no harm results but, unfortunately, drips from the skin to the crop do create a disease risk. Walls and roofs with steep angles do

not drip, but wind flap (which can be prevented) causes dripping or showering of moisture onto the crops.

Another risk factor is dew on the crop. This risk is again much higher in plastic than glasshouses and is likely to occur in unventilated houses soon after dawn when solar heating quickly warms the air and sets up vigorous transpiration to increase absolute humidity of the air while, at the same time the crop warms up more slowly, thus providing an additional surface below air wet bulb temperature for condensation.

Recently published research from Japan suggests two possibilities providing better control of atmospheric humidity in plastic greenhouses. One possibility is to ventilate with relatively dry outside air and use a simple heat exchanger between outgoing and incoming air streams to recover heat from the exhausted air and warm the incoming air. The other possibility does not require ventilation but simply pumps warm moist air through pipes below the soil surface to provide both soil warming and condensation of moisture from the greenhouse air. Both possibilities have obvious applications to the nursery and propagation situation.

Carbon dioxide in the environment. Yield in all green crops is dependent on the process of photosynthesis, the rate of which is directly proportional to light intensity, temperature and $C0_2$ supply. A normal glasshouse is continuously supplied with $C0_2$ by leakage of fresh air into the glasshouse through gaps in the glass, etc. The rate of air change is itself partly dependent on inside/outside temperature differences so that in a closed glasshouse, as solar radiation intensity increases through the day, air temperature differences, the rate of photosynthesis, and the supply of $C0_2$, all increase in a self compensating manner. This is not true for plastic greenhouses where the $C0_2$ supply is limited by the volume of the greenhouse when ventilation is not given. There is, therefore, a very serious risk that crops in plastic greenhouses may be short of $C0_2$ quite frequently in periods of bright, sunny and cool weather. There is little published information on actual rates of $C0_2$ uptake by greenhouse crops. Uptake rates of 1.3 to 4.7 g of $C0_2$ per square meter per hour have been measured in tomato houses but tomatoes are known to take up more $C0_2$ than many other crops. Luckily, data has been published for roses and it is possible to calculate theoretical CO_2 concentrations in greenhouses cropped with roses according to light intensity and temperature. Such calculations suggest that on a typical New Zealand winter day the CO_2 concentration would remain close to ambient (about 340 ppm) in a rose glasshouse but that in a polythene tunnel the rose crop would consume all the available CO_2 (reducing the concentration to about 150 ppm) by about 10:30 am," thus

effectively limiting photosynthesis and growth for the remainder of the day unless ventilation were given. Ventilation on a temperature basis alone would not, however, be justified at that time as the temperature is still below the optimum for roses.

The use of $C0_2$ enrichment, however, would enable optimum $C0_2$ and temperature conditions to be maintained throughout the day providing that humidity considerations did not require ventilation. The economics of $C0_2$ enrichment should be much better in plastic greenhouses than in glass since the temperature difference related leak rate of glasshouses causes considerable wastage of applied $C0_2$ under optimum temperature conditions in winter.

Total environment effect on yield. New Zealand growers are very competent in crop production in glasshouses where temperature is the most important and most easily controlled environmental factor. By contrast plastic greenhouses exert a greater modification on temperature, humidity and $C0_2$ environment and hence make their control both easier and more vitally important if high yields are to be obtained. The exact nature of the changes in management practice required are still poorly understood.

THE RISK FACTOR

The plastic materials in current use all have considerable inherent strength particularly against well distributed loads. All the better materials retain this strength for at least one year's use, when manufactured to the proper standards, and properly installed. The materials can be punctured or torn by flying debris during wind storms, but glass would also break in these conditions. There has been some under-estimation of structural loads on plastic film structures, and adequate design of the structure of plastic greenhouses is essential. Tunnel houses built to the specifications of the more recent Lee Valley Experimental Horticultural Station recommendations probably present little if any greater risk than the average New Zealand glasshouse.

Many current greenhouse practices are designed to reduce the risks of crop failure, disease or poor timing or quality through elaborate environmental control as a consequence of the high value of greenhouse crops. Risks in these areas are associated with the reliability of environmental maintenance equipment rather than the structure. The lower capital cost of plastic greenhouses can free more money for investment in this area. The risk of structural and skin damage in absolute terms is similar for plastic and glass houses but less in capital terms for plastic structures. Financial institutions should be most willing

to lend on plastic structures, as hopefully small borrowing and greater profit margins should lead to quicker repayment.

CONCLUSIONS

Operating costs for traditional glasshouses and some rigid plastic roof greenhouses are nearly double that of the cheapest modern plastic structure. The plastic greenhouses all provide greater control of temperature, humidity and $C0_2$ concentration and offer cost savings where these factors are controlled. Light intensities in all plastic structures are believed to be better than in glasshouses and this should contribute to greater yield potential. However, achievement of this potential yield in plastic houses requires management practices which control (or at least recognise the greater requirements for control) temperature, humidity and $C0_2$ concentration. Differences in management practices between glass and plastic greenhouses are at present poorly understood but the difficulties in this area are not unsurmountable. Developing techniques in energy conservation and in solar heating are more likely to be more easily applied in future to thermally efficient plastic houses than to greenhouses and so I believe that in the long run glass must be displaced by plastics as the principal component of greenhouses.

PROPAGATING EUCALYPTS BY GRAFTING

BRIAN J. WALKER
Walker's Nursery
Hastings, New Zealand

Our aim in grafting eucalypts is to eliminate variability in flower colour and tree type. Grafting will enable us to produce trees true to colour and probably trees in full flower in containers. With *Eucalyptus ficifolia*, for example, we have trees with red, orange, scarlet and pink flowers. Another advantage of grafting is that, because the scions are from mature trees, plants immediately grow into round-headed, multi-branched bushes which are ideal for container sales.

For successful grafting, significant factors seem to be to use fast-growing seedlings for rootstocks and to obtain scions from current season's growth free of diseases and insect injury. Seedlings from October-November (spring) sowing are ready for grafting in late January or early February (late summer). At this time the scionwood is at a suitable stage of growth. Scionwood should be mature with no bud development in the axils of the leaves. Scions with two leaves are best. The leaves are removed

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leaving the petioles. It is important to leave the petioles because the scion will shed them at the base and seal itself naturally.

A cleft graft is used. The top of the rootstock is removed leaving two healthy leaves below the graft. Clean smooth cuts are essential. A scalpel is the best implement to use. The graft is tied with clear polythene grafting tape and, under no circumstances, must the top of the rootstock be covered. Petroleum jelly or vaseline is applied to the cut petioles and the wound area. The grafted plants are placed in full sunlight outside and must not be allowed to dry out. If drying out occurs the scion will be shed by the rootstock.

About two weeks after grafting, the leaf petioles commence shedding cleanly at the base and a swelling commences at the same point. At this stage the plant is potted on. Growths that arise from the rootstock should not be touched until the growth of the scion is about three to five cm. long. They are then tipped and finally removed when the scion is established and growing strongly.

So far, our success rate has not been good but I feel that we shall succeed eventually. I feel that success lies, not in technique, but in knowing when all conditions are right at the same time and in learning from our mistakes. I would strongly suggest to anyone attempting grafting eucalypts to sow seeds in lots of 50 at weekly intervals from late September to early November (spring) to give a succession of grafting material.

SOME OBSERVATIONS ON THE INFLUENCE OF TEMPERATURE ON WALNUT PROPAGATION

VERNON HARRISON

J.V. Harrison Tree Nurseries,
Palmerston North, New Zealand

For over 25 years I have been struggling with the production of named cultivars of walnuts by budding and grafting. This was taken on more by the way of a challenge than any particular interest in the crop.

Results from patch budding varied dramatically from season to season. All attempts at variation in techniques gave no conclusive answers. For several seasons there would be almost complete failure but the next season the percentage would be high and the resultant growth of the buds was always very satisfying, generally growing an average of 1.5 meters in a single season.

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I then realised that temperature subsequent to budding was

an elusive factor and that, in seasons when the success was high, budding would have been followed by hot sunny calm weather for at least 10 days. This seems to be verified by the fact that successful commercial propagators of walnuts were located in climates where the weather at the time of budding or grafting could be relied on to be hot and settled.

Grafting outdoors, using dormant scions on to rootstocks that were beginning to grow, gave very low percentages, if any at all. Scions were collected when quite dormant and stored, half covered, in sawdust in a bin in a cool shady position. One problem was the copious bleeding of the rootstock when cut. It flooded the cut surfaces and seemed to inhibit callusing.

Bench grafting, using bare rooted one or two-year seedlings of *Juglans nigra* or *J. regia*, solved the problem of bleeding but callusing was still poor and the results disappointing. Grafting was done in August (late winter), using scions fresh from the tree. I then came across a reference to work done overseas with bench grafting using a hot box to induce callusing. Our initial experiment was to place a number of bench-grafted walnuts with their roots wrapped in peat in a carton lined with polythene in a hot cupboard at my home. After 21 days the callusing was spectacular but the prolonged period of heat produced another problem, that of a mass of etiolated shoots too tender and delicate to salvage. We did find, however, enough buds on the scions sufficiently retarded to use. The final result of over 60% survival encouraged us to persevere.

As this point I reasoned that the sudden activity of the rootstock and the scion while in the hot box was due to the stimulus of winter cold. If the scion was grafted before it experienced the natural cold stimulus of winter it would remain dormant. We did this by harvesting the scions immediately after leaf fall and before the tree had received much cold stimulus from winter frosts. Grafting was then done as soon as the rootstocks could be lifted after their leaf fall. The bench grafts were then placed in bags and given 15 days in the hot box at 25°C. Callusing and the health of the grafts was pleasing when they were taken out. The grafts were left in their callusing bags undisturbed and placed in an unheated glasshouse until some signs of bud movement occurred before potting. After 60 days the whole batch of 170 remained quite dormant apart from eight which made very weak short growths. This new growth deteriorated until renewed growth occurred in the summer.

Fortunately I had also picked up the information that growers in Oregon, U.S.A., which has a similar climate to ours, were collecting scions in the equivalent to our August so we decided in the past winter to keep at least half of our material for prop-

agating at this time. The second batch was grafted in August using fresh scion wood which was still quite dormant on the trees but had experienced cold stimulus with the natural wintering. When removed from the hot box after 14 days at 25°C both rootstocks and scions showed some bud movement but not excessive enough for damage to occur after exposure to light and air.

Potting of the grafts made in August was done within seven days of their being removed from the hot box. This period gave etiolated shoots a chance to green up and the plant to adapt to the cooler temperature. Plants were potted into long five pint plastic bags and placed in a tunnel house to encourage developing growth and give protection from late frosts. After 20 days the growth was very rapid, some shoots growing 25 cm in this time. In practice, we have not found that undue growth occurs in the callusing period provided they are inspected daily and removed in good time.

After this very evident success of the second batch in August we felt encouraged to continue grafting in September. This was done using scions that had been gathered in August and stored just above freezing in the cool store in peat. By this time both scion and stock had experienced a greater length of wintering and, as a result, started very rapid growth when placed into the hot box. The percentage of success dropped from 90% with the August batch to about 50%.

Fortunately we had not disturbed the first batch, apart from potting the eight that showed signs of growth. This enabled us to place them in their callusing bags in cool storage (0-3°C) in an attempt to give them sufficient cold stimulus to break dormancy. After three weeks one bag was removed and placed in an unheated house but the response to heat was still sluggish and the balance was left in coolstore for a total of seven weeks. Even then their response to warmth was not sudden but was thankfully quite even and steady.

In conclusion, the August batch of grafts was far more satisfactory than either earlier or later graftings and they emerged from the hot box neither too dormant nor too advanced. This has led us to conclude that the amount of cold stimulus that the scions and rootstocks have received prior to grafting could be very important.

MEETING THE CHALLENGES OF A CHANGING NURSERY BUSINESS

SIDNEY B. MEADOWS, JR.

Flowerwood Nursery, Inc.
Mobile, Alabama 36605

The nursery business has been around for a long time, but we can say it has matured into an industry in the last thirty years.

A changing way of life in the nursery business. Anytime we break away from the familiar path of proven practices and procedures and embark upon the unknown trail of new systems, a certain amount of initiative, ingenuity and risk are involved. The comfortable thing for the short run would be to remain status quo. In the long run nothing could be more disastrous. The changing world we live in has dictated that we make changes, and from all appearances this will continue.

Thirty years ago the starting wage for a southern nursery worker was $3.00 for a nine hour day; there was no social security payment, unemployment compensation, or minimum wage.

Today in Alabama we have, for all practical purposes, a $3.00 per hour starting wage, a 6.13% social security tax on annual income up to $22,900.00, and an unemployment tax of 2.7% on $6,600.00 of a worker's annual wage. To calculate all of this takes time and money.

Needless to say, this is enough to bring on some changes, but when we add problems such as energy crisis, OSHA, EPA and social legislation we can readily see the reasons for a revolution. The change that has taken place in the nursery business in the last thirty years could very well be called a revolution.

The nursery business thirty years ago. In 1948 the average southern nursery was rooting cuttings in sand benches in glass houses. When they were rooted, the cuttings were uprooted and potted in clay pots or planted in beds. A year later these bed-grown and potted liners were planted in beds or rows in the field for growing on. Of course, in this process the bed-grown liner had been uprooted twice.

When harvest time arrived these plants were dug up and sold bareroot, or with a root ball held together by a fibrous root system, in the case of azaleas and the like, or with rootball wrapped in burlap.

For all practical purposes all the wholesale nursery business was done during the fall, winter and spring months, when temperatures were cool and plants were dormant. When selling

time came, customers usually visited wholesale nurseries, inspected the plants, and returned home with them in a pickup or bobtail truck.

Retail nurseries of that day for the most part limited their operations to plant sales and landscaping. Business was done in the fall, winter and spring; many closed for the summer.

The nursery business today. Since that day a long list of new nursery work horses have appeared on the scene, such as plastic film, plastic pots, peat pots, intermittent mist systems, improved irrigation systems, digging machines, pine bark and trailer truck transportation. All of these have had their impact on changing nursery practices and systems.

In the retail sector we now have year round total service garden centers catering to the needs and desires of the consuming public.

Changes brought on by escalating costs. Our greatest challenge through all of these changes has been to increase our involvement in the daily lives of the public at a price they can accept and we can afford.

The big key to this project is ECONOMICAL QUALITY PRODUCTION, which results only from the right combination of equipment, procedures and people. All costs have increased, but the front runner has been nursery worker wages. These have tripled in the last ten years — the starting wage has gone from $1.00 to $3.00 per hour. The mandate is very clear today; We must streamline our system and assemble a staff that can operate it to give us the quantity and quality production necessary to survive in the market place.

Personnel management — a must in cost control. Since people are always the most important element in production, and the most expensive, it is well to start with them. The first requirement is to do the very best recruiting job possible in getting help. The second step is to train these people to operate the production system.

There are some basic facts of life we can bear in mind on the subject of workers. They will continue to cost us more, so we must explore every avenue to increase their effectiveness. It is well to remind personnel that there are three levels of cooperation by workers: (1) A worker can anticipate direction, (2) he can respond to direction, (3) he can ignore direction. Obviously it is to everyone's benefit if he anticipates.

It is well to have the crew aware of the three basic qualities of a career worker. The worker must be (1) productive, (2) congenial, (3) cooperative. We want to encourage help to cultivate the art of eliminating the following phrases from their vocabul-

ary: (1) "I assumed," (2) "I took for granted," (3) "I never realized."

In dealing with people we should never be guilty of thinking just because something is so, there is a guarantee of immediate acceptance. People need to be told. In many cases they need to be told again; then they may even need some proof.

All of this comes under the heading of *communication*, and it can vary greatly among individuals. As a matter of fact, the whole art of selling revolves around this very principle. If we are right, we can prevail if we are tactfully persistent. If we are wrong, of course, we will not prevail over the long run, which is all that really counts.

People need a reason for performing. This can be accomplished by giving the three R's — recognition, responsibility, and reward — for production. All three are important, but reward through extra pay for extra production deserves top consideration. This can be done by establishing quota expectations in advance or by paying a piece work rate. This requires counting for quantity and inspection for quality of work, but the trouble is well worthwhile.

Modern practices help control cost. Once personnel are coordinated into a well-organized team, production can proceed. It is wonderful that we can take a cutting, stick it in a peat or plastic pot in a flat, set it under intermittent mist in a plastic or shade cloth house and have it rooted and ready to transplant in 3 to 6 months. At that time it can be transplanted to a gallon can and be ready for sale within 12 months from the day the cutting was made. Should we want a 2 gallon size, we can produce it in 18 to 24 months.

Programs are essential. In the past there was more room for a hit and miss approach than there is now. There will be still less in the future. There should be a program set up for all stages or facets of production and sales, including the following: (1) propagation, (2) container or field production, (3) fertility, (4) weed control, (5) sales, (6) shipping, (7) collection. All of these are to be set up on a factual basis. We must plan on what we grow, how we grow it, how we sell it when it is grown, and how we collect for it once it is sold. This has always been the case, but now it is more important.

Market survey very helpful. No longer do we grow and hope to find a market. It is much better to find a market, then grow the material for that market.

It is well for a new nursery starting out, or an experienced established nursery, to bear in mind one basic characteristic of a wholesale nursery customer. He is slow to come and he is slow to desert if treated right. It is a big risk to enter the market with

only hope there will be an instant customer. We must first find the people with whom we have even limited rapport and convince them of the virtues of our plants, our services, and our nursery. This usually cannot be done overnight.

There is always a market for new plants. There are always markets for established cultivars in particular sizes and shapes. The opportunities can be determined and an orderly production can be arranged to get there at the proper time with material to match the market potential.

Current market — active. The current market is wide open. All available plants can be sold. This situation is the result of severe freeze damage during the winter of 1977 plus a booming new construction business. Currently there is a big production expansion in process to cover this need. This is expected, but at the same time a word of caution should be injected. Keep an eye on new construction; if it drops off, so will the need for landscape type of plant material.

Home gardener sustains nurserymen. The home gardener has been and will continue to be the anchor man in the garden center business. He has a basic desire to keep his home grounds attractive. We want not only to offer him the plant materials to keep his grounds attractive but also to encourage him to make it look better. We can do this by offering a good selection.

Inflation our biggest threat — plan ahead. Currently the biggest crisis in the business community is inflation with its escalating costs. This behooves us to take a hard look at our practices, procedures and facilities with man-hour productivity in mind. Every operation will have to be streamlined to accomplish an objective with the least amount of time and motion. It is much better to make these changes ahead of time rather than to wait until the crisis comes when time and money are both short.

Making a move ahead of time involves a certain amount of convincing personnel of the need, but this is a management responsibility. If we choose to wait for the crisis to convince help, then we have failed to exercise our station in life as a management leader.

STUDY OF COST AND PRODUCTION IN PROPAGATION AT MAY NURSERY

J. BRADFORD MAY

May Nursery
Havana, Florida

May Nursery began operations in September, 1971, with the purchase of 14 three gallon *Pittosporum tobira* 'Wheeler's Dwarf' to be used for stock plants. After we built our first propagating houses, we immediately saw the need to cut production cost. We went from a house constructed of cedar with a concrete foundation, to a galvanized pipe quonset type house, then to a larger PVC framed house. We use ½ to 1 inch heavy PVC strapped on to a fence post. We strap a 45 degree angle PVC guard to the post and slide it over a galvanized support. We space the PVC supports somewhat closer than galvanized ones. There are five galvanized purlins — one down the middle and two on each side. The houses hold up well except in severe storms such as tornadoes.

The houses were first used as winter storage for the plants, which were propagated either in trays or in the ground and then transplanted into 3 inch round cups. One of the biggest savings we made was to eliminate the step of propagating in trays on the ground and go straight to the 3 inch cup for propagation. This made it necessary to install mist systems with solenoid valves in every house. The entire operation of potting from trays to 3 inch cups, or one and two gallon containers was thus eliminated. We also found we had cut the mortality rate to near zero. Once the plants are rooted in the 3 inch cup, 95 percent or better will be sold, barring human error or weather conditions, because once rooted, the plant and root systems are never disturbed.

Our propagating shade areas changed as much as our houses. The first shade area had an all galvanized pipe mist line that could be folded in and out for propagation and moving equipment and plants. In the second shade area the folding pipes were eliminated but the straight galvanized pipes were retained. The next change was to substitute PVC pipes for the galvanized ones. Later we found we could cut cost by using risers with sprinklers.

When we decided to abandon the tray for the 3 inch cup, we ran into the problem of economically filling the cups and placing them in the houses for sticking the cuttings. The mix used for all plants, except azaleas, consisted of equal parts peat, sand and perlite combined with 8 pounds of Osmocote 18-6-12, or 3 pounds of Scotts, 31-5-6 per cubic yard. We omit the slow

release fertilizer for azaleas. We tried several methods before we were satisfied with this operation. First, we tried using a wagon, filling it with empty cups, shoveling mix into the cups, traying up the containers, carrying them into the house, taking them out of the trays and placing them on the tables. When it came time for the plants to be potted, they had to be trayed up again to be carried to the potting barn. The filling part was on piece work, paying 1 cent per cup. We found that this operation was slow and costly. We have changed this procedure in order to reduce man hours used both when filling the cups and when potting. We have been able to eliminate work of two people by using plastic trays with 2¼ inch square cups. We use about 7 people to fill the cups. The cups, trays and mix are at the house. The trays filled with cups are put on the wagon and the mix is shoveled in. They are then put in the house, and this operation is finished. Another crew sticks the cuttings the same day or the day following.

Once the trays are filled with cups and mix, they remain that way until they are potted. It is no longer necessary to tray up, take the cups out and place them on the table, then tray up again when the time comes to pot. We now pay ½ cent per cup instead of 1 cent. The key to success with this procedure is to have a high percentage of cuttings that root. If trays are sent to the barn with a low number of plants rooted, a bottleneck is created in the potting operation.

After we move the filled cups into the house, we try to get the mix damp but not soggy. We have found that last year's or this year's spring wood is the best for cuttings. We use the "snap theory" for determining proper maturity of growth on broad-leaved plants and just down into the brown wood on narrow-leaved plants. The length of the cutting is 3 inches to 3½ inches; the bases are stripped for wounding purposes. We cut the tops on junipers and large-leaf broad-leaved plants but not on small-leaf broad-leaved plants. We have fewer disease problems on the non-cut leaves.

We use no rooting hormones on any cuttings. The main reason is that we found 75 percent of our cuttings were rooting above the powder dip line. After talking with people at Bush Ranch, Thomasville, Georgia, and Ten Oaks Nursery and Gardens, Clarksville, Maryland, I decided to experiment on each cultivar. I found 90 to 100 percent rooting on those without hormones compared to the usual 70 to 85 percent rooting with hormones. The next year, we decided not to use hormones and got excellent results. We have eliminated not only the expense of the hormones but also the time and labor in applying them.

All cuttings are stuck on piece work, paying 1 cent per cut-

ting. Workers get their cuttings, prepare them, and stick them as a group. To insure top production all week, we work or pay on a day by day basis. For example, pay per hour based on group performance using the piece work rate was $2.40 on Monday, $2.80 on Tuesday, $2.90 on Wednesday, $2.60 on Thursday, and $3.00 on Friday. As a result, the workers were paid an average hourly rate of $2.75 for that week. They know that one bad day can readily affect the hard work of a good day. By using this method, we have very few slow days, and workers receive slightly more than present minimum wage. We use seven women and they can easily stick 1¼ million cuttings eight months out of the year. The number varies from 6 to 10 thousand per day, depending on the cultivar. In fact, we now have people that are sticking a total of 25,000 cuttings a day. We try to have the cuttings all rooted by winter, except for the junipers.

We propagate some species from seed. When we use seed that we can handle, we plant it in cups and place it in propagation areas that dry out due to poor mist coverage. Other smaller seeds, such as those of pampas grass, *Cortaderia selloana*, are sown in flats.

We spray those areas under mist with fungicide twice a week except during the winter months. We use Bravo, Benlate, Kocide, and Dithane M-45; however, we use Bravo twice as often as we use the others. Insecticides are used sparingly until the plants have rooted and the mist is cut off. We then spray these areas with insecticide once a week.

One of the most important pieces of equipment we have is a natural gas generator. If there is a failure of the mist control power source, the generator will automatically cut on. This reduces the chance of emergencies during the weekends and on holidays. However, no equipment can be taken for granted; we still have people on duty during these periods.

When rooted cuttings are ready to be potted, they are taken to the potting barn or directly to the field. We are just now getting into field potting and are finding that more plants can be potted in the field with fewer man hours. Field potting also cuts our piece work rate 1 cent per one gallon and 2 cents per two gallons, which is a savings of $10,000 per million one gallon containers and $10,000 per half million two gallons. Also, by cutting the man-hours, we can continue to expand our operation without expanding our labor force. When potting in the barn, we pot 9 to 11 thousand 1-gallon pots per day at 4½ cents per pot. With 2 gallons, we pot 5 to 7 thousand pots per day at 5½ cents per pot, using twenty people. In field potting, we have a straight rate of 3½ cents for both 1 and 2 gallons. Sixteen

people do 12 to 14 thousand per day regardless of whether they are potting one or two gallon containers.

Our potting mix is bark, sand and peat. After the bark is prepared, fertilizer, fungicides and insecticides are added before mixing. Before taking to the field, plants are placed on the wagons and misted by driving the wagons under an overhead sprinkler.

We are firm believers in heavy pruning. Each plant is pruned approximately three to five times, depending on the cultivar, from propagation to the saleable stage. We feel that this gives us quality plants that are more easily moved in highly competitive markets. We use electric and hand clippers. If plants have been bunched, we use a portable generator and electric clippers. When they have been spaced out, we use hand clippers.

Plants are spaced out after they develop a strong root system and the heads begin to crowd each other. We feel this procedure produces a better plant because of the growing room provided. The plants are easier to prune, fertilize and treat with herbicides. The only disadvantage is that not as many plants can be placed in a given area when spaced. However, we would rather sacrifice space than quality.

We use several types of herbicides on our nursery. Roundup and Surflan are used during warm and dry periods, while Paraquat is used in the winter or during the wet seasons. We also use Pramitol around and in our propagating area. However, these herbicides are used primarily in ditches around the beds and around the perimeter of the nursery to stop weed seeds from developing and spreading. In containers, we have tried Lasso on an experimental basis, but have found that it was not compatible with the plant. It gave good weed control but hurt the quality. Ronstar, at 4 pounds active ingredient per acre, is now used. It is not as effective as Lasso for weed control but is relatively satisfactory and gives a better quality plant.[1]

This past summer, we had more problems with weeds in our propagation area than any other year. We had never used a herbicide in this area before, so I began running tests on herbicides at different stages of propagation. We used the same rate here as we did in the fields. The different stages used in the test

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[1] Common and chemical names for herbicides: Roundup = glyphosate, N-(phosphonomethyl) glycine; Surflan = oryzalin, 3,5-dinitro-N^4, N^4-dipropylsulfanilamide; Paraquat = paraquat, 1 1′-dimethyl-4, 4′-bipyridinium; Pramitol = prometon, 2,4-bis(isopropyl amino)-6-methoxy-s-triazine; Lasso = alachlor, Zchloro = 2′, 6′, 6′-diethyl-N-(methoxymethyl)-acetanalide; Ronstar = oxadiazon, 2-tert-butyl-4-(2, 4-dichloro-5-isopropoxyphenol)-delta 2,-1,3,4-oxadiazoline-5-one.

were as follows: (1) one week before cuttings were stuck in mix, (2) the day that cuttings were stuck, (3) one week after they were stuck, (4) when cuttings began to root or callus, (5) after they had rooted and mist was cut off, and (6) after the pot was rootbound. I was very surprised to find that I got the same results regardless of when I put out the herbicide. All cuttings rooted with the normal 10 percent or less mortality.

We feel that the safest time to put the herbicide out is 7 to 10 days after the mist has been cut off, which gives plants time to adjust to the absence of the mist. The area is weeded just prior to application.

COST OF LINER PRODUCTION AT CARTWRIGHT NURSERIES

EDSEL YAGER

Cartwright Nurseries
Collierville, Tennessee 38017

We are all familiar with the increased costs in the production of nursery stock. Labor is our largest production expense. This fact has prompted us to try new techniques in liner production. As an example we found that if we reduced our labor force by 10 people, we could maintain our expenses at the same level as operating costs increased. Using the smaller work force did not allow us to increase productivity but did help us to maintain our production costs rather than increase them. Following is a description of our liner production system.

First of all, we use sand as a rooting medium because we can obtain this material within 15 minutes after we have ordered it. We use a mixture of 50 percent sphagnum and 50 percent Michigan peat for a potting mix. The liners are potted in rose pots and bedded in our lath house with about ¼ to ½ inch of sand over the top. The sand helps to keep them from freezing out of the pot and also helps to hold moisture. These liners are grown here for one year and then planted or sold. During this period good cultural practices are followed. Plants are weeded, treated with insecticides, fertilized about twice with a foliar fertilizer, and given any other needed attention.

The itemized per unit cost of the liner production operation is as follows:

Sticking cuttings	$ 0.01	Soil for potting	0.01
Potting	0.015	Maintenance and repairs	0.01
Weeding	0.01	Pots	0.01
Fertilizer	0.02	Bed preparation	0.02

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Supervision	0.02	Heat (natural gas)	0.035
Employment taxes & insurance	0.04	Depreciation	0.005
		Total Cost Per Liner	$ 0.205

We follow several practices that help cut the cost of producing liners. We are continuing to stick cuttings in the summer under mist. A large percentage of them will root and be ready for potting before winter, which reduces the cost of heat. We are also going back to one of the older methods of rooting. We are sticking cuttings in the winter in inflated poly houses with no heat. We leave them undisturbed until spring, at which time they will root and be ready to pot around June or July.

We formerly tried to maintain a 65°F bed temperature in our greenhouses. However, the price of natural gas continues to rise and we have decided to change to 50°F. We feel that the 50°F will still be warm enough to give us a certain amount of rooting during the winter.

Finally, we have found it is very important to keep a close count on the units a laborer turns out per hour or day. This makes it possible to identify and replace slow employees. In our area it is not difficult to hire new help at the present price of labor.

In conclusion there are three suggestions that can help a firm cope with inflation and stay in business: (1) Purchase only what is essential. (2) Keep good records of what each individual laborer does each day. (3) Watch finances as closely as possible.

SO YOU WANT A CLEAN NURSERY?

HENRY H. CHASE, JR.

Chase Nursery Company, Inc.
Huntsville, Alabama 35811

The objective of having a clean nursery must be important to management for it to be achieved. It must be top priority and it cannot be accomplished without work. By a "clean" nursery we mean one with a minimum of weeds. Plans are important and it is much easier to carry out those that are committed in writing.

Identification of the weeds to be eliminated is the first step. We have found the *Growers' Weed Identification Handbook* (1) published by the Agricultural Extension Service, University of California, to be very helpful. It has full color photographs and descriptions of most weeds. It also shows the weeds in both juvenile and mature stages.

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Second, it is important to decide what course of action to take in the various areas of the nursery, including crop areas; fallow areas; and peripheral areas, such as turnrows, ends, roadsides, meadows, and ditches.

Third, the tools that are available should be reviewed. These can be mechanical or chemical. Mechanical tools include cultivators, discs, hoes and other. I am not going to review all of the available chemicals but only those used at Chase Nursery. These are Treflan, Roundup, Lasso, and Paraquat.[1] It is wise to store all herbicides in a separate, well-marked area or building.

The program we use at Chase Nursery Company is as follows:

We use a Lely Spreader, run closed, pulled behind an International 5We tractor, in low third gear, at PTO rpm, which gives us ground speed of approximately 4.4 mph. We go over every other 48 inch spaced row. We feel that it is important to apply Treflan immediately after planting because the ground is very finely pulverized at this time. This results in better dispersion of the Treflan granules. We do not incorporate the material. In fact, we do not even cultivate until we have had a good rain. This one application gives us good control through two growing seasons. We will make a fall application of granular Lasso in areas that are badly infested with broadleaf weeds.

In addition to the initial chemical application, we believe strongly in cultivators. No chemical will give 100 per cent control. On items that get too tall to go over with a cultivator, such as *Magnolia soulangeana*, saucer magnolia, and *Cornus florida*, flowering dogwood, we harvest every other row so that we can use a small disc. We think this is a very effective system.

Even with chemicals and cultivation, a few weeds survive. The one we find most persistent is *Cynodon dactylon*. We have found that spot applications of Roundup are very effective. Do not cultivate or disturb for 5 or 6 days following treatment. This technique will work equally well on johnsongrass, *Sorghum halapense*.

There are a few hardy weeds that will survive all of this and will need to be removed manually. If the nursery is 90 percent clean already, it is not difficult. We find one person can then take care of 15 to 20 acres.

This covers our program in crop areas. In our fallow areas we use Sudax, *Sorghum bicolor* × *S. vulgare* var. *sudanense*, as a cover crop, if the land is free of bermudagrass and johnsongrass. Generally, we mow it three or four times before turning under the Sudax.

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[1] Treflan = trifluralin; Roundup = glyphosate; Lasso = alachlor

If we have bermudagrass or johnsongrass, we find that discing the ground deeply every five or six days will give satisfactory control. Let me emphasize that the hotter and drier it is, the more effective is this treatment.

Once crop areas are clean, it is important not to let weeds in non-crop areas grow and produce seeds to re-infest them. Roadsides, ditches, meadows, and turnrows can be troublesome. These areas can be mowed easily with a bush hog, or they can be disced. A spray rig equipped with a boom can be used to apply paraquat for a good quick kill on annual weeds. If the temperature is high, weeds will be killed in 3 or 4 hours. Remember, your objective in all of this is to eliminate seed production.

SUMMARY: If management develops a program, commits the program to writing, and makes certain personnel are working the program, the objective of a clean nursery will be achieved.

LITERATURE CITED

1. Fischer, B.B., Lange, A.H., McCaskill, J., and Campton, B. 1974. *Growers Weed Identification Handbook*, Agricultural Extension Service, University of California.

THE ROLE OF SCHOOLS IN TRAINING PLANT PROPAGATORS

VIVIAN MUNDAY

Department of Horticulture
University of Georgia
Athens, Georgia 30602

What is the role of schools in training plant propagators? Unfortunately, there is no authority to say, "This should be taught. That should not." Even when curriculum guides are followed, there is question as to what should be emphasized. Each propagation situation is different, and the most used knowledge or skill in one will not often be the same as that most helpful in a different nursery, greenhouse, outdoor field, or inside lab. However, there should be certain basic concepts and skills that would be important to an individual learning specific requirements for a particular environment. What are these basics?

A representative sampling of propagators was asked to rate certain basic principles, technical knowledge, and applied skills as to their importance. A form, given as Figure 1, was sent to the propagators with the request that each one circle the 10 items most important for an individual interested in becoming a

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propagator. Each was asked to indicate valuable supplementary material with an "X" and to write in other important items that might have been omitted. Finally, each was asked if college training was necessary.

Below is a list of knowledge and skills that may be needed by professional plant propagators. Please circle the 10 items you consider most important for inclusion in a course of study. Put an "X" by any others you feel should be covered, but less thoroughly. This person would be one who could eventually serve in a responsible position concerned with all phases of the propagation operation.

Plant information

Plant identity and nomenclature

Plant structure (anatomy and morphology of leaves, stems, roots, flowers, fruits, seeds)

Plant function (uptake and translocation of water and nutrients, photosynthesis, respiration, growth and development)

Plant nutrition

Plant growth substances and hormones

Plant reproduction, asexual and sexual

Technical information and skills

Media components and mixing

Water — components and control of various systems

Fertilizing methods and how to choose, how to formulate and apply, deficiency and toxicity symptoms

Containers — how to choose, how to fill

Heat requirements and methods of providing

Propagation information and skills

Seeding
- Dormancy and pretreatment methods
- Sowing

Cuttings
- Choice, preparation and storage of materials
- Preparation and use of hormones
- Sticking — field and indoor
- Aftercare

Grafting — choice of material, techniques of budding, techniques of grafting, aftercare

Layering

Other methods, such as division, use of bulbs, rhizomes, tubers and other specialized structures

Micropropagation (tissue culture)

Other knowledge or skills
- Knowledge of business and economics
- Ability to work with people

Is college training necessary?

Figure 1. Form used to survey professional plant propagators' priority ratings of employee skills and knowledge.

In Table 1 the top 10 items are arranged by rank based upon the percentage of respondents circling each one. Those remaining are arranged in Table 2 by rank according to the percentage considered in the top ten.

Table 1. Plant Propagation Knowledge and Skills. Top Ten Priority Items.

Rank		Basic Information	Technical Information or Skill	Percent of Respondents Top Ten	Percent of Respondents No. 1
1-4	Ability to work with people		X	81	31
	Plant nutrition	X		81	
	Fertilizing methods		X	81	
	Preparation of cuttings		X	81	
5	Plant function	X		69	
6	Watering systems		X	63	
7-8	Hormone preparation and use		X	56	
	Aftercare of cuttings		X	56	
9-13	Plant growth substances	X		50	
	Plant structure	X		50	
	Plant identification and nomenclature	X		50	
	Seed dormancy and pretreatment	X	X	50	
	Media components and mixing		X	50	

Table 2. Plant Propagation Knowledge and Skills. Remaining Items by Order of Priority.

	Basic Information	Technical Information	Percent of Respondents
Knowledge of business and economics		X	37
Grafting		X	31
Plant Reproduction	X		31
Micropropagation (tissue culture)		X	25
Cuttings — field and indoor sticking		X	19
Heat		X	12
Division; use of specialized structures		X	6
Containers		X	0
Seed sowing		X	0
Lavering		X	0

The results of this survey brought out several interesting points. Only 3 of the 23 items were not circled by any respondent as being of top priority. One of these was *layering*, a second was *seed sowing*, and the third was *containers*. The omission of layering is not surprising since it is seldom used as a commercial propagation method. However, air layering is fairly widespread in areas where foliage plants are the major crop and deleting it entirely might not be justified. The omissions of seed sowing and container information are harder to explain. Dormancy and pre-treatment of seed appeared in the list; apparently the sowing process was not considered critical when using seeds of woody material. A group of professional bedding plant producers might reverse the position of these two items. It would be hard to explain the lack of concern with containers. Many nurseries have tried and abandoned several designs that proved unsatisfactory. Other low priority items were the technique of *division*, *heat* (another surprise), *sticking cuttings* and *micropropagation*. Seven of the top ten subjects concern technical information or skills; five cover basic background information; while one, seed dormancy and pre-treatment, includes both principles and practices.

In Table 3 all the 23 items are ranked by order of priority as good supplemental material. Only *plant nutrition* was not included. However, 81 percent of respondents had considered *nutrition* high priority. *Fertilizers*, *watering systems* and *ability to work with people* were low here, but very high among the top 10 items. Additional suggested material was *light*, *disease*, *regional adaptation*, *efficient work habits* and the *ability to instruct others*. All are important; the last two would no doubt be priorities.

Obviously, the next question is, "Where should prospective plant propagators obtain this information?" Fifty percent of those surveyed felt 4 years of college work was at least desirable (Table 4); 25 percent indicated intensive 2 year community college was adequate or would substitute for a 4 year curriculum.

The remaining 25 percent did not specify a source of training. Some of the comments are worth noting: "It helps most, but ruins a few! Good information is available elsewhere if an individual is interested in obtaining it." College is desirable but not absolutely necessary. The best propagator I know has not completed high school." "Two year, if any. On the job training is best."

Since there seemed to be agreement that college was not absolutely necessary, let us consider other options. Certainly nothing can replace on-the-job training if the novice is fortunate

Table 3. Important Supplementary Plant Propagation Knowledge and Skills Ranked by Percent

Rank		Basic Information	Technical Information	Percent of Respondents
1	Heat		X	56
2	Containers		X	44
3	Plant reproduction	X		37
4	Grafting		X	31
4a	Knowledge of business and economics		X	31
4b	Seeding — dormancy and pretreatment methods		X	31
4c	Plant identity and nomenclature	X		31
4d	Plant structure	X		31
5	Cuttings — aftercare		X	25
5a	Media		X	25
5b	Division; use of specialized structures		X	25
5c	Plant growth substances	X		25
6	Cuttings — field and indoor sticking		X	19
6a	Cuttings — preparation and use of hormones	X	19	
6b	Layering		X	19
6d	Plant function	X		19
6e	*Seed sowing*		X	19
7	Ability to work with people		X	12
7a	Fertilizing		X	12
7b	Water		X	12
8	Preparation of cuttings		X	6

Table 4. Source of Training Preferred

Type of School	Percent	Comments
Four year college	50	Helps most. Ruins a few. Yes, but not absolute. Some good ones without high school.
Two year college	25	Intensive one would be as good as four year. On the job best, two year next.
Vocational - Technical		None indicated vo-tech as a possibility.
Unspecified	25	

enough to work with an experienced skillful propagator. However, in today's mass production programs, it is difficult to allow for the time required and the resulting production drop when the propagator becomes teacher. Although most industries plan for a short period of orientation, many do not want to spend several, or many, months for the intensive training that would be needed to give new personnel even the minimum priority information. Training would be oriented to specific requirements of the firm — an advantage to the company, a disadvantage to the trainee.

The next possibility would be training at the secondary school level. There has been an amazing increase in the amount of horticultural training given in high schools. Some schools include horticulture subjects in a general agriculture curriculum, but many offer specialized courses of study. Often students spend several hours each day in these programs. Ordinarily they begin in their eleventh grade and continue through the twelfth. Some school districts have area vocational schools serving several high schools. Material given here is more in-depth although most of the alloted time is still spent in practical application. In Florida, curriculum guides are furnished each district by the state for optional use in either high school or post-secondary classes. A side effect from this increase has been that teaching presently has more employment potential for college graduates than any other segment of horticulture

By contrast, 2-year post-secondary training opportunities are limited. Table 5 gives information on high school, post high school vocational and community college programs. Florida, Georgia, North Carolina, South Carolina and Virginia have horticulture at the 2 year college level. Louisiana has 1 post high school vocational curriculum. The Florida program is seemingly the most widespread and intensive, followed by North Carolina, South Carolina and Georgia. The Georgia program at Abraham Baldwin Agricultural College, Tifton, Georgia offers several courses that are given very favorable rating as to depth of content. A thorough post high school vocational horticulture curriculum is available at a post secondary technical school in Clarksville, Georgia.

Table 6 summarizes the responses from 4 year college or university instructors who were asked to comment on their plant propagation courses. Only Cal-Poly at San Luis Obispo presently offers more than one course in propagation. At one time an advanced course was offered at Auburn. However, it was found to be an unaffordable luxury and was discontinued several years ago. *Plant Propagation: Principles and Practices*, by Hartmann and Kester, was used as the advanced text. It is

Table 5. Vocational or Community Colleges with Horticulture Curricula.[1]

State	Secondary	Post-Secondary Vocational	Post-Secondary College	Course Content
Alabama	50	none	none	Extensive applied program 11th and 12th graders.
Florida	210 total secondary and post-secondary			5 options. Course based on comprehensive industry survey. Mostly technical.
Georgia	72	1	1	One intensive technical program; one through two year curriculum.
Louisiana	40	1		Fairly comprehensive.
North Carolina	128	7	15	Thorough. Many areas covered. Most emphasize technology.
South Carolina	56		4	2 offer ornamental. Comprehensive. Supplementary related courses available. Clemson University advises.
Tennessee	25	none	none	Excellent on production technology. Based on survey of area industry needs.
Virginia	50 area vocational		2	Adult classes only at colleges. Offering very limited. High schools give intensive application.

[1] Information obtained from state departments' personnel or individual instructors.

now used for the courses in all of the southeastern area schools. Table 7 summarizes the contents of this text.

If we look at the material presented and recall the top 10 priority items, it seems that students in a class using this text should have at least an exposure to the priority information. Plant function would rarely be covered at high school level or at post high school vocational centers. It might be at 2 year colleges. Although hormone preparation and use would be included in vocational curricula, related background information and theory would not be. The same is true of fertilizing and nutrition. The technology would be given but basic principles would rarely be presented.

We could summarize all of this information as follows:

(1) The majority of propagators in the survey indicated that more than just technology was important.

(2) Four year colleges are not the only places to learn, however.

(3) When the total list of top 10 priority items of information and skill are considered, the subjects are more readily available here than from on-the-job training.

(4) Although junior colleges may offer fairly complete curricula, the number offering horticulture is limited.

Table 6. Four Year College Propagation Courses.[1]

School	Text	Comments
Alabama (Auburn)	Hartmann and Kester	All chapters assigned. Some economics. Short on commercial practices. Should balance science and art.
California (Cal Poly)	Hartmann and Kester	Two courses. Practical but more than just preparatory.
Florida	Hartmann and Kester	Administration favors research. Community colleges better for industry training.
Georgia	Hartmann and Kester	Too much for one quarter. Emphasize observation and interpretation of results. Some economics.
Louisiana	Hartmann and Kester plus handouts.	Text adequate except on spores. No economics. Should not be expected to provide all the needed experience.
Oklahoma State University, (Stillwater)	Hartmann and Kester	Much time on grafting and budding. Lecture emphasizes theory.
South Carolina (Clemson)	Hartmann and Kester	Lectures give research to support lab practices. Two-thirds asexual propagation procedures.
Virginia (VPI, Blacksburg)	Hartmann and Kester	Too much for one quarter. Should not concentrate on research only. Develop critical thinking.

[1]Information obtained from individual instructors.

From this study we can draw conclusions, point out problems and consider improvements. There is a place for each learning method. Experience is still a must, with or without formal education. Vocational secondary programs provide a good introduction and may serve to screen out students who are primarily hobbyists. Training is mostly technical, but a good high school graduate could become a valuable employee. He might be preferable to a college graduate at the outset as he would have spent more time in applied techniques. He might also be more willing to start as a trainee. He would lack in-depth information. Vocational post-secondary training would be given to more mature individuals with a serious vocational interest. Maturity might be the major advantage for the person with this background. He might be more qualified to spot problems but possibly not too well prepared to solve them.

College preparation at 2 year institutions seems to offer real potential. Students have an opportunity to take some supporting courses as they do at 4 year schools. A person with solid 2 year college background should be able to help solve problems as well as recognize them and could compete favorably with a 4 year college graduate. M. J. Young, University of Florida,

Table 7. Plant Propagation - Principles and Practices, by Hudson T. Hartmann and Dale E. Kester. Summary of Contents

Chapter	Contents
1	Introduction
2	Propagating Structures, Media, Fertilizers, Soil Mixtures, and Containers
3	The Development of Fruits, Seeds, and Spores
4	Production of Genetically Pure Seed
5	Techniques of Seed Production and Handling
6	Principles of Propagation by Seeds, Germination Process, Dormancy, Environmental Factors
7	Techniques of Propagation by Seeds, Seed Testing, Pre-Conditioning, Disease Control, Seedling Production, Direct Seeding
8	General Aspects of Asexual Propagation The Clone, Genetic Variation, Pathogen-Free, True-to-Type Clones
9	Anatomical and Physiological Basis of Propagation by Cuttings
10	Techniques of Propagation by Cuttings Wounding, Growth Regulators, Environmental Conditions, Mist Systems
11	*Theoretical Aspects of Grafting and Budding* Healing Process, Polarity, Graft Incompatibility
12	Techniques of Grafting
13	Techniques of Budding
14	Layering
15	Propagation by Specialized Stems and Roots
16	*Aseptic Methods of Micro-Propagation*
17	Propagation Methods and Rootstocks for the Important Fruit and Nut Species
18	Propagation of Certain Ornamental Trees, Shrubs, and Woody Vines
19	Propagation of Selected Annuals and Herbaceous Perennials Used as Ornamentals

writes, "Because of administration attitudes (favoring research), low overall faculty interest in teaching vs research and more rigorous course requirements, our programs do not adequately prepare students to enter production agriculture without a considerable period of on-the-job training. Although their faculties and facilities are often limited, I believe Community Colleges are in a better situation to train students for production agriculture. Coming from California I am familiar with their system of a research-oriented University system and a network of applied colleges. It is a more realistic and workable system."

What then, is the role of a 4 year school? Graduates are not likely to have better technical skill. However, there are certain advantages. Students may gain exposure to new ideas that are being developed. Although modern nurseries also have extensive research in progress, their programs will not include the broad spectrum of activity found at the universities. In addition,

students will usually have an opportunity to acquire a broader background of information not only in horticulture and related sciences, but also in business, marketing, and personnel management.

It is doubtful that an inexperienced 4 year college graduate could compete successfully in the job market with a person having 4 years' practical propagation experience. However, in 4 more years the college graduate would be in a much more favorable position than the person with 8 years' experience. College background should enable him not only to spot problems but also to find reasons for and solutions to these problems. He should be able to set up reliable test situations that would give valid results both for solving problems and trying new techniques.

Several problems facing schools and instructors have been highlighted by this study. Without exception those contacted at the college level felt they were trying to cover too much material. Most of us have students from a wide variety of disciplines -- landscape architecture, agronomy, forestry, education and others. It is estimated that in Florida less than one-third will actually use the techniques as professional propagators. Some have had very little plant science background or practical exposure to plants. Students who have had an intensive 2 year high school course find the 2 year post high school curriculum repetitious. Similarly, those from good 2 year colleges feel the basic plant propagation course at 4 year institutions is elementary. Attempting to choose topics that will be of value and interest to all of these people is more than difficult. Air layering is fascinating to most students, yet it rated low on the list of priorities. Should it be taught? What can we eliminate and thus do a better job with what we are doing?

There is one serious fault in almost all of the training programs discussed here. In Table 1 you will note that 31% of the respondents indicated ability to work with people as the one single most important requirement for success, and 81% placed it in the top ten priorities. Yet we make very little conscious effort to help students learn to work well with others. More often they are competing with fellow classmates for grades in a tense environment. Somehow we should change our approach; the real training must come in everyday situations — not simply in classes such as personnel management where again students are competing more than cooperating.

And, finally, many educators find themselves in a situation where the primary emphasis is research, yet most are sincerely interested in preparing students to face real life situations at the

end of 4 years. Yet it is difficult under present conditions to fit these two aspects of horticulture satisfactorily.

What is the role of schools? Certainly this study does not lay down guide lines; however, it would seem that two steps could be taken to improve our overall situation: (1). An advanced plant propagation class could be designed in a way that qualified students could be placed on their own to design and implement a program of value to them. This could be in the nature of an undergraduate research problem. Very little expense would be involved. (2). More 2 year college programs could be developed. Perhaps, a 2 year curriculum might be designed within an existing 4 year college. Students could be allowed to omit the more advanced theoretical courses. Ideally, instructors would work closely with industry to develop the curriculum. The cost of implementation would be less than that involved in setting up a new junior college facility.

I would like to close by quoting an educator and a professional propagator. Their viewpoints are amazingly similar. Dr. Kenneth Sanderson of Auburn says, "Regarding teaching vs. research, I'd vote for a balance. All commercial operators need to know how to evaluate their activities or results — this is research. Before an evaluation, a propagator needs to know the science and art of performing a task — this is commercial performance. From my recent talks, you must know that I feel that Universities are failing in teaching commercial practices whereas technical schools and junior colleges are failing in teaching the basic scientific reasons for practices. I feel that they are inseparable. Are we teaching managers or laborers? My major concern in teaching ornamental horticulture courses today is the sacrifice of technical, commercial courses and information for the teaching of general home horticulture. Easy horticulture is fine for the amateur; however, without the highly technical side there will be no information generated or plants propagated and produced in the future."

Richard Ammon, Ammon Garden Center and Landscaping, Florence, Kentucky, writes, "Many experienced propagators are skilled in basic knowledge only. They can propagate and do it quite economically but lack technical knowledge for improving their methods, such as understanding hormones and how they work, fertility and how it can be improved. Many of us can propagate, but don't really understand why things do work as they do.

"On the other hand many knowledgable students do not understand production and how to improve on producing for greater profits. They also tend to have limited knowledge on the whole nursery operation. Much of this is only obtained by ex-

perience and they must be made to realize they are much more valuable to a firm, once they are well rounded in *education* and *experience*, and up to that point their value is limited to the amount of skill and production ability they have."

There is no one best way to train individuals for any profession. The most important suggestion of all is to develop closer contact with the people hiring our graduates and discover how our product measures up.

ADVENTITIOUS ROOT FORMATION IN THREE CUTTING TYPES OF *FICUS PUMILA L*[1]

F.T. DAVIES, Jr.[2] and J.N. JOINER[3]

Abstract: Adventitious root formation was studied in juvenile and mature *Ficus pumila L.* (Creeping fig) using stem, leaf-bud and leaf cuttings to find the optimal type for root developmental sequencing research. Leaf-bud cuttings were superior to other types since mature leaf-bud cuttings responded positively to auxin treatment, adventitious rooting occurred *de novo* from internodal areas and rapid rooting was obtained to minimize environmental-physiological variables. Indole-3-butyric acid (IBA) was more effective than indole-3-acetic acid (IAA) in stimulating rooting of leaf bud cuttings.

Adventitious root formation (ARF) in woody plant materials has been studied in relation to application of exogenous growth regulators, endogenous biochemical levels and histological observations. Histological studies of stages in ARF have revealed information on effects of exogenous hormone application on physiological events (3,6,7). Plant material used in developmental sequencing experiments have been herbaceous annuals or hypocotyl cuttings. Biochemical (4) and histological (1,2) changes occur with maturity that decrease ARF so herbaceous materials may not adequately reveal physiological requirements of changing histological events in mature woody materials.

Ficus pumila L. (Creeping fig), a woody ornamental clinging vine was used in this experiment because it has juvenile and mature forms (Figure 1) with differing growth habits, leaf shapes and sizes. Juvenile stems have aerial roots in nodal areas and preliminary studies indicated differences in ARF between juvenile and mature cuttings.

Objective of one experiment was to establish optimal cutting types of *Ficus pumila* from stem, leaf-bud (LBC) and leaf

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[1] Florida Agricultural Experiment Stations Journal Series No. 1660.

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Figure 1. *Above.* Juvenile (J) and mature (M) forms of *Ficus pumila.*

Figure 2. *Below.* Standard propagation techniques for *Ficus pumila* during experiments.

cuttings. Criteria used to judge cuttings included response to auxin treatment, degree of ARF via *de novo* root formation, and speed of ARF occurrance to minimize environmental-physiological influence. Experiments were also conducted to determine the most effective auxin and concentration for stimulating ARF.

MATERIALS AND METHODS

Cuttings were taken from *Ficus pumila* stock plants cultivated on the University of Florida campus at Gainesville. Stem cuttings, leaf-bud cuttings (LBC - lamina, petiole and 2.5 cm piece of stem with attached auxillary bud) and leaf cuttings (lamina and petiole) were obtained from juvenile and mature terminal shoots (Figure 1) and propagated under intermittent

mist (Figure 2) in a sterilized rooting medium of mason sand maintained at 24°C and with a 2 hr night light interruption.

Experiment 1: Cuttings were initially treated with indole-3-butyric acid and 2-naphthalenacetic acid in combination (IBA/NAA) and indoleacetic acid (IAA) applied in a 15 sec basal soak. Juvenile stem and mature stem and leaf cuttings were treated with 10,000, 3000, 1000, 300, 100, 30, 10 mg/l IBA/NAA, and mature stem, LBC and leaf cuttings with similar concentrations of IAA. Juvenile stem cuttings were treated with 10,000, 1000, 10 mg/l IAA. Mature LBC were treated with 10,000, 1000, 100, 10 mg/l IBA/NAA.

There were 5 cuttings per experimental unit with 4 replications per treatment. The experiment was terminated after 90 days when percent rooting, root number and quality were measured. Quality scale ranged from 1 to 4 with 1 = no rooting, 2 = light rooting, 3 = medium rooting and 4 = heavy rooting.

Experiment 2: In a 2 × 3 × 2 factorial experiment, juvenile and mature LBC were treated with 10, 100, 1000 mg/l IAA and IBA applied as foliar applications at time of sticking. There were 10 cuttings per experimental unit with 4 replications per treatment. Juvenile and mature cuttings were terminated after 21 and 42 days, respectively, and percent rooting, root number and length were measured.

Data from both experiments were analyzed by analysis of variance procedure and compared at the 5% level of significance using Duncan's multiple range test.

Table 1. Adventitious root formation in *Ficus pumila* juvenile stem cuttings 90 days after auxin treatment.

Treatment (mg/l)	Percent Rooting[x]	No. Roots[x]	Quality[xy]
IBA-NAA			
10,000	90ab	11.6ab	2.8bc
3,000	90ab	10.3abc	3.1ab
1,000	95ab	12.5a	3.3ab
300	100a	9.5bc	3.0abc
100	100a	9.0c	3.3ab
30	100a	8.5c	3.4ab
10	100a	9.8bc	3.2ab
IAA			
10,000	100a	11.5ab	3.2ab
1,000	80b	8.3c	2.5c
10	100a	10.9bc	3.0abc
Control	95a	8.8c	2.9abc

[x]Means followed by different letters are significantly different at 5% level, Duncan's multiple range test.
[y]Quality scale ranged from 1-no rooting, 2-light rooting, 3-medium and 4-heavy rooting.

Figure 3-7. Origin of adventitious roots in juvenile and mature cuttings of *Ficus pumula*. Figure 3-4, stem cuttings; Figure 3, after 40 days: unrooted mature (M) and rooted juvenile (J): Figure 4, 90 days experiment: rooted J. unrooted and rooted M. Figure 5-7, leaf bud cuttings; Figure 5-6, after 40 days; Figure 5, juvenile: (Left) *de novo* rooting, (Right) nodal area rooting; Figure 6, mature: roots from nodal areas of etiolated shoots; Figure 7, 90 days experiment: unrooted M. and J. leaf cuttings vs. rooted leaf bud cuttings.

RESULTS

Experiment 1. Juvenile stem cuttings treated with 1000 mg/l and 10,000 mg/l IBA/NAA and 10,000 mg/l IAA had more roots than controls, but controls had higher percent rooting and quality (Table 1) than auxin treatments. Macroscopic examination revealed little ARF at base of cuttings with the majority occurring in nodal areas from preformed root initials (Figure 3). Rooting was observed in all treatments by day 18.

Table 2. Adventitious root formation in *Ficus pumila* mature stem cuttings 90 days after auxin treatment.

Treatment (mg/l)	Percent Rooting[x]	No. Roots[x]	Quality[xy]
IBA-NAA			
10000	65a	8.3ab	2.7a
3000	80a	8.3ab	2.8a
1000	80a	9.5a	3.0a
300	80a	7.4abc	2.6a
100	70a	6.5abc	2.4a
30	80a	7.0abc	3.1a
10	60a	4.5abc	2.2a
IAA			
10000	55a	4.8abc	2.3a
3000	85a	5.5abc	2.3a
1000	85a	6.7abc	2.6a
300	55a	3.7bc	2.1a
100	80a	5.7abc	2.2a
30	60a	4.8abc	2.2a
10	55a	4.0abc	2.0a
Control	40a	2.0c	1.8a

[x] Means followed by different letters are significantly different at 5% level, Duncan's multiple range test.

[y] Quality scale ranged from 1-no rooting, 2-light rooting, 3-medium rooting and 4-heavy rooting.

ARF occurred readily at the base and nodal areas of control juvenile LBC (Figure 5).

At day 48 mature LBC sampled from 10,000 and 1000 mg/l IBA/NAA and 3000 mg/l IAA had roots whereas control did not, but by day 90 no auxin treatment was better than control (Table 3). Roots were sometimes initiated from nodal areas of etiolated shoots originating from axillary buds (Figure 6).

No ARF occurred in juvenile leaf cuttings and only 10% rooting was recorded in mature leaf cuttings treated with 1000 mg/l IBA/NAA, but this was not significantly different from controls. Juvenile leaves were sessile and mature petioles were considerably smaller than species normally propagated by leaves such as *Peperomia* (Figure 7).

Experiment 2: There were no differences between juvenile LBC treated with 1000 mg/l IBA or IAA in percent rooting or

Table 3. Adventitious root formation in *Ficus pumila* mature leaf bud cuttings 90 days after auxin treatment.

Treatment (mg/l)	Percent Rooting[x]	No. Roots[x]	Quality[xy]
IBA-NAA			
10000	55a	4.5ab	2.1a
1000	65a	5.3a	2.2a
100	45a	0.6b	1.3a
10	45a	2.8a	1.6a
IAA			
10000	20a	1.3ab	1.4a
3000	25a	1.5ab	1.9a
1000	25a	1.3ab	1.4a
300	25a	1.1ab	1.3a
100	20a	1.0ab	1.3a
30	40a	2.5ab	1.7a
10	40a	2.6ab	1.7a
Control	60a	2.9ab	2.3a

[x] Means followed by different letters are significantly different at 5% level, Duncan's multiple range test.

[y] Quality scale ranged from 1-no rooting, 2-light rooting, 3-medium rooting and 4-heavy rooting.

root length and both had higher percent rooting than controls, but those receiving 1000 mg/l IBA averaged 10.4 roots per cutting compared to 4.5 for those receiving IAA (Table 4). The other treatment that produced a higher rooting percentage than controls was 100 mg/l IBA. No chemical treatment increased root length.

IBA at 1000 mg/l was the only treatment that resulted in in-

Table 4. Effects of IBA, IAA and GA_3 on adventitious root formation in *Ficus pumila* juvenile leaf bud cuttings after 21 days.

Treatment (mg/l)	Percent Roots[x]	No. Roots[x]	Root Length[x]
IBA			
10	48cde	1.7cd	1.2abc
100	73abc	3.7bc	1.2abc
1000	100a	10.4a	1.6a
IAA			
10	70abcd	2.5bcd	0.9abc
100	53bcde	2.0bcd	1.2abc
1000	85ab	4.5b	1.6a
GA_3			
10	20e	0.5d	0.5c
100	30e	0.8d	0.7bc
1000	25e	1.1cd	0.3c
Control + Surfactant	35de	1.2cd	1.4ab

[x] Means followed by different letters are significantly different at 5% level, Duncan's multiple range test.

creased percent rooting, root number and length in mature LBC (Table 5).

IBA was selected as the most effective auxin to be used for future rooting experiments with *Ficus pumila*.

Table 5. Effects of IBA, IAA and GA_3 on adventitious root formation in *Ficus pumila* mature leaf bud cuttings after 42 days.

Treatment (mg/l)	Percent Rooting[x]	No. Root[x]	Root Length
IBA			
10	0b	0b	0b
100	10b	0.2b	0.3b
1000	75a	5.9a	2.9a
IAA			
10	0b	0b	0b
100	0b	0b	0b
1000	8b	0.1b	0.2b
GA_3			
10	0b	0b	0b
100	0b	0b	0b
1000	0b	0b	0b
Control	0b	0b	0b
Control + Surfactant	0b	0b	0b

[x] Means followed by different letters are significantly different at 5% level. Duncan's multiple range test.

DISCUSSION

LBC was the most satisfactory cutting type since juvenile stem cuttings rooted predominantly from nodal areas and not *de novo* as desired and mature stem cuttings rooted too slowly, even with auxin treatment. *Ficus pumila* could not be propagated by leaf cuttings. Juvenile leaves were sessile, while petioles of mature leaves would only callus at the base with poor rooting. Leaf propagation has largely been confined to herbaceous species thus *Moraceae* genera are not commonly propagated by leaves (5).

Control juvenile LBC rooted with ease while auxin-treated mature LBC rooted faster than controls. Roots originated from nodes in juvenile cuttings and from etiolated shoots formed from axillary buds in mature LBC. Nodal areas had to be above the rooting medium in later experiments for ARF *de novo* at base of cutting.

Reasons for faster ARF in auxin-treated LBC vs stem cuttings were not clear. LBC has only 1 leaf vs 4 to 5 leaves of stem cuttings which probably caused differences in quantity of such physiological materials as endogenous growth regulators, inhibitors and carbohydrates. There may have been a tendency to insert the base of stem cuttings further into the medium for

better support where differences in carbon dioxide, oxygen and water saturation in pore spaces occurred.

LBC treated with IBA was established as the best system for ARF studies on developmental sequences in juvenile vs. mature *Ficus pumila*.

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EFFECTS OF FREEZING-THAWING (FAST AND SLOW) IN PLANTS

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A very informative paper by Dr. Robert Wright on the physiology of plant tops during winter appears in the 1977 IPPS Proceedings (Southern Region) (4). Following is a summary of certain concepts presented by Dr. Wright that are pertinent to a consideration of the effects of fast or slow freezing and thawing in plants.

Acclimation is the seasonal transition of plants from a tender growing condition to a hardy overwintering condition in species that go into a rest period. During rest internal factors prevent growth until certain biochemical and physiological requirements have been satisfied. After these changes have occurred, it is possible for growth to resume when there are good environmental conditions. Shortened days in fall and winter with decreased temperatures trigger various biochemical,

better support where differences in carbon dioxide, oxygen and water saturation in pore spaces occurred.

LBC treated with IBA was established as the best system for ARF studies on developmental sequences in juvenile vs. mature *Ficus pumila*.

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Acclimation is the seasonal transition of plants from a tender growing condition to a hardy overwintering condition in species that go into a rest period. During rest internal factors prevent growth until certain biochemical and physiological requirements have been satisfied. After these changes have occurred, it is possible for growth to resume when there are good environmental conditions. Shortened days in fall and winter with decreased temperatures trigger various biochemical,

biophysical and physiological changes in plants. Cells also undergo dehydration at this time. Plants can resist freezing either by avoidance or tolerance of low temperatures. Annuals live over by seeds that usually contain very little moisture. Herbaceous plants have crowns or roots with the ability to regenerate new buds and stems following a dormant period. Since the crowns and roots are below ground, they are protected from the lowest temperatures, and often snow and surface mulches prevent soils from freezing.

Levitt (1) lists four times when cells can be injured from freezing: (1) during freezing, (2) after freezing equilibrium is reached, (3) during thawing and (4) after thawing. Freezing can be either intracellular, within the cell; or, intercellular, outside the cell membranes between the walls of the individual cells. Scientists have believed that the expansion of water as it froze formed ice crystals that mechanically ruptured and tore cells apart. Much evidence exists to indicate that this is not the case in nature, but that the major cause of injury and death of cells is membrane destruction.

Asahina (1) reported that in *Tradescantia* staminal hairs ice crystals were first seen in the distal end. Ice crystals were seen in the cytoplasmic layers in the tonoplast and the vacuoles. When changes in temperature were rapid (at more than 20° F in 1 minute) ice crystals formed within the cells; however, such temperature changes rarely, if ever, happen in nature. Such temperatures disrupt the entire integrity of the cells with clotting of the protoplasmic layer and pulling away inwardly of the cell membrane from the cell walls. Membranes within the cell are destroyed and air spaces are squeezed out. Upon thawing, water fills in where these air spaces were, giving a translucent, water-soaked appearance to the frozen tissue.

Intracellular damage is irrepairable and results in certain death. It occurs in tender plants and those that remain unacclimated when temperature and moisture remain favorable for growth. These plants can and do acclimate under proper environmental conditions. In many tropical plants injury occurs at temperatures above freezing, but some are uninjured at −1 to −3°C. The freezing point could be depressed by cell inclusions and some supercooling. Usually cell membranes lose their semipermeability because the lipid structures in the proteinaceous membranes are altered and cell parts are destroyed.

Levitt (1,3) states that only circumstantial evidence exists that intracellular freezing occurs in nature. If it does, it would be fatal to plants. Asahina (1) reported that when temperature changes were very rapid, movement of water across the membrane barrier did not occur quickly enough to prevent internal

freezing. Nucleators, of which there are few good ones within cells, are needed for formation of ice crystals. This is similar to seeding clouds to form raindrops. Silver iodide crystals are used, which start the vapor to condense into drops. In cells too, particular compounds and sites are needed to serve as nucleators for the formation of ice crystals. Some cells have no good nucleators within the membranes, but outside of them ice crystals form readily on the cell walls. As the fluid moves out of the cell membrane, the ice crystals grow between the cell walls. The cell membrane shrinks to the interior of the cell, and fluids within the cell become very viscous. Since it has become flabby and pulled inward, there is little danger that ice crystals will puncture the membrane. The fluids that move out across and membrane contain K^+ ions, as well as smaller amounts of some CA^{++}, sugars and other compounds.

Plants that survive low freezing temperatures are those with extracellular freezing. Asahina (1) said extracellular freezing is governed by both external and internal factors involving the grade of supercooling, cooling rate, hardiness of the cells and their amount of freezable liquid. These cells continuously lose moisture outside the membrane, and ice masses show remarkable growth in spaces between the walls of the cells. Their protoplasm must resist the stresses caused by dehydration and contraction as the cell volume is reduced. Solutes become very concentrated within the cell membrane, and pH changes occur as many ions move outside the membrane. Asahina (1) states that damage is physiochemical rather than mechanical. If the temperature drop is gradual enough, the freezable liquid moves out of the cell walls even in tender plants.

Very hardy plants which are fully acclimated can withstand very low temperatures without damage. Winter wheat tolerates temperatures down to −25°C; and in a dogwood species, temperatures down to −196°C did not cause injury. However, temperatures must drop slowly if plants are to survive. Cells of these plants tolerate dehydration and contraction of their protoplasm. Most of these plants lack nucleating substances within the cells or have barriers to prevent internal freezing. Often supercooling occurs. As long as there is no damage to the membranes, cells will reabsorb liquids upon slow thawing and then appear normal again.

Pure water can be supercooled to −38°C without freezing. Once crystals form freezing is very rapid. Certain plant tissues supercool to −15°, or −59°F, but not all to the same extent under field conditions. If soils are not cold, moisture can move up from the roots to prevent dessication. In dessicated tissues ice crystals do not spread uniformly, and injury and death can result. This is the case in winter when it is very windy and the

frozen soil makes absorption and translocation of moisture impossible.

In winter, fully acclimated apple tissue can go down to -40° C without injury. If temperatures fall below the homogeneous nucleation temperature, freezing occurs. Both supercooling and extracellular freezing are involved. Hoar frosts can enter lenticels, stomates and wounds to start ice formation. Nucleation points are constant in plants. Water migrates from cambial and phloem tissue to the outer cortex where ice forms on the surface of the cell walls without injury, as described by Wiegand (3).

Slow extracellular freezing occurs in large ice masses at specific sites. Sakai (1) in 1965 reported stems could survive −60°C in midwinter if freezing occurred slowly due to a gradual dropping of the temperature. However, water does not have a chance to migrate to these sites. Levitt (3) reported that killing occured at higher temperatures when rate of freezing was rapid. This was reported in apple twigs by Hildreth in 1926, raspberry buds by Schwartze and trees by Day and Peace in 1937. Rapidly frozen apple twigs were killed at −19°F while those frozen slowly were killed at −25° to −40°F, according to Beach and Allen. This was the case in apple trunks, pine shoots and cabbage tissue. Weiser (1) reported that evergreen foliage was injured at −80°C during slow freezing when acclimated; however, tissue was killed at −19°C when temperatures were dropped 8 to 10°C per minute. Lethal intracellular freezing occurs in hardy plants when temperatures drop fast, as reported by Olien (1). However, Sakai and Suka (1) observed that if ice crystals were small no injury would result from rapid thawing. Some plants were reported to be so frost hardy that no injury occurred regardless of rate of thawing (3).

Repeated freezing and thawing has an amplifying effect on injury in some cells, according to Olien (1). The first time cells were exposed to sublethal temperatures, injury was only slight. Fully acclimated winter wheat could be exposed to −19°C without injury the first time. However, cells were killed after a second freezing and thawing. Gusta (1) (unpublished) stated that when large ice masses thaw, resulting pools of bulk water lead to injury at higher temperatures.

Palta and Li (1) reported tissue frozen for 12 days at −4°C had 0 to 50% intercellular spaces infiltrated with water and all cells alive 7 to 12 days after thawing. In −11°C cells there were 80 to 100% intercellular spaces infiltrated with water and all cells were dead. These cells showed the highest conductivity readings. Semipermeability properties of the membranes were apparently uninjured since cells regained turgor. However, severe damage to the active ion and sugar transport mechanisms

was the cause of death. Therefore, since plants vary greatly in their response to low temperature, it is not possible to generalize as to the extent of supercooling, of intracellular or extracellular freezing. Plants that can be and are fully acclimated withstand very low freezing temperatures if their membranes tolerate stress from contraction and dehydration during freezing. The most serious damage occurs to the ion transport mechanisms in cell membranes. This damage is lethal to frozen cells. Fast freezing and thawing usually cause much greater damage to cells than do slow changes; however, in very hardy plants, rates have no effect on injury.

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QUESTIONS FOLLOWING NURSERY BUSINESS FORUM

RICHARD VAN LANDINGHAM: Question for all speakers. Have any of you done a cost study on the use of different herbicides in a container operation? We recently used Ronstar several times and have used other herbicides in the past. I would like to know which one any of you has found is the cheapest and the most effective to use.

BRAD MAY: We were using Lasso, but it was hurting our quality. It is a little cheaper to put out, but plant quality was going down, so we went to Ronstar. Our coverage was not any better but the quality of our plants returned to what we would like to have. We use Ronstar at the recommended rate every 10 to 12 weeks, depending on the weather.

HARRY HOPPERTON: Question to Henry Chase. Henry, you said you waited for a rain to activate the Treflan. What if it didn't rain for two weeks?

HENRY CHASE: As long as you aren't getting any rain, you are not going to be getting any germination. The Treflan will remain in place. Many times during the summer a heavy dew will solve that problem.

SIDNEY MEADOWS: I'm going to take just one minute here to inject something that I believe in that has worked for us ex-

tremely well. We plant in our cans in April, assign a certain number of cans to two people, and tell them to keep these cans clean until September 15 for a certain amount of money. In recent years, we have used a half million cans for two people for all summer, and they have done it. In fact, they have come out ahead by not having to work full time on it. By working in extra credit somewhere else, they can receive a nice bonus check. Surprisingly, this costs less than a cent a can. The worst job on the place is made a prestige job because they work hard to eliminate any source of weed seed. It works best to start the contract program with newly canned plants, otherwise there will be a build-up of weed seed in the container.

PETER VAN DER GIESSEN: Question for Sidney Meadows. Does the 1 cent that you are paying involve the salary that these people are going to make?

SIDNEY MEADOWS: That is their pay. The contract amount is based on a rate of $2.65 an hour for an 8½ hour day, 42½ hours a week for that period of about 15 weeks. It figures out to be a little less than a penny a can. These people usually earn about $300 bonus on the contract system.

KERMIT MORRIS: Is the weeding in addition to the use of herbicides?

SIDNEY MEADOWS: We don't use any herbicides in this program. If we keep the weeds out of the walk and the perimeter, the contract workers will keep them out of the cans.

BOB LOGNER: Question for Sidney Meadows. What is the difference in cost and the ease of using a plastic pot in comparison with the ease of using a peat pot?

SIDNEY MEADOWS: I've never analyzed it but will give you my opinion. I just tell myself that the ease of using a peat pot is worthwhile because of the amount of trouble in removing a plastic pot from the root ball, storing it and reusing it. I would much prefer to use a peat pot because it is put out there and gone. It is certainly easy just to pick it up and pot it. We do use the 3-inch square plastic in a flat, as Brad discussed, but I believe using the peat is cheaper.

The final choice depends on the character of the root system and the length of time required for rooting. If we are going to stick something in and plant it quickly, we use the peat pot. If the cuttings are going to be in the pot for a long time, Burford holly, for example, we put them in plastic pots. Azalea goes in a peat pot. If the plant remains in a peat pot very long, the pot disintegrates. With many broad leaves we stick them in the peat pots and then transfer them in about 60 days. A peat pot is first choice, and a plastic pot is second choice. As far as rooting quality is concerned, I don't think there is any difference.

TESTING BY THE GROWER FOR SOLUBLE SALTS

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Only a small percentage of southern nurserymen producing plants in containers use a solubridge to test for soluble salts (salinity). This is unfortunate since a solubridge is one of the most important diagnostic tools that a nurseryman can use in making intelligent fertility decisions. A solubridge works on the simple principle that a water solution containing high concentrations of dissolved minerals (ions) is a better conductor of electricity than one with low amounts of minerals. The solubridge is calibrated to measure this conductance of electricity.

Lack of acceptance of this tool in the container nursery industry is basically due to three factors: (1) lack of experience by nurserymen in its use, (2) lack of confidence in interpreting the results due to the wide variations in testing procedures, and (3) cost. Most reliable instruments are in the $200 to $300 range.

Commercial and State University labs will make soluble salts determinations for nurserymen; however, this usually requires at least 10 to 14 days. Most nurserymen need "instant" results in order to make fertilization decisions.

A solubridge allows a grower to "see" the level of salts as a result of dissolved minerals in the water and potting mix plus those from his fertility program. In the south most soluble salts levels are directly related to the amount of fertilizer applied. The instrument allows the nurseryman to decide: (1) if another fertilizer application is needed to stimulate growth, (2) if he should delay application due to the salts level present, or (3) if it would be wise to leach a portion of the salts out by heavy watering in order to reduce a dangerous concentration.

Conflicting information. Unfortunately much conflicting information is available concerning evaluation of soluble salts levels. This is due to the wide variation in testing procedures that have developed throughout the country. The ratio of soil to water in the numerous test procedures has especially resulted in conflicting information. For example, for a pine bark type mix, about four times the amount of water is used for a 1 to 2 soil-water (by volume) test as compared to a saturation paste extract procedure.

Which Procedure to Use. Most scientists agree that a saturation paste extract procedure is the most reliable when comparing a wide variety of potting mixes. This procedure, however, requires vacuum equipment and is more complicated than most nurserymen are willing to follow. The most practical one for nurserymen, in my estimation, is the procedure in which

one part soil is combined with two parts water by volume. The procedure described here is for a quick test that will give a good "ballpark" figure with a minimum of effort and time.

1. *Collecting Samples.* The same individual should collect samples and run the tests in order that identical procedures are always followed. Collect the samples from at least 4 containers in a block. A total of one-half to one cup of soil is adequate. Sampling can be done by a soil sampling tube; however, this can be time consuming. Cutting out a slice of soil as deeply as possible with a garden trowel is much faster. Before slicing, pull back the surface soil in the area if it contains any dry surface fertilizer. Thoroughly mix combined samples. Carry along a container of soil mix to replace the slice removed from each container. It is not essential that the combined samples be air-dried if this will delay results. It is better, however, that the samples not be soggy wet as this dilutes the test solutions somewhat.

2. A small cup is useful to measure one part soil by volume. Firm, but do not pack soil tightly.

3. Add two parts water from the same cup. Plastic freezer containers are ideal for agitating the soil solution. To eliminate confusion, number each container with a nursery marking pen.

4. Stack 4 or 5 freezer containers and agitate for 100 shakes. Test immediately.

5. Pour solution through a kitchen strainer into a tall glass cylinder (to obtain necessary testing depth).

6. Determine temperature of solution. Set temperature dial of solubridge at proper temperature.

7. Dip electrode so that air hole is under water. *This is important.*

8. For Beckman instrument model RD-B15, turn knob until black band appears on green "eye". Stop at widest point on band.

9. Read number on outer scale. The solubridge calibration will be either in Millimhos/cm or Mhos/ $\times 10^{-5}$. The difference is simply two decimal points. Example — a Millimhos/cm reading of 1.25 equals 125 Mhos/cm $\times 10^{-5}$.

10. Check soluble salts of water used in test. Subtract this number from results. If distilled water is used it will not be necessary to do this.

11. Always record results in soluble salts log book.

INTERPRETATIONS FOR GENERAL CONTAINER-GROWN SHRUBS IN PINE BARK MIXES[1] USING 1 TO 2 SOIL-WATER BY VOLUME

Solubridge reading in Millimhos/cm	Solubridge reading in Mhos/cm × 10^{-5}	Remarks
Below 0.25	Below 25	Low
0.25 - 0.50	25 - 50	Low to medium - acceptable for liquid feed or Osmocote programs
0.50 - 1.00	50 - 100	Medium. If above 75 do not re-apply fertilizer.
1.00 - 1.50	100 - 150	High. Do not fertilize. Don't allow soil to become dry.
1.50 - 2.50	150 - 250	Leach with heavy application of water.
Azaleas and Salt Sensitive Shrubs		
Below 0.10	Below 10	Low
0.10 - 0.30	10 - 30	Low to medium. Upper range acceptable for liquid feed or Osmocote programs.
0.30 - 0.50	30 - 50	Medium. If above 50 do not re-apply fertilizer.
0.50 - 0.75	50 - 75	High. Do not fertilize. Do not allow soil to become dry.
0.75 - 1.25	75 - 125	Leach with heavy application of water.

[1] Based upon author's practical experience.

SOLUBRIDGE INTERPRETATIONS IN USE AT WIGHT'S NURSERY, CAIRO, GEORGIA USING 1 TO 2 SOIL-WATER BY VOLUME

General Container Plants in Pine Bark Mixes	
Mhos/cm 10^{-5}	
Below 20	Need fertilizer
25 - 50	Satisfactory
50 - 75	No more fertilizer
75 - 100	Leach with water and do not allow to dry
Sensitive Plants (e.g., Azaleas) in Pine Bark Mixes	
Below 20	Need fertilizer
20 - 50	Satisfactory
50 - 75	Do not add fertilizer Do not allow to dry
Above 75	Leach with water

VARIABLES TO CONSIDER IN INTERPRETING TOXIC LEVELS

1. *Differing Shrub Susceptibility to Salts Injury:* Even in the same medium some shrubs are injured at a much lower soluble salts level than others. Azaleas and rhododendrons, for example, are injured at much lower levels than most other shrubs. Research in California (1) has provided us with a guide to a limited number of shrubs.

SALT TOLERANCE OF SOME ORNAMENTALS

High - *Bougainvillea spectabilis*; *Carissa grandiflora*.

Good - Rosemary (*Rosmarinus officinalis* 'Lockwood de Forest'); *Euonymus japonica*; *Dracaena indivisa*; Oleander (*Nerium oleander*); Bottlebrush (*Callistemon viminalis*).

Moderate - *Juniperus chinensis*; *Pyracantha Fortuneana* 'Graberi'; *Elaeagnus pungens*; arborvitae (*Thuja orientalis*); boxwood (*Buxus microphylla*); *Lantana camara*; *Ligustrum lucidum*.

Poor - *Viburnum tinus*; *Hibiscus rosa-sinensis*; *Nandina domestica*; *Pittosporum tobira*; Algerian ivy (*Hedera canariensis*).

Very Poor - *Ilex cornuta* 'Burford'; pineapple guava (*Feijoa sellowiana*); star jasmine (*Trachelospermum jasminoides*); rose.

2. *Soil Moisture:* Soluble salts do not evaporate along with soil water. As the soil mix increases in dryness, the salts concentration in the soil solution becomes greater. Salt injury to the roots is therefore much greater when the soil mix becomes extremely dry. Soil moisture is often the critical factor in a high salts situation in container production.

3. *Climatic Conditions:* Soluble salts damage to the roots results in drought stress. Plants under this stress are much more severely damaged under conditions of high temperature, high light intensity and also high wind movement.

4. *Time of Sampling:* Growers who do not take periodic samples and do not keep a soluble salts log book can misinterpret results. For example, a grower notes stunted growth or slight foliar symptoms on July 1st and checks the soluble salts level. By that time the soluble salts level could have dropped considerably from when a heavy application of water-soluble fertilizer was applied in late May.

5. *The Potting Mix:* The roots of shrubs in bark mixes are injured at a lower level than those grown in soil. They are also injured at a lower level than are plants grown in finely ground peat-vermiculite artificial mixes.

What To Do If Soluble Salts Problems Develop. Careful watering to keep the soil mix from drying out excessively is important if the level is slightly high. Leaching to reduce exces-

sive salts is recommended if high levels are encountered. Apply 2 to 3 inches of water and test soil again to determine the reduction. Six inches may be necessary to reduce the salts level by one-half. Salts build-up can be prevented to a great extent by applying enough water in each irrigation so that some water runs out of the drainage holes. This is very important in greenhouses where there is no leaching by heavy rains. Needless to say, excess fertilizer rates are the major reason for soluble salts problems in container production.

Developing Your Own Standards. As soon as a nurseryman purchases a solubridge he should begin to develop his own standards for his particular potting mix. Apply varying amounts of fertilizer to several species of plants. Record test results every two weeks along with shrub appearance. This backlog of information will add greatly to a grower's knowledge that will help to make the correct decisions when it becomes critical to do so.

Note the following results that were obtained from applying specific amounts of fertilizer to a mix of 4 pine bark, 1 sand in a one-gallon Lerio container.

SALT LEVELS AT VARIOUS FERTILITY RATES

Teaspoons water-soluble 15-15-15 per gallon container

0 = 4*
½ = 51
1 = 76
2 = 146
3 = 216
4 = 276
5 = 346

Readings in Mhos/cm × 10^{-5} (1 to 2 soil-water by volume)

The following chart is adapted from information from the University of Florida (2).

Soluble Salt Levels at Various Fertility Rates*

	lbs. per 100 sq. ft. 20-10-20		
	0#	1#	2#
Sand + Peat	1*	33*	56*
Shavings + Peat	1	41	83
Shavings + Peat + Perlite	1	37	72
Perlite + Peat	1	45	74
Sand + Peat + Shavings	1	35	76
Sand	1	25	56
German Peat	3	47	71

*SS readings 1-2 soil-water (Mhos/cm × 10^{-5})

Checking Accuracy of Solubridge. Growers must have

complete confidence that their solubridge is working properly. This can be accomplished easily by asking a druggist to prepare a standard reference solution as follows:

Dissolve 0.744 grams of dry C.P. potassium chloride in distilled water and dilute to 1 liter. When the temperature dial is set properly, the instrument should read 1.41 Millimhos/cm, or 141 Mhos/cm $\times$ 10^{-5}. A slight variation from the reading such as 135 Mhos/cm $\times$ 10^{-5} will not affect the usefulness of the solubridge.

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TRANSLATING SOIL TESTS INTO QUANTITY OF FERTILIZER NEEDED

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Converting chemical soil test measurements into recommended amounts of lime and other fertilizer treatments should involve more than simple mathematical calculations. The goal of a fertility program should be to optimize economically the ability of a specific soil to supply essential nutrients for a specific crop.

Many factors affect soil fertility and productivity. Some of these factors are subject to control or change and some are not. We shall not attempt to consider all factors here. However, it should be remembered that when considering the nutritional needs of plants, the controllable, as well as the uncontrollable factors will have a bearing on the fertility program plan and the resulting quality of plants produced.

Crops vary in their nutritional requirements. Soils vary in their ability to supply those nutrients needed to satisfy those requirements. Climatic factors affect crop growth and fertility response as well as management and cultural practices. Standardization of fertilizer recommendations is, therefore, not practical, and we shall not attempt to recommend rates for a specific crop or situation. Our objective simply is to explain certain soil test data and to provide guidelines for translating these into

complete confidence that their solubridge is working properly. This can be accomplished easily by asking a druggist to prepare a standard reference solution as follows:

Dissolve 0.744 grams of dry C.P. potassium chloride in distilled water and dilute to 1 liter. When the temperature dial is set properly, the instrument should read 1.41 Millimhos/cm, or 141 Mhos/cm $\times$ 10^{-5}. A slight variation from the reading such as 135 Mhos/cm $\times$ 10^{-5} will not affect the usefulness of the solubridge.

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TRANSLATING SOIL TESTS INTO QUANTITY OF FERTILIZER NEEDED

BRYSON L. JAMES

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Converting chemical soil test measurements into recommended amounts of lime and other fertilizer treatments should involve more than simple mathematical calculations. The goal of a fertility program should be to optimize economically the ability of a specific soil to supply essential nutrients for a specific crop.

Many factors affect soil fertility and productivity. Some of these factors are subject to control or change and some are not. We shall not attempt to consider all factors here. However, it should be remembered that when considering the nutritional needs of plants, the controllable, as well as the uncontrollable factors will have a bearing on the fertility program plan and the resulting quality of plants produced.

Crops vary in their nutritional requirements. Soils vary in their ability to supply those nutrients needed to satisfy those requirements. Climatic factors affect crop growth and fertility response as well as management and cultural practices. Standardization of fertilizer recommendations is, therefore, not practical, and we shall not attempt to recommend rates for a specific crop or situation. Our objective simply is to explain certain soil test data and to provide guidelines for translating these into

quantities of fertilizer needed to achieve specified levels of nutrient availability.

Colloidal complex. To use and understand soil analysis, we need to understand the importance of the colloidal complex.

The word colloid comes from the Greek word "kolla," meaning glue-like. When used in soil descriptions, it identifies those minute, plastic, sticky portions of the soil having large surface areas in comparison to diameter. Soil colloids show an attraction for base elements (carrying positive charge) and have the capacity to trade or exchange one base element for another. From the complex interactions among soil colloids, the soil solution, and plant roots, we derive the term "colloidal complex."

So, when we speak of the colloidal properties of the soil, we mean the ability of the soil to hold, by adsorption, various plant food elements and to release or exchange these elements under certain conditions. These elements include potassium, magnesium, calcium, manganese, iron, sodium, copper, zinc and others.

It is through these processes of adsorption and exchange that the colloidal complex can be increased in fertility potential through soil treatments. Plants exchange hydrogen for the nutrient elements they need as their roots make contact with the colloidal surfaces or the surrounding soil solution. Cations that are not adsorbed to the colloidal mass of the soil can be removed by leaching when water percolates through the soil. Thus, as a soil becomes depleted through leaching and cropping, the quantity of hydrogen ions on the colloids goes up and the quantity of the other elements goes down. Fertilization becomes a problem of replacing the hydrogen again with the proper amounts and balance of the other elements.

Terms and measurements. Following are some of the terms and measurements given on most soil test reports.

Cation Exchange Capacity, CEC, is the ability of a soil to adsorb and exchange cations (positively charged ions or atoms of the base elements mentioned above). The unit of chemical measurement used is milliequivalents (meq) per 100 grams of soil. To be useful on a field basis in determining the pounds of a nutrient needed per acre, the meq measurements need to be converted into pounds per acre. Meq is a capacity measurement and meq's of calcium, magnesium and potassium differ in weight. Following are some useful conversion factors:

1 meq Ca per 100 grams of soil = 200 ppm

1 meq Mg per 100 grams of soil = 120 ppm

1 meq K per 100 grams of soil = 390 ppm

Parts per million (ppm) is the measurement used to report

nutrient elements. To convert ppm to pounds per acre of the elemental form multiply by 2. This is based on the assumption that the average weight of 1 acre of soil to a depth of 6 2/3 inches is 2,000,000 pounds. For deeper tillage use a proportionally higher multiple. Fertilizer phosphorus (P) usually is discussed in terms of P_2O_5 because this is the way it is guaranteed on the fertilizer bag. To convert ppm P to pounds per acre P_2O_5, multiply by 4.6. Fertilizer potash (K) is usually discussed in terms of K_2O because this is the way it is guaranteed on the bag. To convert ppm K to pounds per acre K_2O, multiply by 2.4

Soil pH is the measure of activity of the hydrogen ion. It is useful in interpreting soil conditions that help or hinder plant growth as it especially affects availability of nutrients.

Buffer pH measures the total soluble and exchangeable hydrogen and aluminum; that is, it measures total acidity rather than just active acidity. Buffer pH is used only to determine lime requirement and should not be confused with soil water pH. Since it is known how much acid is required to lower the buffer solution to a given pH level, lime requirements may be determined from prepared tables similar to Table 1.

Table 1. Tons/acre limestone to adjust soil to pH 6.5

	Mineral soils		Organic soils	
Buffer pH	Plow depth 6 2/3 inches	Plow depth 9 inches	Plow depth 6 2/3 inches	Plow depth 9 inches
7.0	none	none	0	0
6.9	none	none	0	0
6.8	1	1.5	0	0
6.7	1.5	2	0	0
6.6	2.0	3	0	0
6.5	2.5	4	0	0
6.4	3.0	4.5	1	1½
6.3	3.5	5	2	3
6.2	4.0	6	2½	3½
6.1	4.5	7	3	4½
6.0	5.5	8	4	6
5.9	6.0	9	4½	6½
5.8	6.5	10	5	7½
5.7	7.0	11	5½	8
5.6	8.0	12	6	9
5.5	9.0	13	6½	10

Determining the soil need for cations. The balance that soil scientists recommend for the exchange complex is 65 to 75 percent calcium, 10 to 15 percent magnesium, and 2 to 7 percent potassium. Table 2 gives the ppm and pounds of each required per acre to give this balance in soils of different exchange capacities.

The needs of a particular soil sample area are determined

by subtracting the amount of the element present as shown by the soil test, from the amount recommended in Table 2 for a soil of the same cation exchange capacity (meq/100 gm). If fertilizer is applied in excess of cation exchange capacity, soluble salts damage may result.

Three considerations are involved in determining soil needs for the three major cations: (1) The cation exchange ca-

Table 2. *Balanced soil saturation of potassium, magnesium and calcium.* Parts per million necessary to balance the exchange complex of the soil to the final values of 2-7% potassium, 10-15% magnesium and 75% calcium. To convert to pounds per acre multiply by 2.

CEC meq/100 gms soil	For very high yields or high K requirement crops 2½-7%	For normal cropping Potash 2-5%	Magnesium 10-15%	Calcium 75%
50	488	390	600	7500
48	468	375	576	7200
46	449	359	552	6900
44	433	349	528	6600
42	419	344	504	6300
40	406	338	480	6000
38	397	331	456	5700
36	388	323	432	5400
34	377	314	408	5100
32	364	304	384	4800
30	351	292	360	4500
29	345	284	348	4350
28	339	274	336	4200
27	332	264	324	4050
26	325	254	312	3900
25	317	244	300	3750
24	309	234	288	3600
23	300	224	275	3450
22	292	215	263	3300
21	282	205	252	3150
20	275	195	240	3000
19	270	192	236	2850
18	267	187	230	2700
17	262	182	225	2550
16	256	176	218	2400
15	248	170	210	2250
14	240	164	202	2100
13	231	158	193	1950
12	220	152	183	1800
11	208	147	172	1650
10	195	141	160	1500
9	187	135	148	1350
8	177	129	135	1200
7	164	123	121	1050
6	148	117	106	900
5	130	108	90	750
4	110	85	75	600

pacity. (2) The ratio of these elements. (3) The degree of saturation desired. The cation exchange capacity is, for practical purposes, a fixed amount in a given soil. But we can change the ratios among the elements within this total to achieve an adequate blend of the three nutritionally important cations (K, Ca, Mg).

In most instances it is not necessary nor economically desirable to saturate the exchange complex completely with the exchangeable base elements. An 80 to 90 percent saturation of the exchange capacity with a balanced ratio of exchangeable bases will usually be adequate for high yields of most crops. The following example illustrates the calculations used to determine fertilizer requirements.

Example: A soil with CEC = 10 meq/100 grams soil; a potassium reading of 145 ppm; the crop demands high potassium.

Desired potassium level for 10 meq soil, Table 2	195 ppm
Value found (from soil report)	145 ppm
Deficient (to be applied)	50 ppm
Conversion from ppm K to pounds K_2O per acre	×2.4
Annual needs =	120 pounds K_2O

Determining the soil need for anions. Nitrogen, phosphorus, and sulfur are acid-forming materials, or anions, and must be considered as special cases. While many chemical forms of nitrogen, phosphorus, and sulfur exist in the soil, it is principally in the form of nitrate, NO_3^-; orthophosphate $H_2PO_4^-$; and sulfate, SO_4^{--} that plants can utilize these negatively charged elements.

Processes by which nitrogen, phosphorus, and sulfur are converted into nitrate, phosphate, and sulfate from other chemical forms require soil bacteria. Organic matter in the soil supplies food for bacteria and, therefore, the amount present becomes a matter of significant importance.

Estimating nitrogen needs. The most important factor in determining the nitrogen need is the crop to be grown. Wide differences of opinion exist concerning N needs of nursery crops. We suggest 150 to 300 pounds N per acre per year for field-grown stock, with higher rates for lighter soils and high density plantings. For container crops, 800 to 1600 pounds per acre per year are suggested. Many growers and researchers use 2000 pounds or more.

Most field soils are not analyzed for nitrogen. The amounts suggested above are applied in 2 or 3 applications. We try to apply a maximum of 120 pounds per acre of soluble nitrogen (N) plus soluble potash (K_2O) per application to avoid fertilizer

burn from excessive salts. If higher rates per application are desirable, use slow-release nitrogen sources for part of the N applied.

Supplying phosphorus. The addition of phosphorus should have a threefold purpose: (1) To furnish an active form of phosphorus as a starter fertilizer for immediate stimulation of the seedling or liner, (2) to provide a continuing supply of available phosphorus, (3) to insure a good reserve supply of phosphorus. There are several methods used to determine phosphorus in soils. Weak Bray Phosphorus (P_1) determines readily soluble phosphorus. A level of 22 to 30 ppm P, or 100 to 130 pounds of P_2O_5 or more per acre, by this test is theoretically a desirable level for average production of most crops. It is important to remember that in actual practice many factors may affect soil and crop nutrient solubility. The Strong Bray Phosphorus (P_2) test reveals water soluble phosphate, weak acid soluble phosphate and a small amount of the active reserve phosphate. In general if the amount of phosphorus determined by this method is 44 ppm P or 200 pounds P_2O_5 or over, it may be assumed that there is enough phosphorus for at least average crop production.

To convert ppm phosphorus (P) on soil test reports to pounds per acre P_2O_5 multiply by 4.6.

Example: 30 ppm P = 138 pounds/acre P_2O_5
$(30 \times 4.6 = 138)$

Quick reference. Table 3 is a quick reference guide for translating soil test readings into quantity of lime and fertilizer needed. There are no universally best methods or materials to use in applying fertilizer for nursery crop production. This should be kept firmly in mind when applying, writing or interpreting fertilizer recommendations. Local conditions or individual circumstances can alter any fertilizer program amounts, methods or kinds.

Soil testing. Chemical analysis of soils is an important tool for developing successful soil fertility programs. But do not expect one soil analysis to solve all of your problems. Sampling on a regular basis, coupled with detailed record keeping, will provide valuable information for maximizing benefits from fertilizer applications. In addition, these records will point out slowly developing imbalances before they become major problems.

There are many good soils laboratories. It is important to choose a good one and stick with that one. Not all labs use the same analytical procedures or reporting systems. Direct comparisons between labs may not be possible. By switching labs, continuity of information may be lost. Since you may not always wish to buy fertilizer from the same firm, use an independent laboratory or state laboratory. They have no inclination to slant recommendations to fit their product line.

Table 3. Quick reference guide for translating soil test readings into quantity of lime and fertilizer needed.

Measurement for	Desired level	How to adjust
pH	6.5 (for most crops)	Use buffer pH from soil test and refer to chart for lime needed.
Nitrogen (N) (usually not given)	Varies with crop	Add annual requirement each year - split applications.
Phosphorus (P)		
Weak Bray (P_1)	30 ppm	Desired reading = 30 ppm Subtract soil test reading − Xppm Quantity to add = Yppm Multiply Y times 4.6 to get lbs. P_2O_5 per acre per year.
Strong Bray (P_2)	60 ppm	Not necessary to figure both P_1 and P_2 the same year. Adjust P_2 at time of soil preparation using above calculations with a desired reading of 60 ppm.
Potassium (K) Magnesium (Mg) Calcium (Ca)	Varies with CEC. Refer to table showing balance soil saturations of K, Mg, and Ca to get ppm of each required for your particular soil CEC.	ppm from table = X ppm Subtract soil test reading − Y ppm Quantity to add = Z ppm For K multiply Z ppm times 2.4 to get lbs./acre K_2O needed per year. For Mg and Ca multiply Z times 2 to get lbs./acre/year.

This information summarizes methods used for determining optimum amounts of fertilizer to be applied to field soils. This is similar to information for container growing presented by George McVey in a very good paper published in the 1977 IPPS Proceedings (1). Thus, it is hoped that these two papers will provide guidelines for many of your fertilization programs.

LITERATURE CITED

1. McVey, George R. 1977. How soil chemistry can work for you. *Proc. Int. Plant Prop. Soc.* 27:277-284.

QUESTIONS FOLLOWING MEDIA TEST FORUM

JOHN MEACHAM: Question for Gerald Smith. Does it matter how wet or how dry the soil in containers is when the water for the test is added?

GERALD SMITH: Some moisture is required, but soil should not be saturated. Excessive amounts of H_2O will cause more dilution. If 2 parts of H_2O are added to a large amount of H_2O in the soil, it might make a 10 per cent difference.

TED RICHARDSON: Question for Gerald Smith. I would like to know the effect of slow release fertilizer on the soluble salts test.

GERALD SMITH: Even after shaking soil 100 times, there is probably no movement of Osmocote during the testing period. Urea formaldehyde would give no appreciable increase. All you are measuring is what is available at this time, not what will be available 2 weeks from today.

VIVIAN MUNDAY: Wouldn't that give the overall picture? The effect today with slow release formulations should be the same as any other during the release period.

GERALD SMITH: Yes, the advantage of slow release fertilizer is maintenance of an even level of fertility.

BRYSON JAMES: I believe you will get a reading of Osmocote on soluble salts test because of the laboratory's grinding process. Thus, Osmocote gives a high reading because it is all released. Urea formaldehyde is not affected because bacterial action is required for release. Grinding or water have no effect on urea formaldehyde.

JAKE TINGA: Isn't it possible to make a mistake with Osmocote in the soil by thinking fertilizer is needed when it is not?

GERALD SMITH: Yes, which is another reason to keep records of what was put on and when.

RICHARD AMMON: Then we are discussing all salts; there is no indication of which ones are present?

GERALD SMITH: That is true. The salts could be from the water.

JAKE TINGA: Question for Bryson James: Would a test emphasize magnesium when there was an acute magnesium shortage?

BRYSON JAMES: The balance of nutrients in the soil complex is important. If there is a very low per cent base saturation of magnesium yet phosphorus and calcium are very high, there could be magnesium deficiency even though the ppm reading is good. If there is a 3:1 ratio of potash to magnesium, there will

be a magnesium deficiency anyway. To correct this, add dolomite limestone, which contains both calcium and magnesium carbonate, or add epsom salts (magnesium sulfate). Magnesium is a highly ionizable salt; therefore, watch the amount. Be sure to use the CEC and know what it means. Sandy soils will give a low CEC.

WILEY ROACH: Question for Bryson James: Would one application of 13-13-13 give enough phosphorus and potassium in bark:sand to be adequate for one season?

BRYSON JAMES: It is possible to apply all at one time if enough is put on. Soluble salts have no influence on CEC. Humus and organic matter have 3 to 4 times as much effect. Clay also has a high CEC. A good CEC range for bark:sand is 6 to 11. It is possible to add the nutrients when mixing soil, although this will probably not provide enough potash for the long term. A good fertilizer ratio to use is 3½ to 4 to 1 to 1.

WILEY ROACH: So if 13-13-13 is added to soil it might be necessary later on to go back and add potash and nitrogen.

BRYSON JAMES: That is correct.

FRED MAY: Is a pH of 6 to 6.5 ideal for azaleas?

BRYSON JAMES: No, it is a good range for general growing. 5.5 is probably as high as is practical with bark. The balance of ions is more important. Because of the high CEC of bark, it is not practical to adjust the pH.

METHODS USED TO APPLY FERTILIZER TO CONTAINERS AT GOOCHLAND NURSERIES

R.E. "ED" BROWN

Goochland Nurseries, Inc.
Pembroke, Florida 33866

All of our container-grown plants are fertilized with dry fertilizer applied by hand. Water soluble fertilizer is used on our liners.

We machine pot all of our 1 gallon and 3 gallon containers and hand pot 7 and 15 gallon containers.

We buy our potting mix already prepared. This consists of three parts local peat, one part builders' sand, and two parts cypress shavings; 110 lbs Hy-cal lime, 70 lbs dolomite, 72 lbs Perk minor element mix and 5 lbs chlordane are added to an 18 yard load of the potting mix. Fertilizer is applied to one gallon containers by using a plastic teaspoon, which holds ½ ounce of 6-6-6 or Osmocote. The first application is made within a few

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days after potting, using a 6-6-6 formulation containing minor elements. The nitrogen is all derived from organic material. The 6-6-6 is used as a starter because no fertilizer containing nitrogen, phosphorus or potash is added to our potting mix. This application is made after plants are placed in the beds.

The second fertilizer application is made within 2 to 3 weeks using Osmocote 19-6-12, 3 to 4 month formulation. We have found Osmocote becomes available by the time the 6-6-6 is depleted. Again we use the ½ ounce plastic teaspoon.

Three gallon containers are fertilized first with 6-6-6, second with Osmocote using the same time spacing of applications as with the one gallon containers. Fertilizer for 3 gallon containers is measured using a plastic top from a gallon acid jug available from a lab adjoining the nursery. The top measures 1¼ inch diameter by 1¼ inch deep and holds approximately 1½ ounce of 6-6-6 or Osmocote. We form a handle for convenient use with a 12 gauge galvanized wire wrapped around the top and twisted out to a length of 15 to 18 inches.

Seven gallon containers are hand potted, placed on trailers for transporting to the field and fertilized. The same materials and timing are used, but 2 measures are applied each time. This equals 3 ounces per container per application.

Fifteen gallon containers are handled in the same way as the 7 gallon using 4½ ounces of 6-6-6 for the first application, and 4½ ounces of Osmocote for the second. Timing is the same as for smaller containers.

Ordinarily the third, fourth and fifth applications of Osmocote are applied in the same manner as described above. Sometimes a small additional amount is added to each container because of heavier root formation and top growth.

Plants showing a deficiency in minor elements are given an application of Vertagreen Minor Element Mix, professional formulation 791[1] according to directions of manufacturer.

A water soluble material, Millers Nutri Leaf 60, is used to fertilize liners. The solution is run through our mist heads from our stationary spray tank with a pump attached for fertilizing. This application is started as soon as some roots are showing and continued every two weeks until the plants are well rooted. At this time a light application of Osmocote is broadcast over the bed.

We have found that these methods are adaptable to our

[1] Vertagreen Minor Element Mix 791, contains the following percentages of minor elements: Mg, 9.17; Mn, 2.32; Cu, 0.24; Zn, 0.69; Fe, 3.50; S, 2.00; B, 0.06; chelated Fe, 0.23; Mo, 0.002.

production system and enable us to produce high quality plants.

METHODS USED TO APPLY FERTILIZER TO CONTAINERS AT TOM DODD NURSERIES

TOM DODD, III

Tom Dodd Nurseries, Inc.
Semmes, Alabama 36565

The objective of our fertilization program is to provide the proper nutrients at the proper levels in the least expensive manner. There are several problems with containers that make it necessary to modify standard fertilization methods. One major problem is the soil medium itself. We normally use two parts milled pine bark and one part German peat moss for the majority of our ericacious plants and add sand for other container ornamentals. The nutrients available initially in the peat and bark medium are not adequate for optimum plant growth. We, therefore, must add nutrients as required. The other major problem is leaching. With containerized stock, irrigation practices are different because more water is used to wet this self-contained environment properly, and we observe considerable leaching. Thus, we have a loss of many nutrients and depression of soil pH.

In attempting to overcome these problems economically, we divide our program into three basic methods: 1. Premix the medium and the nutrients. 2. Side dress. 3. Apply by injector.

Let us look first at our pre-mix procedure: Initially, the two (or three) medium components are mixed by a front-end loader. As they are mixed the second time, dolomite, nutrients, and trace elements are added. We sometimes also add chlordane at this stage. The mixture is then turned at least five more times before it is delivered to the potting machines or to the potting wagons for use. There are certain drawbacks to this procedure that will be pointed out later. All of our soil medium is mixed with dolomite at a rate of 6 pounds per cubic yard. For most of the azaleas we add either Osmocote 18-6-12 at 10 pounds per cubic yard, or Osmocote 18-5-11 at 12 pounds per cubic yard, and one ounce of Peters FTE 503. For *Ilex* and other ornamentals we add Scotts 24-9-9 Premix plus minors at a rate of 3.5 pounds per cubic yard to the two-bark, one-peat, and one-sand mixture. For *Ilex* liners we lessen the rate to 2 pounds per cubic yard. For our azalea liners and some of our native species, we add only dolomite to a one-bark, one-peat mixture and add food by top dressing or with the injector system.

that we have 100 tubes for each week of 6 weeks. On 3 square feet of shelf holding the 100 tubes we obtain 6.3 divisions per tube. One division is used for replacement into fresh stage 2 medium. These numbers give us a production of 500 plus plantlets per week.

The Pretransplant Step and Establishment in Soil. The plantlets are rooted in stage 3 containers in 2 to 3 weeks and then moved into the outside world. The plantlets are placed in trays containing 72 cavities holding medium of 1/3 sand, 1/3 peat and 1/3 loam. The cavity is 2 inches square and 2¼ inches deep. After placing in the moist soil the plantlet is watered well and covered for 5 to 6 days with a near clear plastic dome. After the dome is removed, they remain in the glasshouse under 10,000 lux (1,000 foot-candles) for 3 weeks. These plants develop a superior root system in this period of time and are then transferred to a 6 inch container for growing onto a finished product.

Six months after the plantlets come out of the lab (5 months from the liner stage), we have 18-inch finished plants.

SETTING UP A TISSUE CULTURE SYSTEM

GEORGE OKI
Oki Nursery, Inc.
Sacramento, California 95826

Plant tissue culture is the placing of excised plant cells, tissues or organs in an artificial environment for the purpose of controlling the development of the explant. Plant tissue culture is pertinent to those in commercial horticulture as a method of achieving rapid vegetative multiplication. Shoot tip or shoot apex culture is the usual method; however, other tissues such as bulb scales, leaf parts, petioles, and embryos are also often used.

Plant tissue culture is not a new science as Haberlandt was the first to place leaf tissues into a nutrient solution for observation in 1902. Successful embryo cultures were achieved in 1904 by Manning. In 1934 White succeeded in culturing tomato roots, which display unlimited growth. These cultures are still being maintained; 1934 was also important due to the discovery of the auxin, indoleacetic acid. Gautheret and Nobecourt in France, and White in the United States, all reported the indefinite culture of callus on an artificial medium. Van Overbeek in 1941 reported the control of differentiation into embryos or callus with coconut milk treatments, and in 1946 Ball obtained

production system and enable us to produce high quality plants.

METHODS USED TO APPLY FERTILIZER TO CONTAINERS AT TOM DODD NURSERIES

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In attempting to overcome these problems economically, we divide our program into three basic methods: 1. Premix the medium and the nutrients. 2. Side dress. 3. Apply by injector.

Let us look first at our pre-mix procedure: Initially, the two (or three) medium components are mixed by a front-end loader. As they are mixed the second time, dolomite, nutrients, and trace elements are added. We sometimes also add chlordane at this stage. The mixture is then turned at least five more times before it is delivered to the potting machines or to the potting wagons for use. There are certain drawbacks to this procedure that will be pointed out later. All of our soil medium is mixed with dolomite at a rate of 6 pounds per cubic yard. For most of the azaleas we add either Osmocote 18-6-12 at 10 pounds per cubic yard, or Osmocote 18-5-11 at 12 pounds per cubic yard, and one ounce of Peters FTE 503. For *Ilex* and other ornamentals we add Scotts 24-9-9 Premix plus minors at a rate of 3.5 pounds per cubic yard to the two-bark, one-peat, and one-sand mixture. For *Ilex* liners we lessen the rate to 2 pounds per cubic yard. For our azalea liners and some of our native species, we add only dolomite to a one-bark, one-peat mixture and add food by top dressing or with the injector system.

Our second method of feeding is top dressing. We must side dress many of our containers as the months pass because the leaching we have precludes availability of nutrients for a full year, or until the container is sold or repotted with nutrient enriched medium. With the medium containing Osmocote we can expect six to eight months of adequate nutrient availability. Our high temperatures plus heavy rain and irrigation require us to add more Osmocote, or Stagreen 13-4-6 Nursery Special, or McMillan and Harrison 12-4-6 Nursery Special. We also foliar feed with Peters Soluble Trace Element Mix (STEM) and/or 20-20-20 when needed. With the Scotts Premix medium, we can expect only three to four months of good activity and therefore, we also side dress on a regular basis during the warmer months. Since side dressing is the most expensive method of nutrient application, it is done only when a solubridge reading indicates that it is needed.

Our third method of applying fertilizer is with an H.E. Anderson injector system. As we pot our azalea liners, we place them in beds that are irrigated initially with only water. Later, as they recover from transplant shock, we start feeding them daily as we irrigate. We mix our liquid concentrate as follows: 125 pounds of Peters 20-20-20, 10 ounces of STEM, and 100 gallons of water. This concentrate is placed in the main tank and is metered into the irrigation system at a rate of 300 ppm total food. We have found the 20-20-20 quite economical when purchased in large quantities, and it gives no trouble in the equipment.

There are many advantages to an injector system. We can vary the ratios of the various macro- and micronutrients, we can vary the levels of these nutrients, we can add pesticides, and we can be reasonably sure that all the plants receive the same amount of nutrients. We have all these advantages with the use of two valves. Since we have had good results with our injector, we have purchased another one for use in a new area. We will be able to control it with a small microprocessor interfaced with conductivity probes. In addition we will be able to control all the irrigation, heat, and light in the new area.

There are drawbacks to the pre-mix procedure. Even though the medium is turned by the front-end loader five or more times, a check at different locations in the pile with a solubridge will give readings that can sometimes vary as much as 50 percent from the desired norm. We are currently investigating several methods that will mix our various media better and faster. Another drawback is that we must use our medium soon after it is mixed. Otherwise we not only lose some nutrients but also experience more salt accumulation each time it rains.

For further information, I suggest that you read Dr. George McVey's article (2) published in the 1977 IPPS Proceedings (Volume 27) and the article (1), *Nutrition And Its Role In Plant Production*, by Dr. Ernest L. Bergman in the October 1, 1978, issue of "American Nurseryman." There are also numerous articles on the same subject that have been published in the Proceedings of the last few Southern Nurseryman's Association Research Conferences.

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1. Bergman, Ernest L. 1978. Nutrition and its role in plant production. *American Nurseryman*. 148, No. 7 and 8.
2. McVey, George R. 1977. How soil chemistry can work for you. *Proc. Inter. Plant. Prop. Soc.* 27:277-284.

METHODS OF FERTILIZING CONTAINERS AT GREENLEAF NURSERY

CURTIS W. WILKINS

Greenleaf Nursery Company
El Campo, Texas 77437

The nursery industry is continually faced with maintaining a balanced fertilization program for optimum plant growth and low production costs. The nurseryman must compare the maximum beneficial effects of fertilizers with the cost of application of the fertilizer. After making this comparison then one can consider which method of application is most suited for a particular operation. Let us consider the options for applying fertilizers to container-grown stock: 1) balanced fertilizer added to the soil medium prior to the canning of stock; 2) granular or slow-release bulk fertilizer applied as top-dressing; 3) liquid-feed (fertigation), generally provided to the plant material at continuous levels. All of these methods have their distinct advantages and disadvantages. However, the nurseryman must decide which mode of application or combination of applications is best suited for the individual operation.

Greenleaf Nursery has adopted a modified combination of top-dress application and a liquid-feed program. The programs are modified in the sense that neither one singly provides adequate nutrition for optimum plant growth, but in combination both provide a balanced and productive fertilizer program at minimal costs.

Top-dress application. As a rule of thumb, 2 to 3 weeks after canning, or once the liner has established itself after transplanting, we top-dress a new crop with fertilizer. With our

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Greenleaf Nursery has adopted a modified combination of top-dress application and a liquid-feed program. The programs are modified in the sense that neither one singly provides adequate nutrition for optimum plant growth, but in combination both provide a balanced and productive fertilizer program at minimal costs.

Top-dress application. As a rule of thumb, 2 to 3 weeks after canning, or once the liner has established itself after transplanting, we top-dress a new crop with fertilizer. With our

spring one gallon crop we top-dress with Osmocote 19-6-12 (3 to 4 month formulation) at ⅓ ounce per 1 gallon container. This provides the basis of our fertilization program. Overfertilization is extremely dangerous at this stage of growth because of the sensitive root system of young liners; therefore, a slow-release fertilizer seems to be best suited for this application. This task of hand application is accomplished with specially prepared spoons. We have fabricated several fertilizer spoons according to the amount of fertilizer to apply to a container. With our spring 1 gallon crop, spoons were designed that held exactly ⅓ ounce of Osmocote. A small diameter of the cylindrical shape eliminates any possibility of a heaping effect. There is now a commercially-produced fertilizer spoon (O.M. Scott Program spoon) on the market for container application.

Generally, two employees working an eight hour day can hand-feed 30,000 to 36,000 1 gallon containers using the spoon method. However, this past year, we introduced two commercially-produced drop-tube fertilizer applicators (O.M. Scott) into our top-dress program. Two employees now can top-dress approximately 55,000 to 60,000 1 gallon containers per day with suitable accuracy. The drop-tube applicator can be adjusted to dispense various amounts of fertilizer depending on the container size. Besides increasing the number of cans per day that we can now top-dress, we can get more uniform distribution of material from container to container by using either the spoons or the drop-tube applicator. We like to have the fertilizer spread evenly in the containers, but after the 20,000th can it may be placed in a pile. There is some question as to how significant this is, but we prefer to have it spread evenly.

Following our fall planting of 1, 2 and 5 gallon containers we top-dress with Osmocote 18-6-12 (8 to 9 month formulation). One gallons are fed with ⅓ ounce per can; 2 gallons with ⅓ ounce per can and 5 gallons with 1½ ounces per can. Our top-dress fertilizer program then is complimented by our liquid-feed program to produce optimum growth of plant materials.

Liquid feeding. The actual items of equipment involved for fertigation are two storage tanks, one or two nurse tanks, a Silas Jones injector tank or two Milton Roy diaphragm injector pumps for each block.

The process begins by filling the nurse tanks from the storage tank(s). In our liquid-feed operation we use a 32 percent Uran solution supplemented with a 10-34-0 blend. However, soil analysis determines the frequency of application of the two formulations. The 500 gallon nurse tank is transported to the block injectors and filled with the proper amount of solution. The rate is usually figured as 1.66 pounds actual nitrogen per

sprinkler head. Approximately 1.5 pounds actual phosphorus per sprinkler head is used.

The 40 gallon injector tanks are installed in such a fashion that the fertilizer solution will siphon directly into the 4 inch aluminum irrigation line. This action is accomplished through a ¾ inch inlet line directly to the tank from the 8 inch main irrigation line immediately *preceeding* the 4 inch brass gate valve to the block irrigation. A ¾ inch outlet line is attached on the tank to the 4 inch aluminum irrigation line *after* the valve. Once the tank is completely filled, primed, and pressurized with the water system pressure, the fertilizer will siphon into the irrigation line with the raw water. This expulsion process requires about 30 to 40 minutes of watering. Initially we have a concentration of 1500 ppm, but after the required time lapse our fertilizer concentration is only 5-10 ppm. At this point, the injector tank valves are closed so no fertilizer will be siphoned and the block is watered an additional 15-20 minutes with raw water to rinse off any high concentration of fertilizer.

This system has performed extremely well in years of usage. Fortunately, there appears to be an even distribution of fertilizer throughout the 615 feet of irrigation line because no irregular growth has occurred with the plants. Likewise, there have been no ill-effects observed with the high initial concentration of fertilizer *provided* the precautionary rinse procedure is maintained.

Also, at the Texas Division of Greenleaf Nursery, we have installed two Milton Roy diaphragm injector pumps at the irrigation well. Each pump has a 2 inch *suction* line directly from the 4250 gallon storage tank. The pumps inject the concentrated fertilizer directly into our 8 inch main irrigation line. One pump provides 32-0-0 and the other injects 10-34-0. The injector routes a constant and pre-determined amount of fertilizer into the entire irrigation system. The process obviously eliminates filling and refilling the block injectors. This system can provide a constant fertilization program; however, we choose not to use it as such, yet. The sole disadvantage to this system is that all of the blocks watered during a particular time period (in this case 5 blocks) must be fertilized. With the Silas Jonas block injectors, as few as 1 block or as many as 5 blocks can be fertilized during the watering time period. We believe this problem can be solved by a minor adjustment in our standard operating procedure. The major advantage again is the elimination of added labor to fertilize with the block injectors. With the Milton Roy injectors a precautionary rinse is not necessary immediately after liquid feeding. Also, with this fertilizer system we have a more accurate control of nutrient levels for optimum plant growth.

The obvious advantage of our liquid-feed system is that we can inject any water soluble nutrient into the irrigation system. Any minor elements in the chelate form are easily dispensed through irrigation, thus creating a considerable cost savings when compared to hand-feeding or spraying. However, water must be applied to release the fertilizer. In the spring and fall months, the climatic rainfall does not necessarily facilitate this process. In South Texas a nurseryman using fertigation solely is faced with the problem of underfertilizing or overwatering the crop. Obviously this fertilizer system is best suited in areas where rainfall is minimal, such as the U.S. West Coast. There it is a common practice to constant-feed nursery stock. With our combination of fertilization methods, the top-dress method forms the basis for maintaining nutrient levels during rainy seasons while our liquid-feed "tops out" the total fertilizer program for optimum plant growth. With any fertilizer program a constant check must be maintained for proper nutrient levels. This is especially true with the liquid fertilization method.

Soil analysis is an equally important part of our fertilization program. Through weekly analysis of soil samples using the Simplex Soil Testing procedure, we can obtain the accurate data required for maintaining nutrient levels. Our analysis of soil samples not only determines the frequency of fertilizer application but also the proper blend of fertilizer to use. Generally with one initial top-dress application of fertilizer we need only to maintain optimum nutrient levels with liquid blends applied through the irrigation system.

Without periodic soil analysis, any fertilizer program can end in one of three adverse results: (1) Insufficient fertilizer application for optimum growth; (2) more fertilizer than required for optimum growth; (3) overfertilization resulting in death of a particular crop.

With these three possibilities in mind one can easily see that soil analysis is important. It is the essential element for making any fertilizer program effective and productive, regardless of the method of application.

In summary, Greenleaf Nursery has not relied on any single method of fertilization, but instead, we have utilized the combination of two fertilizer application methods, top-dressing and liquid-feeding. In our operation neither method is solely effective; but when both are combined and accurate and frequent soil analyses are made, optimum plant growth can and will be obtained.

QUESTION PERIOD FOLLOWING FERTILIZING FORUM

BOB LOGNER. Can any of you suggest a method of fertilizing that would be suitable for a small nursery? How is it possible to avoid the cost of a large injector system?

ED BROWN: A good method would be to use 25 pounds of Nutri-leaf and a fungicide applied with a 500 gallon spray tank.

BRYSON JAMES: Some of the greenhouse equipment, such as a Gewa injector, is suitable for a small nursery. I would like to point out that at the rate Ed suggested, we are applying the equivalent of 7500 pounds total fertilizer per acre. This is a very high level of nitrogen for the amount of water. If we are losing much in run-off, we may face problems with EPA.

SIDNEY MEADOWS: Question for Curtis Wilkins: Did I understand you to say that you used N and P but not K_2O

CURTIS WILKINS: Yes, we have found K_2O to be most economical at $135 per ton. It is water soluble and easy to dispense; therefore, we buy it separately.

ROBERT WRIGHT: Question for Curtis Wilkins: Could you give the specifics on when to fertilize?

CURTIS WILKINS: We use the solubridge but rely more on soil testing by the Simplex method, texture, and various other factors. We try to maintain plant material levels in the 35 to 50 ppm range for N, 5 to 7 ppm for P and 10 to 15 ppm for K.

RICHARD VAN LANDINGHAM: Question for Curtis Wilkins: Did I understand you to say that you did not use any fertilizer in your soil mix?

CURTIS WILKINS: At one time we were adding fertilizer to our soil mix prior to canning. Then the question of leaching came up. We are now canning directly out in the field. We are not using a potting machine or anything like that. In order to use bare root liners, the mix in the can has to be wet. This takes about 3 to 4 days of watering, and again the question of leaching arose. Therefore, we now have really eliminated any fertilizer in the soil.

RICHARD VAN LANDINGHAM: What about pH control?

CURTIS WILKINS: We have really had no problem with pH. We try and let the plants tell us when adjustment is needed. Pine bark seems to take care of it.

RICHARD VAN LANDINGHAM: What is the pH of your water?

CURTIS WILKINS: Raw water is about 7.2, but we have had problems with bicarbonate. Usually bicarbonate runs about 300

ppm, so we have to inject sulfuric acid. Once we do, the pH drops to about 6.2.

DICK AMMON: Question for Curtis Wilkins: Do you have any problem getting your phosphates through your mix?

CURTIS WILKINS: No.

BOB KNECHT: Question for Tom Dodd. How do you avoid leaching minor elements from the pot?

CURTIS WILKINS: With the injector system, everytime they are fed, which is daily during the summer, they are getting minor elements. Out in the fields we use the fritted trace element mix. In addition we may use foliar trace element mix.

COMMERCIAL TISSUE CULTURING AT OGLESBY NURSERY

RAYMOND P. OGLESBY and RANDALL E. STRODE

Oglesby Nursery, Inc.
Hollywood, Florida 33023

Ornamental plant tissue culture successes in California have stimulated Florida growers' interest. Because of refinements in laboratory technique and the availability of commercially produced and packaged tissue culture media, tissue culturing commercially has become practical and profitable. This report will describe steps in rapid propagation of certain ornamental plants, including *Ficus elastica* 'Decora Burgandy.' Methods, technique, conditions and duration are described in detail from the initial shoot tip explant to outdoor planting and growing in 6-inch containers.

The tissue culture lab at Oglesby Nursery is just into its fourth year. Our present facility occupies 2,000 square feet and has a capacity of over 60,000 culture tubes, or a production level of over four million plants per year. We employ 13 people. High school students are used to wash the glassware. The development of the lab has been a tremendous expense; its operation is also expensive. Its function is to utilize *in vitro* culture procedures to these ends: (1) mass produce several desired cultivars for Oglesby Nursery, (2) provide tissue culture service for other nurseries, (3) produce retail consumer products *in vitro* and, (4) establish plant stocks that can be certified for freedom from certain pathogens and pests.

The starting tissue (explant): A shoot tip is cut with a pen knife from the parent plant. The outermost tissue, including all leaves, is removed. After a 10 mm by 20 mm piece of tissue is

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The starting tissue (explant): A shoot tip is cut with a pen knife from the parent plant. The outermost tissue, including all leaves, is removed. After a 10 mm by 20 mm piece of tissue is

excised, it is washed in soapy water for several minutes to remove any dirt.

The shoot tip is then cut further to about 5 mm by 12 mm. At this point the explant would include the meristem plus many tiny leaf primordia and subadjacent stem tissue. Approximately 20 shoot tips are cut and put in a 50 ml beaker for disinfectation. We use a disinfectant solution of 10 percent Clorox (laundry bleach) and a drop or two of liquid Joy detergent per 50 ml of autoclaved water. The shoot tips are agitated in the solution for 10 minutes by a slowly revolving magnet and are then rinsed 3 times with autoclaved water.

The shoot tips are then cut further using aseptic techniques under a laminar-flow clean air hood. The laminar flow hood is essential for preventing contamination. This final cutting is done under a dissecting microscope on a sterile petri dish using sterile forceps and a scalpel. The finished explant is approximately 1 mm by 3 mm in size and is inserted into the sterile culture tube containing the growing medium. The most expensive part of the entire operation is obtaining sterile first explants.

Nutrient medium. The Murashige-Skoog salt mix with minimal organics is used for the basic medium. It can be purchased in packages sized to make either 1 or 5 liters of medium.[1] The composition of the Murashige-Skoog Salt Mix is given in Table 1. Various recommended amendments are added to this. Table 2 lists the other constituents of the medium for the first and second stages. During stage 1 the plant becomes established and starts growing in sterile culture; in stage 2 it begins to multiply rapidly. Table 3 lists those constituents used for the rooting of *Ficus elastica*. This period is referred to as stage 3.

Table 1. The Murashige-Skoog salt mix with minimal organics.

Compound	mg/l	Compound	mg/l
NH_4NO_3	1650.0	i-inositol	100.0
KNO_3	1900.0	Thiamine HCl	0.4
$CaCl_2 \cdot H_2O$	440.0	H_3BO_3	6.2
$MgSO_4 \cdot 7H_2O$	370.0	$MnSO_4 \cdot H_2O$	16.9
KH_2PO_4	170.0	$ZnSO_4 \cdot 7H_2$	8.6
$Na_2 \cdot EDTA$	37.3	KI	0.83
$FeSO_4 \cdot 7H_2O$	27.8	$Na_2MoO_4 \cdot 2H_2O$	0.25
minimal organics	mg/l	$CuSO_4 \cdot 5H_2O$	0.025
Sucrose	30,000.0	$CoCl_2 \cdot 6H_2O$	0.025

The medium is mixed in 1 to 5 liter portions. The pH is adjusted to 5.6 with drops of 1 molar solution of NaOH or HCl. The media for stages 1 and 2 are dispensed into tubes 25 mm

[1] The source is Gibco-Invenex, 250-3, 17800 Chillicothe Road, Chagrin Falls, Ohio 44022.

Table 2. Nutrient addenda used for stages 1 and 2.

Addendum	mg/l	Addendum	mg/l
NaH_2PO_4	170.0	IAA (indole-3-acetic acid)	0.1
Adenine sulfate·H_2O	80.0	2iP	30.0

by 150 mm, 10 ml per tube, by means of a funnel, rubber tube, clamp and a plastic tube (40 cm) bored with 4 holes. This arrangement makes it possible to fill 4 culture tubes with the same volume at the same time. The tubes are capped with Bellco Kaputs caps and moved about in stainless steel racks of 36.

Table 3. Nutrient addenda used for rooting or stage 3.

Addendum	mg/l	Addendum	mg/l
NaH_2PO_4	170.0	IAA (indole-3-acetic acid)	1.0

The stage 3 medium is prepared in 5 liter batches in a large stainless steel stock pot. It is then transferred to two 4,000 ml Kimax bottles, which have an outlet at the bottom (#14605). Aluminum foil is placed over the opening at the top and 1 foot of amber tubing is attached to the bottom. A pinch clamp is placed at the dispensing end of the tube. Aluminum trays (EKCO Products, Inc. #705-30) are placed in a Mylar bag and autoclaved. Both the medium and trays are autoclaved for 15 minutes at 250° F, 15 lbs. pressure.

Clear polystyrene lids (EKCO Products, Inc. #9105-19) for the trays are soaked for 30 minutes in a bucket containing a 10 percent Clorox solution. They are then rinsed with hot sterile water. This procedure is done under a laminar flow hood. The medium is then dispensed into the sterile trays under a laminar flow hood and the sterile lid put on. The third stage container, now complete, is placed on an enclosed cart to cool.

The culture room. During stages 1 and 2 a constant temperature of 28°C is provided in a culture room illuminated 16 hours daily with 1,000 lux (circa 100 foot-candles) light from cool white fluorescent lamps. Stage 3, the pretransplant step, is illuminated with 10,000 lux (1,000 footcandles) cool white power groove fluorescent lamps.

The multiplication process: After 4 to 6 weeks the explants have increased in size to about 10 to 20 mm and at this point are put into fresh medium. Within 6 weeks divisions should be evident. Again a transfer is made into fresh medium. Once they are apparent, divisions are separated and put into fresh medium every 6 weeks until we have reached the number of stage 2 culture tubes we need to maintain a given output from the lab.

In our program we started with 6 groups of 100 tubes so

that we have 100 tubes for each week of 6 weeks. On 3 square feet of shelf holding the 100 tubes we obtain 6.3 divisions per tube. One division is used for replacement into fresh stage 2 medium. These numbers give us a production of 500 plus plantlets per week.

The Pretransplant Step and Establishment in Soil. The plantlets are rooted in stage 3 containers in 2 to 3 weeks and then moved into the outside world. The plantlets are placed in trays containing 72 cavities holding medium of 1/3 sand, 1/3 peat and 1/3 loam. The cavity is 2 inches square and 2¼ inches deep. After placing in the moist soil the plantlet is watered well and covered for 5 to 6 days with a near clear plastic dome. After the dome is removed, they remain in the glasshouse under 10,000 lux (1,000 foot-candles) for 3 weeks. These plants develop a superior root system in this period of time and are then transferred to a 6 inch container for growing onto a finished product.

Six months after the plantlets come out of the lab (5 months from the liner stage), we have 18-inch finished plants.

SETTING UP A TISSUE CULTURE SYSTEM

GEORGE OKI
Oki Nursery, Inc.
Sacramento, California 95826

Plant tissue culture is the placing of excised plant cells, tissues or organs in an artificial environment for the purpose of controlling the development of the explant. Plant tissue culture is pertinent to those in commercial horticulture as a method of achieving rapid vegetative multiplication. Shoot tip or shoot apex culture is the usual method; however, other tissues such as bulb scales, leaf parts, petioles, and embryos are also often used.

Plant tissue culture is not a new science as Haberlandt was the first to place leaf tissues into a nutrient solution for observation in 1902. Successful embryo cultures were achieved in 1904 by Manning. In 1934 White succeeded in culturing tomato roots, which display unlimited growth. These cultures are still being maintained; 1934 was also important due to the discovery of the auxin, indoleacetic acid. Gautheret and Nobecourt in France, and White in the United States, all reported the indefinite culture of callus on an artificial medium. Van Overbeek in 1941 reported the control of differentiation into embryos or callus with coconut milk treatments, and in 1946 Ball obtained

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complete plants of *Lupinus* and *Tropaeolum* through shoot tip cultures.

A fundamental principle in plant tissue culture was introduced in 1957 by Skoog and Miller when they found differentiation of plant organs in tobacco callus was controlled by the interactions between auxins and cytokinins.

In 1960 Morel described the first commercially applicable methods of tissue culture for rapid vegetative production of orchids. Many orchid tissue cultures are erroneously termed meristem cultures, or mericlones, but it wasn't until 1970 that Smith achieved the first true apical meristem cultures.

Basic principles and procedures were made available to commercial horticulturists through the research of Murashige on the rapid multiplication of ornamental plants. This has led to the development of commercial tissue culture laboratories for the purpose of propagating plants. These labs are able to take advantage of the potentially high multiplication rates. For example: given a single explant of plant tissue and conditions which yield a 5-fold multiplication rate at the end of the subculture period, with subculturing occurring every four weeks (if the first culture period yields no multiplication, which is common), at the end of a 40 week period two million plants can be obtained.

My first introduction to tissue culture was in the mid-1960s when the California Association of Nurserymen (CAN) Research Committee contributed $1,000 to the University of California, Riverside, Plant Science Department to foster and encourage research in tissue culture. This research at UCR and subsequent events convinced me that while tissue culture was only commercially feasible for a few specific plants, it could be an invaluable form of propagation.

In 1967 the California Association of Nurserymen made its first horticultural tour to Hawaii. The most impressive part of the trip was the visit to the University of Hawaii Plant Science Department with its numerous growth chambers and extensive research in plant tissue culture. I couldn't believe what I was seeing. It is of no wonder the University of Hawaii was so advanced in this field as Dr. Tosh Murashige completed his doctorate program here and is recognized today as one of the foremost plant tissue culture experts of the world.

Orchids, bromeliads, and anthuriums, together with other plant genera, were being successfully propagated by this method. I was convinced that now I must seek and find a commercial tissue culture laboratory upon my return. I found one in South San Francisco less than a hundred miles from our nursery.

During a visit to Rod McClellan's Nursery in South San Francisco, a company known for its orchids and other greenhouse products, I witnessed orchids in commercial propagation for the first time. Though "primitive" by laboratory standards, nonetheless seemingly "millions" of orchid plantlets were in production. There seemed to be test tubes everywhere, on rotating racks and stationery racks, with plantlets in all different stages of maturity. Mayonnaise jars for the final stages appeared to have been collected in abundance. I was impressed that a clone could be reproduced in these numbers in such a concentrated area.

There are two areas of importance for successful tissue culture: (1) a knowledgeable person, and (2) the lab facilities. Fortunately, both of my two sons expressed interest in horticulture in general, and it took little persuasion to have my number 2 son, Loren, specialize in tissue culture. Now the timetable was critical, for it would be nearly six years before we had full time access to his newly acquired skill and knowledge. The timetable was near perfect.

The tissue culture laboratories existed only in Universities and at Rod McClellan's. A thorough evaluation was made and a list of equipment necessary was compiled. It was not long before we recognized that this was not an ordinary project. Even though we have nearly a million square feet of greenhouses, by comparison the capital required for this venture was extensive for so small a square footage.

Our initial laboratory was less than 700 square feet and by the time it was operational the capital expenditure exceeded $70,000. Since we were thoroughly convinced that we would be in the tissue culture business, all new equipment was purchased. Microscopes, balances, laminar-flow work areas and autoclaves, not to mention many support facilties were required to make the laboratory operational.

In the meantime we searched for a technician that could use his knowledge to coordinate our facilities and personnel. Through our contacts at various universities we found a person that wanted to move to California, and we arranged a mutually beneficial arrangement. The tissue culture venture, after a snail-paced start, was finally launched.

In 1975 an expansion program was started and the tissue culture laboratory was expanded to more than 2,000 square feet of laboratory and work area and more than 5,000 square feet of culture rooms. We are very proud of what I believe are the best in commercial facilities.

Most people who show an interest in tissue culture are already aware of its potentials. Those in commercial horticulture

are interested in the high multiplication rates, which were mentioned. Other considerations must be made in planning facilities required for tissue culture, particularly the culture rooms and greenhouses to house the quantity of cultures being produced.

To use the previous example, to produce the two million cultures mentioned, a culture room of about 2500 square feet is required to house the culture tubes (a total shelf area of 24,500 square feet is required). If the cultures are transplanted into cell packs, a greenhouse of approximately 75,000 square feet is required. Also, the greenhouse must be equipped with special facilities to be able to maintain the high humidities required for the culture-to-soil transition. The laboratory facilities, such as transfer, sterilization, and washing equipment, must also be adequate to support the work required to produce the quantities of cultures discussed.

However, primary to all of the facilities required are personnel, which are the key to the success of the lab. A supervisor who is trained in the sciences related to horticulture, with background in tissue culture, is as required as the lab itself. Procedures for each plant type are to be determined since the requirements may differ among species and perhaps even among cultivars. Special skills and imagination are necessary for obtaining good results.

Plant tissue culture, not a new science, is most important to commercial horticulture for providing rapid vegetative multiplication and is also useful for the recovery of disease-free plants. Despite the great potentials, however, there are great requirements in the utilization of these methods.

In conclusion, tissue culture is a complex scientific method of micropropagation, requiring extensive capital, knowledge and facilities. Therefore, before you launch into this venture I recommend:

1. Define your company objectives. Are crops you anticipate culturing economically feasible? Is there an alternative? What is the planned magnitude of the operation?

2. Consider your available resources. Do you have substantial cash flow to expend the capital necessary to build this facility and furnish it with the necessary equipment and technical labor? Cash flow from your products cannot be expected for nearly two to four years.

3. Determine the availability of personnel. Are they fully qualified? Are they thoroughly knowledgeable in the science of tissue culture? What is your probability of survival should your key technician decide to leave?

4. Last but extremely important, be realistic about profitability. Are we looking for that "pie in the sky", or is tissue culture profitable? Is it only a status symbol? I ask, "Is tissue culture profitable?" and I can answer, "Yes, but when?"

QUESTIONS FOLLOWING TISSUE CULTURE FORUM

CHARLES PARKERSON: Question for Raymond Oglesby. Why did you decide to get into tissue culture? Was it to grow a particular type of plant you could not obtain any other way?

RAYMOND OGLESBY: I became very interested after taking the short course that is offered at Lake Placid. Information can be obtained from the W. Alton Jones Cell Science Center, Old Barn Road, Lake Placid, New York, 12946. There is a great demand for *Hemerocallis* cv Aztec Gold for landscaping in our area. We found that we could produce 15,000 daylilies on 20 square feet in 30 weeks. We sold the 15,000 'Aztec Gold' for $1.50 each. This inspired us to do more. I would definitely recommend taking the short course to anyone interested in tissue culture.

PROPAGATION OF LILACS

NICHOLAS P. HAND
Ozark Nurseries Company
Tahlequah, Oklahoma 74464

Cultivars: At Ozark Nurseries we propagate the following lilac cultivars: *Syringa vulgaris*, produced from seed on raised beds, *Syringa rothomagensis* (Chinese lilac), *Syringa vulgaris* 'Charles Jolly', *Syringa vulgaris* 'President Grevy', *Syringa vulgaris* 'Mme. A. Buckner', *Syringa vulgaris* 'Mme. Lemoine'.

The average combined number of cuttings stuck each year is 240,000. Of this number, 160,000 are French lilacs.

Cutting beds: Our cutting beds are 60 feet by 40 inches mini-Quonset structures. Retaining walls are constructed of 2 by 6 inch lumber. A 2 by 4 inch board is used to frame the beds. In our older beds a clay drain tile is run down the center of each, and in our newer beds French drains are used. A French drain is a ditch filled with gravel and is not too satisfactory. We use a medium of native soil (light clay loam) with peat moss added each year to increase the organic matter. The amount of peat added varies with each individual bed. Osmocote 18-6-12 is then added at the rate of 15 pounds per bed and cultivated into the soil to a depth of six inches.

Methyl bromide is used to sterilize the beds, applied at a

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rate of 7½ lbs per bed 60 feet by 40 inches. This is primarily for weed control.

Covering: Six by six inch concrete reinforcing wire cut to correct size and bent in a half-circle is placed on the beds. The beds are then covered with 4 ml clear plastic 8 feet wide. The plastic comes from a roll with one fold. This is important because the folds are the first places to degrade. It would be possible to use a plastic with an ultraviolet light inhibitor to delay the degrading process, but the plastic is only required, at most, to last 8 to 10 weeks.

Cuttings: Cuttings are obtained from plants in the field and from a recently established "stock block." Timing is most critical as cuttings taken too late have a much lower rooting percentage. In our case it is not possible to supply even minimum heat to our cutting beds. Therefore, it is advisable to wait until after frost danger has past, even if the cutting material is of correct size earlier. Cuttings taken later in the year do not grow off well due to Oklahoma's extreme summer temperatures. The best size cuttings are 5 to 6 inches long. Smaller cuttings we found will root, but do not fit into our production system easily, due to the fact that they are harder to handle. Cuttings are cut and counted into bundles of 26, and the bottom third stripped of leaves. They are stored in ice chests until brought to the propagation area.

Once brought to the propagation area the cuttings are placed on a "crisper," which is an open wire bench with a time clock controlled mist line over it. Here they wait no longer than 24 hours to be stuck.

Cuttings are first dipped in a solution of captan, 1 tablespoon per gallon of water. Next they are given a 5 second quick dip in a solution of ¼ per cent IBA.

Approximately 12,000 cuttings are stuck per "mini-Quonset," which gives a spacing of 1½ inches between cuttings in the row and about 2 inches between rows. Two girls can stick approximately 20,000 to 25,000 per day.

Mist is supplied to the cuttings through Eddie mist nozzles controlled by 12 minute time clocks, giving a minimum of 12 seconds of mist every 12 minutes. I feel a shorter mist interval would be more satisfactory.

The mist is controlled manually, hour to hour, day to day with 24 hour clocks controlling the 12 minute clocks. The rule of thumb I follow is to use the least amount of mist that still keeps the cuttings turgid.

Once the cuttings are stuck, a weekly spray program is initiated, using captan, zineb, and Benlate in rotation. Banrot to

combat soil borne diseases is used when needed to control localized problems.

Rooting: Callus formation can be expected after 2 to 3 weeks. This is a critical time in controlling the mist as too much will result in a large buildup of callus and little or reduced root development.

Once 60 to 70% of the cuttings have developed the beginnings of a root system, the first stages of hardening off begin. (1) The top is cut out of the bed and pinned back. (2) Three days later the east side is let down. (3) Three days later the west side is let down. (4) The mist is reduced in stages as soon as the plants will tolerate a reduction. (5) Shade is removed only after mist has been off at least three days.

Care After Rooting. The plants are sheared using a household hedge trimmer. This helps to increase stem caliper and also prevents some of the slower developing plants from being shaded out in the early stages.

The main disease problem we have found with lilacs is powdery mildew. To prevent and control this, plants are sprayed every three weeks with captan and Benlate, depending on the seriousness of the problem. The beds are hand-weeded, and surrounding areas are treated with paraquat. We are hand watering the cuttings once they are rooted. The main advantage is that there is less weed growth in the aisles. However, the cost of watering is becoming prohibitive.

Osmocote in the beds usually takes care of the plants' nutrition. However, top dressing with ammonium nitrate is occasionally needed. We apply at a rate of 400 pounds per acre or 2½ pounds per bed. We irrigate immediately after application.

Percentage Liners Produced. We have found we can expect the following rooting percentages for the different cultivars: (1) *Syringa rothomagensis* — 80 to 90 per cent successful with 90 per cent of these number 1 liners. (2) French lilacs, with the exception of Lemoine — 65 to 70 per cent success achieved, 90 per cent of these are number 1 liners. (3) With MME Lemoine we have only been able to achieve 35 to 40 percent success, even in the best years. Ninety-five per cent of these are number 1 liners, however, since the lower percentage of rooting prevents crowding and shading.

Future Developments. Our main limiting production factor is lack of early cuttings. To help overcome this we stuck some cuttings this year in late August. They rooted satisfactorily in the cooler late summer weather. But only time will tell how many number 1 liners they produce and how they overwinter.

PROPAGATION AND PRODUCTION OF *ACER PALMATUM* 'DISSECTUM' CULTIVARS

BILL CURTIS

Wil-Chris Acres
Sherwood, Oregon 97140

In Oregon, we use two successful methods for increasing the several named clones of *Acer palmatum*. The older method is the side graft, used in the grafting of many ornamentals. This operation is done in the greenhouse during late winter — January and February. For a number of years several nurserymen have been using a modified budding method called "The Bud Stick" method. Those who are doing it this way are getting excellent results. I will cover both methods in this paper.

We use *Acer palmatum* for understock, shifting a heavy seedling or rooted cutting from a 2¾ inch rose pot to a standard 1 gallon container. This is done in the early spring to assure growth by the dormant season of the following fall. This understock is grown in a covered plastic structure and reaches a height of 3 to 4 feet with a caliper of a lead pencil size or larger by the time it is budded. In the Southeast the shade house would do the same job.

Side graft. About two weeks before we are ready to graft, we shift the understock to a heated house, cutting the understock back to a height of 2 feet. We trim off the side branches, leaving a few close to the tip of the understock with an eye or two to encourage sap uptake to the area where we will be placing the side graft or bud stick. While in the process of shifting the understock to the grafting house, we segregate according to caliper and height of standard. The understock of smaller caliper is set aside for grafting the upright cultivars. We label each block of understock so that we know beforehand how many of a cultivar we will graft.

Just as soon as the buds begin to swell, we start grafting. In the meantime we cut the scion wood and store it in plastic bags in a cool place. We use some wood from the field; however, the majority of our scion wood comes from several large stock trees. We take only enough wood from storage for 2 hours grafting. Some of the wood is of small caliper, and the buds are small. If kept warm it could easily become dry. We use a heavy scion with one pair of "eyes," or on lighter understock we may use a scion with 3 pairs of "eyes" or more.

A thin, long cut is made in the understock about 1¼ to 1½ inches in length. At the base of the cut we go a little deeper to help hold the scion in place as the graft is wrapped with budding rubber. A long slim wedge cut is made on the scion 1¼ to

1½ inches in length. A little of the lower end of the wedge is "dubbed" off and pushed down firmly into the cut on the understock. The cambium of the understock and the scion must match on one side. If possible, match both sides. Starting at the top of the graft, we wrap down with some tension on the budding rubber. We use Tree Seal, undiluted, applied with a narrow brush, to cover the entire graft. A good grafter can get by without the Tree Seal; however, it is good insurance.

We use the same side graft method in grafting the upright Japanese maples. The upright Japanese maples are grafted low, yet high enough to make it easy to make the cut and properly wrap the graft. The upright maples are a great deal easier to graft. They also grow faster. Some 'Sango-kaku' and 'Sherwood Flame' will be 3 to 4 feet after one year in the field.

Following completion of the grafting, aftercare is most important. The understock will send out new growth from top to bottom. Cut back half of this new growth to reduce competition. Since new growth helps the movement of sap, we save at least one side shoot close to the graft until the graft is in vigorous growth.

The newly grafted plants are kept in a covered plastic building until early fall. They are then lined out in the field in rows, 4 feet apart, with 2 feet spacing in the row. The lighter standards can be staked for the first year.

Stick budding and regular budding. Both methods of budding are done during the late summer months in the field on established understock. A "T" cut is made on the understock used for stick budding just as in regular budding. A small diameter wedge shaped scion about 1 inch long is inserted in the "T" cut and wrapped with a budding rubber. On large understock we use several buds, which sometimes will give a saleable tree sooner than the greenhouse side graft.

We who are a little old fashioned feel that this large understock may not transplant too well, for it has been in the nursery row too long without being root pruned. There are several other drawbacks to "T" budding. If budded early enough, several inches of new growth may develop. A hard frost in mid-September can kill the buds or so injure the new growth that the supposed advantage is wiped out. Some years it is a problem to get mature wood or buds at budding time. Besides, it is most pleasant grafting in a warm house when the weather is unpleasant outside.

It has been reported that rooted cuttings of *Acer palmatum* lack the vigor of the seedlings and should not be used for understock. We have used both and see no difference in the end results. We stick dormant node cuttings in flats of sand:perlite,

1:1, 300 to 400 per flat. We use Hormodin #3 for the rooting compound and bottom heat of 70°F. A supply of cuttings is insurance against the time when *Acer palmatum* seedlings are not available.

PROPAGATON OF *PICEA GLAUCA* 'CONICA'

CARL BAUER
Phytotektor, Inc.
Huntland, Tennessee 37345

We began experimental production of *Picea glauca* 'Conica,' dwarf alberta or dwarf white spruce, about 3 years ago in search of some new items to add to our production. It was our opinion that we could propagate this plant without too much difficulty, but we were not sure that we could adapt it to our operation. Our production is such that it is not feasible for us to root any plant that we cannot propagate in quantity.

We began by sticking a limited number of cuttings in December in the manner that we stick *Taxus* cuttings. The cuttings were stuck in ground beds in a poly house. The medium consisted of soil, finely ground pine bark and coarse sand. Since there was no heat in the house, the cuttings did not root until early summer after the soil had warmed to about 70°F. During the winter, the cuttings were kept turgid by light intermittent mist. The mist was removed after rooting had been accomplished. The plants were grown under 50 percent shade and responded well to fairly heavy applications of fertilizer. During the following winter, the plants were kept in a poly house with no heat. During the second summer, the plants were grown under shade in the same beds in which they were rooted. By the end of the summer the plants were 3 to 6 inches tall and large enough to go into a gallon can.

Now that we were fairly sure of our procedure, we were ready to put this plant into production. Our big problem was finding enough cuttings to justify propagating the plant. We were able to purchase some unrooted cuttings and continue our experiments for an additional two years. During the intervening period we talked with as many propagators as we could to gain more knowledge about the plant and about its propagation procedures. We were of the opinion that taking dormant cuttings during the winter was the best method. However, we discovered that some people were rooting cuttings in pure sand during the summer with excellent results.

This year we decided to purchase sufficient plants for cut-

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tings. In October of this year I made a trip to Oregon and purchased 2,000 one gallon *Picea glauca* 'Conica' plants. While in Oregon, I visited most of the nurseries in the Portland area with particular emphasis on propagation and production of *Picea glauca* 'Conica.' I found that these nurserymen were not only rooting *Picea glauca* 'Conica' in quantity, but were also rooting *Picea pungens glauca* and *Picea abies nidiformis*. Most were using normal greenhouse procedures and were rooting in sand or a mixture of sand and perlite.

In summary our procedures are as follows:

1. Cuttings are made of current year's growth as it begins to harden off. Under ideal conditions a plant will make about three flushes of growth and will root in summer or winter. We use upright and side shoots with equal success.

2. We put in our cuttings anytime during the year that we can find a satisfactory cutting that has hardened off sufficiently, whether it be winter or summer. The cuttings that we stick in the winter do not root until the following spring when the soil has warmed up to about 70°F. Unheated open beds are used. The medium is a mixture of approximately equal parts of soil, pine bark and sand. Any mixture that drains well seems satisfactory. The cutting is stuck through the mix to dirt bed. We expect the cutting to root in the mix and the roots to extend into the dirt bed where it will be grown undisturbed for two years.

3. A fairly strong hormone, 1 percent (10,000 ppm) liquid quick dip, is used.

4. Plants are grown under 50 percent shade. In winter plants are protected by a plastic and shade cloth covered structure.

5. Plants are liquid fed with 20-20-20. Two year, 4 to 6 inch, liners are sold bare root. These are large enough for a gallon can.

We normally obtain 80 to 85 percent rooting under good conditions and have found that we can thus profitably adapt production of *Picea glauca* 'Conica' to our operation.

PROPAGATION OF *PYRUS CALLERYANA* 'ARISTOCRAT' PEAR

HARRY W. HOPPERTON

Hopperton Nursery, Inc.
Warsaw, Kentucky 41095

Mr. William Straw is the originator and patent owner of the Aristocrat pear, *Pyrus calleryana* 'Aristocrat.' This new thornfree cultivar was found in 1969 growing among seedlings of *Pyrus calleryana* at the Carlisle Nursery, Independence, Kentucky. Mother Nature created and holds the mystery of the ancestry.

In our budding procedure of this plant, we start out with a good balanced, pliable soil with a pH close to 6.1. We apply 275 to 300 pounds potash and phosphate per acre. We then line out seedling understock of *Pyrus calleryana*, pencil caliper with a good fibrous root system. We had trouble with our seedlings but finally found a selection out of Whiterock Nursery, Crockett, Texas, which is one of the best. It has a good root system and we have had excellent success. For example, in one row of 510 seedlings, we may have only 30 misses. We consider this a good stand. We like to plant our understock especially deep to help prevent drying. In addition herbicides that are used have a harder time reaching the root system. It is important to set the plants upright when planting. If this is not done, root development tends to be heavier on one side. After planting, the seedlings are side dressed with ammonium nitrate to get them established quickly. Budding is much easier if the plants are in a good growing condition.

It is important to select budwood that is not too green nor too hard. Either condition will result in a failure. We have budded successfully as late as November. However, that was unusual. We start checking for budwood a week or so before actual budding time. We go through the block and look for wood with bark that will slip easily. The buds of ideal wood should separate from the wood without pulling. We find the lower branches are best for budwood. We feel the most critical part of the operation is collecting the budwood. The decision as to when buds are suitable is very important. We usually begin budding in June.

When wood is ready, we cut, or scratch, the soil away from the understock so we can bud as low to the ground as possible. In this way we avoid a long shank of exposed understock. The understock is always best and most succulent just under the ground. The budder then inserts a T-bud into the west side of the understock using the T-bud method. We like to bud towards

the prevailing wind as this makes the bud much more wind resistant.

It is just as important to have a good wrapper as a good budder. He must go behind the budder and wrap uniformly and tightly above and below the newly inserted eye. The tightness of wrapping is a second critical factor. If it is too loose, the bud will fail to take. If it is too tight, the bud will be cut off. Therefore, be sure the rubber bands are the correct length. Princep[1] is then sprayed on the area immediately after budding has been completed.

In two weeks we check back on the buds. We will know then what percentage of take we have attained. The buds will either be growing or will have turned black. If it appears that we have a poor stand, we still have time to go back and rebud. We insert this bud on the opposite side. Although some propagators make two T-buds the first time, it takes a great deal more time. We prefer to see what our stand is, then go back and rebud, if necessary, as early as we can. Then, if the second bud fails, we still have time to chipbud.

It has been our experience that pears tend to shoot out sideways rather than grow upwards. Therefore, we stake our buds with Gro-Straight stakes for about 3 to 4 weeks. We stake them just as soon as the tops are cut back the following spring. We obtain the Gro-Straight stakes from J. Frank Schmidt Nursery in Oregon.[2] These stakes are then replaced with six foot steel stakes, and plants are tied to stakes. We go back every week or so and add more ties depending on the growth of the plants.

In a good season, our buds will grow an average of five to eight feet, branched. We find that we have far less mortality if the finished plants are dug and planted in the spring. They must not be allowed to dry out. We have found the above procedures give us a high percentage of quality plants.

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[1] Princep is the trade name for simazine, 2-chlor-4, 6-bis (ethylamino-S-triazine.

[2] J. Frank Schmidt & Son Co., 9500 SE 327th Avenue, Boring, Oregon 97009

PROPAGATION AND PRODUCTION OF DWARF CONIFERS IN CONTAINERS

JOHN (ED) KINSEY

Kinsey Gardens, Inc.
Knoxville, Tennessee 37914

Kinsey Gardens is located near Knoxville, Tennessee, where we get competition from the far south but also have the cold climate. We have many disadvantages of the north and some advantages of the south. We have two nursery locations. Although the management is different, the company is the same. We started out as a retail landscape nursery and have slowly changed into a wholesale operation. Since 1971 our primary crops are azaleas and rhododendrons with emphasis on azaleas. Since we are a relatively small nursery, we are trying to maximize use of our present facilities. We feel we can do so by growing items that are difficult to produce in the far south, such as rhododendrons.

Recently, there has been a demand for hardy landscape plants that do not grow rapidly, require little maintenance, and have good foliage and form contrast. We have been surprised by the interest in new and unusual dwarf conifers. Color is receiving the most attention. Any plant that is blue, gold, or variegated is popular. The conifer line offers many possibilities.

These dwarf conifers can be used in many locations. They are attractive in rock gardens, in pocket gardens, in Japanese gardens, in bonsai arrangements and simply as collections. We are, therefore, increasing significantly our line of dwarf and unusual conifers.

Heretofore, dwarf conifers and many choice companion plants have been largely unavailable south of New Jersey and east of Oregon. We are always looking for new plants or plant groups, which can be propagated economically within our present schedule, which require little winter protection in our area and in which there is little competition. Many of the dwarf conifers and companion plants fill these requirements.

Although many of these conifers may grow quite large after a number of years, the growth rate of the dwarf cultivars is certainly slower than that of the species; and they will provide longer term utility, scale, and beauty than their species counterpart. We feel that this broad definition of dwarf plants enables us to include many slow growing very desirable shrubs that may otherwise be excluded from this class by an ultimate height limitation.

We are primarily growing cultivars of the following species:

Cedrus atlantica	- 3 cultivars
deodara	- 1 cultivar
Chamaecyparis nootkatensis	- 1 cultivar
obtusa	- 12 cultivars
pisifera	- 10 cultivars
thyoides	- 1 cultivar
Cryptomeria japonica	- 7 cultivars
Juniperus chinensis	- 2 cultivars
communis	- 5 cultivars
procumbens	- 2 cultivars
squamata	- 2 cultivars
Pinus densiflora	- 3 cultivars
strobus	- 4 cultivars
thunbergii	- 1 cultivar
Picea abies	- 2 cultivars
glauca	- 1 cultivar
pungens	- 2 cultivars
Thuja occidentalis	- 5 cultivars
orientalis	- 3 cultivars
plicata	- 2 cultivars
Tsuga canadensis	- 3 cultivars

We have been producing many of these for several years and are now on a fast stock buildup program. We are adding a few cultivars each year and dropping a few as we constantly evaluate them and learn which adapt best to our environment.

We propagate all the above cultivars from cuttings, except Atlantic cedar, upright junipers, pines, blue spruces and hemlocks. We are learning to graft these more difficult to root cultivars. There is ample discussion in the past IPPS Proceedings on the grafting procedures.

At present we are still sticking most of the dwarf conifer cuttings in January and February after the fall-stuck rhododendrons are lifted from the benches. We use raised bences, hot air, bottom heat, 40:60 peat:perlite medium and intermittent mist. We also root many of the *Chamaecyparis* and *Arborvitae* cuttings in late summer in flats under mist without bottom heat. Cuttings of most cultivars are simply stripped and treated with 0.8 percent IBA in talc. We take as small a cutting as we can safely strip without tearing up the bark and ripping off part of the stem. We try to clean up the base of the stem to prevent disease. We usually set aside a certain number of gallon or two gallon size plants to use as stock for winter propagation.

I wish I could tell you that dwarf conifers are very difficult to propagate and that only we have learned to do many of these successfully, but, for many of them the opposite is true. With bottom heat some will root in 2 to 3 weeks while others take 6 months or more.

Stock buildup has been one of the most limiting factors to immediate mass production, but it can be greatly speeded up by

taking the smallest possible cuttings. However, it takes longer to produce a salable plant with these small cuttings.

All of these plants can be overwintered in our area with little protection except cultivars of *Cedrus* spp, *Cryptomeria japonica*, and *Thuja orientalis*. We are, for the present time, avoiding cultivars of *Chamaecyparis lawsoniana* because of their susceptibility to root rot fungi and their lesser degree of hardiness. We want to be careful to sell only those cultivars that we know are relatively easy to care for. We do not want any customer disappointment, which might give these plants a bad name and limit their acceptance.

We are constantly planting out displays of these conifers around the nursery to help show people their relative growth rates and heights and how they can be used, as well as to provide stock for future propagation. It seems if these plants are not in the ground, it is difficult to hold some back for stock. It is difficult to refuse to sell your last few plants to a good customer. These plantings also give us the opportunity to evaluate the plants under average growing conditions similar to what the landscaper may encounter.

Our prices on these are significantly higher than on the commonly available plants. This higher cost is easily justified because of the scarcity of material, the exotic nature of the material, the difficulty of propagation of some of them, and the higher cost of labeling and assembling assortments. Since very few people are familiar with these plants, most are sold as individually labeled assortments.

As soon as we build up sufficient stock on each cultivar, we are shifting from greenhouse propagation to outdoor mist bed propagation. We will be able to leave the cuttings in these outdoor beds for one full growing season and thus eliminate the need for the potted liner stage, which requires constant weeding, careful watering and protective over wintering. It will also eliminate the need for bottom heat in the rooting stage, eliminate one potting operation and provide us with ample juvenile stock for the next season's crop. We can then pot a large bareroot liner directly into a gallon pot and finish the plant in one season.

At this time, we find it best to buy some of our liners or rooted cuttings from speciality producers. Dwarf blue spruce, *Picea pungens*, and nest spruce, *Picea abies nidiformis*, are examples. We pot these in quart pots for one season and then transplant them to beds in the field. We buy and also root some dwarf Alberta spruce liners, *Picea glauca conica*, but grow them all the way in a pot.

We pot the rooted cuttings or liners into one gallon cans in

a mixture of pine bark, expanded shale and sand. We place them in full sun (except for some white variegated conifers) on gravel under Rainbird impulse sprinklers until sold. Fertilizing is accomplished by Osmocote 18-5-11 incorporated in the mix and supplemental liquid injection through the waterline. We use Ronstar[1] for weed control as we find that it does not damage the variegated foliage. We did find injury when we used Lasso. The majority of these dwarfs make a salable one gallon plant in 1 to 2 years from rooted cuttings.

Many people have said one cannot make much money growing dwarf or unusual conifers due to their slow growth rate. We feel that this is not wholly true if one is brave enough to ask a compensating price. We also feel that this line of plants helps attract customers to our nursery to buy the more conventional plants along with the dwarf and unusual. Aside from the financial return, dealing with these little specimens makes the nursery business more fascinating and challenging.

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[1] Ronstar is the trade name for oxadiazon, 2-tert-butyl-4-(2.4-dichloro-5-isopropoxyphenol)-delta 2, -1,3,4-oxadiazoline-5-one.

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PROPAGATION OF *CORNUS FLORIDA* CULTIVARS BY CUTTINGS

CARL BAUER

Phytotektor, Inc.
Huntland, Tennessee 37345

Last year at the IPPS, Southern Region, meeting I gave a paper on producing dogwood, *Cornus florida*, by cuttings, which dealt mainly with producing dogwood by softwood cuttings. This paper is published in the Proceedings (1). Since that

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time we have had another year's experience with propagating dogwood by cuttings.

Although most of our work has been with softwood cuttings, I think we should get into the Proceedings our experience with dormant cuttings since we have seen no papers on this subject. Dormant cuttings have one distinct advantage over softwood cuttings in that no special protection is required during the winter. However, after our experience during 3 years' work, we have decided to give up on this approach. At best we were able to get only about 30% of the cuttings to root as compared to 85% from softwood cuttings.

Our procedures were as follows:

1. Cuttings were taken in mid-winter when completely dormant. This is a must. Cuttings taken a little early or a little late produced leaved in the spring and then died.

2. Cuttings were stuck in ground beds consisting of soil, finely ground pine bark, and coarse sand.

3. During the winter cuttings were syringed lightly about once a week. As soon as the cuttings produced leaves in the early spring, they were placed under intermittent mist until rooted.

4. Cuttings were wounded and given a quick dip in 2 percent (20,000 ppm) IBA solution.

5. By late May all cuttings were rooted or dead, and the mist was removed.

6. Cuttings were grown undisturbed in beds and made 4 to 6 inches of growth during the summer. Since the cuttings had made new growth during the summer, no winter protection was required. They were dug as dormant liners and planted in the field during the following spring.

We had hoped to use hardwood cuttings, but after four years experimenting with rooting dogwood we have finalized our procedures using softwood cuttings. Perhaps the two most important findings are: (1) Young cuttings must have winter protection, and (2) they will not transplant successfully until they have made some new growth. In the past we have used heated houses for winter protection. This year we are going to use Microfoam, produced by Dupont, for our winter protection. I might add that we have had no experience with this material but, based on other experiments, we feel fairly sure that it will work.

Beginning next year I expect at least 50 percent of our dogwood production to be on their own roots and this number will increase annually until our entire production is changed

over. We now have 25,000 cuttings in our 12 by 98 foot house. Our detailed procedure will be as follows:

1. Softwood cuttings will be rooted in the summer from June 15 to August 15 in ground beds under intermittent mist.

2. Only tip cuttings 4 to 5 inches long will be used with about half of the leaves cut away. Second cuttings will root but will give crooked trees, eliminating the advantage of the straight trees that are not easily obtained by grafting.

3. All cuttings will be wounded and treated with a quick dip in 2 percent IBA, which we mix.

4. Winter protection will be accomplished by sealing the beds air tight with Dupont Microfoam after dormancy.

5. Liners will be potted in the spring after they have made some new growth. As soon as the plants are well established in the pots, usually a month later, they will be transplanted to the fields.

6. Most liners will be dug in the field and sold as bare root liners during the second year.

Field budding is the normal procedure for propagating dogwood in Tennessee. Now that we have considered all known factors, we feel that production of dogwood on its own roots will produce a superior plant at less cost.

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QUESTION PERIOD FOLLOWING PROPAGATION FORUM

WILEY ROACH: Question for Nick Hand. Have you had any experience with rooting the Taiwan or the common lilac?

NICK HAND: We have had no experience with Taiwan lilac but have rooted common lilac, *Syringa vulgaris*.

VIVIAN MUNDAY: Question for Nick Hand. When do you take most of your cuttings?

NICK HAND: We take most of the cuttings around April 15, using 5 to 6 inch cuttings from the plants in the field. Later we go back over and take a second cutting. The cuttings that are stuck at that time will grow until December. We then dig, box and store them in cold storage until they are planted in the spring.

VIVIAN MUNDAY: So your cuttings are coming from plants that will be salable?

NICK HAND: The stock that is ready for sale is what we are using for cuttings.

DICK AMMON: Question for Nick Hand. I would like for you to tell me something about grafting lilac onto green ash.

NICK HAND: It is easy. We changed from privet to green ash, *Fraxinus pennsylvanica*, to avoid suckering. Ash seem to act as a nurse graft. We bench graft in February.

LYNN TABER: Question for Dick Ammon. How are the maples handled after the graft is made? Are they put into a structure, or is material packed around them? What is the procedure after the grafting takes place?

DICK AMMON: From what I have seen most of them are put into a poly tent until they harden and there is some callus. This is the way we do it. We make sure there is a good callus before we take the plastic off.

WAYNE SAWYER: Question for Carl Bauer. Have you experimented with ground heat? You said rooting did not occur until soil temperature reached 70 degrees. If you kept the soil at 70 degrees all the time, could you cut down this production period of 2 years?

CARL BAUER: You probably could, but I don't think you could justify production costs. Without heat, the cuttings usually root uniformly. By waiting until the soil warms naturally, we obtain a uniform crop. I think heating would accelerate the growth, but the cost would not be justified.

MIKE HALLUM: Question for Carl Bauer: I would like to ask if you use any fungicides in preparation of cuttings.

CARL BAUER: I think it would probably be a good practice to use a solution of captan prior to sticking. We have done this. We are not sure whether or not it is absolutely necessary. This is the only preparation we use.

PINE BARK IN POTTING MIXES, GRADES AND AGE, DISEASE AND FERTILITY PROBLEMS

RAYMOND L. SELF

Ornamental Horticulture Field Station
Auburn University Agricultural Experiment Station
Mobile, Alabama 36608

Pine bark (phloem and cork cells) is produced by vascular cambium and cork cambium. Vascular cambium is the 2 to 4 cell layer which separates the phloem from the wood (xylem). The living part of the phloem consists primarily of food trans-

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porting cells called sieve tubes, which live one to two years before dying and becoming the outer bark. Cork cambium is the outer portion of the living phloem and produces the protective layer of cork cells. The inner bark, or living phloem, is often erroneously referred to as the cambium.

The literature on pine bark usages and problems is becoming voluminous but with several years of usage in many geographic areas, a clearer picture is now arising as to desirable grades, effect of aging, effect of composting and problems of disease and fertility.

Grades. Grades refers to particle size and composition. Both particle size and composition from a single species of tree will be influenced by season of harvest, the equipment used to remove the bark from the log or pole, and screen size of the hammerhill. Knives (Rosier head), Cambio debarkers, and rollers are the most common debarking equipment in use. The Rosier head consists of a series of knives on a head that rotates around the log, removing all of the bark and some of the wood, producing a straight pole or log. The Cambio debarker also consists of a revolving head with several projections, which are spring loaded so as to exert only enough pressure to remove the bark and cambium but not the wood. The log goes through the head, which turns at 200-300 R.P.M. Other equipment consists of a series of rollers over which the log is passed as the log rotates. Sometimes the logs are first passed over the rollers to remove the bark, then through the Rosier head. A drum type debarker is also used by Hiwasse Land Company, Guntersville, Alabama. This consists of a large revolving drum with screen.

The tumbling action of the logs removes the bark, which falls through the large screen. This bark is passed over a 3-inch screen, then a second screen which catches the ¾ to 2-inch chunks, then over a third screen which retains the ⅜ to ¾-inch chunks and allows the fines to fall through. The large chunks retained by the first screen are passed through a chipper and then over the other screens again. The final products consist of decorative bark chunks, ¾ to 2-inch mulch, ⅜ to ¾-inch flakes (used in potting soil), and fines. The barks for potting soils are aged 4 to 6 months to decompose some of the phloem, to improve wettability, and to produce a darker color.

The bark removed by the cambio debarker of Crosby Lumber, Bay Minette, Alabama, is very desirable for the nursery trade. The usual screen size used on the hammermill is one inch, which produces particles varying from dust to chunks or slivers ranging from 1½ inches in length up to slightly less than 1 inch in width. Seventy to 80 per cent of the particles range from ⅛ to 1/42 with the remainder consisting of larger par-

ticle sizes. This is an excellent range for a growing medium. (Smaller screens, ½ to ¾ inch, and not in use at this mill, produce finer particle sizes that are more desirable for propagation.)

Pine bark from trees harvested in the fall or winter, when the sap is down, will have more dust and smaller particles than that harvested in spring or summer when the sap is "rising". Various impurities often present in bark include living phloem, wood, sand, and soil adhering to the logs and metal from the debarker or hammermill.

Excessive amounts of dust and fine particle sizes are undesirable as they result in waterlogging of the mixture. These sizes are converted to humus during composting. Coarse bark:sand mixtures are hard to wet at first and initially do not retain sufficient moisture for early plant growth without frequent watering. Wettability improves as the coarse particles disintegrate or after addition of a wetting agent.

Aging. Aging is unnecessary except to stockpile the bark for future use and improve wettability. During aging, the stockpile goes through a heat, resulting in darkened color. Some phloem and bark is partially decomposed and may develop a burned appearance. This decomposition, which occurs in big piles with inadequate aeration, is undesirable.

Aging without nitrogen addition does not result in composted bark, because the temperature of the pile does not get high enough to kill the pathogenic organisms.

Composting. Composting of pine bark is the reduction of the cellulose part of the fine bark particles and bark fiber into humus through reduction of the carbon:nitrogen ratios by the action of bacteria and fungi when nitrogen is added. The remaining larger, various particle sizes break down slowly over several years.

Hoitink and Poole of Ohio State (1) report that composting of pine bark can be accomplished in 8-feet high by 15-feet wide stacks in 6 weeks by turning the pile every two weeks, after one pound of actual nitrogen has been added per cubic yard. Hardwood requires 2 to 3 pounds of nitrogen per cubic yard and 10 weeks to compost.

Benefits of composting include the destruction of pathogenic organisms and the reduction of the carbon:nitrogen ratio so that plants need not compete for nitrogen (2). This advantage is largely eliminated by the use of slow-release forms of nitrogen and the elimination of wood cellulose, phloem, and dust bark particles.

Fresh pine bark contains compounds harmful to some seed-

lings and young rooted cuttings. Aging or composting destroys these compounds. Hoitink and Poole (1) have determined that fresh pine contains compounds that retard development of root pathogens such as *Rhizoctonia*, *Phytophthora*, and *Pythium*. They state that these compounds are destroyed by composting.

Experimental work has been conducted at the Ornamental Horticulture Field Station, Auburn University, to determine the necessity of composting pine barks. (3)

It was determined that fresh bark could be used very successfully to produce 6-inch container-grown plants. Very little difference in growth rates were observed with 0, 30, 60, and 90 days composting. Ammonium nitrate as the source of nitrogen reduced growth rates of all plants tested as compared to Nitroform and Osmocote sources of nitrogen. Salts built up to a toxic level between 30 and 60 days of composting, but were readily removed by leaching. Enough fertilizer remained to carry the plants to maturity without further fertilization of the best treatments.

Interviews with nurserymen regarding mixes from the two common sources of bark in the Mobile area reveal divergent opinions. However, these can be explained by the differences in their methods of using the bark. The Crosby bark mentioned earlier is produced by the revolving Cambio head and is hammermilled through a 1-inch screen. The resulting product consists of a range of particle sizes from 1½ inches to dust.

It is highly satisfactory for production of plants in 6-inch or larger containers, but some nurserymen find it too coarse for propagation. We have screened this bark through a ½-inch screen and produced a medium very suitable for rooting of cuttings. We have further enhanced its value as a rooting medium by incorporating 2½ lbs of Osmocote 18-6-12 or 19-6-12 per cubic yard.

One year we mixed this bark with Birmingham shale at a 4:1 ratio with excellent results when the bark was not aged or composted. However, the mix would have been improved by the addition of more fines, peatmoss, or the removal of the coarse particles by passing over a ½-inch screen.

Another grade of bark commonly used in the Mobile area is referred to as Stemo bark. This bark is available in 2 or 3 sizes, ranging downward from ½ inch. It has been aged several months and has a dark brown to black color.

With mixes of hardwood bark and pine bark often produced by some mills, composting is necessary to eliminate problems of high pH, excess manganese and tannic acids or other unknowns. Certain facts are generally known from research re-

ported by Gartner of the University of Illinois and by Hoitink of the Ohio State University. These facts are as follows:

1. Hardwood bark pH reaches a high of 8.0 plus in composting, and requires one pound of elemental sulphur per cubic yard to reduce the pH to 6.5 plus.

2. Manganese level of hardwoods is excessive but can be balanced by the addition of one pound of ferrous sulfate or chelated iron per cubic yard.

3. Tannic acid or phenoic acid level is excessive but can be reduced by composting. Gartner reports tannic acid content is very high. Composting procedures recommended are 5 lbs. of superphosphate and 6 lbs. of ammonium nitrate per cubic yard.

The above recommendations apply to the composting of hardwood barks, which requires a minimum of 60 days, along with several complete mixings and turnings of the piles.

The above facts confuse the picture if one thinks he is working with pine bark when the material is really a mixture of pine and hardwoods.

A recent sample of composted material toxic to young seedlings was submitted to the Station for examination. Both the pH and calcium as well as phosphorus and potash levels were very high. The material appeared to be aged, partially decomposed bark, but was really aged mahogany chips and sawdust.

Fertilization Problems. The use of pine bark in the potting mixture poses no serious problem if the pH is adjusted upward and slow-release forms of nitrogen are used. The pH of raw pine bark is 4.1 to 4.2, and increases slowly during composting to a high of 4.5 or higher. It is postulated that the increase in pH is due to the release of calcium, magnesium, and potassium which are present. Pine bark contains approximately 1.0 percent minerals whereas pine wood is reported to contain approximately 0.3 percent minerals.

Research at this Station has indicated that if the potting mixture contains 50 percent or more of pine bark, 15 pounds of dolomite lime per cubic yard will be needed to maintain a pH of 6.0. We are producing excellent plants in 100 percent fresh pine bark or 3:1:1 (bark:peat:Birmingham shale) amended with a complete fertilization program.

The pre-plant mixture for the above two media consists of the following poundages per cubic yard: 15 dolomite; 2 superphosphate; 2 gypsum; ¼ Nu-iron; micronutrients FTE 504, or 008 at ¼, FTE 555 at 1, or 2 Esmigran at 4; ⅛ FTE 187; 2 FTE 519 potash; 3.5 Nitroform; and 10 Osmocote 18-5-11. This mixture can be supplemented by liquid feeding or dry topdressing with complete slow-release fertilizers.

Disease Problems. Pine bark removed from trees infected with *Phytophthora cinnamomi*, the causal agent of the littleleaf disease, may pose a serious problem. Occasionally the *Phytophthora* has been identified in mixes containing pine bark, presumably removed from infected trees which are very often sawmilled.

Another fungus disease occurring very often in pine bark mixes several months after potting has been *Rhizoctonia* root rot. The association of this fungus with older bark supports the observations of Hoitink regarding the disappearance of the protective chemicals as the bark ages.

We have demonstrated a definite improvement in survival and growth of cuttings rooted in a bark mixture containing four ounces of Banrot 40 WP per cubic yard.

Another problem with bark is waterlogging, which leads to root rot caused by lack of air. This occurs when excessive fines are used, or when shavings, wood chips, or slivers incorporated with the bark have decomposed with a reduction in air space.

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COMPOSTING AND USE OF HARDWOOD BARK MEDIA FOR CONTAINER GROWING

GREGORY L. AMMON

Ammon Wholesale Nursery
Burlington, Kentucky 41005

In our container growing operation we have tried various soilless media. Since cost was the biggest factor to be considered, we had to search for the most available raw material that could be used. We have no source of peat moss or softwood bark within 400 miles. Hardwood bark is available about 100 miles distant. Information based on research work done by Dr. Jack Gartner at the University of Illinois led us to decide this would be our most practical medium. Due to the tannic acid content and heat build up, raw bark must go through a composting period before it can be used as a growing medium. We purchase raw hardwood bark from the Mead Paper Company in

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Chillicothe, Ohio, and do the composting at our nursery. They also have available composted bark.

The already composted hardwood bark delivered to our nursery is $20.50 per cubic yard in 55 cubic yard loads. To this we add coarse sand and Kenlite (expanded shale) at a 3-1-1 ratio by volume, giving us a total cost of $24.00 per cubic yard of potting medium that is ready to use.

When composting the bark ourselves, we have had excellent results in using a manure spreader manufactured by the New Idea Company. This spreader is powered in a stationary position by the power take-off of a tractor, and the mixing is accomplished by weighted beaters throwing the mixture into the air onto our stock pile. The bark, sand, and shale are in separate piles on a black top surface. The raw materials are dumped into the spreader with a Bobcat skid-steer loader. Fertilizer is mixed in a small concrete mixer at the following ratio per cubic yard: Seven pounds ammonium nitrate, 3 pounds superphosphate, 1 pound iron sulfate, and 1 pound elemental sulfur. Our spreader holds 3½ cubic yards of mix. We dump one loader bucket of bark, one of shale, then another bucket of bark. On top of this we evenly spread 42 lbs of our fertilizer mix. One bucket of sand and one bucket of bark are them dumped into the spreader. This load is then run through and piled on the black top. Two men can mix a 55 cubic yard load of raw bark in about 5½ hours.

Our potting medium thus consists of 3 parts hardwood bark, 1 part coarse sand and 1 part expanded shale. Per cubic yard of mix we add 7 lbs. ammonium nitrate, 3 lbs. superphosphate, 1 lb. iron sulfate, and 1 lb. elemental sulfur.

During the composting period the bark should be piled approximately 8 feet high and kept in a moist condition. The pile should be turned in 2 weeks and remain for a minimum of 60 days. Before using the medium it should be tested for soluble salts with a solubridge. After potting, drench the containers with water to leach out excess salts.

The following is our cost, including labor expense, for composting hardwood bark:

55 cubic yards raw bark, delivered	$ 442.55
27 tons sand	108.00
15 tons Kenlite (expanded shale)	481.50
600 lbs ammonium nitrate	45.00
250 lbs superphosphate	12.00
75 lbs iron sulfate	13.00
75 lbs elemental sulfur	12.00
Total	$1,114.00

After shrinkage of the bark this mix will provide approxi-

mately 65 cubic yards of potting medium, at a cost of $17.25 per cubic yard, or about $7.00 per cubic yard less than buying the bark already composted.

PINE BARK MEDIA IN CONTAINER GROWING AT WIGHT NURSERIES

RICHARD D. VAN LANDINGHAM

Wight Nurseries, Inc.

Cairo, Georgia 31728

The growing medium for plant production in a container nursery must be considered with utmost care. Many leaders in the industry feel that the growing medium is the single most important element in a container growing operation. Many of the production problems faced by nurseries today are directly affected by the growing medium used. Some of these problems are: root and stem diseases, fertilizer deficiencies or buildups, and moisture retention.

The importance of a good growing medium has been recognized at Wight Nurseries. Several changes have been made since our original mix of two parts peat moss and one part sand. Today we use a mixture of three parts pine bark, one part sand and one part shale for all plants. For years growing media using peat moss, or peat moss and sand, were the most widely accepted. Other soil media were evaluated only when the increasing cost of peat and the spiraling freight cost of transporting high quality German peat made its cost prohibitive. It was in this way that pine bark became the principal ingredient in the growing medium at Wight Nurseries. Since pine bark is organic matter, it needed to be carefully analyzed.

Many important characteristics of pine bark make it an ideal growing medium. Its physical make up is well suited for plant production. Pine bark can be obtained at a reasonable cost and in large quantities in our area. Bark is also a renewable resource. Pine bark can be milled and screened to produce a consistent material, and it also has a slow decomposition rate. With these advantages pine bark can be used to produce a uniform standard mix.

The pine bark used at Wight Nurseries is contracted through a local fertilizer company. To insure a high quality consistent material, all our bark comes from one sawmill. No sawdust or wood chips are allowed in the bark. All bark must be stored on concrete slabs at the sawmill and at the fertilizer

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plant for sanitation purposes. The bark used is usually from 5 to 20 days old.

Before the bark is delivered to the nursery, it is put through a hammer mill and passed through a 9/16 inch screen. Porosity of the mix is very important and with this size bark, adequate drainage and water retention are balanced, resulting in successful growth of many kinds of plants. After the bark is screened, dolomitic lime and trace elements are precisely metered and mixed thoroughly into the bark. The pH requirements of plants vary. Three rates of lime are added to the mixes to allow for the different pH requirements. Conifers are grown in a 5.8 to 6.5 range; broad-leaves (holly, *Ilex sp.;* pyracantha, *Pyracantha sp.;* ligustrum, *Ligustrum* sp.), 5.0 to 5.8; azaleas *(Rhododendron sp.),* around 4.5 to 5.0. Three pounds nitrogen per cubic yard are added to make up for the nitrogen tie-up occurring during the natural decomposition of the bark. Chlordane for fire ant control is also added to the bark at this time.

Samples of each ingredient of the mix are sent to the Soil and Plant Laboratory, Inc., 352 Mathews, Santa Clara, California, 95052, for routine testing and analysis to insure a high quality and standardization of the medium.

Once the bark is delivered, it is mixed with the shale and sand on a concrete slab with a front end loader.

The greatest problem that has been found with the use of pine bark is the inability to wet the mix initially. As the unmixed bark sits on the slab, a sprinkler is constantly wetting the pile. However, most of this water runs through the pile before it is absorbed into the bark. Once the bark is mixed and plants are placed in it, the newly canned plants are watered daily for two weeks, giving the equivalent of approximately 7 inches of rain. This method has proven satisfactory even in the hot summer months when heat stress is greatest.

Wight Nurseries does not practice any bark or soil mix sterilization. The expense and practicality of chemical sterilization or composting were found to be too costly. A complete pesticide program for control of insects, diseases and weeds is initiated once plants are in the medium.

The use of pine bark as the principal ingredient of our synthetic soil mix for the future is not without complications. With the increasing cost of natural gas and electricity, the use of wood by-products for energy sources is also increasing. Some sawmills are now burning their bark, sawdust and other waste as a substitute for natural gas. These practices put a higher value on bark and the price of bark has increased accordingly. Other materials for growing media must be analyzed to insure

alternatives to pine bark if its future price makes it uneconomical to use.

A SYSTEM OF WATER TABLE CONTROL FOR SUBSURFACE DRAINAGE AND IRRIGATION

JOHN F. BRAILSFORD

Shady Grove Plantation and Nursery
Orangeburg, South Carolina 29115

Agriculture is a risky business. The extremes of weather are, perhaps, the worst of the many hazards faced. Most weather-related hazards are uncontrollable. However, any action that can be taken to alleviate the extremes helps to reduce the risk and increase crop production.

Our initial problem was one of drainage. While attempting to solve this problem, we devised a system of water table control, with the help of the Soil Conservation Service, that presently serves 108 acres. This system has provided us with drainage as well as protection from drought. It has enabled us to transplant successfully during the growing season. A water table control system with modifications to fit other situations may be of benefit.

We own two farms that are located just east of the city of Orangeburg, South Carolina, in an area that is commonly known as the "Flat Woods." The nursery is located on the farm nearest to town. The other we refer to as the "Lower Farm". We had a serious drainage problem during periods of excessive rainfall. For years we had accepted the fact that these farms were low and wet.

A survey by the Soil Conservation Service revealed that we could gain three feet of additional fall by deepening and enlarging about 1½ miles of an old inadequate outfall canal on our lower farm. This enabled us to deepen our lateral ditches sufficiently to permit the installation of several miles of agricultural tile (one foot lengths of six-inch clay pipe) for subsurface drainage. We were amazed by the efficiency with which this system removed excess water. (See Figure 1.)

We requested a survey of the nursery farm to see if we might have additional fall here also. We gained five feet of fall by deepening and enlarging just one mile of our old outfall canal. We were not low — just flat!

We became completely carried away with deepening our old lateral ditches to take advantage of every inch of our new-

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WATER TABLE CONTROL PLAN
FOR
SHADY GROVE NURSERY

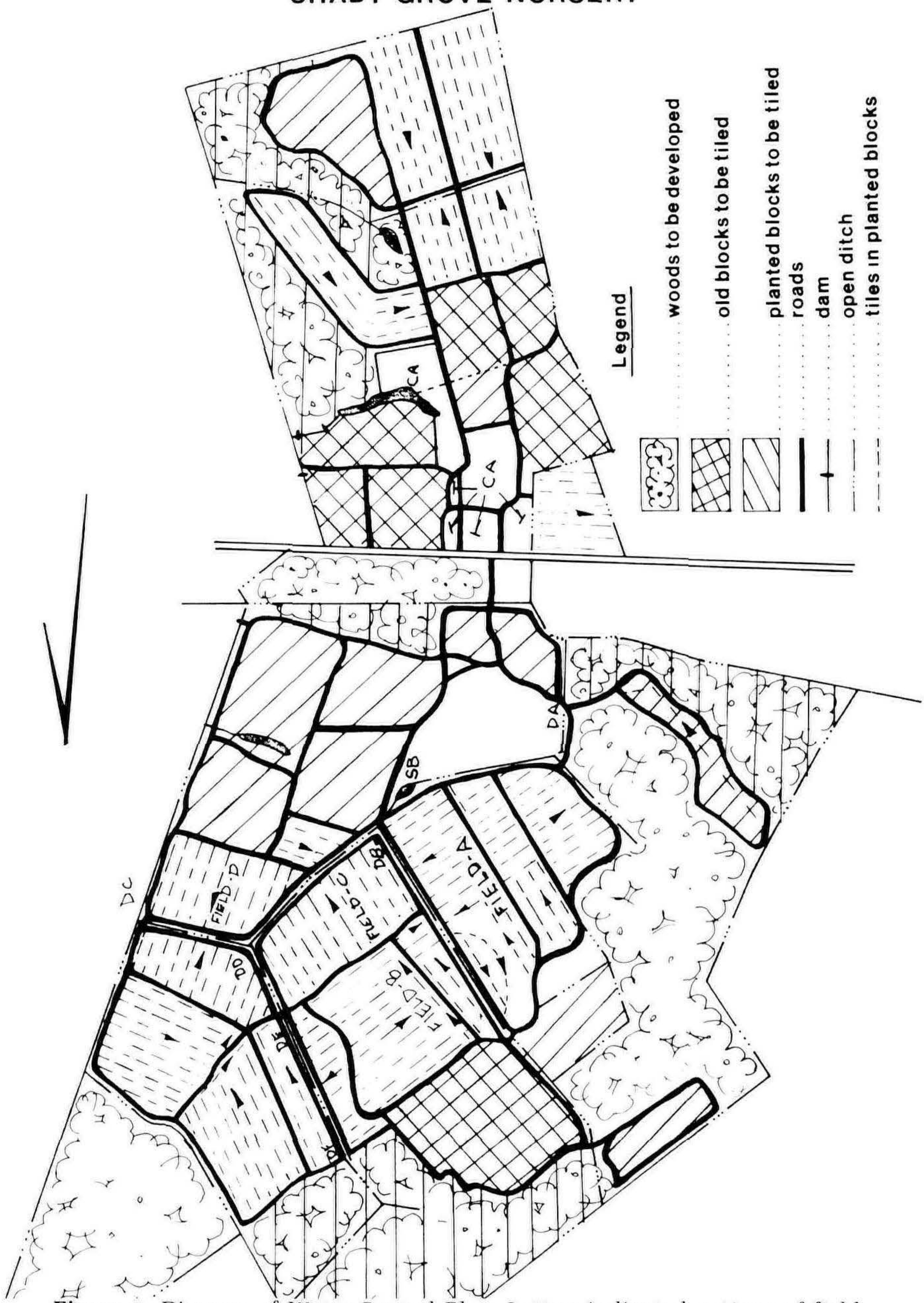

Figure 1. Diagram of Water Control Plan. Letters indicate locations of fields, dams, and pumps described in text.

found fall. In the midst of all this digging Lewis Howell of Newbern, North Carolina, stopped by to visit. Lewis urged us to construct control dams in our laterals, as had been done at Greenbriar Farms, so that we could release water only as required. We had an ideal situation for this type installation with the canal and highway bisecting the narrow center of our farm. Most of our water would enter the canal from two laterals on our lower property line. We followed Lewis' advice and constructed dams with flashboard risers near the mouths of these laterals.

Several dry years followed and the dams alone were inadequate to maintain the water table. To take care of a newly-planted nursery field, we were forced to resort to portable overhead irrigation with all the inherent agony. There had to be a better way to distribute water during periods of inadequate rainfall.

One day after an extremely heavy rain, while watching the rapid removal of excess water by the drain tile on our Lower Farm, the possible solution became apparent. If tile was able to remove water from our soil so efficiently, why could it not be installed in a manner that would permit the same system to return water during periods of inadequate rainfall?

After much discussion and study, a trial plan was finalized for a 6 acre block. Following this plan, six inch agricultural drain tile was installed in parallel lines 80 feet apart at a depth of 2½ feet. The grade was 0.12 feet of fall per 100 feet to insure self-cleaning. Five inches of crushed stone were placed on the top of the tile to serve as a filter. The remainder of each ditch was backfilled with the soil that had been excavated. A 10 foot section of rigid pipe was installed on the discharge end of each line in lieu of constructing a head wall. These lines discharged into an open header ditch that had a dam with a flashboard riser located just below the last tile drain outlet. An open pit-type reservoir was dug in a low spot nearby as a source of water.

All of this construction was expensive, but we were sure that since it served the dual purpose of rapid drainage and irrigation it was financially practical.

We had just completed all of our installation when we went into a prolonged period of heavy rain. Our tile system removed all of this excess of water at a rate even exceeding expectations, and we were able to complete our lining out on schedule.

We enjoyed the success of the drainage function so much that we made a near fatal mistake. We permitted our field to drain completely before we added boards in our riser to limit

the flow of water. As so often happens in our area, we went from a period of excessive rain directly to a drought situation.

Our system was designed on the premise that we would add boards to catch spring rains and hold our water table at an acceptable level, which was yet to be determined. Our source of water was adequate only to supplement this impounded water--it could not bring us back from bone dry. Fortunately, we were able to pipe sufficient additional water from our main reservoir. The tile did a beautiful job of distributing moisture through the field. This saved our crop.

We learned a lot from this little field: (1) it is feasible to install a system of tile for the dual purpose of subsurface drainage and irrigation, (2) we needed to incorporate grading for surface run-off of excess water, (3) we had much to learn about the management of such a system.

After our drought experience of the first summer, we overreacted the second summer by holding the water level in the ditch so high that we nearly drowned our crop. We then realized that the proper management procedure would be to maintain the water table at a depth that would permit only optimum capillary moisture to enter the root zone of the trees. This gave us excellent performance and has become our guide for growing season water management through the years.

We were elated when we began to realize fully the potential of such a system of water table control. Our deep outfall canal had put us in the position of turning the flat topography that had been so detrimental through the years into one of our finest assests.

This pilot field was installed in 1960. Its successful operation for several years had a big influence on the decision we made after pausing to take a good hard look at the trend of the nursery business in the U.S. Southeast. It was moving rapidly toward the production of small stock in containers for the mass market. Our main interest was the production of materials for the landscape professional market, which had been generated while we were landscape contractors. This market was being conspicuously neglected. We evaluated our assets and found that our labor, location, land and potential system of water table control would enable us to specialize in the production of specimen-size landscape materials.

We had learned from our pilot field that even with closely spaced tile for subdrainage, grading for surface drainage would be very beneficial. The Soil Conservation Service laid out the entire field in 100 foot grids, and we graded sufficiently for all surface water to be able to move out of the field.

Since perforated plastic tile has come on the market, we have used it exclusively because of its lower cost and ease of handling. We experimented with laying tile ourselves with our Davis 300 trencher and found this was not practical. Since then we have contracted all tile installation.

We realized that it might become necessary for us to resort to mechanical spade digging in the future, so we increased our row width to 8 feet with 4 foot spacing in the row. We were aware that 8 feet would probably not permit us to dig selectively down each row so we decided to plant blocks of eight rows of the same plant material and skip every ninth row. This would give us a 16 foot space between blocks that we would utilize to dig into the sides of the blocks.

Our plan was to start marketing trees at 2 inch caliper and selectively thin to provide wider spacing for growing to larger sizes. If we continued to hand-dig, the skip row would serve as a pick-up road for our crane truck which could easily remove trees from the center of each 8 row block.

We feared that activity in the skip row might cause sufficient compaction to limit the lateral movement of water from the tiles. To alleviate this potential problem, we installed our tile in the middle of each eight-row block. The distance between the lines was 72 feet. We decided that a depth of 3 to 4 feet would be better than the previously used 2½ feet as it would allow us to lower the water table farther when digging large trees. It would also permit us to maintain a minimum of 4 inches of free water above the tile during the growing season, which would protect it from possible tree root penetration.

We were rapidly approaching the point that we had to do something about a larger and more dependable source of water. The most logical solution was to dig a deep well. No data was available to help us size the well. Our best calculation was that 400 gallons per minute should take care of the 120 acres of land with the system we were installing. We were advised that a 10 inch well should give us about this volume. We were elated when the well initially produced 450 gallons per minute and is now producing close to 500 gallons per minute. This well is located so that it can supply both sides of the highway with a minimum of pumping. To serve the north side of the highway, the water free-flows in a ditch under the highway into a large sump. From this sump two pumps lift the water approximately 7 feet over a dam, the main pump is a 4 inch 5 horsepower with a 400 gallons per minute capacity. The other is a sump pump with 150 gallons per minute capacity. It operates automatically as the water level fluctuates.

This dam is equipped with a flashboard riser and controls

the water table in the western half of the 20 acre field (A). Surplus water flows in an open ditch to a sump (SB) from which it is pumped by a 5 horsepower pump above a second dam (DB). This dam is also equipped with a flashboard riser. The lift is only about 18 inches to a ditch that feeds the northern half of the 20 acre field. It is also located to supply the high ground portion of the field B that we developed in 1973.

Below dam B are approximately 20 acres of land, the elevation of which averages 2 feet below the high ground of fields A and B. We dug our feeder ditch through the center of this lower area and constructed a dam (DC), with a flashboard riser before the ditch entered the large lateral canal on our lower property line. Water flows over the adjustable boards of dam B to supply this feeder ditch. Dam C holds this water at about 2 feet below the level of the water at dam B.

We installed the eastern half of field D in 1972. To our delight the Soil Conservation Service changed their recommendation for filters from rock to sawdust. We were assured that a 2 foot by 2 foot plug of sawdust sealed underground would last indefinitely. We were not hard to sell because the cost of rock had gone out of sight.

Heavy digging of orders in the winter and spring of 1972-73 prevented our lining out this field until May. We were able to irrigate this newly planted stock with water from below, and we had a beautiful result.

The big jump in the cost of all petroleum products nearly made us back out of the construction in fields B and C, scheduled for 1973. We closely evaluated and decided to make the installation. We went through the same agony of indecision in 1974. This time it was even worse because we were experiencing a slump in sales. We were scheduled to install 14,000 feet of pipe in the field north of dams C, D, E, and F that year; and the total cost appeared prohibitive. When the total cost was broken down on a per tree basis, it amounted to only 69 cents. With this low cost per tree, there was no way we could justify not making the installation. The increases in growth we have obtained in this field the last two drought summers have repaid the original 69 cents many times.

The major portion of our trees go on jobs with rigid construction schedules. Seldom do these schedules consider that trees may have a preference as to the time of year they are transplanted. Twelve to fifteen years ago we began finding ourselves confronted with more and more jobs requiring summer planting. We were forced to work out a technique to accomplish this successfully. Our procedure is simple and very safe as long as we strictly adhere to the following steps:

(1) Dig only trees in a turgid state with reasonably mature wood. The trees in our water-table-controlled areas are turgid during the growing season.
(2) Spray with an antidesiccant prior to digging.
(3) Thin out trees.
(4) Hold in a hardening-off area (light shade and light water on foliage) for a week to ten days.
(5) Spray again with an antidesiccant before loading.
(6) Haul only at night, covered, and try to have all trees planted no later than 10 a.m.

Water table control does have certain disadvantages:

(1) Initial investment is relatively high. Present total cost is approximately $600.00 per acre. Open ditch costs are not included.
   A. Tile installation costs approximately $360 per acre.
   B. Twelve dams and flashboard risers each cost approximately $650. Per acre share is approximately $72.00.
   C. Well and pump cost is approximately $15,000. Per acre share is approximately $140.
   D. Distribution pumps and installation cost approximately $3,800. Per acre share is approximately $35.
(2) There is some water loss due to seepage from our transmission canal.
(3) The system cannot be used to apply fertilizer and pesticides.

However, we believe these are outweighed by the advantages:

(1) Operating cost is low because of lifting water only a few feet. During what is said to be the worst drought in our county since 1924, the cost of electricity was $1,650 for pumping from January 1 to December 1. Total cost to operate per acre during this period was approximately $15.28.
(2) Distribution of water is highly efficient. The only loss to evaporation is from the surface of the ditches.
(3) There is minimum loss to seepage because distribution ditches are located between fields.
(4) Optimum moisture is maintained right where it is needed in the root zone of the trees. This encourages a compact fibrous root system and a uniform rate of top growth.
(5) The field surface is not muddied nor does weed seed germinate.

(6) The system operates 24 hours a day, seven days a week, with a minimum of monitoring. Ours ran continuously during the entire drought period with only two minor breakdowns.

(7) In the event of a big rain, it takes only about 20 minutes to switch off the pumps and remove enough boards to reverse the entire system to drain.

(8) Winter drainage is almost as valuable as summer irrigation. At the end of the growing season, we remove all boards from the risers and drop the water table as low as possible. This gives us a head start on wet weather. Our tile removes water so efficiently after each rain that we can usually get back in the field within 24 to 36 hours and resume digging operations.

This type system is more quickly responsive in soil types such as Lynchburg, Goldsboro, and Raines. These have some sand mixed with clay in the subsoil and permit rather rapid movement of both free and capillary water. We do have some Coxville and Grady (both rather heavy clays) included in our control area. These types will work, but time to adjust back to optimum is much longer. There are clays that will not permit tile to drain. In these soils, our system would not work. If tile cannot take water out, it cannot put it back.

A fairly level topography is desirable. Even with our flat land, we had to do a surprising amount of grade changing. The more uniform the depth of the water table can be maintained below the surface of the field, the better the results. We have been able to reduce field surface grade changing to a minimum by the use of dams with flashboard risers to control the water table to fit fields of different surface elevations.

We have found the optimum depth for us to maintain our water table during the growing season is within the range of 2 to 3 feet below ground level. Free water at this depth prevents deep rooting and promotes a fine fibrous root system. We are as interested in what we are growing below the ground as on top.

This water table control system has solved many of our problems. It has provided us with drainage and irrigation. It has extended our production season. And it has enabled us to produce a superior product.

QUESTIONS FOLLOWING GROWING MEDIA FORUM

BILL COLBURN: Question for Richard Van Landingham. Do you root your azaleas in the pine bark mix? As I understand it, you do grow them in that mix.

RICHARD VAN LANDINGHAM: We do root them in that mix. Almost all of our propagation is also done in this medium. For one or two species we add a small amount of perlite, but for 90 percent of our plants we use the basic mix.

CHARLES PARKERSON: Question for Richard Van Landingham. What is the air space in that mix?

RICHARD VAN LANDINGHAM: I do not know exactly. We had talked about removing the shale because we felt we did not need it. However, we decided that the shale was important since it does not change or decompose as the bark does. We would like about 20 percent air space.

CHARLES PARKERSON: Question for John Brailsford. Is the soil type critical for successful subsurface irrigation?

JOHN BRAILSFORD: The reaction time varies considerably with soils, but we overcome this by maintaining a uniform water table.

BOB LOGNER: Question for Carl Bauer. Do you wound your dogwood liners on both sides of your cuttings or just one side?

CARL BAUER: No, we wound only one side.

TED GOREAU: Question for Ed Kinsey. Do you use anything higher than 0.8% IBA?

ED KINSEY: No. I think that lately we have been reducing the amount. Most of the plants that root at higher concentrations will root just as well at a lower one.

NICK HAND: Question for Harry Hopperton. I would like to know what ties you used for your chip budding and what rate your budders can bud.

HARRY HOPPERTON: We use a plastic tie for our chip budding, but rubber works equally well. Our top budder, now 77, has done 3500 per day. Now I would say he is down to 1500 to 2000 a day.

GREG AMMON: Question for Ed Kinsey: What is the medium that you use on dwarf conifers?

ED KINSEY: We are using pine bark, shale, and sand in a 4:1:1 ratio, which is primarily what we are using for our other plants. We are not adding Osmocote in the mix but are just liquid feeding with the injector system.

HARRY HOPPERTON: Question for Carl Bauer. What herbicides are you using?

CARL BAUER: On our dogwoods, we are using Surflan.

DICK AMMON: Question for Ed Kinsey. What application rate of Ronstar do you use?

ED KINSEY: 4 lbs active ingredient per acre.

CARL BAUER: Question for Harry Hopperton: When do you cut trees back to encourage development of a head?

HARRY HOPPERTON: We do not cut them back. Most of our customers want a 10 foot trunk.

JAKE TINGA: Question for Harry Hoitink. Would you comment on composting hardwood bark.

HARRY HOITINK: Composting is important in crops such as bedding plants where time is critical. Composted bark is more uniform. Most fresh barks inhibit the growth of certain pathogens. In fact, hardwood bark helps control *Rhizoctonia*, although pine bark does not. Composting reduces this ability. However, hardwood barks usually contain toxins, which make it necessary to compost. The Southeast is fortunate, as pine bark is readily available, does not contain these toxins, and therefore does not require composting.

QUESTION BOX

LES CLAY: I would like to know more about icing plants for winter protection.

JAKE TINGA: Dr. Charles Hendershott, who is now at the University of Georgia, made his fame on studying freezing and thawing in plants. He prevented freezing in several crops of Florida oranges. When water freezes, it releases a tremendous number of calories. This is called heat of fusion. When liquid water is put on from an irrigation system and it freezes on impact, heat is released. I prefer to say cold is absorbed. As long as liquid water is put on, temperature will stay right at 32°F. If the water is turned off and ice forms, that ice will go to 31°, 30°, 29° and on down. When the temperature drops as far as 15 degrees below freezing, it is very difficult to put the water on fast enough to keep the temperature at 32°. I have iced out a field and saved that field just by turning on the irrigation. It must be turned on before freezing starts and left on until after all the ice is melted. Do not turn it off after everything is iced down.

BOB McCARTNEY: What about anti-dessicants?

JAKE TINGA: I have used anti-dessicants. Timing is very critical as they tend to flake off; thus, they must be applied repeatedly. My experience has indicated they are not reliable.

GARY HUTT: I tried microfoam last year for overwintering and had fairly good luck with it. I was wondering if anyone here has used microfoam and if so, how he used it?

JAKE TINGA: Microfoam is bubbly plastic foam material ¼ inch thick.

FRANK HOGAN: I have three rolls, but I haven't put it out

ED KINSEY: 4 lbs active ingredient per acre.

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QUESTION BOX

LES CLAY: I would like to know more about icing plants for winter protection.

JAKE TINGA: Dr. Charles Hendershott, who is now at the University of Georgia, made his fame on studying freezing and thawing in plants. He prevented freezing in several crops of Florida oranges. When water freezes, it releases a tremendous number of calories. This is called heat of fusion. When liquid water is put on from an irrigation system and it freezes on impact, heat is released. I prefer to say cold is absorbed. As long as liquid water is put on, temperature will stay right at 32°F. If the water is turned off and ice forms, that ice will go to 31°, 30°, 29° and on down. When the temperature drops as far as 15 degrees below freezing, it is very difficult to put the water on fast enough to keep the temperature at 32°. I have iced out a field and saved that field just by turning on the irrigation. It must be turned on before freezing starts and left on until after all the ice is melted. Do not turn it off after everything is iced down.

BOB McCARTNEY: What about anti-dessicants?

JAKE TINGA: I have used anti-dessicants. Timing is very critical as they tend to flake off; thus, they must be applied repeatedly. My experience has indicated they are not reliable.

GARY HUTT: I tried microfoam last year for overwintering and had fairly good luck with it. I was wondering if anyone here has used microfoam and if so, how he used it?

JAKE TINGA: Microfoam is bubbly plastic foam material ¼ inch thick.

FRANK HOGAN: I have three rolls, but I haven't put it out

yet in North Carolina. I hope to do so and hope to have the same luck you did last year, Gary.

WILL WITTE: A nursery in North Carolina lost containerized material valued at about 6 or 7 thousand dollars one winter. They began using microfoam and did not lose a single plant. Their method was to pick out the tender plants and bunch them in beds about 5 feet wide with railroad tie edges. They left small plants with a good head standing but laid down the taller plants. All plants were watered thoroughly, then sprayed with a fungicide. Beds were covered with weak plastic from an old greenhouse, microfoam was put down, then another layer of poly was put on top. They put it on in December and left it until early spring.

BOB McCARTNEY: Two years ago in Williamsburg I used microfoam as a covering for a plastic greenhouse, which was a modified cold frame about 50 feet long and only about 6 feet wide. We used it to store tender container plants such as palms and citrus. Temperature did not go below freezing even with no artificial heat at all. However, with just plastic protection the temperature did go below freezing. We ventilated the structure on hot days. One problem with the microfoam is that it becomes brittle and degrades during hot weather in late winter. It can easily become shredded and scattered all over the nursery.

JIM SABO: Work at Ohio State indicates that it should be put on as late as possible and off as early as possible to prevent heat build-up. Microfoam is now available 6 feet wide, 250 feet long and ¼ or ⅛ inch thickness. The cost is $90 to $100.

GARY HUTT: One nurseryman has been able to use it for 4 years by removing it and storing it in the dark.

JAKE TINGA: We believe it is easier and more economical to throw it away. It costs to take it up, it costs to roll it up, it costs to store it. The next year it is a weaker product that may not be dependable. I would consider it an annual expense. Remove it and dispose of it before it scatters.

BOB LOGNER: I would agree with Gary Hutt that microfoam can be reused. Another possibility is to put it through a shredder and substitute it for perlite in the mix. It is becoming increasingly important to be cost conscious.

GARY HUTT: We use black plastic for weed control. Last year was the first year that we used microfoam, and we did not take up the black plastic. If you cover the plants with microfoam and leave the black plastic there, it is important to make sure that there is no standing water anytime. We had a few low spot areas underneath the microfoam where the water accumulated, and the plants in these areas were subject to rot.

We did not use any fungicide. If the foliage was dry and the black plastic on the ground was dry, we had no problems.

BILL COLBURN: I would like to know if anyone has a procedure for germination of *Nandina domestica* seed? We tried it in Florida some years ago and had variable results. We suspect it has a cold requirement. Can anyone tell me what the requirements are?

HUNTER BOULO: We have success by scattering the seed in a flat of 80:20 bark:sand mix, with seed covered about ¼ inch. We put the flats in poly covered houses where the temperature is around 35°F. We plant in November.

JUDSON GERMANY: We collect all the seeds we can find in the fall and store them dry at room temperature. We sow *Nandina* in June in vermiculite and perlite, about ½ inch deep. We put the flats in the greenhouse or under the shade of trees. Usually by October we get seedlings. I think you could plant them anytime from the time you collect on up to June.

BOB McCARTNEY: We are not raising *Nandina* to sell commerically, but we have many *Nandinas* in our landscape program at Williamsburg. We mulch *Nandina* with pine bark very heavily, and it stays mulched all winter. In the summer the berries fall into the pine bark and germinate. By fall the mulch is full of seedlings. That is what they do in nature.

BOB BOCH: Years ago we sowed in outdoor seedbeds in the fall, but they did not come up until the following year.

DR. STADTHERR: We tried them in Baton Rouge. We collected them around December and planted without any stratification. I think you don't have to stratify them. However, our germination was about 1 or 2 percent at the most. It may be that there is an afterripening period after the seed is collected. There may be an immature embryo.

JUDD GERMANY: It is important to remove the pulp promptly.

DICK STADTHERR: We did that.

JIM CAGLE: I believe that the cold requirement is essential.

WARREN SNEAD: For many years we have been growing some *Nandina* from seed. We have planted in the spring, but they do not come up until fall.

RONALD COPELAND: I am interested in seed propagation of calleryana pear, *Pyrus calleryana.* Is it too late to collect seed in December?

BRYAN NELSON: We have collected in January and February. We then cleaned the seeds, stratified them in moist sand

for 60 to 90 days, then planted them in a warm greenhouse under mist in a peat:sand:perlite mix.

NICHOLAS HAND: We have collected in December then stratified for 45 to 50 days before planting in sawdust in outdoor beds. We obtained good germination.

DICK STADTHERR: We have cleaned the pear seeds by allowing them to ferment in water at room temperature, then running through a blender with the blades covered or removed. A wire screen can be used to break the outer seed coat.

WILEY ROACH: I am interested in the palm that is prevalent here in Charleston. Does anyone know the name?

BOB McCARTNEY: It is *Sabal palmetto.* This palm is found from the Charleston area to Florida and along the Gulf Coast to Pensacola. It is hardy up to Virginia Beach area. The smaller dwarf form found all through the swamps is *Sabal minor.*

DICK STADTHERR. What is the hardiest palm?

BOB McCARTNEY: I might be able to answer that. We grow 6 species of palms, and *Sabal palmetto* is not the hardiest. I think that a mature plant with a full crown of foliage will withstand 10°F above freezing for a short period. The hardiest palm that grows upright is probably *Trachycarpus fortunei,* windmill palm. *Washingtonia* is another good hardy palm. The *Phoenix* palm is hardy to Charleston.

BOB LOGNER: What can be done to prevent bark splitting of *Indica* azaleas?

JAKE TINGA: Grow a hundred miles farther south!

BOB COSGROVE: It happens in Orlando, Florida, too, possibly because the plant does not become dormant.

DICK STADTHERR: This splitting occurs when there have been no cool temperatures preceding a sudden freeze. Plants have had no chance to go into their rest period, or become acclimated. Under these conditions they freeze very, very easily. They may freeze just a few degrees below freezing, whereas later in the winter they can take much lower temperatures. If plants are still growing rapidly, the water content in their cells is very high and freezing occurs intracellularly. The last portion that goes into rest is the base of the plant. Water content is high, solute content is low. They freeze easily and expand, which causes a longitudinal split.

CHARLES PARKERSON: One nurseryman on the east shore of Virginia is using Offshoot-O to help harden the plants. It seems successful.

DICK MARSHALL: I know his procedure. He is spraying one year old plants with Offshoot-O (methyl octanoate and

methyl decanoate) about the middle of September. These have been planted out in May, and he sprays in September to help them through the winter.

DICK STADTHERR: We have done just a very little of this also. I feel that Offshoot-O and similar compounds tend to delay the bud action on the top and stop growth. This, then, may trigger a change into rest period. We use a 3 to 5 percent concentration. The smaller cuttings are the ones that go into their rest period slower than older plants. Cultivars also differ in their response to low temperature.

PHIL BEAUMONT: I have read about atrinal (dikegulac-sodium) in reports from England. I also understand it is being used experimently at North Carolina State University to regulate branching on azaleas. Can it be obtained commercially?

RICHARD SMALL: No, it is not released yet. It has been approved for use on azaleas and probably will be available in the spring.

CHARLES PARKERSON: Last year at a symposium in Columbus, Ohio the theory was presented that when a plant starts going into dormancy the lethal temperature begins to drop and continues to do so. However, after just one day of extreme heat that temperature will rise very rapidly, and it then takes about two weeks for it to get back down again. The reason I was so concerned about it is that we use clear plastic in our houses, thus building up heat in the day. Actually what we might be doing very rapidly is turning around this hardening process. We might actually be making the plants winterkill at a higher temperature even with the poly.

JUDD GERMANY: I have noticed in the past freeze damage that occurred only in one spot down close to the base of the plant might callus and heal and the plant eventually recover. It would be interesting to see if wrapping with budding strips or vinyl tape would improve the chance of healing.

TED GOREAU: Can anyone give me a simple method for calculating air space or pore space in potting mix?

BILL DAUGHTRY: We cut the bottom off of a gallon plastic milk jug, turn it upside down, and put a screen over the hole in the bottom (originally the top). The screen is inside the jug so that the screw cap can remain in place. We then measure off 3000 milliliters on the jug and mark this line. We fill to the line with mix and slowly add water until it is saturated. We allow it to stand for two hours, carefully remove excess water from the top, remove the bottom cap and drain remaining water into some other container. The percent pore space can be calculated

by measuring the water drained from the bottom and dividing by 3000. We like to have 20 percent.

CHARLES PARKERSON: Question for Brad May. I want to know about your juniper production.

BRAD MAY: We begin sticking *Ilex* in the middle of July. As soon as we finish, we begin with junipers. We stick juniper cuttings in a mixture of peat:perlite:sand in approximately equal amounts. We add either 3 pounds per cubic yard Scotts 31-5-3 or 8½ pounds per cubic yard Osmocote 18-6-12. We stick the cuttings in square cups, then put the cups in flats. The mist is on about 7½ seconds every 7½ minutes. We do not use hormones. We have found that we get better rooting if we strip the cuttings. We also cut back tops. We use 30 percent shade but do not put on poly until we need it for winter protection, usually in October. The only time we heat a house is for the azaleas when it gets below 25°F. We then keep the heat at 35°F. We are not pushing for any winter growth.

RICHARD AMMON: Is any hybridizer interested in developing a hardy azalea with a good color? We find 'Karens' is hardy, but the color is not good.

TOM DODD: We are doing some hybridizing.

JIM SABO: Pete Girard, Girard Nurseries, Geneva, Ohio, has also worked with them.

HARRY HOITINK: The PJM rhododendron is called an azalea, but there are no really hardy azaleas up north.

RICHARD STADTHERR: Azaleas that tolerate high pH would also be valuable. Breeding should be done in the location where they will be grown in order to subject the new cultivars to the selective pressures of that environment.

JAKE TINGA: I would like to hear more about the use of both hardwood and pine barks, and the effects of composting in each case.

HARRY HOITINK: The South is fortunate to have pinebark. This bark is 90 to 95 percent lignin and only 5 to 10 percent cellulose. Spruce contains 20 percent and oak 25 to 30 percent cellulose. Other hardwood barks are even higher. The cellulose breaks down into sugar, which provides an ideal carbon source for microorganisms that, in turn, deplete the supply of available nitrogen. This is one of the reasons it is not possible to grow in fresh hardwood bark. Both pine and fir bark have a higher content of lignin and lower content of cellulose. This difference makes it possible to grow in fresh pine and fir barks. Harvest and debarking methods are changing also. In Ohio we are now getting 60 percent instead of 20 percent cellulose. As the composition changes, the bark loses air space and becomes hyd-

rophilic leading to root rot. Some barks also contain toxic materials and will need to be composted for this reason.

HUNTER BOULO: We are using 80:20 bark:sand and are composting because of heat and the high potassium level.

HARRY HOITINK: It is probably best to stock pile in pots and keep moist. Wettability is often a problem.

HARRY HOITINK: One grower in our area (Ohio) adds 4 lbs urea and 1 lb triple superphosphate per cubic yard plus 50 percent water by weight. He puts the bark in windrows and turns every 2 or 3 weeks if he plans to use it in 3 or 4 months. If it can be left a year, turning is not necessary. It is important to avoid an anaerobic condition as the pH can then become as low as 1.9. It is, therefore, important to choose a well-drained site for composting.

SOME CAUSES OF SEED STERILITY IN CERTAIN NATIVE AUSTRALIAN PLANTS

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Many of our most beautiful and horticulturally desirable native plants are remarkably seed sterile. The empty cones of so many *Banksia* species and the sparsity of seeds amongst *Verticordia* fruit collections bear witness to this. The phenomenon is not necessarily one imposed to test the patience of plant propagators; it is more probable that natural selection has incorporated sterility into the genetic systems of these plants as part, or as a consequence of, a reproductive strategy that has hitherto proved to be quite successful. Detailed analyses and real understanding of the genetic systems is available in a very limited number of native plant groups. *Isotoma petraea* and *Stylidium* spp. are rather horticulturally unimportant, but they are fascinating plants, and lessons learnt from their genetic systems may well be useful in understanding biological strategies in other plant groups which may be less amenable to investigation.

The sexual cycle in plants. Seed formation is the result of successful sexual reproduction in plants. It requires all the biological miracles of cell division, growth and differentiation leading to the production of flowers on a surviving adult plant. Within the flowers, meiosis takes place in the ovules and anthers leading to the production of the haploid gametophytes. The embryo sac is nurtured in the tissues of the ovule where it ultimately produces an egg. Pollen is released from the anther and is transferred by pollinating vectors to the receptive stigma, where it germinates to produce a pollen tube which grows down through the style and into the ovary, finally delivering two sperm nuclei to the embryo sac within the ovule. One sperm nucleus fuses with the egg to produce the new embryonic plant, the second fuses with two embryo sac nuclei to produce the endosperm. The ovule, now containing a living food storage tissue, the endosperm, and a new plant, the embryo, develops into the seed.

Seed production requires all these steps to be successfully fulfilled. Seed sterility is the result of any one of these steps failing.

The biological role of sexual reproduction. Seed production is not necessary for reproduction. Numerous, perhaps most plants have the capacity to be reproduced vegetatively by cuttings, budding, or grafting, or naturally by means of rhizomes,

corms, bulbils or other asexually produced propagules. Sexual reproduction is the mechanism of generating heritable change. *It is a genetic phenomenon, and sexual reproduction, embracing* meiosis and fertilization, is the field of the genetic system.

In sexual reproduction, each parent contributes a set of hereditary factors or genes, via the gametes, to the fertilized egg and thus to the progeny individual that develops. This diploid (doubled) set of genes is copied and passed intact and unchanged to each cell of the developing individual, including those cells which undergo meiosis in the anthers and ovules. At meiosis, the diploid set of genes is segregated into a variety of haploid sets, some of which may be identical with the maternal gametic set, some may be identical with the paternal set, but the vast majority will be mixtures of the maternal and paternal sets. If all individuals of a species were genetically pure and identical, this mixing of the parental gene combinations could yield nothing new. The generation of novel gene combinations through the meiotic process requires genetic differences to exist between the maternal and paternal gametic gene sets; i.e., it requires the diploid individual to be heterozygous or hybrid. The mixing of genes into new haploid combinations is termed recombination, and it is an essential component in the genetic system.

Sexual reproduction involving heterozygous individuals *leads to the generation of potentially infinite numbers of* different gene combinations. Within populations of sexually reproducing species, therefore, the potential exists for the presence of a vast number of different genotypes, but only a relatively limited subset of these genotypes are adapted, and they are naturally selected. Under stable environmental conditions, the tendency in natural populations is for the less fit genotypes to be removed by natural selection and for the population to exhibit an increasing adaptation and fitness over time. Two strategies which enhance fitness may be discerned in natural populations. Firstly, recombination may be limited by various mechanisms. Such conservative devices assure an increased probability that the genotype of the offspring is similar to that of the parent, and hence is likely to be adapted and fit. In some cases, this conservation of parental genotypes is so precise that a lineage loses its capacity to generate new genetic combinations; the ultimate consequence of such folly must be extinction, for the environment will change. Secondly, genotypes will be selected which have enhanced powers of tolerating genetic variation yet achieving the adapted phenotype, and in ever wider ranges of environmental conditions. This inbuilt homeostasis is difficult to conceptualize and explain in exact terms, but its importance and physiological basis is an area of controversy in some aca-

demic circles. It is analogous to, and perhaps identical with hybrid vigour and the reduced phenotypic variance commonly associated with hybrids. It is an important component in the genetic system of all higher organisms, and is especially well serviced by breeding systems which ensure biparental sexuality and the generation of optimal levels of hybridity.

Evolutionary changes in the genetic systems can thus be explained in terms of two phenomena — the pursuit of hybridity and the control of recombination. This approach to genetic system analysis was first developed by Charles Darwin and, in its modern format, by C. D. Darlington. It provides a fascinating insight into a turbulent world of genetic pragmatism beneath the placid surface of our elegant and gracious native plants.

Complex hybridity in *Isotoma petraea*. *Isotoma petraea*, the rock isotome, is an herbaceous perennial member of the *Lobelia* family which occurs in rocky habitats throughout the wide central regions of the Australian continent. Over most of its distributional range, it is a fairly conventional species having a pollination mechanism (Figure 1) adapted to promote crossing and a diploid set of 14 chromosomes which form bivalents at meiosis (Figure 2). The species extends to the granite rocks of the eastern wheat belt in Western Australia, where it occurs in discrete populations on individual granite domes. In certain of these populations, high levels of inbreeding became established. This was brought about by a short circuiting of the pollination mechanism so that the stigma became receptive while still contained within the anther tube (Figure 1) making the flowers effectively cleistogamous. Now, self pollination has the result of rapidly eliminating hybridity in sequential inbred generations and is debilitating, both of the inbred plants themselves and of their genetic flexibility and evolutionary potential. As with so many other species of plants which have adopted self pollination, systems which conserve hybridity and resist the debilitating consequences of inbreeding have been incorporated into the genetic system. In this present case, complex hybridity has been evolved. This has been described in some detail elsewhere (2,3,5,6). Briefly, complex hybridity is a genetic system which departs from normality in that recombination at meiosis is virtually totally suppressed (Figure 3); recombinant gametes are generally inviable. In addition, when the two viable parental gamete forms are associated by self pollination, only the heterozygotes survive; the homozygotes are eliminated by a balanced lethal system (Figure 3). The net result, in *Isotoma*, is that 80% of the ovules may be aborted through gametic elimination, while half the remainder are lost following fertilization;

this derived genetic system imposes a seed sterility of up to 90%.

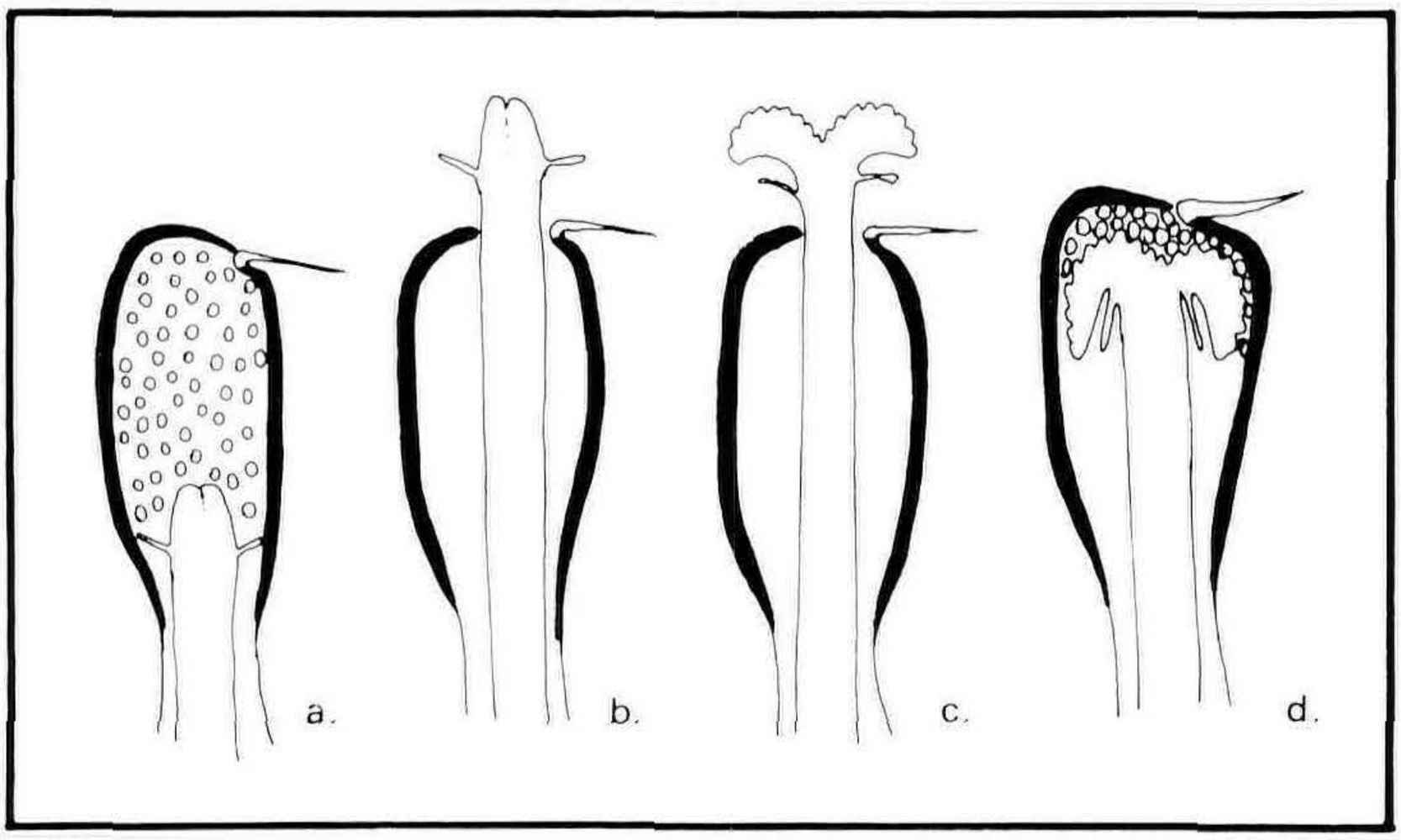

Figure 1. Pollination mechanisms in *Isotoma petraea*. Pollen is shed into a tube formed by the fused anthers and released onto visiting vectors through a pore opened by depressing the large terminal bristle (a.). The style elongates, pushing the still non-receptive stigma through the anther tube (b.) whereupon the stigma becomes receptive to pollen (c.) delivered by insect vectors. (a.) to (c.) represent the primitive cross pollination system. In (d.) the stigma becomes receptive within the anther tube and self pollination is effected. Since the stigma is not exposed, cross pollination is not possible in flowers exhibiting this behaviour.

We have inquired into the consequences of the evolution of this genetic system by means of two investigations summarized below, but which will be described in detail elsewhere.

We examined the distribution of variation within the two parts of the species, the one, primitive, characterized by normal chromosome behavior, the second, derived, characterized by ring formation. This was done by measuring some nine items on 5 samples from some 868 glasshouse-grown plants which were derived as seed from native plants in 4 primitive and 3 ring or complex hybrid populations. The hierarchical arrangement of the investigation is illustrated in Figure 4. Statistical analyses permitted the allocation of components of variation to various levels within the hierarchy, and the average results are illustrated in Figure 5. From this figure it is clear that the evolution of complex hybridity has been associated with a redistribution of variation within *Isotoma* populations. The derived complex hybrids exhibit much more variation between populations than within populations, and quite importantly, the variation between samples within individual plants is less, in the derived complex heterozygotes, than in the primitive forms. Indeed, the enhanced robustness of the complex hybrids was

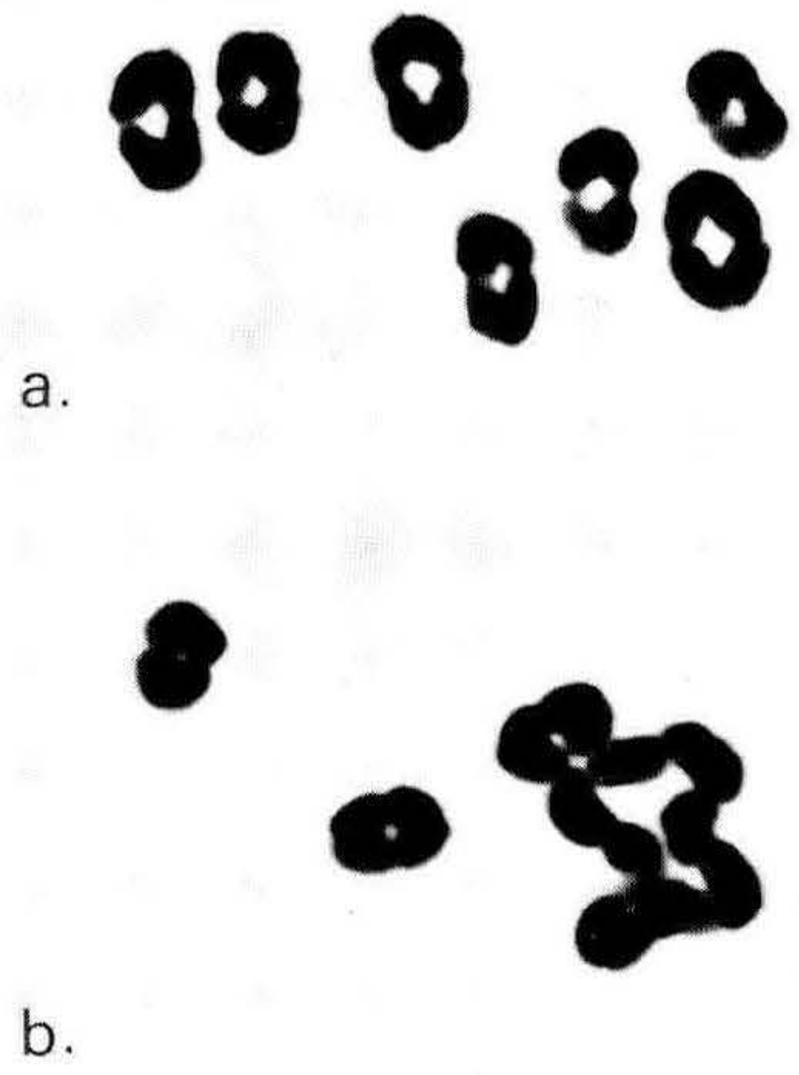

Figure 2. Photographs of chromosomes at first metaphase of meiosis in *Isotoma petraea*. (a.) - the primitive condition in which the fourteen chromosomes form seven bivalents, each being two chromosomes held together by terminal chiasmata. (b.) - a derived complex heterozygote in which eight of the fourteen chromosomes form a ring association (⊙ 8) and six form three bivalents. Complex heterozygotes may exhibit ring associations of 6 (and 4 bivalents) through to 14 (with no bivalents). The effect of ring formation is to prevent the independent assortment of genes carried on the different chromosome pairs.

borne out in the second experiment (Table 1) in which a replicate of the first was grown under rather adverse conditions in the garden in which approximately 50% mortality was in evidence. In this experiment, 92% of the complex hybrids survived, while only 25% of the primitive forms survived. It is clear from these investigations that the evolution of complex hybridity has resulted in the production of a very superior lineage, able to withstand environmental vissicitudes much more effectively than their progenitors, and capable of passing their superior genotype unchanged to their offspring. Even though the genetic system demands a 90% seed sacrifice, the accountancy of nature has proven the benefits. But, the cost-benefit analysis is short-sighted, and the *Isotoma* complex hybrids have renounced their genetic flexibility. Complex hybrids are known in only three, perhaps 4, other groups of plants; the rarity of the genetic system bears witness to its ultimately limited utility, and we may confidently conclude that the *Isotoma*

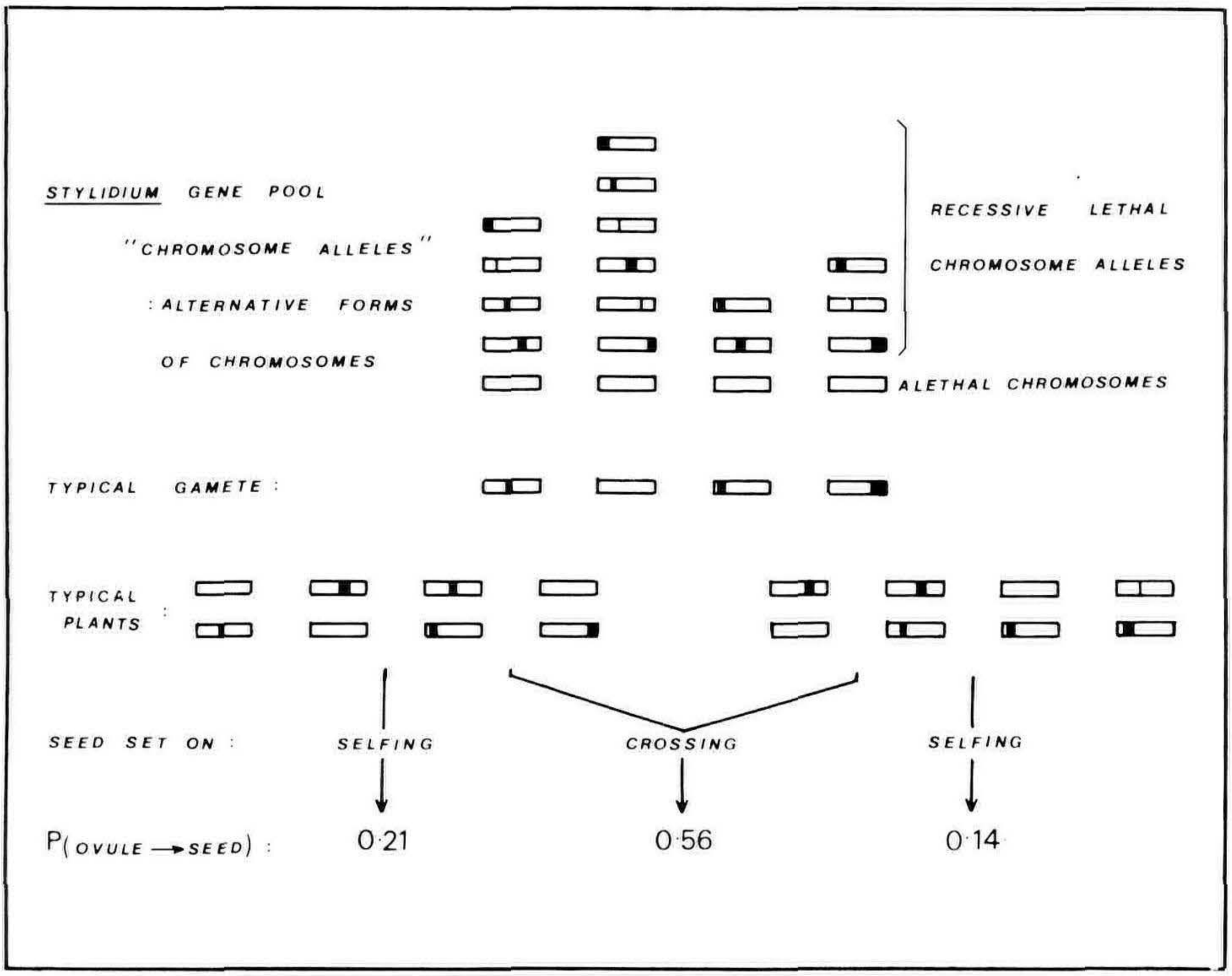

Figure 3. Causes of seed sterility in *Isotoma petraea* complex hybrids. All complex hybrids exhibit a 50% seed abortion due to their zygotic lethal system. The degree of gametic inviability depends upon the number of chromosomes included in the complex. The 80% estimate for gametic inviability here refers to complex hybrids with all 14 chromosomes in the ring.

Table 1. Survival among garden-grown *Isotoma petraea* plants.

Genetic System	Survived	Died	Total	P(survival)
7II	25	75	100	0.25
⊙	69	6	75	0.92
Total	94	81	175	0.54

$X^2_{(1)}$ Homogeneity = 77.5
p ———> 0.0

complex hybrids are doomed to extinction.

Lethal systems in *Stylidium*. Triggerplants, of the genus *Stylidium* have a sensitive column or trigger which bears, in sequence, the anthers and then the stigma. This sensitive column arches back and may be triggered by visiting insects so

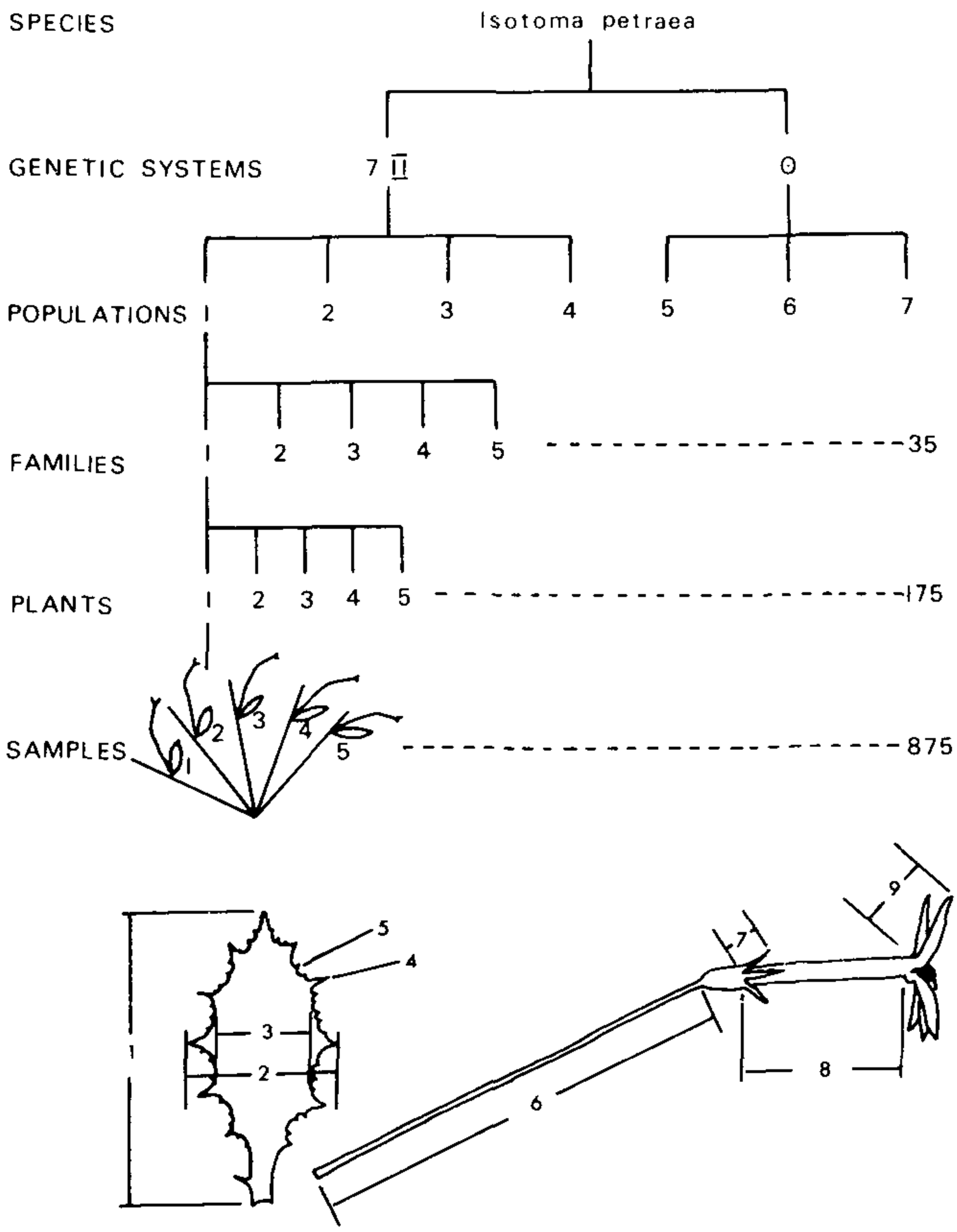

Figure 4. The hierarchical design for the analysis of variance of *Isotoma petraea*. See text for details. Of the possible 875 samples, 868 were measured for each of the nine characters indicated.

that they are struck by the rapidly moving column. The released trigger then resets and awaits the next visitor. In this way pollination is achieved. It is obviously a mechanism to promote cross pollination. But, cross pollination between flowers on the one plant is also possible and this is equivalent to self pollination. Most *Stylidium* species in Western Australia can discriminate between crosses and selfs so that few seeds are set following self pollination, while seeds are set much more freely following cross pollination, especially if the parents involved come from closely adjacent but different populations. This behavior imposes very substantial seed sterility upon *Stylidium*. The discrimination between crossing and selfing is achieved by a widespread occurrence of recessive lethal genes in the *Stylidium* gene pools (Figure 6) The relevant information has

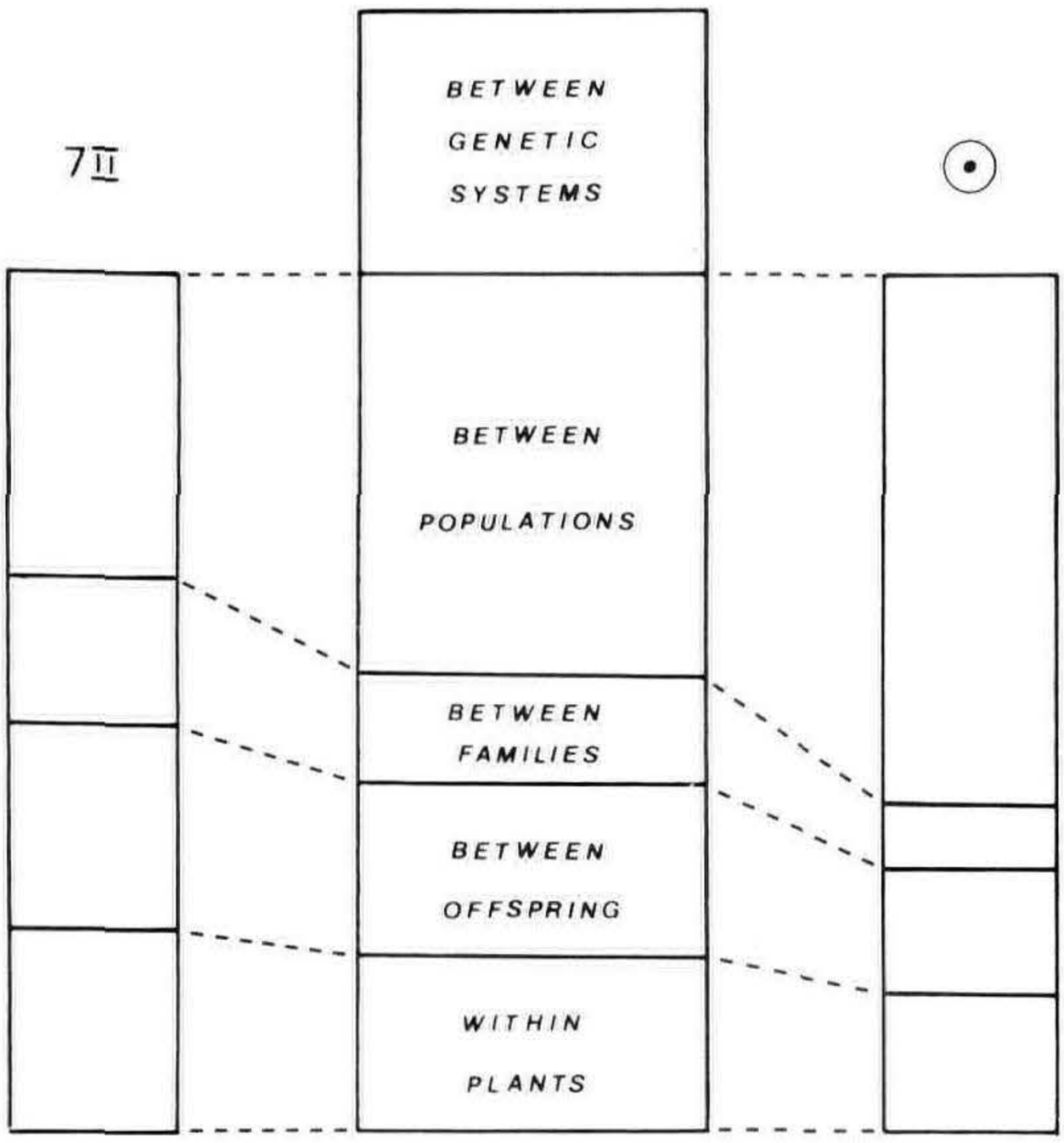

Figure 5. The distribution of variation in *Isotoma petraea*. The relative estimates of variation at each level of the hierarchical experimental design were estimated by relatively adjusting and linearly averaging the unbiased estimates of variance components calculated for each of the 9 measured parameters, indicated in Fig. 3, by the unequal sample size method of Snedecor and Cochran (1967: 291-294). See text for general interpretation.

been described elsewhere (1,7) or is being prepared for publication.

Again, this curious genetic system is best explained in terms of a pursuit of hybridity. Zygotes homozygous for particular recessive lethal genes die virtually at their conception; only those zygotes heterozygous for at least a substantial proportion of their genotype survive. All this has consequences upon the distribution of variation with *Stylidium* species. Individual species, e.g. *S. crossocephalum* (4) have their distributional areas subdivided into local areas in which the lethal systems tend to be relatively homogenous, while different suites of lethals characterize different units of the distributional mozaic. As in *Isotoma*, the pursuit of hybridity has lead to discontinuities in the variation pattern, at least at the chromosomal level, concentrating differences between local areas. More than 100 species of *Stylidium* occur in Western Australia, and it appears that this rich and extensive speciation is a consequence of the aberrant genetic systems exploited by the group.

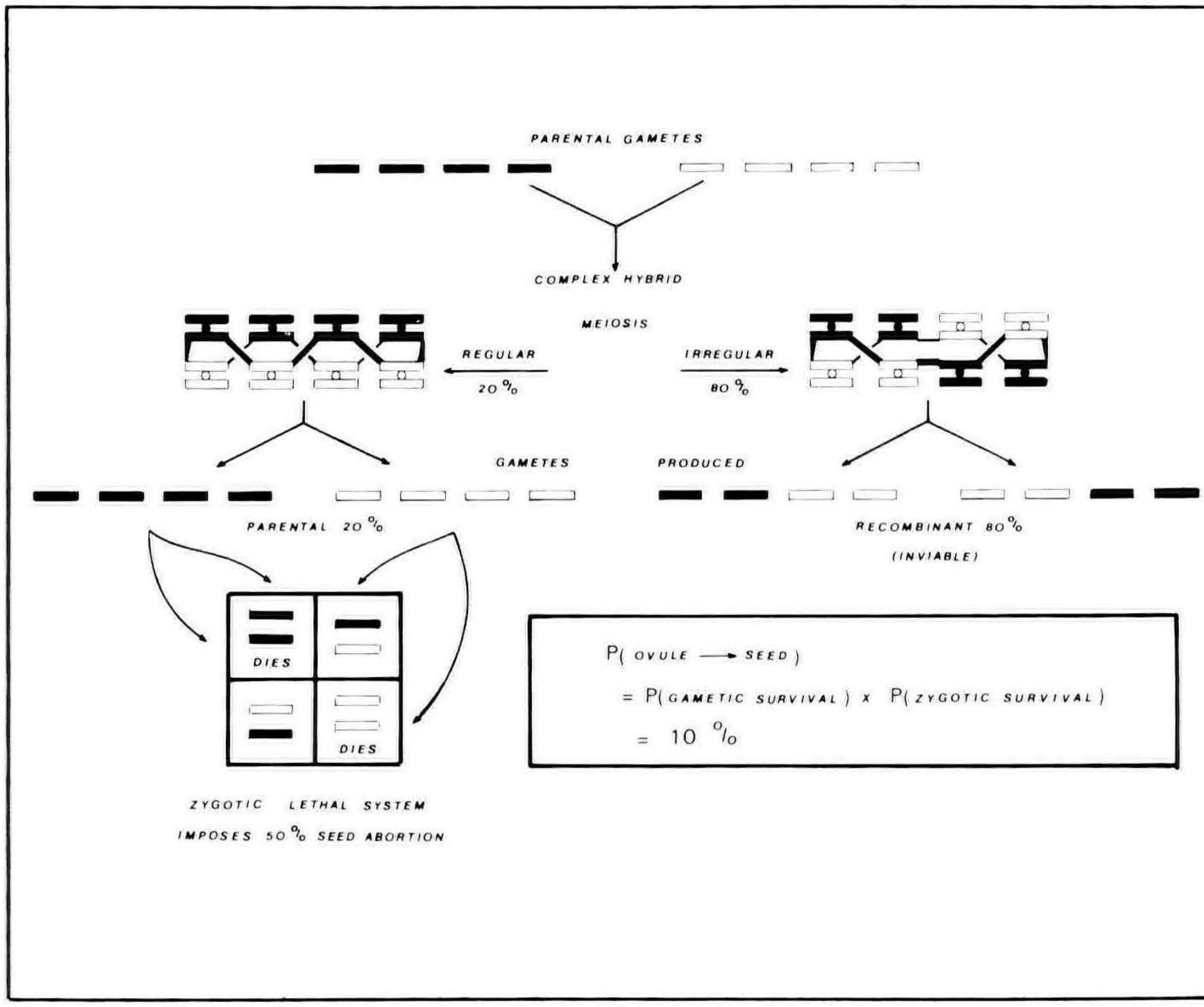

Figure 6. The architecture of a *Stylidium* species' gene pool. Within populations, each chromosome exists in a number of forms; an alethal form, and several to many forms carrying one (or more) recessive lethal genes. Each gamete must carry one chromosome drawn from each stack, and each plant has a genotype produced by the union of two gametes so that it is effectively made up of two chromosomes from each stack. If the two chromosomes from any one stack are carrying identical lethals, the plant, being homozygous for that recessive lethal gene, dies soon after its conception. The seed set probability for the typical plants given is readily reduced from elementary Mendelian principles; the first plant, on selfing, produces ($\frac{3}{4} \times \frac{3}{4} \times \frac{3}{4} \times \frac{1}{2} \times \frac{3}{4} = \frac{27}{128} = 0.21$) surviving seeds, the second produces ($\frac{3}{4} \times \frac{1}{2} \times \frac{3}{4} \times \frac{1}{2} = \frac{9}{64} = 0.14$) surviving seeds, while crossing between the two plants produces ($1 \times \frac{3}{4} \times \frac{3}{4} \times 1 = \frac{9}{64} = 0.56$) surving seeds. (The identity of particular recessive lethals may be determined visually in this diagram.)

Other richly speciated groups in the Australian flora may also owe their diversity to an exploitation of conservative genetic systems. This is quite probably the case for the Styphelieae (Epacridaceae) (9) and the Chamaelauciinae (Myrtaceae) (8) in which aberrant genetic systems have been described. At present, a great deal of research needs to be done before a really satisfactory understanding of the role of the genetic system in

the evolutionary biology of native plant groups can be claimed. However, a general principle which seems to be emerging is that where poor levels of seed set are encountered amongst native plants, there is a high probability that sophisticated genetic systems which ensure a high quality of seed, in terms of their genetic content, will also be found. It is also becoming apparent that these derived genetic systems, if conservative, are also restrictive, and though they may contribute to taxonomic diversity, they almost surely limit the long term evolutionary potential of their lineages.

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PROPAGATION OF SELECTED FORMS OF CALLISTEMON

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Growing cutting-propagated callistemons in containers has almost made production from seed impractical. Several cultivars are now available and the ones I prefer for nursery production are:

'Park Special' — originated in W.A. and has proved to be a magnificent red cultivar.
'Gawler Hybrid' — a large red-flowering form from South Australia.
'Endeavour' — one of the best and one of the most popular.
'Dawson River' — a lovely vivid red with a weeping habit.
'Viminalis Prolific' — very compact flowered form.
'Hannah Rae' — a pleasant red, most useful for tub specimens.
'Captain Cook' — a most imposing dwarf form with deep red flowers and very useful in mass plantings.
'Western Glory' — a splendid delicate pink.

Cuttings are taken around November at the beginning of the summer months, although when I have been very pressed for stock I have taken cuttings during the winter months and had quite good results. There are two types of wood used depending on the cultivar. Half-ripened tips are used for 'Park Special', 'Viminalis Prolific', 'Captain Cook', 'Hannah Rae' and 'Dawson River'. For 'Endeavour', 'Gawler Hybrid' and 'Western Glory' more mature type tips give best results. Cuttings approximately 10 cm long are stripped of leaves over half their length. In my experience it does not seem to make any difference in the rooting of these cuttings if heel or node cuttings are used. "Pyco 4" hormone powder is used and the rooting medium is 50% peat and 50% polystyrene foam. Cuttings are inserted into flat trays 2 cm apart and placed under mist with bottom heat for approximately three to four weeks, by which time roots should be apparent through the bottom of the trays. Trays of cuttings are then removed to a hardening-off area, such as a shade house, for two weeks or more before further potting on.

PATHOGENS IN PLANT PROPAGATION

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Before going deeply into this subject it is essential that you realise a fundamental truth in relation to plant disease. For a plant disease to develop, whether it be during propagation or following planting out, three things are essential. There must be:

(a) a susceptible plant
(b) the disease-causing organism, and
(c) a favourable environment for the pathogen.

Unless all three are present at the same time disease will *not* develop.

(a) **The susceptible plant.** All plants are not susceptible to the same diseases. Even within the same broad group of plants, *some are resistant while other are susceptible.* With the resistant plants they can be susceptible at the very early stages of growth, but with susceptible plants they are more liable to attack by disease causing organisms only at certain growth stages, e.g. just after emergence as tender seedlings.

(b) **The disease organisms (pathogens).** These may be bacteria, fungi, nematodes or viruses. Some organisms, e.g. *Botrytis*, are almost ubiquitous in their distribution, whilst others are sporadic.

(c) **The favourable environment.** This is a major factor because pathogens can only cause disease when temperature, moisture and other conditions are favourable. These conditions vary with the different pathogens. In the nursery situation, of course, the environment is ideal for many of the pathogens, but it can still be manipulated to some extent to reduce the ravages of disease. By understanding this basic principle a person can often make it work for his benefit.

The adverse role of plant pathogens in propagation can be considered from four main aspects:

(a) The plant material being used for propagation.
(b) The propagation medium being used.
(c) The water used for misting and irrigation.
(d) The environment in which the plants are grown.

You have all heard the old adage, "Prevention is better than cure." Nowhere is this more true than in the field of plant pathology. It is far better to adopt measures which will prevent a disease developing than to try to control it once it has become

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established. The latter is seldom really successful, hence the ideal is to grow a healthy plant in a clean mix and environment when diseases can often be completely avoided and only minimal spraying is necessary. Diseases simply cannot be afforded.

(a) **Plant material being used.** This may be either seed or vegetative material used for cuttings.

Seeds. Seeds can carry a number of disease organisms either externally as spores on the seed coat or internally in the seed. Ideally, sowing of disease-free seed is the best way to start growing plants. However, there is no way of guaranteeing that any and every seed line is free of disease-causing organisms. Therefore appropriate seed treatments should be carried out as a routine measure, especially for particular seed types known to be a disease risk. Such treatments include hot water, air-steam and fungicidal steeps or dusts. Hot water and air-steam treatments are particularly important for internally borne diseases such as the bacterial diseases — black rot of crucifers and bacterial canker of tomatoes, and for some fungal diseases like the downy mildews and damping off. In fact many nurserymen have told me they have been unable to efficiently grow some plants prior to using air-steam seed treatments. Since using this treatment few, if any, problems have occurred. The temperature and time of exposure to this temperature varies with different types of seed, but it is usually around 50°C for about half an hour. The maximum temperature seed will tolerate is about 53°C; above this the seed is likely to be killed.

Fungicides of value for seed treatment include the benzimidazoles, thiram and captan. The best treatment to use will vary with the seed and the disease to be controlled and it is largely a matter of experience. After treatment, seed should be put into a clean container, labelled and kept separate from untreated seed, if it is not being planted immediately.

Vegetative material for cuttings. Cuttings should only be taken from healthy plants, preferably growing in containers, and kept protected from possible disease by regular spraying for disease and pest control and replaced on a regular basis to ensure that soil-borne problems do not develop. Mother plants growing in containers are preferred as it is impossible to maintain "open ground" grown plants in a completely clean condition. When cuttings are taken, secateurs, knives etc. should be regularly dipped in a disinfectant, such as 2% formalin, to ensure that diseases are not introduced to cuttings or plants. Particularly if open ground mother plants are used, cuttings are best taken at least 30 cm above the soil to avoid the risk of pathogen contamination from the soil. Cuttings can be dipped in fungicides or disinfectant solution, such as hypochlorite.

In some cases heat treatments can be given, e.g. air-steam can be used on mature wood or canes of *Dieffenbachia*, *Aglaeonema*, *Philodendron* and *Syngonium*, dormant tubers and bulbs, and on *Fittonia*. In the last case the leaves are killed but the stem remains viable. It could be well worth experimenting with some of the disease prone types. Cuttings should be kept clean at all times after collection and, particularly, after treatment, e.g. they should only be placed on benches which have been thoroughly cleaned down and disinfected (e.g. with formalin or hypochlorite) and in an area where contaminated material is not present.

(b) **The propagation medium.** At this stage it is essential that one start with a pathogen-free medium which is free draining but still capable of holding moisture. It is wise, therefore, to prepare mixes using only pathogen and pest-free components to prevent re-contamination. Most of you will be well aware of the types of mixes which are suitable for cuttings, but are you sure that they are really clean? For example, peat may have been in contact with surface soil; the bags may have been placed on contaminated soil; sawdust may have been put in dirty bags or picked up from soil, and so on. Nematodes have been regularly recovered from peat. Hence, although relatively slight, there is a risk that mixes of this type may not be sterile and it is, therefore, advisable that they be sterilised at least in the propagation stage. Suitable methods include air-steam, full steam, microwave treatment, solar heat or a chemical method such as methyl bromide.

The air-steam method is favoured because it does not kill all organisms and so create a biological vacuum, but only kills the pathogens. Hence, if by misadventure subsequent contamination does occur, a pathogen will not develop as rapidly as it does when complete sterilisation is carried out, since this treatment also kills antagonistic organisms. In addition, there is no risk of toxicity build-up in the soil which can occur with full sterilisation. Once the soil mix has been treated, ensure that it does not become recontamined by keeping it covered and in a clean area until used. The containers (either pots or trays) used for propagation need to be clean — preferably new — but if being re-used they should be thoroughly washed and disinfected. Suitable methods of disinfection include air-steaming, methyl bromide fumigation, hypochlorite dipping and, in some cases, formalin and copper naphthenate swabbing or dipping.

(c) **The water used for misting and irrigation.** As a general rule water taken from the mains or from deep bores will be free of pathogens. However, water which has been in contact with surface soil such as in dams, rivers, creeks etc. can be contami-

nated with pathogens such as *Pythium* spp., *Phytophthora* spp. and nematodes. The water can be freed of these pathogens by several methods, including chlorination, filtration and UV sterilisation.

The filtration method appears to be the safest and most reliable. Remember to ensure that hose nozzles etc. are not left in contact with soil; they can pick up and transmit contamination. Misting does not encourage disease build-up and spread of fungal disease, probably because the leaves are subject to continued wetting, washing off spores before they can germinate and penetrate. However, it is important that cuttings are free of disease when misting is used because it will encourage development of disease already present. Obviously it is also essential that water used for misting be clean, both biologically and chemically.

(d) **The environment in which plants are grown.** This, of course, includes the actual glasshouse or frame being used as well as the temperature and humidity at which it is kept. The walls, roof, benches and floors of these houses must be cleaned down regularly, sprayed, swabbed or fumigated with disinfectant which will kill spores lodging in crevices as well as on the surface. Copper naphthenate, hypochlorite and formalin are suitable for benches and floors.

If the house is well ventilated and plants are adequately spaced, disease can be avoided or appreciably reduced because leaf surfaces do not remain wet for very long so reducing the chance of infection if spores do land on them.

DISEASES WHICH ARE OF MAJOR IMPORTANCE IN PROPAGATION AND SUBSEQUENT GROWING OF PLANTS

(1) *Bacterial diseases*, like black rot of crucifers and bacterial canker of tomatoes.

These are seed-borne and can be controlled by heat treatment, as mentioned earlier.

(2) *Pythium* and *Phytophthora*

These are important in causing damping off, root rots, collar rots, cutting rot and in some plants, *Phytophthora* can cause leaf and stem blights, e.g. in *Philodendron* and *Dieffenbachia*. Care in treatment of mixes, water and propagation material used is vitally important in controlling these diseases. If subsequent contamination occurs, fungicidal drenches will reduce losses.

Suitable chemicals are Terrazole, Le-San DX or one of the newer chemicals shortly to be made available such as Ridomil, Fungarid, LS 74-783 (Alliette) and Previcur.

(3) *Rhizoctonia* spp.

Although this fungus is important in causing disease in its own right, it is also often associated with *Pythium* in causing damping off. It is active all the year round but develops best in warm moist conditions. It has a very wide host range and can attack all types of plant tissue. Adequate spacing of plants, increase in ventilation and reduction in watering will assist in control.

Suitable chemical drenches include quintozene (PCNB, Folosan, Terrachlor, Brassicol, Lanes Purasoil), benzimidazoles (Benlate, Topsin) and when available iprodione (Rovral).

(4) *Botrytis* spp. (Grey mould)

This develops rapidly where dead or damaged leaves or other tissue are left in pots and, particularly, if plants are closely spaced so reducing aeration. It is usually worse in the cooler periods of the year. This fungus can only attack through dead or dying tissues, but can develop rapidly once infection has occurred, causing a wet softish rot. Control can be achieved by improving spacing of the plants, improving ventilation and removal of dead tissue.

Suitable spray chemicals are the benzimidazoles, captan, dichloran (Allisan), and when available iprodione (Rovral).

(5) *Peronospora* and other downy mildews

These are mainly of importance to the seedling growers — particularly in the crucifers (cabbage, cauliflower, stocks etc.), onions and lettuce. The disease causes yellowing of the leaves often associated with a bluish haze caused by the sporing of the fungus. These diseases are very difficult to control unless preventive sprays are applied and plants kept as dry and warm as possible. Seed treatment is important.

Suitable sprays are dithiocarbamates like zineb and maneb, mezineb (Antracol), captafol (Difolatan) and when available the newer chemicals, Fongarid, Ridomil, LS 74-783 and Previcur.

(6) *Oidium* and other powderly mildews

These fungi do not need free moisture on the leaves to cause infection. Shading is very conducive to disease development. The fungus spores prolifically on the leaf surface, producing a dense white powdery layer.

Control can be helped by good aeration and spacing to avoid shading, and spraying with benzimidazoles, sulphur compounds, dinocap (Karathane), pyrazophos (Afugan), oxythioquinox (Morestan), binapacryl (Morocide) or one of the newer chemicals soon to be availabe, namely Bayleton, bupirimate (Nimrod).

(7) Leaf spots caused by various fungi such as *Alternaria* and *Cercospora*

These fungi develop leaf spots and sometimes stem rots. The colour and form of the spotting varies with the particular fungus.

Control is usually by the application of fungicides such as the dithiocarbamates (zineb and maneb), captan, captafol, mezineb, benzimidazoles and chlorothalonil (Daconil and Bravo). Where the benzimidazole fungicides are used, it is unwise to use these chemicals solely because fungi can develop resistance to them. They should be used either mixed with or alternated with another suitable unrelated fungicide.

(8) *Aphelenchoides* spp. (Leaf nematodes, e.g. in ferns)

Blackish patches develop between the leaf veins. Control can be achieved with insecticides such as Metasystox.

(9) Tobacco Mosaic Virus on tomatoes

This disease is seedborne. Seed should be treated with 1% trisodium orthophosphate for 15 minutes and then with 0.5% sodium hypochlorite for 30 minutes.

It is quite possible that in the future much of the sterilisation of potting mixes now carried out may be unnecessary. A considerable amount of work is being carried out on antagonists to various pathogens; some look quite promising. Certain mixes containing types of organic material, like composted bark for example, have been shown to develop antagonism to some fungi, e.g. *Phytophthora cinnamomi* and *Fusarium*. The reasons for this are not yet properly evaluated.

In Western Australia many nurserymen are incorporating jarrah (*Eucalyptus marginata*) sawdust in their potting mixes. Again, we have noted that there appears to be a reduction in disease development. This is only circumstantial evidence. Unfortunately, it has not been possible to conduct experimental work to evaluate this as yet, but it will make an interesting project for the future.

These forms of possible biological control show promise of future success. The main difficulty is that it is unlikely that antagonists effective on all types of pathogens will be found — usually they are effective on one only.

NOTE – Fungicides mentioned in this paper should only be used if registered for the purpose in your state or country. I have included fungicides which have shown promise experimentally and will probably be registered.

PRODUCTION OF PECAN TREES

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The pecan nut (*Carya illinoensis*) is a close relative of the walnut; both are members of the family Juglandaceae. The pecan is native to the eastern half of the U.S.A., embracing the states of Illinois down to Texas and east to the Atlantic Ocean. Since the European settlers were first introduced to it by the Indians, the pecan has enjoyed a tremendous popularity in the U.S.A. Huge pecan groves have been established in California, Texas and New Mexico. Some forty years ago trial plots were planted in Australia and in a number of other countries which have a suitable climate.

The pecan tree can produce fruit for over 100 years and it can grow to an enormous size. To illustrate, there are old orchards in the U.S.A. where four trees occupy a full acre. The trend there and elsewhere is to select or breed cultivars and match them with rootstocks which will produce medium sized trees, rather than the giants of the past. Of course, as with all relatively uncommon crops such as avocadoes, macadamias, pecans etc., our knowledge of cultivar performance relative to areas or regions is confused, to say the least.

Flowering. Separate male and female flowers are produced on each tree. Male flowers, which appear as catkins, are formed in buds in one season and complete their development and shed pollen during the early season's growth the following spring. Female flowers are produced on new season's growth. In most pecan cultivars, pollen release and stigma receptiveness do not coincide. Therefore a plantation needs to be interplanted with pollinators.

Seed Treatment. Seed is obtained from a well run orchard in June (early winter) and stored at an even temperature until August (late winter). We do not store fresh seed in plastic bags as it may turn moldy. Hessian (burlap) sacks are best. We soak the seed for 48 hours, by stacking bags of it in a tank; weighting them down as they are extremely buoyant, and then letting water into the tank.

Preparation of Seed Beds. Two months prior to seeding, an area of sandy loam soil designated for outdoor seed beds is ripped to the depth of 18″, graded for runoff, then fumigated with methyl bromide, about 750g per $10m^2$.

Planting and Care of Rootstocks. Seeds are planted into long drills by mid-August. Seedlings set out in rows are easier to keep clean. The main advantage lies in the use of a mechan-

ical digger when seedlings are dug and prepared for planting out into the field nursery. After seeding, the bed is rolled down, then covered by two inches of potting medium which is also rolled down. After the beds are soaked, they are completely covered with mulching film (40 μm or 0.0015″) held down by a thin layer of soil spread evenly over the film. This mulching plastic provides the seed with an even temperature and moisture for three weeks. This is usually long enough to start even germination. The mulching film is then removed and 60% Sarlon frames are put up to prevent the emerging seedlings from being scorched.

We have learnt from past experience that we must take all these precautions in our climate. Our temperature fluctuations are enormous, especially in winter. In August, we can go from 0°C at night to 35°C during the day. The Sarlon frames are removed as soon as the seedlings have formed their own leaf canopy. Seedlings are transplanted into the open field nursery the following winter in July.

Open Field Planting. Prior to planting, the field is treated with Treflan, a pre-emergent weedicide which remains effective for about six months. We apply Treflan every six months on all field nurserystock and obtain an excellent control of grasses.

Seedlings are precision planted along a spacer line 96 cm (3′2″) × 20 cm (8″). This spacing allows adequate growing room for each plant and all our row crop implements and high clearance tractors are set to this spacing. These seedlings stay here for three years, first as seedlings and then as grafted plants.

Preparation of Grafting Wood. In any nursery a stock patch of mother plants is essential, unless, of course, the nursery is near a fruit growing area and grafting wood can be drawn from clean orchards. Our nursery is completely isolated from fruit growing areas by hundreds of miles so we are compelled to grown our own mother fruiting plants. There is a distinct advantage in this as diseases prevalent in some orchards cannot easily be carried into the nursery. Grafting scions (young mature branches) are cut from pecan mother plants at the end of July (mid-winter). Vigorous mature growth makes the best scion wood. The tips of these scions, although mature, are discarded because of the soft pithy condition. Wood with large pithy centres is also useless.

Since the wood cannot be used immediately it is prepared for cold storage. The wood is cut to a suitable length and sorted into sizes; the large sticks for patch budding and the smaller sticks for whip-grafting. Correct wrapping for cold storage is of the utmost importance as the wood cannot be left to dry out, nor can it be stored too wet. After many trials, we found that

newspaper is by far the best packing material available. Moss, peat, or sawdust are not satisfactory for wrapping of scion wood. Eye patches release much better and whip-graft scions give better takes when wrapped in moist paper. Finally plastic is wrapped around the lot with a label on the inside and a label on the outside, giving cultivar and origin. Wood may be stored safety for up to 12 months at 1°C to 4°C (35°F to 39°F). Preferably hold the temperature as near freezing as possible.

Grafting. The whip and tongue method of grafting pecans is being used in our nursery. Established seedlings in the open field require very little preparation. They are merely cut off some 8″ above the ground prior to grafting and thoroughly rubbed clean, as any dirt will dull the knife; one cannot work well with a blunt knife, as pecan wood is very hard.

Grafting scions are taken out of cold storage as required. We usually work in teams of two persons, a propagator who is experienced in a particular grafting method and his tyer, usually a junior or casual worker. The whip and tongue method is used so that the graft stays in place until it is tied with one inch wide plastic tape. As pecan wood is so hard it is very difficult to establish a safe union. After tying with plastic the top of the scion is sealed with Colgraft (a bitumen substance).

The timing of grafting or budding, as in all propagation, is of the utmost importance. Complete records should be kept from year to year to avoid mistakes when planning a major job like grafting pecans.

Budding. As pecans do not accept T buds, but will accept patch buds this method is used. Patch budding is faster than grafting, but unfortunately, it will not produce a tree as fast. A double bladed knife is used for patch budding. A bark patch about 1″ long and ¾″ wide is removed from the rootstock and discarded. A patch of similar size, with an active bud in the centre, is removed from the grafting wood and placed onto the rootstock. The whole thing is then tied with a plastic band. The method is relatively simple.

Propagation using dormant bud-wood requires more detailed attention and two approaches are possible. The first and more popular method is to cut fresh but mature wood directly from the mother plant and use it immediately for patch budding. Any delay or exposure will cause dehydration and the wood will not release the bud patch. Patches which are forced off or scraped off will not take. Timing is critical and it varies with the cultivar. In principle, budwood fresh from mother plants must be mature enough so that patches can form callus in their own right. If the wood is taken too young the patches will simply shrivel up. If the wood is taken too late (mother

plants approaching dormancy) the wood will not release suitable patches. The correct time for this method is during summer.

In the second method, cold-stored, fully dormant wood which was cut from mother plants in mid-winter is used. Since the rootstocks begin to release their bark in mid-spring there is no point in applying this method sooner as everything depends upon a free release of bark from the stock and from budwood. Timing is not as critical here as budwood can be prepared at will any time during their peak growing period from November to March. After March pecans begin to enter their dormant stage.

Budwood is removed from cold storage and exposed to moisture and warmth. This gets the sap moving which, in turn, allows us to remove the bud patch for budding. There are several methods which can be used with varying success. Wood is buried in sand or in peat or wrapped in paper or placed under mist in the propagation house, all of which can cause all sorts of problems. The trouble is that while you are getting the sap moving, you also get the buds underway. Advanced bud-growth is not suitable for budding, so the trick is to get the sap moving for easy bark removal but hold bud growth back. To achieve the correct conditions, we find that evaporative cooling gives good results. Dormant wood is stood in 1 in. of water and hessian is draped over the wood with the ends of the hessian in the water. Water draws up the hessian keeping the budwood moist and cool by evaporative cooling. The wood is ready for budding within six days. When it is ready it must be used without delay because this type of wood also suffers from dehydration if exposed to dry air after this treatment.

Post Graft Treatment. Before we graft a position plan is made for each cultivar; all cultivars are always positioned in alphabetical order. If a stock book is lost or mislaid, cultivars are easily found by deduction. In all of our propagation of plants, we try to give ourselves two chances to succeed. In pecans, we use the whip graft in September and October and, if a large percentage fails due to severe climatic conditions or shortage of suitable grafting wood, we can fall back onto patch budding as soon as grafting failures are evident.

The usual post-graft treatments are applied; de-suckering, trimming and finally crowning.

The trees are ready in July. We use power digging by hitching two high clearance tractors one in front of the other. The heavier tractor has a digging blade with depth control attached to its three point linkage. Pecans have a strong carrot-like tap root which we sever about twenty inches below ground level. After digging, the trees are graded into three sizes: large,

medium and small. They are heeled into a sheltered area prior to dispatch.

PROPAGATION OF BEDDING PLANTS IN SOILESS MEDIA

GEORGE O. GAY

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Gosnells, Western Australia

When bedding plant production commenced in Western Australia early this century soil used for seedling trays was basically composted plant material, the source being straw, weeds, expended plant material, stable manure and straw, or any decayed plant material available. As the demand for larger volumes of growing media outstripped the supply, various mixtures of loam, sand, cinders and stable manure were used.

The acceptance of the U.C. system for container grown plants saw, for the first time, a soil mix with actual measured amounts of the elements required for plant growth. Spagnum peat and fine sand provided the basis of inert material. Problems continued with the volume of sand used. The local sand supply was abundant although the particle sizes were considered small. Variable pH meant a close watch was needed on this. The weight factor was a problem in loading up mixing machines, conveyors, conveyances and caused increased delivery costs.

In recent years, because of the high cost of spagnum peat, a substitute lightweight material was searched for. Local sedge peats were available but did not prove a satisfactory substitute for spagnum peat in seed raising mixtures. After a great deal of trial and error, our hardwood sawdust showed great promise. Firstly, it is low cost; it is plentiful, very lightweight, low pH and contains no growth affecting toxins. It leaches well and has a moderating affect on temperature. Hardwood sawdust appears to inhibit root destroying pathogens that are problems with peat and fine sand mixtures.

As a result of a visit to Holland during 1977 I decided to experiment with a sand-free medium, using a mixture of ⅔ jarrah (*Eucalyptus marginata*) or wandoo sawdust and ⅓ medium-grade spagnum peat of German origin. Using 6 lbs. of urea formaldehyde or I.B.D.U. to each cubic yard of sawdust to control the consumption of nitrogen by the slowly composting process we were able to stabilize the situation and add the balance of elements required for plant growth. Success in the field was immediate. The only heavyweight component was water.

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Gosnells, Western Australia

When bedding plant production commenced in Western Australia early this century soil used for seedling trays was basically composted plant material, the source being straw, weeds, expended plant material, stable manure and straw, or any decayed plant material available. As the demand for larger volumes of growing media outstripped the supply, various mixtures of loam, sand, cinders and stable manure were used.

The acceptance of the U.C. system for container grown plants saw, for the first time, a soil mix with actual measured amounts of the elements required for plant growth. Spagnum peat and fine sand provided the basis of inert material. Problems continued with the volume of sand used. The local sand supply was abundant although the particle sizes were considered small. Variable pH meant a close watch was needed on this. The weight factor was a problem in loading up mixing machines, conveyors, conveyances and caused increased delivery costs.

In recent years, because of the high cost of spagnum peat, a substitute lightweight material was searched for. Local sedge peats were available but did not prove a satisfactory substitute for spagnum peat in seed raising mixtures. After a great deal of trial and error, our hardwood sawdust showed great promise. Firstly, it is low cost; it is plentiful, very lightweight, low pH and contains no growth affecting toxins. It leaches well and has a moderating affect on temperature. Hardwood sawdust appears to inhibit root destroying pathogens that are problems with peat and fine sand mixtures.

As a result of a visit to Holland during 1977 I decided to experiment with a sand-free medium, using a mixture of ⅔ jarrah (*Eucalyptus marginata*) or wandoo sawdust and ⅓ medium-grade spagnum peat of German origin. Using 6 lbs. of urea formaldehyde or I.B.D.U. to each cubic yard of sawdust to control the consumption of nitrogen by the slowly composting process we were able to stabilize the situation and add the balance of elements required for plant growth. Success in the field was immediate. The only heavyweight component was water.

Because the sand was deleted completely we had removed all of the abrasive material, stabilised the pH and taken the weight load from working personnel, resulting in greater expediency in the production area. With the advent of polystyrene-foam trays, a box of seedlings has reduced in weight from 5kg to 1kg. For long distance freighting, wooden crates have been substituted with waxed cartons, further reducing labour and freight costs.

With the introduction of various type cell packs and mini punnets I believe that a deal of scope is evident for bedding plant growers to propagate many seed lines for the container growers. There is evidence overseas of bedding plant growers producing started plants of cyclamen, F_1 geraniums, begonias, asparagus ferns and similar plants at attractive prices, in keeping with their mass production and seed raising facilities. Plants could be raised on a contract basis incorporating a forward ordering system. My own nursery operates this system in a limited way.

CAPILLARY WATERING OF CONTAINER-GROWN PLANTS

M. RICHARDS

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The importance of using the best possible techniques for watering plants is not always recognised in commercial nurseries, largely because plants have a very considerable ability to survive less than ideal conditions, without showing visible signs of the effects of those conditions. It is only when such plants are compared with plants grown under better conditions that the full effects of poor watering techniques can be appreciated.

Plants use very large quantities of water for growth, yet comparatively little of this water is retained in the plant. In the lower surface of the leaves are the stomata; during daylight hours these are open to permit air to enter the leaf. Inside the leaf the air comes into contact with cells whose walls are bathed with water; carbon-dioxide is absorbed into this water, and passes into the cells, where it is used in photosynthesis. At the same time, water is evaporated from the cell wall and carried outside the leaf in the air current. This process, called transpiration, is an essential part of the uptake of CO_2 by the plant, but it results in a steady loss of water from the plant.

Normally the water lost from the leaves by transpiration is replaced with water which is taken up by the roots. Provided

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that the roots can absorb all of the water which is being, or could be, lost by transpiration, all is well. If, however, the roots are unable to supply all the water which could be transpired by the leaves several things happen; the cell walls become less wet, less CO_2 can be absorbed, the rate of photosynthesis slows down and the rate of growth of the plant is reduced. This reduction in growth cannot be detected by any visible signs.

If the rate of water uptake by the roots is further reduced other changes start to occur. The stomata close and the plants start to show signs of visible water stress, such as changes in colour, slight loss of turgidity, etc. and observant growers will apply water. By this time it is too late to maintain maximum growth.

In the container, roots may encounter problems in absorbing water. Water in the growing medium exists as a film in and on the particles of the medium, held there by tension. As the amount of water present in the medium is reduced, the tension by which is is held increases, so that it becomes increasingly difficult for the plant to secure all of the water which it could use.

The work of the roots is further complicated by the presence of substances dissolved in the water. These dissolved substances, including nutrients, create further pressure (osmotic pressure) against which the plant must work to absorb moisture. If we are to provide the high levels of nutrients which the plant can use we must be especially careful that they do not restrict growth by restricting water supply to the plant. The only way in which this can be done is to ensure that there is a large quantity of water present in the root zone to maintain a dilute solution of nutrients.

We must also bear in mind that the roots generally extract water from the root zone more rapidly than they extract nutrients, therefore as water is taken from the growing medium the salt solution becomes more concentrated creating artificial drought.

Bearing these points in mind, the best technique for watering plants can be very easily described. Provide a growing medium with a high water holding capacity. After potting, water the medium until it is holding all of the water it can retail against drainage i.e. it is at container capacity. From then on, as one drop of water is removed by the plant, it should be replaced, so that the medium is maintained at container capacity all of the time.

Capillary watering provides the most practical means by which this can be done. Basically it consists of standing the containers onto a material which provides a reservoir of water.

Under glasshouse conditions, this generally consists of an unsealed bench, on top of which is placed a layer of felt. The felt is kept wet by application of water once or twice a day.

The plants are watered when they are stood upon the felt, this establishes a column of water from the growing medium into the felt. As tension is increased on the water in the growing medium, water is drawn from the felt into the medium to maintain container capacity.

Outdoors, beds of fine sand, over plastic film, have been used to achieve the same results. The sand must be a type which can hold enough water to supply the plants.

Provided the benches or sand beds are not sealed, water can be applied easily without sophisticated controls. We use a time clock to operate a solenoid valve and apply water for 20 minutes, night and morning in summer, once per day in winter. Any excess, above what the reservoir will hold, simply drains away.

When using capillary watering it must be remembered that the normal water flow is reversed so that there can be a build up of salts in the container. To overcome this problem, we water from above the container once per week, using enough water to flush any build up of salts out of the container.

Capillary watering has been shown to give considerable increases in growth when compared with conventional watering techniques. Many nurserymen remain convinced that their existing watering techniques are perfectly adequate. If you are in this group, perhaps you owe it to yourself to try capillary watering on a small area of your nursery.

CLONAL PROPAGATION OF WOODY PLANTS USING TISSUE CULTURE, WITH SPECIAL REFERENCE TO APPLES

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Abstract. A critical review of the published papers on plantlet regeneration of woody species shows that very few reported systems are ideal for clonal propagation. Some depend on use of embryonic, juvenile and endosperm tissues, or on tissues such as the nucellus of *Citrus* that show unusual properties. In others plantlets regenerated from callus have poor vascular connection between roots and shoots and die on transplanting to pots.

Culture methods that induce multiple shoot production from excised shoot tips or axillary buds, and the subsequent rooting of these shoots without the involvement of excessive callus offer greatest potential. One such

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Culture methods that induce multiple shoot production from excised shoot tips or axillary buds, and the subsequent rooting of these shoots without the involvement of excessive callus offer greatest potential. One such

method, that developed by Jones and coworkers (37) for apple, is described and is being applied to apple rootstocks in quarantine in Western Australia. The question of the role of the phenolic compound phloroglucinol is discussed.

INTRODUCTION

Relatively simple methods of micropropagation have been developed for many herbaceous plants and these techniques are suitable for commercial application (25,50,53). However there are few reports of success for woody angiosperms — trees, shurbs, creepers and vines.

Assessment of the desirable attributes of woody plants usually cannot be made until the plant is mature. In some species, by the time the plant reaches this stage of growth, vegetative propagation by conventional methods is slow or difficult, if not impossible. Thus propagation using *in vitro* methods would be most useful. It is possible to assemble an impressive list of woody species for which there are reports of organogenesis or embryogenesis *in vitro* (Table 1). However, when one examines the cited papers in detail it becomes clear that in many cases the tissues or methods used are not suitable for large scale clonal propagation. Also, there are very few examples in which the plantlets survive transfer from the culture tubes to pots.

Embryo culture of woody species is possible, but examples are not included in Table 1, for while embryos raised in this way may be valuable hybrids that would otherwise abort, the method does not result in clonal propagation.

Several of the examples in Table 1, e.g. *Ilex*, *Prunus*, *Ulmus* and *Azadirachta* involve regeneration of plantlets from callused embryos or seedling tissues. While such cultures may give us some clues on how to handle the species *in vitro*, the regeneration *in vitro* may be much easier when material is derived from seedling or juvenile explants than that from explants of mature plants (50).

Similarly, although endosperm cultures may give rise to plantlets in woody species of the Loranthaceae and Santalaceae, the triploidy or higher ploidy of this tissue results in undesirable polyploid plants.

Cultures of nucellar tissue of *Citrus* and related genera have been used successfully for plantlet regeneration, but unfortunately the development embryoids from nucellar tissue has not yet been induced in species outside the Rutaceae.

Meristem cultures may provide an efficient way of eliminating viruses, as in *Musa*, *Manihot* and *Ribes* (Table 1) but generally yield only one plantlet per explant and are time consuming to set up.

The systems most useful for propagation utilize relatively large explants, which in culture yield many plantlets per explant. A high yield per explant can be achieved in two ways. Either the explant can be induced to form a callus on which shoots and roots or embryoids are subsequently differentiated or, alternatively, the buds on the explants can be induced to proliferate with little or no callusing, and the multiple shoots then excised and individually rooted.

The first possibility, involving the use of callus, has been successful in several cases, *Coffea*, *Citrus* and *Populus*, (Table 1), but it has several disadvantages. Cells proliferating to form a callus frequently undergo cytological changes. These may result in abnormal plants being regenerated and probably contribute to a decline in regeneration potential over time, which is usually observed. A further difficulty is that, although roots and shoots may arise from the same piece of callus, there may be little or no vascular connection between them and this has predictably disastrous consequences for the young plant on pricking out to pots.

The culture methods that utilize large explants and result in numerous rooted shoots offer most potential for clonal propagation. The species for which such techniques have been developed include *Bougainvillea*, *Rubus*, *Eucalyptus* and *Malus* (Table 1).

The system of culturing apple shoot tips has been developed by O.P. Jones and colleagues at East Malling Research Station. I have investigated the use of their methods for propagation of apple rootstocks of interest to Western Australian growers. New material can be brought into Australia through quarantine in very limited amounts, and the methods of rapidly multiplying material in tissue cultures can be exploited while the "parent" plant is still held in quarantine. Thus when the line is cleared from quarantine, many plants are available to growers.

PROBLEMS IN ESTABLISHING APPLE TISSUE AND ORGAN CULTURES

1. Sterilization. Apple shoots are killed or damaged by common surface sterilants, and a 2-step sterilization procedure is necessary (30,37). Shoots (1.5 - 2 cm long) bearing small leaves are first dipped into wetting agent (0.01% Tween 80) then in sodium hypochlorite (0.14%) for 1 min, then washed 3 times in sterile water. They are placed on culture medium overnight, and next day they can tolerate 40 mins. in 0.4% sodium hypochlorite. Using this sterilization method, I obtain around 50% uncontaminated shoots, though different batches give 0 - 100% uncontaminated. Bud material is more resistant to

Table 1. Woody Trees, Shrubs, Climbers, Vines and Parasites which regenerate shoots and/or roots in culture.

Species	Explant	Regeneration	Survival After Transfer to Soil	Reference
MONOCOTYLEDONS				
MUSACEAE				
Musa sapientum	Meristem	shoots, roots	Yes	5
M. acuminata (Syn., *M. cavendishii*	Meristem	shoots	—	50
PALMAE				
Elaeis guineensis	Meristem, Embryo	callus, embryoids leaves, roots	?	56,57
DICOTYLEDONS				
ACTINIDEACEAE				
Actinidia chinensis	stem and shoots	shoots	Yes	24
AQUIFOLIACEAE				
Ilex aquifolium	embryo	embryoids from cotyledons — plantlets	No	26
EUPHORBIACEAE				
Hevea brasiliensis		embryos, shoots	?	53
Jatropha panduraefolia		callus, shoots, roots	No	64
Manihot esculentum	stem, tip, meristem	(callus) shoots, roots	Yes	40
Putranjiva roxburghii	endosperm	callus — shoots, roots	No	65
Ricinus communis	endosperm	callus — embryoids	No	60
GROSSULARIACEAE				
Ribes grossularia	meristem	single shoot	Yes	35
LEGUMINOSAE				
Acacia koa	stem	callus — shoots, root	?	63

Table 1. (Continued)

Species	Explant	Regeneration	Survival After Transfer to Soil	Reference
LORANTHACEAE				
Dendrophthoe falcata	endosperm	callus — shoots, haustoria	No	52
Nuytsia floribunda	embryo	callus — shoots, roots	No.	51
Scurrula pulverulenta	endosperm	callus — shoots, haustoria	No	6
Taxillus vestitus	endosperm	callus — shoots, haustoria	No	52
T. cuneatus	endosperm	callus — shoots, haustoria	No	52
MELIACEAE				
Azadirachta indica	mature embryo	callus — shoots, roots rare	No	59
MORACEAE				
Broussonetia kazinoki	stem	callus, shoots or roots	No	53
Morus alba		callus — shoots		21
MYRTACEAE				
Eucalyptus bancroftii	seedling nodal stem pieces	shoots, roots		13,20
E. citriodora	lignotubes	(callus)shoots, roots	?	2
E. deglupta	seedling nodal stem pieces	shoots, roots		13

Table 1. (Continued)

Species	Explant	Regeneration	Survival After Transfer to Soil	Reference
MYRTACEAE (Continued)				
E. ficifolia	stem tips nodal stem pieces, from mature trees	shoots, roots multiple shoots	Yes	19
E. grandis	nodal stem pieces from seedling and mature trees	shoots, roots	Yes	13,14,20
NYCTAGINACEAE				
Bougainvillea glabra	stem tips	shoot proliferation from callused base	Yes	12
ROSACEAE				
Malus sylvestris	endosperm	callus shoots, roots	—	47
	seedling shoot tips	(callus)shoot proliferation, roots	No	1
	mature plant shoot tips	(callus)shoot proliferation roots	Yes	3,32,37
	embryo	(callus) shoot proliferation roots	—	48
Prunus dulcis (Syn.: *P. amygdalis*)	seedling	callus — shoots, roots	No	43
Pyrus communis	embryo	(callus) shoots, roots	—	48

Table 1. (Continued)

Species	Explant	Regeneration	Survival After Transfer to Soil	Reference
ROSACEAE (Continued)				
Rosa multiflora	meristem, stem tip	shoots, roots	?	17
Rubus fruiticosus	stem tip	shoot proliferation, roots	Yes	8
RUBIACEAE				
Coffea arabica	stem	callus — shoots	No	46,62
C. canephora	stem	callus — embryoids plantlets	Yes	46,66
RUTACEAE				
Citrus aurantifolia	ovules nucellus	callus-embryoids callus - shoots roots	No	45
C. maximum (Syn.: *C. grandis*)	stem, leaf	callus - shoots roots	Yes	11
C. microcarpa	ovules nucellus	callus-embryoid plantlets	No	58
C. paradisi	ovules nucellus	callus-embryoids	Yes	42
C. sinensis	nucellus	callus-embryoids plantlets	Yes	9,42
	stem, leaf	callus — shoots shoot proliferation, roots	Yes	11
Citrus (other species)	nucellus or seedling stem	embryoids	—	10,50

Table 1. (Continued)

Species	Explant	Regeneration	Survival After Transfer to Soil	Reference
RUTACEAE (Continued)				
Eremocitrus glauca	nucellus	embryoids	—	50
Fortunella crassifolia	nucellus	embryoids	—	50
Fortunella japonica (Syn.: *C. mandurensis*	seedling stem	callus - shoots roots	Yes	22
Microcitrus australasica	nucellus	embryoids	—	50
Microcitrus warburgiana	nucellus	embryoids	—	50
Poncirus trifoliata	nucellus	embryoids	—	50
SALICACEAE				
Populus tremuloides	stem sections	callus - shoots roots	Yes	72,73
P. trichocarpa	catkin primordia	callus - female structures	No	4
		callus - shoots, roots		
P. nigra		callus — shoots, - roots (never together)	No	21
	internodes	callus - shoots, roots	No	69
SANTALACEAE				
Exocarpus cupressiformis	endosperm	callus - shoots	No	38
Leptomeria acida	endosperm	callus - shoots	No	38
ULMACEAE				
Ulmus americana	seedling	callus, shoots	No	15

sterilizing than are growing shoots. The outer scales are removed and stem segments bearing buds are given 15 minutes in 0.5% sodium hypochlorite and then washed three times (16). However, using the culture methods of Jones *et al.* (37) I have found that explants of dormant axillary buds on short lengths of stem are satisfactory, but growth over the first five weeks or so is far slower than for explants of growing shoots.

2. Browning of explants. Apple tissues frequently turn brown in culture due to oxidation of polyphenols. This can be overcome by the use of polyvinylpyrrolidine (PVP) (70,29) and after 4 - 8 weeks in culture, PVP can be omitted when subculturing. In other species, various other anti-oxidants have been used to prevent browning of tissue and media: [*Eucalyptus* (19) *Coffea* (46)], or, an expensive alternative, the tissue has been changed to new media each day: *Rubus* (8). The browning of apple shoot tips sterilized by the 2-step method of Jones (37) is negligible.

3. Regeneration of shoots. There are several reports in which apple callus or organ cultures have produced sporadic shoots but in which rooting was difficult (16,18,31,47,48,70). The discovery by Jones and colleagues (32,33,37) of the effect of phloroglucinol on shoot proliferation and rooting in culture has made micropropagation of applies a viable proposition.

DEVELOPMENT OF THE METHOD OF PROPAGATION

Jones was examining the growth promoting substances found in apple xylem sap, and detected a growth promoting substance whose effect was enhanced by IAA at concentrations too low for the IAA to be effective by itself (36). This growth promoting substance had characteristics of a phenolic, phloroglucinol. Phloroglucinol or phloretic acid (2 breakdown products of phloridzin) in association with auxin were found to more than double the proportion of 'M 7' apple rootstock which rooted *in vitro* (33). Phloridzin itself and other structurally related compounds (caffeic acid, catechol, pyrogallol) were ineffective.

Jones (32) then reported an impressive proliferation of shoots in cultured 'M7' and 'M26' apple shoot tips when cultured with benzylaminopurine, gibberellin, auxin and phloroglucinol or phloridzin. The new shoots grow from the axillary buds of the original explant; they do not arise *de novo* from callus. After some 12 weeks in culture up to 38 shoots 2-5 cm long arise from each single shoot.

In a paper in 1977, Jones *et al.* combined the rooting and shoot proliferation methods they had devised; theoretically, the following method can yield 60,000 shoots from a single shoot

tip of some lines in 8 months (37). Shoot tips 1.5 - 2 cm long are cultured for 4 weeks in 10 ml medium, after which each tip has produced 2 - 5 shoots. Single shoots are transferred to 125 ml medium in 250 ml flask for further 8 weeks, by when each shoot has produced 2 - 42 shoots, 2 - 5 cm long. Shoots are cut off and placed in rooting medium, and within 6 weeks 97% of shoots have produced roots. Rooted shoots are transferred to glasshouse pots with 85% survival.

I have been using this method with trivial alterations — I use 100 ml of media in screw cap bottles rather than the 250 ml flasks. Also I find a forest of shoots difficult to handle so I prefer to sub-culture shoots after 4 weeks, when each clump has 6 - 10 shoots. Mullins *et al.* (49) have also used much the same technique as Jones except that they have attempted to induce roots on shoots under non-sterile conditions.

Rootstocks I am using are 'MM 104' and 'M 109', in which shoot proliferation is similar to that in the stocks 'M 26' and 'M 7' used by Jones. Rooting is only successful for 50% of shoots in my cultures. Other lines, e.g. 'M 106' and 'Merton 793', do not proliferate as readily as 'M 26', and preliminary experiments have not yet revealed an appropriate combination of hormones.

Jones (37) has reported that 'M 27' behaves in culture as well as 'M 26'. Interestingly, they report that 'Pixy' plum rootstock and 'F12/1' cherry rootstock respond well to media containing phlorglucinol, though alteration of the cytokinin level may be required. I am attempting to use similar methods to propagate cherry lines in quarantine in Western Australia.

Effects of phloridzin, phloroglucinol and phloretic acid, *in vivo* and *in vitro*. Phloridzin is a phenolic restricted to *Malus* despite some early erroneous reports of its occurrence in other species of Rosaceae (28,71). In apples it occurs in bark, root, fruit skin, seed coat, embryo and leaves, where it may rise to 3-7% dry weight (32). Its actual role in *Malus* is something of a mystery as it seems not to be involved in resistance to disease as was earlier suggested (27). Its concentration is not connected with seasonal growth and is much the same in both standard and dwarfing rootstocks (28,55) though callus from a dwarfing rootstock, 'EM IX', was found to contain more phenolics than callus from a semistandard stock, 'EM XIII' (44). Its presence in seed coats and embryos is thought to be only indirectly related to after-ripening and seed dormancy (7).

In apple plants two breakdown products of phloridzin, phloroglucinol and phloretic acid can be detected in the xylem sap. In the presence of auxin, both phloroglucinol and phloretic acid markedly increase rooting of shoots while phloridzin itself is ineffective (33). For other species, some phenolics enhance

the effect of auxin on rooting and their action was attributed to suppression of auxin oxidation (41). This does not appear to be the case for apple rooting (33).

In cultured apple shoots (again in the presence of auxin) both phloridzin and phloroglucinol stimulate shoot proliferation, but closely related compounds such as caffeic acid, catechol and pyrogallol are ineffective. Also, the phenolics found in other genera, such as arbutin in *Pyrus*, or salicin in *Populus*, do not have a stimulatory effect on *Malus*. Arbutin does, however, cause a growth increase in pear cultures (32,33,-34). Thus Jones has suggested that the effect of the glycoside may be to promote growth only in the tissues in which it occurs naturally. This does not seem to be the case, however, as while phloridzin is indeed inhibitory for many plant and animal systems (23,39,61,67,68), it is also reported to have a stimulatory effect on photosynthesis in genera other than *Malus* (see reference 23). The effect of phloroglucinol too, is not confined to *Malus* as, in the presence of auxin, it promotes shoot proliferation in cherries and plums and oat mesocotyl growth (37,54).

An investigation of the mechanism of action of phloridzin and phloroglucinol may be interest *per se*, as well as possibly giving further information on the mechanism of sucrose uptake and utilization by *in vitro* plant cultures, and the role of auxin.

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TISSUE CULTURE PROPAGATION OF *EUCALYPTUS FICIFOLIA* F. MUELL.

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Abstract. Cultures of seedling material on a rooting-medium develop one type of root system in the absence of riboflavin and another type in the presence of this growth factor; these effects appear to depend on either the light intensity or quality during incubation.

The interactions of IBA, BAP, gibberellic acid (GA_3), riboflavin, and sucrose in the culture medium and their effects on the multiplication and rooting of adult material are described. Riboflavin and GA_3 inhibit callus and rooting; GA_3 is antagonistic to BAP; IBA is essential for callus and rooting and these effects are enhanced by a low contentration of BAP. High concentrations of sucrose impair the health of cultures. More callus and rooting is induced on media with low concentrations of nitrate.

INTRODUCTION

Our previous papers on tissue culture propagation of the red-flowering gum, *Eucalyptus ficifolia*, described the use of nodes from aseptic seedlings to select culture media for their multiplication and rooting (2,8,9,10). This work with seedling material could be valuable for the rapid multiplication of progeny from hybridizations and from elite seed orchards; it might also be useful in cases where seeds of a species are rare, difficult to collect and/or expensive. However the main objective of this work with seedling material was to find cultural conditions suitable for the commencement of research to achieve clonal propagation of adult material. In fact, one of the four media selected from our first screening experiment with seedling material was found suitable as a basal medium for adult *E. ficifolia* material. The medium selected,[1] medium - MHMH (19), was modified with subsequent experimentation to: $[MH_{Fe}]$ $IBA_{10\mu M}MH$ (9) and then to: $[MH_{Fe}]$ $IBA_{5\mu M}MH$ (3), and then to: $[MH_{Fe}]$ $IBA_{5\mu M}BAP_{2\mu M}H$ (8). During this period, large clonal populations of adult material were being built-up through repeated subculture of shoots obtained from buds in early 1977. This paper describes the research which has been done on this subcultured adult material in our attempts to achieve satisfactory growth, multiplication rates and rooting.

The research on seedling cultured material was in its final stages in 1978 when, in large experiments with individual growth factors, the significance of riboflavin was first discovered. This paper not only describes the interesting interac-

[1] The coding system describing culture media is described under *Materials and Methods*.

tion of riboflavin in the culture medium with type of incubation using seedling material, it also describes some of the effects of riboflavin with adult cultures.

MATERIALS AND METHODS

Plant material: Seedling material used had been repeatedly subcultured at approximately 2-month intervals over a 3-year period. Adult material (originating from 25 year old trees) had been repeatedly subcultured over an 18-month period.

Culture media: Specific details of basal media used at various stages of experimentation are described in the *Results* section. The majority of the experiments had a factorial design. All culture media was dispensed into UC3OP polycarbonate tubes fitted with polypropylene screw-on lids (Disposable Products Pty. Ltd., Paget Street, Ridleyton, S. Australia). The culture media were sterilized in an autoclave. The gibberellic acid treatments were applied by dissolving in ethanol, applying 10μl amounts to sterile filter paper squares and, on evaporation of the ethanol, adding the squares to already sterilized media.

Incubation: Best growth and multiplication occurred with incubation in low intensity light (10μEm^{-2}s^{1}) at approximately 25°C; an 8/16 h light/dark regimen was used.

Coding of media and treatments: The basic 4-letter code of culture media relates to four categories of ingredients, namely, (1) minerals, (2) auxins, (3) cytokinins, and (4) growth factors, amino acids and sucrose. The concentration in each category is described as low, medium or high and abbreviated as L, M and H respectively. Thus, medium-MHMH consists of the medium (M) concentration of minerals and cytokinins and the high concentration (H) of auxins, growth factors, amino acids and sucrose. Occasionally, Z(zero) is used in the code to mean absence of a category.

[MH_{Fe}] means the medium concentration of minerals except for a subcategory which includes $FeSO_4$, NA_2EDTA and Na_2SO_4 at the high concentration. The specific concentrations of each ingredient are described in (7).

Substitution of the fourth letter of the code by two letters in parentheses means different concentrations of growth factors and amino acids on the one hand and of sucrose on the other hand. For example, [MH] would mean the medium (M) concentration of growth factors and amino acids and the high (H) concentration of sucrose.

When a category has been reduced to a single ingredient, the ingredient and its concentration are stated. For example, IBA $_{10\mu M}$ means that only one auxin is used and that auxin is IBA at 10μM.

Abbreviations of chemical names: IBA (indolebutyric acid), BAP (benzyl amino purine), GA (gibberellic acid), R (riboflavin), GF (growth factors and amino acid category).

RESULTS

Seedling Cultures

The interaction of riboflavin and incubation conditions on the induction of rooting in subcultured shoots: Twenty replicates of uniform shoots from repeatedly subcultured material of seedling origins were placed on medium (Table 1) containing either (1) all growth factors (GF), (2) all GF except riboflavin (R), (3) no GF, or (4) riboflavin alone at 10μM; there were three types of incubation, namely (1) 300μEm^{-2}s^{-1}, (2) 10μEm^{-2}s^{-1}, and (3) in darkness. Light quality was also different but was not quantified. The temperature of incubation was 25°C. There was a total of 240 cultures in the experiment and the results, after 4 weeks incubation, are described schematically in Figure 1.

The high intensity light incubation was clearly inhibitory to rooting in general, except for cultures on medium without growth factors which developed large calluses with root-like teratomas; some of these teratomas burst at their apices and developed strong normal-looking roots.

Dark incubation favoured rooting irrespective of growth factor additions to the culture media. At low light intensity, there was a high percentage of rooting, but the effect of riboflavin was on the morphology of these roots. Its presence produced the development of one or two strong, normal-looking roots per culture in contrast to the almost fibrous root systems that developed on media without riboflavin.

The effect of riboflavin on shoot growth (on a multiplication medium) was beneficial.

Adult Cultures

Multiplication and shoot growth: The multiplication medium at the start of this series of experiments was [MH_{Fe}] $IBA_{5\mu M}BAP_{2\mu M}H(8)$. This medium, and its forerunners, permitted a slow but steady build-up of clonal populations of adult cultures. The growth of the shoots on this medium was apically dominant and compact, that is, with short internodes and little or no development of axillary buds. However, the growth rate was slow and was accompanied with the development of excessive red-coloured basal callus and a dark exudate with extended culture periods.

A large number of experiments was done with this material, particularly with IBA, BAP, gibberellic acid — GA_3, riboflavin and sucrose. GA_3 had striking effects on these cultures

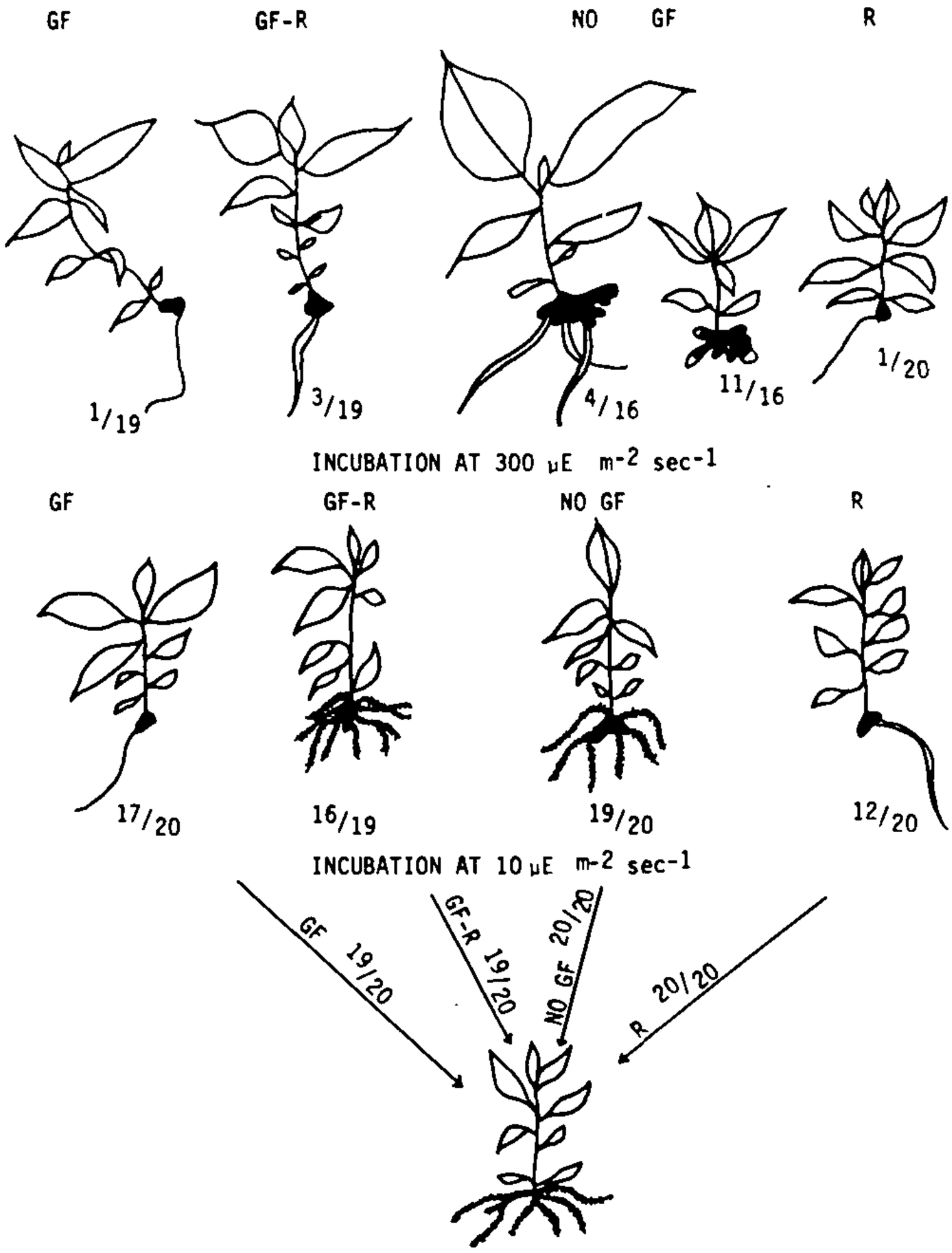

Figure 1. The effect on root formation of media with and without riboflavin, under different light intensities, after four weeks incubation; GF = all growth factors; R = 10 μM riboflavin; fraction under each sketch indicates number of cultures over the total number of cultures, exhibiting illustrated morphogenesis.

and, in particular, stimulated the growth of axillary buds. Both 10μM GA_3 (applied aseptically in alcohol to sterile pieces of filter paper which were then added, after evaporation of the alcohol, to sterile media) and 100μM GA_3 (autoclaved with the culture medium) had this effect; the latter treatment having a far greater effect. However, these GA_3 additions also caused internodal elongation, the formation of abnormal leaves, and eventually callus formation at the base of axillary branches. As a result of this callusing, the axillary branches fall off. The combination of constituents inducing axillary branch formation and least leaf abnormality was:

$$[MH_{Fe}]\ IBA_{5\mu M}BAP_{0.2\mu M}GA_{10\mu M}\ [R_{10\mu M}H_{sucrose}]$$

Table 1. Composition of culture medium for the induction of root formation in cultures of seedling origin.

Macronutrient elements (mM): NH_4NO_3 (5), $MgSO_4$ (0.5), KCl (1.9), $CaCl_2$ (1), NaH_2PO_4 (1).

Micronutrient elements (μM): H_3BO_3 (150), $MnSO_4$ (100), $ZnSO_4$ (40), $CuSO_4$ (1.5), Na_2MoO_4 (1), $CoCl_2$ (1), KI (5), $FeSO_4$ (100), Na_2EDTA (100), Na_2SO_4 (650).

Auxins (μM): IBA (5).

Main Carbon Source (mM): Sucrose (120).

Agar (g/l): Fluka agar (9).

The pH of all culture media was altered to 5.5 with 1N NaOH prior to autoclaving.

Experiments with different concentrations (60, 90 and 120mM) of sucrose led to the use of the medium concentration (60mM) in preference to the higher concentrations of sucrose. The higher concentrations not only induced red-coloured basal callus and exudate formation, they markedly increased the tendency for a shoot to dieback when transferred to a 'rooting' medium. The medium most suitable at present for the multiplication of adult material is:

$$[MH_{Fe}]\ IBA_{5\mu M}BAP_{0.2\mu M}[HM]\ \text{(Table 2)}$$

This medium not only eliminates the callus and exudate problem, but also produces a strongly apically-dominant plant which is not compact in form; it induces faster growth of cultures than on media with 2μM BAP.

Table 2. Composition of multiplication medium $[MH_{Fe}]\ IBA_{5\mu M}BAP_{0.2\mu M}$ [HM] for adult *Eucalyptus ficifolia* cultures.

Macronutrient elements (mM): NH_4NO_3 *(10),* KNO_3 *(10),* NaH_2PO_4 *(1),* $CaCl_2$ *(2),* $MgSO_4$ *(1.5).*

Micronutrient elements (μM): 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), $FeSO_4$ (100), Na_2EDTA (100), Na_2SO_4 (650).

Auxins (μM): IBA (5).

Cytokinins (μM): BAP (0.2).

Growth Factors (μM): Inositol (600), Nicotinic acid (40), Pyridoxine HCl (6), Thiamine HCl (40), Biotin (1), D-Ca-pantothenate (5), Riboflavin (10), Ascorbic acid (10), Choline Chloride (10).

Amino acids (μM): L-Cysteine HCl (120), Glycine (50).

Main carbon source (mM): Sucrose (60).

Agar (g/l): Fluka agar (9).

A new cycle of experimentation is about to begin using this basal medium, and re-testing the effects of various concentrations of IBA, BAP, GA_3 and riboflavin (all of which were previ-

ously tested on a different more complex basal medium). The aim of this new series of experiments is to achieve the same healthiness of the cultures as on the most recent basal medium but with higher rates of multiplication either of the apically-dominant or the axillary branch type.

Rooting: In our earlier papers, we reported the successful rooting of seedling cultured material, and failure of the same techniques to induce rooting in adult cultured material.

Again, a large number of experiments have been done to try to induce root formation in adult material. The majority of roots that have been induced to form have come after the formation of very large basal callus exhibiting root-like teratomas. In our earliest attempts at rooting, no such root-like teratomas were induced but instead, the roots were thin with no development of laterals and were associated with dark granular callus. Now, strong roots with some laterals arise from the teratomas and in some cases (for example, on media with 0.02μM BAP) thin roots arise from between the teratomas. Ideally, we would like to have root formation arising directly from the shoot without the prior formation of callus. However, it may be necessary to settle for a small amount of callus prior to rooting as occurs in many rooted cuttings.

The presence of IBA (e.g. 5 or 10μM) in the culture medium was essential for the formation of callus and then of roots. However, 10μM IBA in a "rooting" medium, for example [MH_{Fe}] $IBA_{10\mu M}BAP_{0.02\mu M}$ [ZM], led to rapid deterioration of the shoots.

The presence of either 10μM riboflavin or 10μM GA_3 in the "rooting" medium completely inhibited callus development (and thus rooting) even in the presence of IBA; carry-over effects of GA_3 were also apparent since shoots from GA_3 multiplication media did not form any basal callus on IBA-containing 'rooting' medium. In general, GA_3 and BAP had antagonistic effects.

Rooting in cultures of many species often occurs in the absence of a cytokinin but, with adult *E. ficifolia* cultures, improved callusing and rooting occurred in media containing 0.02μM BAP. Cultures on 0.2μM BAP medium produced callus but no roots. Calluses on 0.02μM BAP had a healthier appearance than those on BAP-free media.

Reports of research with the rooting of some species have indicated a preference for particular K^+/NH_4^- ratios, NO_3^+ concentrations, and for lower concentrations of minerals (1,5,6,11, 12); other workers have reported improved rooting when shoots have been placed upside-down in the culture medium (1).

K^+/NH_4^+ ratios in the culture medium ranging from 20/0, 16/4, 12/8 through to 4/16, 0/20 (mM) have been tested in a factorial experiment with IBA (0,10μM) and BAP (0, 0.02μM).

K^+/NH_4^+ ratios ranging from 8/0, 6/2 through to 2/6, 0/8 (mM) have also been tested in all combinations of Ca^{2+}/NO_3^- ranging from 0/0, 1.25/2.5 through to 5/10 (mM) in the presence of 10μM IBA and 0.02μM BAP.

The results of these experiments indicated that both potassium and calcium were essential for callus formation and rooting, and most rooting occurred on cultures on media containing lower concentrations of NH_4^+, NO_3^-, and K^+ and with a higher concentration of Ca^{2+}, than in [MH_{Fe}] of the basal "rooting" medium.

The highest K^+/NH_4^+ ratio tested (that is 20/0 mM) induced large calluses in the presence of 10μM IBA with either 0 or 0.02μM BAP, whereas no callus formed on media with all other K^+/NH^+ ratios. This suggests that NH_4^+ ions inhibit callus formation. Shoot growth was healthiest on media with the highest K^+ ratio, and on cultures with the highest CA_2^+/NO_3^- ratio.

The testing of full strength, half strength and no minerals of [MH_{Fe}] showed that minerals were necessary for callus and rooting, but there were no significant differences between shoots on full and half-strength minerals.

The inversion of shoots in cultures resulted in much more rooting — but all from callus developed at the apical end; none of the basal ends of upside-down shoots produced callus or roots.

The next series of experiments will be based on these previous experiences. Strong shoots will be selected from cultures grown on media *with* 60mM sucrose and 0.2μM BAP and *without* riboflavin and GA_3. "Rooting" media will include 0.02μM BAP, but other cytokinins and other concentrations need to be re-tested. The mineral constitution of the "rooting" media will be re-tested, particularly with an overall lower level of NO_3^-. IBA and other auxins need to be re-tested at different concentrations, and it might be possible to induce rooting with certain auxin concentrations but avoid their deleterious effects on shoot health by the addition of low concentrations of riboflavin or GA_3.

DISCUSSION

For logistical reasons and by mischance, we have not yet tested one potentially important factor in our study of the tissue culture propagation of *Eucalyptus* (as envisaged in (3) and (8)). This involves the wounding of a tree at its base to induce shoot formation. Such shoots can be induced to form roots in some

cases and, if buds from such rooted cuttings were used to initiate a tissue culture programme, it seems highly probable that they might respond in the same way as seedling material to the multiplication and rooting systems already developed for such material. It is hoped that rooted shoots from the base of adult trees will be available soon for the testing of this idea.

The work described in this paper has confirmed the difficulties involved in the rooting of adult woody material. The successful completion of this research would be valuable because of the abundance of buds on an adult tree and because with some species there is no other alternative, for example, where shoots from the base of the tree cannot be induced to form or, if they are formed, are as difficult to root as from any other part of the tree.

The inclusion of riboflavin alone (that is, with no other growth factors and amino acids) in the multiplication medium (Table 2) will be a great simplification of the medium and is likely to give as good shoot growth and health of cultures as for those grown in the presence of all growth factors and amino acids in this category. Further investigation of the IBA-BAP-GA_3-riboflavin interaction will no doubt result in a programme with higher multiplication rates.

The induction of rooting in such adult cultures remains the big difficulty and, though the effects of many factors are now known, less optimism can be expressed at this time for the successful induction of rooting. The picture will be clearer after we have tested some of the numerous suggestions discussed in this paper. There are difficulties associated with the interpretation of experimental results in rooting research when *one* of the effects of a chemical, such as IBA, is "good", e.g. in producing callus and roots, but *another* effect is "bad", e.g. shoot dieback and death. A shorter duration of exposure to the chemical or the modifying influence of another chemical in the culture medium might lead to a suitable balance between root and shoot growth and health. One other possible method to induce rooting of cultured adult roots is to attempt this outside of the culture tube, using standard propagating procedures. This approach was used successfully for the rooting of tissue-cultured rhododendron cultivars (2), and for cultured Douglas fir shoots (4). Treating the base of cultured shoots of *E. ficifolia* seedling material with 10μM IBA for 1-2 days prior to planting out was successful in this work.

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TISSUE CULTURE PROPAGATION OF TWO *GREVILLEA* HYBRIDS

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Abstract. Favourable results have been achieved in the tissue culture propagation of *Grevillea* cv Robyn Gordon and *Grevillea* cv Crosbie Morrison. Multiplication rates have been fairly high, despite the fact that both hybrids have tended towards single rather than multiple shoot development. Success with rooting cultures has differed, 'Crosbie Morrison', giving 98% success and 'Robyn Gordon' about 60%.

The growing on of cultured plants in soil has presented some problems, and it is obvious that they require more careful attention than normal cuttings.

The methods of propagation are described and successful media for the multiplication and rooting stages are given.

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The growing on of cultured plants in soil has presented some problems, and it is obvious that they require more careful attention than normal cuttings.

The methods of propagation are described and successful media for the multiplication and rooting stages are given.

INTRODUCTION

Grevillea cv Robyn Gordon is a spontaneous hybrid of *Grevillea bipinnatifida* and *Grevillea banksii*. It was released commercially at the end of 1975 and its large attractive blooms and deeply cut lacy foliage have made it a very popular garden plant (1). *Grevillea* cv Crosbie Morrison, is an eye-catching shrub with red and cream flowers and hairy grey-green foliage. Its parents were *Grevillea lanigera* and *Grevillea lavandulacea* (2).

Unlike the parents which have ample viable pollen, hybrids have practically no pollen. Further, if grown from seed there is a high probability that the seedlings will be different from the original hybrid. Propagation, therefore, has to be from cuttings. The cuttings of 'Robyn Gordon' are fairly difficult to root and, in most cases, growers achieve between 10% and 40% strike. There is more success with 'Crosbie Morrison', but because of the large demand on the hybrid, it would be desirable to achieve higher levels of production. For both hybrids, tissue culture propagation offers the potential for this increased production.

MATERIALS AND METHODS

Disinfestation: This procedure involves the removal of micro-organisms from the surface of the explant. The suppression of the micro-organisms is essential since they are strong competitors with the explant when it is placed on a culture medium.

Stem lengths from the two hybrids were washed under running tap water for 60 minutes as a preliminary procedure. They were then disinfested in a 5% (w/v) solution of calcium hypochlorite made up in 0.1% (v/v) 7X detergent for 20 minutes, and rinsed in two changes of sterile water. The 'Robyn Gordon' plants had been kept in pots in a glasshouse and were maintained in a fairly clean state. The 'Crosbie Morrison' plants were growing in the field. In the case of field grown material, which is vulnerable to insects and disease, disinfestation can be an enormous problem and contamination can occur in as many as 100% of cultures. It is therefore desirable to keep stock plants under glass.

Explant Source: For 'Robyn Gordon', buds were aseptically dissected out from the stem and transferred (one bud/culture tube) to a holding medium consisting of minerals and sucrose (Table 1). The purpose of this holding medium is to allow contaminated cultures to be screened out before they are placed onto more complex media. The explants generally remain on the holding medium for 7-10 days.

Table 1. Constituents and concentrations of the holding medium.

Macronutrient elements (mM)
NH_4NO_3 (10), KNO_3 (10), NaH_2PO_4 (1), $CaCl_2$ (2) $MgSO_4$ (1.5)
Micronutrient elements (μM)
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_2 EDTA (50), Na_2SO_4 (450).
Main carbon source (mM)
Sucrose (60)
Agar ('Fluka')
9g/litre

In the case of 'Crosbie Morrison', the explants taken, consisted of stem pieces, one to two nodes in length. Leaves were cut back to 1 mm. The nodes were transferred aseptically to the holding medium.

Culture Media: For the purposes of plant propagation, the ideal culturing sequence is firstly to find a medium which will induce multiple shoot formation and secondly to find a medium which will induce rooting. Unfortunately, for most species, there is not a single medium which will combine both functions. The use of the multiple shoot medium allows a rapid build up of small shoots and the single shoots can either be induced to proliferate further, or be placed onto a rooting medium to form complete plants which can then be grown on in soil.

In all cases, explants were grown in transparent polycarbonate tubes (with screw caps), containing 10 ml of culture media. All culture media were adjusted to pH 5.5 prior to autoclaving.

Multiplication.

a. *'Robyn Gordon'*: There was about 30% loss of explants from contamination. Explants which were apparently aseptic were transferred to seven replicates of a mini Broad Spectrum experiment. The full Broad Spectrum experiment (3) consists of combinations of four broad categories of constituents, namely (1) minerals, (2) auxins, (3) cytokinins, (4) sucrose plus growth factors plus amino acids, each at three concentrations, 'low', 'medium' and 'high'. This gives an experiment with 81 treatments (media). The mini Broad Spectrum consists of 18 treatments in which the minerals are used only at 'medium' concentration, the auxins and cytokinins are used at all three concentrations and the sucrose, growth factor, amino acid group is used at 'medium' and 'high' concentrations. The full Broad Spectrum is only suitable when large numbers of aseptic explants are available, but it allows a more rigorous testing of media than the mini Broad Spectrum.

To facilitate medium identification, a specific four letter coding is used, e.g. MLHM. The first letter represents the min-

eral component — in this case at 'medium' (M) concentration, the second letter represents the auxin component in this case at 'low' (L) concentration, the third letter represents the cytokinin component — in this case at 'high' (H) concentration and the *fourth letter represents the growth factor/amino acid/sucrose* component — in this case at 'medium' (M) concentration. In some experiments, the sucrose concentration is varied independently of the growth factors and amino acids and in this case, a five-letter coding is used, e.g. MLH[MH]. The medium represented by this code is identical to medium MLHM, except that whilst growth factors and amino acids are at 'medium' concentration, sucrose is at 'high' (H) concentration. Where a constituent is not present in the medium it is designated by the letter Z, e.g. MMZM indicates that there are no cytokinins present. The coding convention described will be used to express media constituents in this paper.

From the mini Broad Spectrum experiment, seven media were chosen as having good potential as multiplication media. Further tests were done on these to choose the best and medium-MMLH was selected. Then followed a number of experiments aimed at refining this medium: —

i. a cytokinin experiment testing PBA, BAP, Kinetin, 2iP and Zeatin (see Appendix I) at various concentrations, whilst keeping the other constituents at the original level.

ii. an auxin experiment testing IAA, IBA, NAA, NOA, pCPA and 2,4-D (see Appendix I) at various concentrations whilst keeping the other constituents at the original level.

iii. experiments testing combinations of auxins and cytokinins, whilst keeping the other constituents at the original level.

The experiments on 'Robyn Gordon' were commenced in December 1977 and initially explants were incubated under two conditions: a) a growth cabinet giving (8/16 h light/h dark) at 25°C, and b) a shadehouse covered with 50% shadecloth where the culture tubes were hung in clear plastic 'sausages'. At this time of year, growth was better in the shadehouse. However, as winter came round and the shadehouse was covered with polythene, but unheated, the cultures grew better in the growth cabinet. Some cultures were incubated in a heated glasshouse in winter, but did not grow as well as those in the growth cabinet, probably because the light intensity was too high.

b. '*Crosbie Morrison*': There was about 85% loss of explants from contamination and many hundreds of explants had to be

cultured before enough could be obtained for transfer to complex media.

Apparently aseptic explants were transferred to three replicates of the full Broad Spectrum experiment. The cultures were initially incubated under fluorescent light with 8/16 (h light/h dark) in a room without temperature control. The growth cabinet and shade house were unavailable for incubation at the time, but both later proved to be more suitable.

From the Broad Spectrum experiment, medium-MLHM was selected as being the best for multiplication. This was further refined after an auxin experiment testing IAA, IBA, NAA, NOA, pCPA and 2,4-D at various concentrations, with the other constituents being kept at the original level. Incubation of this experiment (done during winter) was in the growth cabinet and in a heated glasshouse.

The fact that the two hybrids belong to the same genus would suggest that they may have similar medium requirements for multiplication. Although two different media were chosen, this may have been due to chance experimental error and therefore as a comparison, cultures of each hybrid were tested on the medium selected for multiplication of the other hybrid, i.e. 'Robyn Gordon' was tested on MLHM and 'Crosbie Morrison' was tested on MMLH.

Rooting. None of the cultures from the Broad Spectrum experiments done with the two hybrids developed roots. A series of likely media was therefore tested using complete shoots rather than nodal explants. Basically, this series consisted of 'medium' concentration minerals, IBA at various concentrations, cytokinins at zero and 'low' concentrations and growth factors and sucrose at concentrations varying from zero to 'high'. The series was developed from experience, it being assumed that IBA would be the best auxin for promotion of rooting (since it is used in commercial rooting powders) and that the use of low or no cytokinins would also be likely to encourage rooting. Incubation conditions were the same as for the multiplication experiments. Culture medium - $MIBA_{10\mu M}Z$ [ZM] proved to be very successful for both hybrids.

Further experiments were done to refine this medium for 'Robyn Gordon'. These experiments involved: i. use of a liquid medium on shakers, ii. testing of individual growth factors in combination with the other constituents, iii. testing of other individual auxins, and iv. testing of sucrose levels.

Growing On. Facilities for the care of rooted explants, have, until recently been fairly limited and initial failures to grow on the plants in soil can be attributed to this lack of facilities. Many plants produced in culture tend to be very 'soft', and the

transfer from a sterile, non-stressed, fully supporting environment to one in which factors such as temperature, moisture and nutrient status are constantly varying, must be a great shock. Experiments on soil mixes, types of containers for growing on, and general environmental conditions were done.

RESULTS

Multiplication.

a. *'Robyn Gordon'*: The type of multiplication obtained was not a multiple shoot system. Rather, single apically dominant shoots were produced. The shoots developed an average of six nodes over a four week period and when subculturing it was possible to take a single node as an explant. Application of a 'high' concentration of cytokinin did not overcome the apical dominance. The auxin experiment indicated that a 'low' concentration of NOA as the only auxin gave the best type of growth and the cytokinin experiment indicated that a 'low' concentration of 2iP as the only cytokinin would give best results. However, when a medium was used which combined low NOA and low 2iP the growth of the cultures was not as favourable as expected. Further experimentation has suggested that medium — $MM2iP_{0.1\mu M}H$ (Table 2) may be the most suitable. Still more work needs to be done on testing the growth factor and the mineral groups. About 20% of cultures on this multiplication medium also developed roots.

Associated with the effect of the media on multiplication, there also appears to be an incubation influence. Generally, the 'Robyn Gordon' cultures preferred the conditions in the shadehouse during the late summer and early autumn. They did, however, grow fairly well in the growth cabinet.

Many explants have shown signs of a brown coloration of the older leaves, after several weeks in culture. This coloration begins as isolated spots but eventually spreads to the whole leaf. If affected explants remain too long in culture, they eventually die. Those which have been rooted and planted out in soil appear not to suffer and new growth is free of the browning. If affected explants are subcultured, the subsequent explants may or may not develop the coloration. Microscopic investigation of an affected leaf showed that it was not caused by a fungus. It is probably some physiological disturbance which may be due to inappropriate media conditions.

'Robyn Gordon' explants transferred to the 'Crosbie Morrison' multiplication medium (MLHM), did not grow very well.

b. *'Crosbie Morrison'*: The system of multiplication obtained was of the multiple shoot type, but there have been variations. In initial experiments about four shoots arose from the base of

Table 2. Constituents and concentrations of multiplication media for the two *Grevillea* hybrids.

Constituents	'Robyn Gordon' ($MM2iP_{0.1\mu M}H$)	'Crosbie Morrison' (MZHM)
Macronutrient elements (mM)	NH_4NO_3 (10), KNO_3 (10) NaH_2PO_4 (1), $CaCl_2$ (2) $MgSO_4$ (1.5)	NH_4NO_3 (10), KNO_3 (10), NaH_2PO_4 (1), $CaCl_2$ (2), $MgSO_4$ (1.5)
Micronutrient *elements* (μM)	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_2 EDTA (50), Na_2SO_4 (450)	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_2 EDTA (50), Na_2SO_4 (450)
Auxins (μM)	1 μM of each of the following auxins: IAA, IBA, NAA, NOA, 2,4-D, pCPA (see Appendix I for full names)	None
Cytokinins (μM)	2iP (see Appendix I) 0.1μM	10 μM of each of the following cytokinins: Kinetin, BAP, (see Appendix I)
Growth Factors (μM)	Inositol (600), Nicotinic Acid (40), Pyridoxine. HCl (6), Thiamine. HCl (40), Biotin (1), D-Ca-Pantothenate (5), Riboflavin (10), Ascorbic Acid (10), Choline Chloride (10).	Inositol (300), Nicotinic Acid (20), Pyridoxine. HCl (3), Thiamine. HCl (2), Biotin (0.2), D-Ca-Pantothenate (1), Riboflavin (1), Ascorbic Acid (1), Choline Chloride (1).
Amino acids (μM)	L-Cysteine. HCl (120), Glycine (50)	L-Cysteine. HCl (60), Glycine (5)
Main Carbon Source (mM)	Sucrose (120)	Sucrose (60)
Agar ('Fluka')	9g/litre	9g/litre

the explant. These had fairly long internodes, and generally, from 4-5 nodes/shoot developed over a four week period. Single nodes could be taken as explants. In the most recent experiment however, the multiple shoots which developed had much shorter internodes and there were more shoots (Figure 1). No obvious reason for this could be seen especially as the type of explants taken and the incubation conditions were unchanged. The cultures from which the explants came were about two months older than usual, and it is possible that this may have had an effect although why it should have is not clear. Further experiments need to be done to confirm and to clarify this observation.

The medium chosen for multiplication was $MIBA_{0.1\mu M}$ [HM], but the most recent experiment has indicated that equally good multiplications can be obtained by leaving out IBA altogether (Table 2). The incubation condition which best complemented the effect of the medium was found to be that in the shade house during late summer and early autumn. The growth cabinet gave the next best incubation conditions.

'Crosbie Morrison' explants transferred to the 'Robyn Gordon' multiplication medium (MMLM) did not grow very well.

Figure 1. An unusual 'Crosbie Morrison' culture showing development of both multiple shoots and an apically dominant shoot, on the same medium. More usually only one type of development occurs.

Rooting.

a. *'Robyn Gordon'*: Roots developed after about three weeks on rooting medium. The roots obtained were generally brown in colour, thickened and were associated with some degree of callusing (Figure 2). The root system was considered to be fairly massive for the type of shoot development. It was hoped to reduce the callusing and root thickness by experimenting with auxins and growth factors and also by using liquid media, but there was little success. The medium $MIBA_{10\mu M}Z$ [ZH] (Table 3) was chosen as being the best and about 60% of cultures on this medium developed roots. Results from the growth factor experiment indicated that the inclusion of Biotin in the rooting medium allowed better shoot development but a lower rooting percentage was obtained. Cultures on media without growth factors tended to be small and development of shoots was slow. When the cultures were planted out in soil, however, these smaller ones grew just as well as the larger plants. Incubation conditions did not seem to affect types of roots or rooting percentage.

Figure 2. 'Robyn Gordon' culture showing root development on rooting medium — $MIBA_{10\mu M}Z$ [ZH].

Table 3: Constituents and concentrations of rooting media for the two *Grevillea* hybrids.
'Robyn Gordon' ($MIBA_{10\mu M}Z[ZH]$)
'Crosbie Morrison' ($MIBA_{10\mu M}Z[ZM]$)

Macronutrient elements (mM)
NH_4NO_3 (10), KNO_3 (10), NaH_2PO_4 (1), $CaCl_2$ (2), $MgSO_4$ (1.5)
Micronutrient elements (μM)
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_2 EDTA (50), Na_2SO_4 (450).
Auxins (μM)
IBA (see Appendix I) 10 μM.
Main Carbon Source (mM)
'Robyn Gordon' — Sucrose (120)
'Crosbie Morrison' — Sucrose (60)
Agar ('Fluka')
9g/litre

b. *'Crosbie Morrison':* The best rooting medium was found to be $MIBA_{10\mu M}Z[ZM]$ (Table 3) and 98% of cultures formed roots. The roots were slightly thickened and there were more roots/culture than occurred with 'Robyn Gordon'. There was some callusing. As with 'Robyn Gordon', it took about three weeks for roots to appear on cultures; shoot growth was good on the rooting medium. Incubation conditions did not seem to affect types of roots or rooting percentages.

Growing On. As mentioned earlier, there were problems with this stage mainly because of poor facilities. The acquisition of a misting system in recent months has helped considerably.

The 'Robyn Gordon' plants seem particularly sensitive to growing on conditions. Of the rooted plants which have been transferred to soil, only about 40% have survived (Figures 3 and 4) whilst the success rate with 'Crosbie Morrison' has been 80%.

The best procedure so far, for planting out and growing on of both hybrids has been as follows:

1. Remove the lids from the culture tubes and leave the tubes standing in the glasshouse for several days. Water, if the plants become stressed.
2. Take the plant from the culture tube and gently wash off as much agar as possible from around the roots. It has been found that leaving too much agar on the roots may lead to problems with fungal growth.
3. Transfer the plant to a soil mix which is fairly sandy. Good drainage is essential. Plants seem to require heavy shading initially and the light intensity is increased gradually. Polystyrene seedling containers have been the most successful type of container used to date.

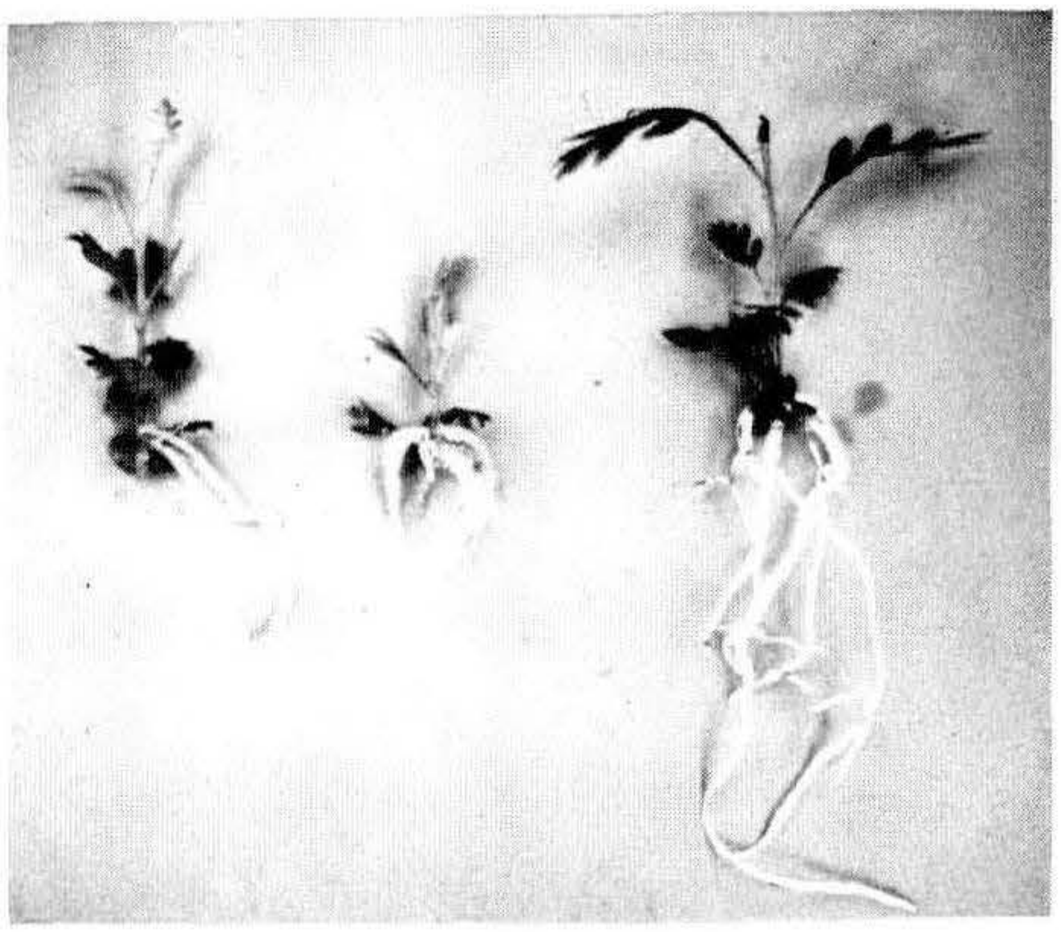

Figure 3. Development of roots in 'Robyn Gordon'. All plants are the same age. The two plants on the left have remained in culture on rooting medium for eight weeks. The plant on the right was transferred to soil after four weeks on rooting medium.

Figure 4. A tissue cultured 'Robyn Gordon' plant, eight weeks after planting out.

4. Leave the plants under fairly frequent mist until new root and shoot growth has occurred. Gradually decrease the misting frequency. Both hybrids need to be left for several weeks under mist; new roots develop quickly, but shoots take longer and the foliage is susceptible to wilting.

DISCUSSION

The level of production so far achieved with the two hybrids has been promising and further experimentation aimed at refining the existing media and improving the growing on stage, should result in a very favourable propagation system.

One of the factors which has been limiting is incubation of cultures. The use of 'natural' incubation, i.e. incubation in

glasshouses and shadehouses has been favoured and it is felt that this may be more relevant to nurserymen who wish to try tissue culture techniques and who would not have the artificial incubation facilities. However, there are obviously problems with maintaining continuity of conditions as seasons change, and even from day to day there are fluctuations. Further, particular cultures have particular requirements and it is therefore important to have some degree of flexibility in the 'natural' incubation, e.g. temperature control, control of light intensity through use of shadecloth. Both *Grevillea* hybrids grew best under the conditions found in the shade house during summer and autumn. Unfortunately, the lack of heating in the shade house prevented its use during the colder months.

The rates of multiplication achieved so far have been good. For 'Robyn Gordon' in which six explants can be subcultured every month, one single explant could yield 6^{12} (2,000,000,000) plants in a year. The yield is even higher for 'Crosbie Morrison' for which at least ten explants can be taken from a single culture each month. The percentage of 'Robyn Gordon' cultures to form roots on a rooting medium was not as good as hoped for and it seems that species which are hard to root by normal nursery methods, may also present a problem in tissue culture propagation.

The growing on stage is the one which will prove critical if tissue culture is to be used commercially. It is useless to be able to obtain millions of rooted cultures if they cannot be successfully transferred to soil. The *Grevillea* plants grown in culture are very 'soft' and require more care than would probably be given to a cutting. They are susceptible to moisture stress and take several weeks to establish and start producing new shoots.

The problem of heavy contamination losses with 'Crosbie Morrison' as compared with 'Robyn Gordon' in the initial culturing, highlights the need for explants to be taken from stock plants which are kept under cover and which are routinely sprayed for insects and disease. Contamination losses represent a waste of labour, money and time and careful plant hygiene can generally overcome the problem.

A very interesting point to emerge from the work done on the two hybrids is the fact that their media requirements for multiplication are so different. It was assumed that because they belonged to the same genus they would have similar nutritional and hormonal requirements. A possible reason for the difference between them may lie in the fact that morphologically they are very different (Figure 5) and therefore, by inference, their morphological attributes are associated with physiological differences at the cellular and biochemical level.

Grevillea cv Robyn Gordon

Grevillea cv Crosbie Morrison

Figure 5. Morphology of the two *Grevillea* hybrids.

For both *Grevillea* hybrids, tissue culture propagation offers the potential for increased production. The numbers of plants which can be grown in culture and transferred to soil, is very high. The time intervals for one complete cycle, i.e. from the taking of an explant to planting out, for both hybrids are about 4-5 *weeks on multiplication medium*, 3-4 *weeks on rooting* medium, 1 week for 'hardening off' in the culture tube and 4-6 weeks in soil under mist.

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Appendix I. Full names of the auxin and cytokinin components used in experiments.

Auxins:

IAA (Indoleacetic acid), IBA (Indolebutyric acid), NAA (α-naphthalene - acetic acid), NOA (2-naphthoxyacetic acid), 2,4-D (2,4-dichlorophenoxy - acetic Acid), pCPA (para-chlorophenoxyacetic acid).

Cytokinins:

KINETIN (6-Furfuryl amino purine), BAP (N^6-Benzyl amino purine), PBA (6-(benzylamino) - 9 - (2-tetra hydropyranyl) - 9H - purine), 2iP (N^6 - iso pentenyl amino purine), ZEATIN (6 - (4 - hydroxy - 3 methylbut - 2 - enyl) - amino purine).

ASSESSING A NEW SOIL MEDIUM[1]

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When assessing a new soil medium there are three broad areas to be considered: the chemical environment of the medium, the physical environment of the medium, and managerial aspects. Each of these areas can be analyzed logically.

Chemical Environment. There are four factors to be analyzed:

1. What are the ideal nutrient levels;
2. How does the applied fertilizer's output vary with time;
3. What are the detrimental by-products within the fertilizers;
4. What beneficial chemicals are present.

Firstly, the question of ideal nutrient levels. Below is a roughly ideal general soil analysis (ppm): nitrogen (total) 170; phosphorus 85; potassium 185; magnesium 320; iron 500; calcium 1750; copper 2; boron 2.5; manganese 50; molybdenum 2; zinc 25.

One may well have an analysis like this but those nutrients may not be available to the plant. Since nutrient availability is linked to soil pH, aeration, water supply, soil texture and symbiotic micro-organisms, these factors must be considered too.

A pH of 5.8 to 6.2 results in a happy trade off between the availability of the various nutrients. Most plant nutrients are actively taken up by plants. That is, the plant expends energy in the extraction of nutrients from the soil. Sugars are burnt in the presence of oxygen to supply this energy. Thus, low oxygen in the soil leads to a low metabolic rate and poor nutrient uptake irrespective of the applied fertilizers.

The nutrients that plants manage to take up are carried in solution around the plant. The plant also uses some water in its metabolism. So, poor water supply results in poor nutrient uptake. Microscopic particles in the soil carry electrostatic charges that will bind up plant nutrients. So a soil should be low in colloid and dust.

Certain plants have evolved in environments low in particular nutrients. The result is the development of symbiotic-like associations between plants and certain bacteria and fungi. These organisms "digest" certain nutrients for the plant in ex-

[1] This paper was presented at the 1977 IPPS Australian Region meeting.

change for sugars and proteins. The result is a situation, for example with Proteaceae, where it is very difficult to chemically compensate for the absence of these organisms.

One last comment on the ideal nutrient levels. Provided total dissolved salts are low, a plant will not be harmed by the presence of super-optimal levels of most nutrients. The plant generally will not take up more than it needs although boron and manganese are exceptions. These can be taken up to toxic levels.

The next factor to be considered is the variation of nutrient levels with time. There are two parts to this question. Firstly, how do the plant's requirements change with time. Nutrient supply must match plant growth rates. Thus an accelerating supply followed by a lower maintenance level is needed in container-grown plants. Secondly, how do the nutrients supplied by the soil vary with time. One should consider how the fertilizer itself changes and how the soil changes. Organic fertilizers and those like VF38 give a big release of nutrients early then taper off quickly, so liquid feeding is needed. Liquid feed schedules give a boost at each watering followed by starvation. Combinations using Osmocote are ideal.

The soil itself will change chemically; for example, as pine bark decomposes iron is released. As sawdust decomposes nitrogen is tied up in the bodies of the decomposing organisms. The soil also changes physically resulting in reduced oxygen and water levels and so reduces the available nutrient levels.

The final factors in this section on the chemical environment are detrimental and beneficial chemicals. The fluorine associated with phosphate production harms proteaceous plants via a phosphate-iron-microorganism association. Preservative-treated timbers can kill. On the beneficial side, the phenols produced during *Pinus radiata* bark decomposition controls *Pythium* and *Phytophthora*. By the way, some barks release phenols, etc. that can kill plants.

Physical Environment. There are four factors to consider:

1. The physical support of the plant;
2. Detrimental organisms;
3. Beneficial organisms;
4. The physical resistance to root growth.

The growing medium should act to prevent the plant from blowing over.

Detrimental organisms can be inherent in some media, for example *Pythium* on peanut hulls. Heat or chemical treatment can eliminate these organisms. Beneficial organisms will be

killed by methy bromide and the like, so re-introduction may be needed. Heat treatment (150°F for 30 minutes) removes detrimental but not beneficial organisms. Pine bark in a heap reaches 170°F, thus no steam treatment is needed. Bacteria are essential for the release of nitrogen from VF38 and for the uptake by some plants of some nutrients.

The soil can physically obstruct root growth. Reductions of up to 50% can occur in heavy clay soils.

Managerial Aspects. There are five factors to consider in this area:

1. Cost;
2. Availability;
3. Ease of use;
4. Ease of treatment;
5. Customer acceptance.

Cost is often analyzed in a strange way. Each ingredient is emotionally ranked as too dear or too cheap based on the bill you get when one ton is delivered. Cost per pot for the total mix is a more reasonable system. This cost will usually be a quarter of the cost of the pot and about equal to the cost of the label.

So you have found the ideal medium but the ship from Transylvania sinks with this miracle medium aboard and you go broke. Availability and reliability of supply is then as important as the nitrogen level, etc.

The soil is too dusty or too heavy to move, or the ground glass in the mix is rapidly reducing your work force, to say nothing of your soil mixer. Management must consider the "ease of usage". Bark "pasteurises" itself, so treatment is easy. Loam does not, and needs steam treatment with the associated cost. Such cost should be calculated per pot.

Now after this huge analysis you come up with the super medium but the customers do not relate to a purple soil, nor a smelly or rough soil, so you go broke, again. Individuals ultimately buy your plants, so they *must* be happy with your choice of a potting medium.

SUMMARY

Below is a list of twenty questions to be answered when deciding on a new medium:-

1. pH now and over time.
2. Analysis of untreated media now and over time.
3. Fertilizers required.

4. Release pattern of the selected fertilizer.
5. Total dissolved salts, boron and manganese.
6. Half saturation percentage now and over time.
7. Oxygen levels at saturation now and over time.
8. Any detrimental chemicals and their levels.
9. Effect of detrimental chemicals.
10. Weight per cubic yard.
11. Physical resistance to root growth.
12. Colloid level and ion exchange capacity.
13. Intrusive flora and fauna.
14. Necessary hygiene treatments.
15. Other treatments (nitrogen stabalization of sawdust).
16. Ease of usage.
17. Dust levels.
18. Customer acceptance.
19. Availability.
20. Cost per pot.

EFFECT OF SUPERPHOSPHATE AND HIGH LEVELS OF LIME ON THE GROWTH OF WESTERN AUSTRALIAN BANKSIAS[1]

R. K. ELLYARD and D. K. McINTYRE

National Botanic Gardens and City Parks Research Unit, A.C.T.

Western Australian species of the genus *Banksia* have, in general, proved very difficult to grow in Eastern Australian states. In many cases the fungus *Phytophthora cinnamomi* has been blamed.

Webb (5) has, following extensive observation as to the soil environment of successfully grown Western Australian species and on the basis of field trials, concluded that the addition of high levels of lime to soils permitted the successful growing of many Western Australian *Banksia* species in Canberra.

At the National Botanic Gardens there has been considerable difficulty in propagating Western Australian *Banksia* species. In most cases death occurred soon after pricking out into the standard UC mix used at the Gardens. This mix contains a high level of phosphate (1200g superphosphate, 1200g blood and bone/m^3). Since most Australian species, and Western Australian species in particular, have evolved in an environment

[1] This paper was presented at the 1977 IPPS Australian Region meeting.

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low in phosphate it was felt that the high levels of superphosphate in the mix might be contributing to plant death. In the work presented here the effect of the presence and absence of superphosphate on the growth of 12 *Banksia* species was studied. The effect of the addition of limestone chips and powdered lime ($CaCO_3$) to the superphosphate-free mix was also studied.

MATERIALS AND METHOD

Seeds of 12 species of *Banksia* were sown in August, 1976, in a sand-perlite mix. When the seedlings were 2 to 3cm high they were pricked out into 75 mm plastic pots and placed in a cold frame. In November, 1976, the plants were potted into large plastic bags (9 litre). A basic UC mix consisting of 70% washed river sand, 25% peat, and 5% organic sand was employed. To each cubic meter was added calcium carbonate, 1200g; dolomite lime, 393g; superphosphate, 1200g; blood and bone meal, 1200g; potassium sulphate, 79g; Essminal, 111g. This was modified to give the following 5 soil mixes.

1. UC potting mix
2. UC potting mix over 3 to 4 cm limestone chips
3. UC potting mix without superphosphate, over limestone chips
4. UC potting mix without superphosphate, plus additional lime (18Kg/m^3)
5. UC potting mix without superphosphate, plus additional lime (64Kg/m^3)

The pH's of these mixes were 5.5; 5.5; 6.0; 8.1 and 8.7, respectively. Subject to seed availability, 5 replicates of each treatment for each species were used. The potted plants were arranged in five bench areas within a glasshouse. Each area contained one replicate of each treatment per species. The plants were watered by hand as required. All plants were given 2 x 1g of iron chelate (1g/L) 9 and 10 weeks after potting into the above soil mixes. The experiment was terminated 16 weeks after potting on.

RESULTS

Nine weeks after potting into the five soil mixes, data on the relative vigor and appearance of each plant within a group[2] was collected. The plants within a group were allocated the numbers 1 to 5, from least to most healthy. The rating of repli-

[2] The term "group" refers to the plants of a particular species arranged on the same bench.

cates was averaged and the data, together with deaths per treatment, is presented in Table 1.

Table 1. A comparison of the health and vigour of plants grown for nine weeks in five different soil mixes.

Species		No. of replicates	Soil Mix 1	2	3	4	5
Banksia	*ashbyi*	5	1.2[1] (3)[2]	1.8 —	4.2	3.6	4.2
B.	*baxteri*	5	1.2 (4)	1.2 (4)	4.8	3.8	3.4
B.	*elderana*	3	1.0 (3)	1.0 (3)	5.0	3.6	3.4
B.	*hookerana*	4	1.0 (4)	1.0 (4)	5.0	3.5	3.5
B.	*lehmanniana*	3	1.0 (3)	1.0 (3)	5.0	3.0	4.0
B.	*nutans*	5	1.8 (2)	2.2 (2)	4.0 (1)	4.0	3.4
B.	*occidentalis*	5	1.0 (5)	1.8 (2)	4.2	3.2 (1)	4.0
B.	*prionotes*	5	1.0 (5)	1.0 (5)	5.0	3.6	3.4
B.	*quercifolia*	4	1.5 (2)	1.0 (3)	4.5	4.0	3.0
B.	*sceptrum*	5	1.0 (5)	1.0 (5)	4.8	3.8	3.4
B.	*verticillata*	5	1.4 (2)	2:8 (2)	5.0	3.2	2.6
B.	*victoriae*	4	1.2 (2)	2.0 (1)	4.5	2.8	4.0

[1] Average rating of the replicates
[2] Number of deaths

For the control treatment, (soil mix 1), plant death was observed with all species. All replicates of this treatment died in the case of *Banksia elderana*, *B. hookerana*, *B. prionotes* and *B. sceptrum*. High death rates were observed for *B. ashbyi*, *B. baxteri*, *B. lehmanniana* and *B. occidentalis*. For 11 of the 12 species a death rate similar to that observed in soil mix 1 was observed for soil mix 2. With these two treatments a yellowing, then browning, of the leaves (initially the older leaves), from the margin inward occurred. This was followed by leaf curl and death.

The most vigorous plants were those in soil mix 3. Plants in the two soil mixes containing additional lime, with the exception of *B. ashbyi* and *B. sceptrum*, showed severe chlorosis especially in the new growth. This yellowing disappeared within two weeks of the application of 2 grams of iron chelate and, within six weeks, these plants were performing as well as those in soil mix 3. In the case of *B. ashbyi* and *B. sceptrum*, plants in soil mixes 4 and 5 were, for the duration of the experiment, as vigorous as those grown in soil mix 3.

DISCUSSION

It is well recognized that the Australian flora has evolved in an environment low in phosphate and studies which have been undertaken on proteaceaous species emphasize their tolerance to low phosphate availability (1,4). Lamont (3) has suggested that the presence of proteoid roots permits very efficient extraction of nutrients, including phosphate, from the soil.

The plant deaths observed in soil mixes 1 and 2 clearly suggest phosphate toxicity. Further work is required to eliminate the possibility that factors other than phosphate were involved. This result, however, is in agreement with the findings recently reported by Webb (5).

The good growth rate observed in soil mixes 4 and 5, following the application of iron chelate, clearly shows that all species studied could be successfully grown in the presence of high calcium levels and at pH's in excess of 8. The present results, however, do not indicate any direct beneficial effect of calcium or high pH. Further work is in progress to clarify this and to investigate superphosphate, calcium and pH interactions. The results reported by Webb (5) were obtained using natural Canberra soils in comparison to our use of UC mixes. It has been shown that calcium inhibits *Phytophthora cinnamomi* (2) and high pH is known to reduce phosphate availability. It is possible that the calcium effect observed by Webb is an indirect one, acting via a control of phosphate or *P. cinnamomi* levels or other factors.

Acknowledgement. The authors would like to acknowledge the technical assistance of Mr. B. Hadlow. They would also like to thank Mr. J. Webb for useful discussion relating to this work.

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5. Webb, J. 1977 *Australian Plants*, 9, 109-12.

NATIVE AUSTRALIAN PLANTS FOR INDUSTRIAL DEVELOPMENT

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By definition a native plant is one which occurs naturally in any given region. Thus Australian native plants are those which occurred prior to the invasion of the white man and his

attendant introduced species. Therefore it can be truthfully said that native plants are the ultimate in evolution to the physical conditions of the Australian environment. Paraphrasing that, natural selection and thus resultant evolution under the pressures of the physical conditions of the Australian environment have led to vegetative survivors over a vast period of time being the modern native plants. These survivors are, perforce, those which are most able to persist in a given environment. This does not belittle the value of acclimatized species which often produce excellent prime growth. Because of their optimum value, Australian native plants are of tremendous importance for industrial projects which may change or modify or have an affect on the Australian environment. Let us make it quite clear that any man engendered project has an effect on the existing natural environment.

At the beginning of European man's invasion of the Australian continent, emphasis was placed on the acclimatization of European and other world plants to Australian conditions on the basis of economic needs and agricultural demands. There was a deep feeling of alienism about the Australian bush and a drive to subjugate this land-structure. Replacing it with familiar plants and animals of the European landscape made good sense. So much so, that individuals were given knighthoods if they subjugated sufficiently vast areas of the Australian landscape. In those unenlightened and uneducated days, industrialists and developers were the saviours of mankind — everexpanding, everincreasing, and everchanging the environment to something familiar and beloved.

All of this began no more than ten human generations ago. By a quirk of human nature, the sixth generation of changers began to question the validity of the argument to change for its own sake and, for the first time, Australian-born generations recognized the intrinsic value of the evolved species of the Australian landscape. This awareness manifest itself in a number of ways: most significantly in changes to legislation, backed by public opinion, which denied developers the untrammelled right of destructive change. These changes brought with them specialized requirements such as environmental impact statements, plans of management, and rehabilitation and restoration programs. Today new industrial projects proceed conditionally and often require either restoration to original condition or rehabilitation to the satisfaction of the relevant authority.

In practical terms it comes down to restoration, i.e. returning to practical original condition or rehabilitation, or the returning to a condition which does not cause long term damage to the area nor loss to other land uses in the vicinity. Such requirements are completely new in the history of engineering

and development. Most areas of expertise must be developed to consider them in the context of the proposal. As previously stated, requirements can be firstly: restoration to the original condition by virtue of the desirability of the original condition. For example, any development in a designated National Park would have as a mandatory requirement, restoration to its original condition validated by the vestment of the land area for a particular purpose, viz. natural bushland. Any alternate uses must be cognizant of the original designated use and comply accordingly.

The second category of requirement is that of aesthetic value. A project may impinge on the eye of the beholder in such a way as to cause distress. There is a decrease in the concept of beauty in the eye of the beholder. The developer may be required to beautify an area which is normally done using landscape techniques.

The third area of concern is camouflage. Many projects require fixtures which although functional and well designed are not aesthetically attractive. The screening of these for both visual and auditory aspects is often accomplished by the use of vegetative plantings.

Faced with these mandatory requirements any good developer looks to a solution which is cost effective. Consideration must be given to such things as preparation of an E.I.S., cost of plant stock, cost of planting, and ongoing maintenance. The latter factor is perhaps the most significant single cost factor in any such decision making. It becomes obvious that the self-maintaining drought-resistant plants evolved in the Australian environment are the ones most desirable to fulfill the obligatory needs of licensing authorities.

The methods of establishing native plants for required areas are variable and reputed experts disagree about technique to a considerable degree. However, there are three major techniques:-

1. **The orthodox gardener technique.** This requires ground preparation, the addition of seed and fertilizer and ongoing maintenance such as watering. Seed stock and fertilizers need to be chosen with an awareness of environmental factors such as tolerance of plant species to existing conditions, amount of erosion likely prior to existing conditions; amount of erosion likely prior to initial growth, stability of chosen species in terms of colonizing plants, toxicity values of chosen fertilizers to particular species, age and structure of selected plant species, and the self-perpetuating values of selected species. That is by no means an exhaustive list of considerations.

The use of stock plants is valid in some circumstances.

Such circumstances require constant maintenance depending on planting size, i.e. tube plants have a long survival rate without maintenance whereas advanced plants have a greater cover value but for a shorter time.

2. **The use of sprays.** Sprays involve a carrier which may be wood pulp, paper, sugar cane fibre or meadow hay; a bonding agent, which may be bitumenous or cellulose gel; plus seed or cuttings, and fertilizer. These are all mixed with water and pressure-sprayed onto the treatment area. There are an infinite number of combinations of formulae — as might be expected when one considers the infinite number of ecosystems with which we are dealing in Australia.

3. **Mulch or tritter** is commonly used in areas of high sensitivity. Existing plant cover is broken down to a mulch or wood chip and respread over the surface to be restored. This has a number of advantages: there is no loss of fertility from existing sources and the seed load is derived from original stock material. This is a distinct advantage in reducing alterations to the genotype of localized native species concerned, Nursery stock, albeit the same nominated species, is very often drawn from a different genotype and the invasion of this may bring to pass quite unintended environmental side-effects.

Although these are the main methods of using native plants, combinations of these methods are viable. Dependent on the requirements of an area, combinations lead to the best possible results under any given circumstances.

In using native plants to overcome environmental impacts, both natural and sociological, there are a number of problem areas which must be considered when making the decision as to the technique to be employed:-

a) The question of seed viability. When native plant seed of certain species is mixed with phosphate fertilizers or loam there is often a loss in seed viability. Native plant seed which is stockpiled in soil, or dry stored has a similar viability loss over a period of time. Seed which is broadcast scattered in wet media may have a germination rate which is not backed up by a continued growing season, leading to a total loss of some species in the mix.

b) Cutting viability in mulches and sprays is of particular significance. Few plants will accept the non-sterile situations involved in mass cutting planting; the exceptions are stoloniferous native plants which will accept chopping and replanting, provided sufficient of the adjacent colloidal soil communities are contained with the cuttings. Generally speaking, mass cutting is a specialized approach which should only be used by skilled personnel.

c) Nursery stock offers a number of problems, the most common being the "pampered" syndrome. Nursery stock is nurtured in selected soil, under optimum light, watering and fertilizing conditions. This permits maximum growth of the plant under the idealized conditions. The removal of such a pampered individual into the harsh reality of survival often leads to trauma, resulting in death. Because of this pampered syndrome, nursery stock must only be considered in terms of ongoing maintenance unless plantings can be guaranteed in seasons or conditions which permit the overcoming of the transplant trauma.

d) Another problem not pertinent to the realities of plant propagation but highly significant in the regeneration of disturbed areas is governmental authority awareness. Some government authorities still maintain Europeanization as an ideal and not only have no information about alternate methods of restoration but do not wish to know about them. A designated governmental authority may dictate to a developer that he will plant poplars, willows, petunias and roses instead of much more functional and cost-effective native plants. In this area it is essential that the International Plant Propagators' Society and allied organizations accept their proper role in educating the decision-making authorities as to the value of native plants. These contractually fulfill with cost effective, low maintenance species plants guaranteed to meet the needs of the most meticulous government servants.

In conclusion, I believe that the Plant Propagators and allied people in Australia have not faced up to the fact that industry requires by mandate an enormous ongoing amount of restoration and rehabilitation. Members of this Society are content to sit back and wait for orders to come in from the development industries across Australia. You have the capacity, the knowledge, and the stock to advise the developers of what they should be doing and looking at — all that you lack is the awareness, and I sincerely trust that this paper will make you more aware.

CONTAINERIZED ROSE GROWING

I. W. DAWSON

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Roses are propagated throughout the world using the same basic techniques. What we are doing that is different from the

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Roses are propagated throughout the world using the same basic techniques. What we are doing that is different from the

bulk of the trade is carrying out the entire process in containers.

Roses do very well in Western Australia where dry summers ensure that we have no fungal problems for at least half of the year. Our deep sandy soils have little water holding capacity so permanent irrigation systems are needed to provide regular and frequent waterings. Selection of rootstock to suit this soil type is most important. We use *Rosa fortuniana* rootstock for its vigour in our hot dry summers and its roots thrive in the high soil temperatures that we have.

We have changed from field growing of roses to fully containerized production largely to reduce the pressure of handling all the stock in the winter months. With containerization we have year-round sales. We do most of our promotion for autumn sales and are generally running low on stocks by the beginning of summer. Containerization also results in a high degree of self service by the customers and having the roses in flower is a major help in ensuring customer satisfaction.

We have tried using both the traditional stock bed, and striking directly into 9-inch containers, with variable results. We are now striking cuttings in tube trays and foam cell trays with better results. This also gives much better results when planting out than does the stock bed method. We plant out into the smaller 6-inch pots for budding and then go directly to the buckets. Using the smaller pots also requires much less space.

Open ground produced *R. fortuniana* have very few buds coming away in the first year so must be sold as two-year-old bushes. Containerized production under our conditions gives a most presentable, multistem rose from three to four feet high and in flower in 15 months.

HARD-TO-PROPAGATE WESTERN AUSTRALIAN NATIVE PLANTS

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INTRODUCTION

The flora of Western Australia contains a very large number of species and includes some of the showiest plants in the world. The majority of West Australian wildflowers are no different from any other plants in terms of propagation. It may be argued that all plants can be propagated but considerable difficulty is experienced when attempting to propagate many of

bulk of the trade is carrying out the entire process in containers.

Roses do very well in Western Australia where dry summers ensure that we have no fungal problems for at least half of the year. Our deep sandy soils have little water holding capacity so permanent irrigation systems are needed to provide regular and frequent waterings. Selection of rootstock to suit this soil type is most important. We use *Rosa fortuniana* rootstock for its vigour in our hot dry summers and its roots thrive in the high soil temperatures that we have.

We have changed from field growing of roses to fully containerized production largely to reduce the pressure of handling all the stock in the winter months. With containerization we have year-round sales. We do most of our promotion for autumn sales and are generally running low on stocks by the beginning of summer. Containerization also results in a high degree of self service by the customers and having the roses in flower is a major help in ensuring customer satisfaction.

We have tried using both the traditional stock bed, and striking directly into 9-inch containers, with variable results. We are now striking cuttings in tube trays and foam cell trays with better results. This also gives much better results when planting out than does the stock bed method. We plant out into the smaller 6-inch pots for budding and then go directly to the buckets. Using the smaller pots also requires much less space.

Open ground produced *R. fortuniana* have very few buds coming away in the first year so must be sold as two-year-old bushes. Containerized production under our conditions gives a most presentable, multistem rose from three to four feet high and in flower in 15 months.

HARD-TO-PROPAGATE WESTERN AUSTRALIAN NATIVE PLANTS

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INTRODUCTION

The flora of Western Australia contains a very large number of species and includes some of the showiest plants in the world. The majority of West Australian wildflowers are no different from any other plants in terms of propagation. It may be argued that all plants can be propagated but considerable difficulty is experienced when attempting to propagate many of

these species in commercial quantities and at acceptable prices. It does not necessarily apply that it is easier in quantity; for example, try making 10,000 *Hemiandra pungens* cuttings. Because of its uniqueness there is much to learn about the flora of Western Australia. It ranges from those species found deep in the Karri forest to those thrashed by the elements on the coastline and to inland species bordering the desert. As further progress is made more and more of these magnificent specimens will be marketed and displayed happily in home gardens.

Consider some of the reasons why more of our native plants do not appear in the majority of garden centres. Lack of identification or promotion of the plant is important. In order to sell a plant to the public one must be able to observe the end product, a fully grown specimen plant and its flowers. It must have appeal to the prospective buyer.

Propagation of our indigenous species by vegetative means has not been widely adopted because of their reputation for being hard to grow. A plant is only hard to grow if you do not know how to grow it! If you do not know then set yourself the task of searching out and eliminating the difficulties.

Plant species grown from seed are notorious for their variability and for delayed flowering. For example, *Kunzea baxteri* grown from seed takes approximately 4 years to flower whereas from cuttings it flowers the first season in the pot to the delight of the buyer. We can overcome delayed flowering by vegetative propagation. Native plants received a bad reputation years ago because it was claimed they were scruffy and had no appeal. Careful selection of plant and flower variants has improved their standing.

To bring a new plant into production growers obtain cutting material directly from the natural site of that particular species. Results of these exercises are usually very poor, leading to impatience on the part of the grower and perhaps even discarding that species because it is too hard to grow. To overcome the problem the grower needs to provide himself with sufficient suitable vegetative plant material. This requires a long term plan whereby a small quantity of material, carefully selected form a parent plant in the field, is propagated and planted in a garden environment where it is evaluated for its horticultural merit. If it has real merit then these plants become the mother plants for future propagation material. Gradually the harsh bush plants are transformed into more manageable, productive and spectacular species. Of course, this process cannot be completed in one season but requires a program over as much as five years.

PROPAGATION

In considering the propagation of plants for commercial purposes one needs to obtain maximum productivity. To achieve this we must be very careful in choosing the plant material. Considerable effort must be made to get clean cutting material and so to reduce the incidence of fungal infection.

Hormone powders are used extensively as an aid to root formation. We have used the proprietry hormone powders Seradix 1 and 2, and Pyco 3 and 4. We have experimented with mixtures of indolebutyric acid (IBA) and naphthaleneacetic acid (NAA), both in liquid and powder forms. As a rule we use Pyco 4 for most cultivars.

The medium used for propagation has varied considerably over the years but at this stage we use peat and perlite in the ratios 1:1 or 1:2. We have used these materials directly without sterilisation and obtained satisfactory results but for long term protection steam/air pasteurisation is used. Pasteurisation is performed at 60°C for 30 minutes followed by immediate cooling. This material has been recycled many times (mainly because of the cost of perlite) but each time new peat and perlite is introduced. When the content of decomposed plant material increases too much the mix is used in the tubing process.

To maintain a minimum level of infection in the glasshouses a spray programme using Captan or Thiram is implemented each 7 to 10 days. The cuttings are placed either into flat trays or directly into seedling foam trays (110 units) according to space availability. Mist sprays are used to keep the cuttings moist. Because automatic systems are available it does not mean all problems are solved. It must be remembered that all plants cannot be treated alike. Some of the Western Australian species are from dry areas, others are wet area plants. Some plants can be propagated very moist or even wet but the majority of the dry area plants turn black and drop their leaves under constant mist. Therefore we start them in mist, move them to a no mist area, then to a warm area of the glasshouse, igloo or bushhouse depending upon the time of the year. This is a slow process but ensures a high yield in the long term. In due course the plants are tubed up into larger units.

Over the years, large numbers of the more difficult species have been lost during the potting-on stage. This requires careful timing to reduce losses, but an even better solution would be to eliminate that costly stage by growing the cuttings in individual units.

SPECIFIC EXAMPLES

Legumes, such as the acacias and gastrolobiums, gompho-

lobiums, eutaxias, (that is the bacon and egg family) have some of the showiest flowers. Most plants in this family are normally grown from seed, but because of their lack of appeal without flowers they prove difficult to sell. We can overcome this by producing flowering plants by vegetative means.

Adenanthos species — e.g. *A. cuneatus* and *A. teges* give good results if hardwood cuttings are used.

Billardiera bicolor (syn.: *Marianthus pictus*) This is one of the showiest of the shrubby twiners and bears reddish colored flowers with stripes in the throat during mid-summer. Moderate success is obtained during autumn using the intermediate wood between the soft tips and the old wood.

Banksia spp. *and Dryandra* spp. have for many years been the envy of the gardening enthusiasts. The difficulty with these is probably mainly due to the shortage of seed, but we can overcome this to some extent by growing them from cuttings.

Generally cuttings of large firm tips 5 to 15 cm. long, selected from medium to hard wood strike reasonable well. This material normally appears during autumn to winter. *Banksia* species grown in this manner are *B. occidentalis* and *B. verticillata*. It seems as though the species from the wetter areas in the south strike fairly readily. As a general rule they do not respond to strong hormones. In future years we should see banksias flowering in containers!

Calytrix fraseri. Large tips are taken after flowering, late in summer because they are relatively soft. Place under mist and use a soft wood hormone.

Conospermum, (smokebush) Because seed is very hard to collect, it is better to use large tip cuttings from autumn to mid-winter.

Darwinea spp. (mountain bells) are some of the most sought after species amongst the W.A. flora. The greatest difficulty is producing suitable stock from which a consistent supply of cuttings can be obtained.

Grevillea spp. to date have been regarded as hard to grow. They do not appear to tolerate overmisting. Best results are obtained by pruning the plant harshly, then irrigating to induce a large quantity of soft new growth. This material is soft and easy to propagate.

Grevillea obtusifolia propagates best by using large firm tips in winter. The smaller growing species are easy to propagate but the large, woody species are difficult.

Grevillea bipinnatifida is a difficult species to propagate; even more so than 'Robyn Gordon'. In this case it is important to select the best forms available to grow. Three valuable selec-

tions are greyish-green foliage with orange flowers; grey foliage and red flowers and a green foliaged form with red flowers. To date, best results have been obtained in direct units using soft to medium wood about 10 cm. long during summer.

Hakea cuculiata (scallops). Generally, hakaes are not propagated from cuttings but it can be done, primarily to display flowers in pots. Hardwood cuttings are taken around autumn.

Hemiandra pungens is hard to consistently produce. It tends to rot off, an indication that it should be propagated fairly dry. Because it is a vigorous ground cover the harder wood (not tips) yield a greater percentage during winter.

Hibbertia hypericoides. A difficult species to get started. The softest material seems to strike easiest. Other *Hibbertia* species, such as *H. cuneiformis* and *H. stellaris*, from the wetter areas in the south are easier to strike.

Kunzea pulchella. Three selected forms are being propagated; a green foliage red-flowered form during winter to spring, a grey foliage form with cerise-pink flowers from winter to spring, and a grey foliage, red-flowered form during early to mid-summer. Vegetative propagation from these selected forms has been slow but we can now get a high percentage of cuttings to strike using medium to hardwood cuttings about 10 cm long. The main difficulty has been due to continuous misting. This, of course, is a dry area species.

Petrophila linearis (pixie mops) can be grown from medium to hardwood cuttings, approximately 5 to 8 cm long during winter.

Verticordia spp. (Morrisons, or feather flowers) are propagated from firm tips which are produced after flowering. As previously described it is important to produce stock plants from which suitable cuttings material can be obtained.

CONCLUSION

The flora of Western Australia has immense horticultural potential. For many years these unique flowers have been exploited for their value in the fresh cut flower trade and for dried arrangements. It is now urgent that these species be introduced into cultivation.

A plant is only rare if you do not know where to find it and only hard to grow if you cannot successfully encourage it to grow. Basically all plants are equal but there is a need to develop new techniques especially applicable to species adapted to dry areas. Once these techniques are developed a serious promotion and marketing programme is required to ensure that these magnificent species become part of all gardens.

GROWING FERNS BY CAPILLARY MEANS

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It may be that many nurserymen regard the production of ferns from spores as a peculiarly specialist activity. It is true, of course, that some specialism is developing in Australian nursery practice and perhaps this is a sign of professional maturity. We have in Australia some specialism in ferns, conifers, palms and claims of specialism in native plants. In this latter field it should be noted that the expertise existing, while it may be considerable, is frequently over a somewhat restricted range of genera and species and, in general terms, may be said to disregard the native ferns, the native grasses and, in some respects, the native palms. Thus the degree of development of nursery specialisation in Australia is not yet great and most of us are still interested in growing a wide range of plants for sale. Were it not for the work of George Sonter and his family it is doubtful if the current interest in and enthusiasm for native ferns would have reached the present pitch. Impetus has been added to this enthusiasm by the publication in 1976 of a book on Australian native ferns which is at once authoritive and informative (1), and a useful addition to other references on fern culture (2,3).

The time for producing ferns could never be more propitious. If we are still in the situation of being general propagators there must be a reason why so few of us include the production of ferns as a significant part of our activities. This paper is prepared on the supposition that lack of fern production is due to lack of production techniques and to offer a simple method which is capable of exploitation to produce viable and saleable ferns in large numbers.

It should be emphasised that I am not insensitive to the future of tissue culture or to the astronomical production number possibilities of this method. However, I base the following on the view that many of us are unlikely to face the considerable demands both in capital and staff for the economic development of these methods particularly in nurseries of moderate size. Further, since spore producing ferns (as distinct from sterile cultivars) have a potential for producing similar numbers, there remains a case for propagation from spores.

My experience leads me to believe that an adequate technique for the production of sporophytes is that which is dependent on watering both the spore beds and the subsequent

juvenile ferns by capillary means. Such a method has the following obvious advantages.

1. It permits the establishment of a microclimate of near sterile conditions.
2. Since necessary moisture is always available it prevents some, at least, of the future intrusion of foreign agents into the microclimate.
3. It permits the treatment of the water external to the microclimate to further reduce the possibility of infection from without.

Let us suppose that we are dealing with a small spore sample (say, one capable of producing several hundred sporophytes). The following method is recommended.

1. Take a standard wine flagon and remove the base. This may be done either with: a) a glass cutter; b) burning a string around the bottle and subsequent immersion; or c) (my own method) turn the flagon in the palm of the left hand over a simple spirit burner. Test heat with the thumb of the left hand and immerse in 2 cm of water (Present record is 36 per hour). When the bottom drops out you will have created the cheapest bell jar on the market.

Now take a pot which is a snug fit in the flagon. I use a standard yoghurt can which is an exact fit. Partially fill the pot with rock wool and add propagation medium. In Western Australia the local sedge peat with the trade name of Compeat is adequate, but various mixtures of imported peat and sand have been used with success.

Sterilise the flagon and its cap. Use of chlorine needs care as the bottle must be thoroughly rinsed. Mild disinfectants such as potassium permangenate seem to work. Sterilise the yoghurt container, the medium and the rock wool with boiling water. Place the flagon with cap intact over the can. Return to the task of sowing spores when the medium is cool (say 1 hr.).

Keep spores in pepper shakers, kitchen herb containers or other like equipment, all of which must have a top seal (the kitchen herb bottle is superior). Sow spores by simply "peppering" the medium. Now place the entire assembly in a water tray, say an ice-cream can container pierced at sensible height to prevent flooding. Add water so that the surface of the medium and the spores are obviously moist. The addition of potassium permanganate will provide additional guard against infection. The water tray used may be of such dimensions as to hold many flagons and should be situated under a greenhouse

bench, in a shade house or in any like situation which will ensure reasonable lighting but no direct sunlight.

Rates of germination will vary from species to species and will be more rapid in summer than in winter or again more rapid in a warm house than in a cool one.

One of the essential strengths of the flagon germinator is that moisture condensing on the glass does not drop on the spores but because of the shape of the bottle it finds its way down the sides and back into the water tray.

When spores germinate they may be left to develop in the original pot. However it should be realised that even with the most careful initial sterilisation some infection may occur. Indeed one may be sowing some fungal spores with those of the fern. Should this occur the uninfected areas of germinating spores or developing prothalli may be "pricked-out" into a peat pot. Normally 20 to 30 mm clumps are lifted with forceps and spaced in the new medium at similar distances. As a general policy the use of such methods will minimise losses both by infection and by sporophytes "choking" each other. Pots may be left until strong sporophytes develop but pricking early is a good rule to prevent losses as a result of the more precocious sporophytes suppressing the less vigorous. I find that individual ferns are best pricked into mist tubes and that smaller tubes give a better result than larger. The tubes should be placed in a suitable tray or container rigged for efficient capillary watering and covered with a polythene hood. As the ferns grow on they may be "hardened off" by the partial raising of the hood and finally its total removal. At this stage the sporophytes may be fed, particularly with nitrogen, and should be ready for potting within a month of their removal from their miniature greenhouses.

A comment on methods of spore collection.

1. Place fertile fronds in paper bags and dry out quickly. Put the resultant dehisced spores through a fine sieve to remove some of the roughage from bursting sporangia.
2. Sow as soon as possible. The viability of fern spores is intensely variable. While spores of *Cyathea* may be stored for several years those of other species lose viability very quickly. Some species have what, in lay language, are called 'green spores'. These must be sown within hours of their extraction. *Todea barbara* is a good example of this.

Finally, by following the simple techniques detailed here I believe that the use of capillary watering in fern production is not particularly difficult, expensive or tedious and that by it's

use fern production may become a very rewarding part of general nursery practice.

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NURSERY HYGIENE

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Successful propagation involves the integration of many interrelated factors such as the correct time and method of taking cuttings with the right temperature, light and water supply. However what a pointless exercise if, after gaining the knowledge and expertise of taking cuttings, we lose them to diseases and pests. The industry has become more and more specialised with larger quantities of the same plant being grown at any one time. In this way we have created very suitable environments for the disease organisms and pests which can cause such dramatic losses in cuttings and defeat the purpose of our work. We must take great care to prevent the spread of these organisms.

Hygiene is the most important factor we have to contend with. We must be certain our clothes, shoes, hands and even fingernails are clean and sterile in a hygienically controlled propagation system. Everything we use must be clean and free of infection, from the trolleys we use for transport, to the benches where we pot our stock. All tools used in the preparation of cuttings must be sterilized and kept in a spotless condition, whether they be a knife, a pair of secateurs, or whatever we use. If a number of cuttings are to be taken off one plant, it is preferable to disinfect the instruments before going on to the next plant. Of course the sharper the instrument the cleaner the cut, and the less chance the infection has of becoming established. A small bowl of disinfectant should be adjacent to the operator so that he can regularly dip his utensils. By this means disease, if present, is restricted and more easily contained. However, as happens in the best of establishments, an infected cutting can slip through, so that the regular disinfection of fingers, benches and instruments is first priority. How often have we been in the position of working on our cutting propagation

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bench, when another staff member may stop to say a few words, and place his infected hands or container on your sterile bench, whilst he has a smoke. This simple example shows how our system of sanitation can break down and ruin our otherwise healthy cuttings. The working bench should be scrubbed every afternoon with a mild disinfectant solution, and any discarded plant material should not be allowed to accumulate.

Clean stock material is of the first importance. It can be obtained from a known clean source, either from another grower or from one's own plants that have been cleaned of contamination. One should never presume when buying new plants, that they are clean. It is always preferable to isolate them from the other stock for sufficient time for any disease or pest to manifest itself.

There are two main sources of vegetative propagation material, both being used in most nurseries, yet each requiring different treatment. One is the use of mother-stock plants, which are usually located away from the general production area. The main advantage with this is that it is easier to maintain a higher standard of stock health and cleanliness for a few plants in a limited area. The main disadvantage, however, is that the stock plants end up in odd corners all over the nursery and, as a result, do not receive proper care to maintain healthy, disease-free plants.

The second source is young plants under production in the nursery where a replacement cutting is taken before the parent plant is sold. With this system the mother plants receive the general nursery preventative spray programme. A common failing with this system though is that, if a crop does not give sufficient propagation material, we are forced to go to older plants which may not be in such a good state of health.

Thorough and consistent weed control should be practised as an essential part of the programme as many weeds act as excellent hosts for many diseases and pests that trouble our commercial plants. It may be beneficial to drench mother stock with a fungicidal solution a few days before taking cuttings. Plants such as poinsettias seem to respond to this extra treatment.

Cuttings on the preparation bench are often covered with a cloth to prevent them drying out, but did we insure that the cover was properly disinfected before and between each batch? Having made sure of this, the cuttings should now be stuck in the propagation medium which has, of course, been fumigated or steam-air treated, and moved as quickly as possible into the propagating structure and onto a bench that has been disinfected with a drench. This bench should have been prepared by removing all debris, hosing down and scrubbing. Even the mist

nozzles in the propagation unit should be scrubbed and disinfected. An essential part of the sanitation of the propagation structure is the maintenance of clean ceilings and grooves. Infection can be transmitted by air or by condensation on walls and floors. Footwear can carry infected soil particles. Watering nozzles must be kept off the ground at all times, splashing eliminated, and smoking prohibited with some crops. Immediate isolation and and preferably destruction of infected plants as they appear, should be a daily chore. We must make sure our properly sterilized containers are not put on infected ground or trolleys, or that we do not use a non-sterilized shovel to move the mix, or leave the mix open to airborne spores and seeds or adjacent to surface water. These are essential considerations if we are to be serious about disease prevention.

For advice on the use of pesticides we should look to our Government Departments and when we find a suitable system we should adhere strictly to it to maintain our success rate. The most rewarding and comprehensive books on this subject is, "The U.C. System for Producing Healthy Container-Grown Plants" (1). It should be read and re-read by all who hope for 100% success rate.

Preventative control is the most successful method for containing diseases and pests in propagation. It is essential that all staff understand this and are trained to maintain the standard of hygiene.

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PROPAGATION OF SOME SOUTH AFRICAN PLANT SPECIES

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Most of the nurseries in Southern Africa propagate a range of plants similar to that grown here in Western Australia. The best of the nurseries are probably not as sophisticated as the best in this country mainly because, in general, Southern African labour is not brought up in technological surroundings, and nursery hygiene is a new subject, difficult to get across. But that does not mean that every nursery owner himself is behind the times. On the contrary several nursery owners have done a lot of trial work into crops which have an export potential. Cut

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flowers of the family Proteaceae are one example and I would like to outline some of the problems of the enthusiast nurseryman; enthusiast in the sense that he does not just grow bread and butter lines. In relation to proteas I define an enthusiast as one who regards this weird and fascinating family as an ever present challenge. How far any commercially oriented organisation can afford to go along this road of specialised and often expensive trial work is an issue which I would like to touch on later.

There are about 400 species of Proteaceae in Southern Africa. The genera *Protea*, *Leucospermum*, *Leucadendron*, and *Mimetes* are well known. About 12 genera are of commercial importance. There are three essential requirements common to all these twelve genera:-

1. Water must be fresh, very low in salts.
2. Soil must be low in nutrients.
3. Warm humid conditions must be avoided. Cold humidity is all right and a breezy exposed site is ideal.

But it is not as simple as that — the genus *Protea* required costly research before the nurserymen of South Africa could exploit its potential. Some species grow in dry conditions, a few in very wet soils but *only where the water is clean*. Most grow best on acid soils, for instance, *Protea cynaroides*, the king protea, grows in a pH as low as 3.6. Others like *P. neriifolia* can take an alkaline soil of pH 7.3. Some are tender, others, like *P. grandiceps*, grow in nature high up in a winter snow belt. The three I have mentioned are three of the twelve important species. One of them, the king protea, has three important geographical variants. Another, *P. neriifolia* has five geographical variants, at least two of which are exceptions to the low nutrients requirement: they can take salts in solution at 400 ppm. Indeed the cultivation of the proteas is hardly straightforward.

As might be expected, the propagation of other members of Proteaceae is not very straightforward either. The pincushion, *Leucosperum cordifolium*, is a very popular species which is related to the proteas and it is fairly easy to propagate from cuttings. Hence several clones have become established in the trade. Members of the genus *Protea* are not easy to root nor are they satisfactory even when rooted. For instance, a cutting of the king protea usually ends up as a stumpy plant with 30 cm of stem growth and fails to develop further. So seed propagation is the only practical means. Each nurseryman has his own tricks; some are freely communicative but a few are not. I am indebted to Prof. Van Staden of Natal University, Pietermaritzburg for much of the factual information.

Proteas which have wide, shallow, cup-shaped flowers (using the term "flower" loosely) ripen their seeds in 6 to 7 months. The deeper cupped forms take up to one year and, if the flower heads are removed sooner, then any viable seeds can germinate immediately but, if not sown, would have a poor shelf life. If a flower head is removed later there are likely to be more viable seeds but germination might take longer, and there is a great risk of insect damage on the plant. As long as the flower head remains on the plant variations in temperature and humidity can also be detrimental, so it is difficult to know what to do. In nature pollination is generally poor and good seed can comprise less than 3% of the total. Most *Protea* seeds are partly covered with soft bristles. An experienced seed sorter can distinguish good seed from shrivelled seed and from lignified empty seed by the feel of it. (Botanically, the seed is a nut). To control the pests (and there are about 200 known pests of protea shoots and leaves), some nurserymen inject developing seed heads with 5% carbaryl dusting powder; young plants can be sprayed with a systemic insecticide to protect them from most insect damage. To accurately determine the time to harvest it is preferable to mark flower heads when flowering with a coloured strip of plastic. After harvesting, seed heads are stored and the seed falls out of its own accord. Where harvesting cannot be done every 3 to 4 weeks, the seed head is enclosed in a muslin bag to collect seeds as they are shed naturally. Seed can be stored in sealed bags for quite long periods in a refrigerator or in a freezer down to about -5°C.

Protea seeds are notoriously erratic in germination. Apparently they do not contain substances which will inhibit germination, although there are substances which inhibit seed germination in other Proteaceae genera. *Protea does respond to* growth promoters and these can be induced to form within the seed by getting oxygen through the hard pericarp. Oxygen is the limiting factor. The embryo can obtain oxygen if the seed is scarified. A file will do this or a small grindstone but the embryo should not be exposed, cut or damaged in any way because of the risk of fungal infection.

The seed is then sown *scarified side upwards*. If this side is placed downwards there is a marked reduction in germination. Most nurserymen sow their seeds virtually on the surface of a very sandy mix (70% sand at least) and the seed is barely covered. Some nurserymen add sawdust purposefully to reduce available nutrients, especially nitrogen. Some place the seed individually into containers using stiff card tubes and cover these with moistened absorbent paper. Some pre-germinate the seed between two layers of damp hessian (burlap) then pot up the seed singly. I have not been to any nurseries where germination

is initiated in flasks of oxygen, but this method works well in the laboratory. The earlier system of germinating was to sow protea seed in seedbeds about 5 cm apart, but percentage germination was very low and was spread over three years or more.

If the young seedlings are required for stock they are planted out while still very small just as the first pair of true leaves are appearing. They are set very low to avoid damage to the tender young stem by sun or blowing sand. They are watered frequently, as much as every day at first with clear water, preferably rain water or mountain stream water and, of course, the site must be very well drained and low in nutrients. Most seed is sown in March and April and seedlings are ready for planting in late winter/early spring.

Whichever way you look at it, growing young protea plants for sale is not very lucrative. This brings me to the point of whether the profit motive should control the whole thinking of a nurseryman. I would say not. A nurseryman has to keep going, of course, but I think the serious nurseryman, once established, has an obligation to his community. He should serve his public as well as profit from it. Merely bringing new plants to the notice of the public and having smart promotions is not necessarily serving; to my mind such plants should always be genuine improvements on the older ones, or should be reliable additions. They should have as wide an application as possible.

I think it is time for the nurseryman to look less at the catch-penny lines or what is in fashion at the moment, and look instead at plants when they are not in flower. Foliage is usually there for twelve months — flowers rarely for more than two months. So foliage is more important than flowers in the structure of a garden. Foliage can be dense and screening, or it can be wispy. It can have interesting colours; it can be shiny or dull. Here we are getting into aspects of design, but it is important for the nurseryman to think along these lines too. We should be the ones to offer to the garden architect new material which is reliable and interestingly different and to tell him what he should be planting. Gardens are not going to get any larger: in fact they are more likely to be smaller, so the garden owner has to be more critical in the choice of the few he has room for and make sure that all his plants work successfully and perform more than just one function. By that I mean that a fruit tree can at the time serve as a shade tree and a screening tree or a shrub; besides having flowers it can have interesting foliage which might last well when cut for the house.

So the nurseryman, besides looking at the profit margin of his lines, should also consider the texture and habit of the

plants and whether that they are truly adapted to a local environment.

That's all very well, you will say — but you have not got the time to play around like this — or the capital — and why should you do all the donkey work anyway? — That is where the Protea story comes in: — From about 400 species, only 12 were selected. There were problems: sorting out these problems was not a one-sided affair. The nursery trade did not progress very far on its own until it had help and cooperation from research bodies and from universities.

I am sure that there is a great future for the native flora of this country. The potential of some genera is enormous. But no nursery concern can afford the trials — or has sufficient expertise — to develop what is on our doorstep. So I suggest that the nursery trade take a look at this: a long creative look without quibbling; get together, put up a combined front; in fact, formulate a policy and then approach government and research organisations for support.

EFFECTS OF WATER QUALITY IN RELATION TO PROPAGATION

R. W. MIDDLETON
Nicholson Road, Canningvale,
Western Australia 6107

During the last 20 years the propagation of a general range of shrubs and trees has been undertaken using poor quality irrigation water. Some practical observations and methods we have developed over this period of time under these conditions are as follows:

The quality of underground water we use is approximately 800 ppm of total soluble solids; the majority of the salts being sodium chloride 350 ppm; iron 0.3 ppm; calcium 34 ppm; zinc 0.10 ppm. The pH is approximately 7.5.

While cuttings of most species can be struck successfully, the overall percentage is poorer than if superior quality water is used. A fairly wide range of species are propagated, including both natives and exotics. Some susceptible species, such as soft-leaved deciduous shrubs and trees and azaleas are no longer attempted as the results are too poor to warrant the perserverance.

The damage to plant tissue from poor water quality seems to follow a fixed pattern, namely:

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The damage to plant tissue from poor water quality seems to follow a fixed pattern, namely:

1. The first signs are damage to the leaf tips and margins.
2. Next comes damage and possible death to the plant or cutting, commencing at soil level and proceeding upwards.
3. The final effect observed is damage to the roots.

After many trial and error approaches to propagation by cuttings, we have settled on a basic formula as follows:

(a) Where it is possible to propagate with different types of wood the firmer cuttings generally give better results than the extremely soft ones.

(b) We try to avoid the hottest and driest period of summer as a time to take cuttings.

(c) We use more shade than normal.

(d) Because of the increase of soluble salts through evaporation, plastic pots are used in preference to clay.

(e) The benches are slightly inclined and covered with crushed slag or metal aggregate so as to ensure efficient drainage.

A mesh grid also worked effectively as a bench, but because of the necessity of maintaining a high humidity adjacent to the plant material, the solid type bench gives better results.

The area is treated with a copper oxychloride fungicide before every use.

(f) The propagation house is double skinned (glass outer, polythene or corflute inner) with a 6" air space between skins. The double skins help maintain even temperature, assist in shade control and ensure a very high humidity.

Misting systems have proved to be unsatisfactory and are not now used. The frequent light applications of moisture by misting causes excessive buildup of salts on leaves and soil surfaces. The creation of a high humidity (sweat) chamber appears to give better results.

(g) Shallow propagation pots are used to help drainage — 5" squat pots mainly. Tubes are not used because of the problems associated with maintaining adequate moisture.

(h) The propagation medium we use is, by volume, 70% sharp sand, 10% crushed slag, ($^3/_{16}$") 10% foam styrene ($^3/_{16}$"), and 10% crushed pine bark. This mixture has good drainage properties and allows us to water quite heavily, a desirable thing as it helps to flush the salts from the medium. Media containing peat moss, sphagnum, sawdust etc. in quantity have not been as successful as the above mixture, probably because they do not drain as well and retain too many salts. The sand should be very coarse — up to 1/16th". Man-made sands, e.g. crushed

aggregates are not as efficient as naturally occurring creek bed sands, probably because the man-made sands do not drain as readily.

(i) The selection of the most desirable plant material is necessary; weak or inferior wood affects the rooting percentage quite dramatically.

(j) The inclusion of any soluble material in the irrigation water appears to increase the problems encountered. However, we do include sulphuric acid (98%) at a rate of 25 ppm and polyphosphate 918 at 3 ppm, in the irrigation water to adjust to a pH of approximately 6.5 and to help in the cleaning of the leaves.

All materials that are added to the irrigation water appear to increase the total solids. Therefore we try to apply fertilisers, insecticides, fungicides etc. through the roots as they are less succeptible to damage than leaves. We try to avoid any form of liquid foliage feeding during extremely hot, dry periods. Should foliage feeding become necessary we use weak concentrations of fertilisers and apply them in the evenings on dull days. We water heavily and frequently to prevent the soils drying out but they must drain well.

Cuttings propagated with this inferior water take longer to strike (up to twice as long), the percentage of take is poorer, and the resultant growth slower than those propagated with demineralised water.

POTENTIAL FOR HORTICULTURAL DEVELOPMENT IN THE NORTHERN TERRITORY OF AUSTRALIA

DENNIS A. HEARNE

Tropicus Nursery
P.O. Box 505 Darwin, Northern Territory

It is now 150 years since the first documented evidence of incipient horticultural activity in the Northern Territory and, in that time, it has suffered from the vagaries of numerous officials. Horticultural activities have been dampened by a lack of sympathetic government action and a severe lack of technical knowledge of suitable crops.

During the past 12 years, I have become more and more aware of the tropical fruits and their potential in the Northern Territory. With the advent of drip irrigation and a better understanding of tropical techniques (instead of "modifying" southern Australian techniques) even those plants condemned for

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having origins in wet zone tropics become distinct probabilities for local cultivation.

Table 1 lists some 40 species encompassing almost 200 fruit cultivars currently growing in Darwin. Most of these have been either introduced, or reintroduced, by the author and his associates in the past 6 years.

Obviously enough, the selection of seeds or propagating material is of prime importance. There are many fruit cultivars growing in the area that are not representative of the species and which do not realise anywhere near the full potential of that species. However I feel that if a cultivar — even a very inferior one, will grow successfully here and crop, no matter how indifferently, then that species should be made subject to as wide a testing as possible, utilising as many clonal sources as are available.

The Litchee (*Litchi chinensis*, syn.: *Nephelium litchee*) and longan (*Euphoria longan, syn.: Nephelium longana*) fruits are two such examples. With litchee several seedling trees of unknown origin have borne fruit of a sort but only after cold, harsh, dry seasons. Marcotts, on the other hand, of the cultivar Kwai Mee, have cropped reasonably well, if inconsistantly, with good sized, well filled fruit in as little as 18 months from establishment. Longan, taking even longer than litchee to bear from seed, is recorded as fruiting, but fruits are almost inedible, with large seed and thin flesh. To my knowledge no clonal material from areas similar to our own has ever been introduced.

The guava (*Psidium guajava*) is well known throughout the tropics. However the usual type is too rank in flavour and aroma, and has too many hard seeds to be a really popular fruit with most Europeans. We have made two distinctly different selections. The first we called "green apple guava", in allusion to the size, shape, colour and vaguely the flavour, all of which resemble the 'Granny Smith' apple. The original plants came from the seed of one fruit, found at Toa-Payoh in Singapore. Seedling variation exists, and we are now producing marcotts of a superior form, named 'Green Jade'. The basic selection has a large (6 to 9cm) round to slightly ovoid fruit, a thin skin and relatively few seeds. The fruit is exceptionally well fleshed and seeds are confined to a small core area. The fruit is palatable when fully formed but green, when the flesh is crisp and apple-like in texture. More conventionally, the fruit is eaten when the skin changes colour to a pale lemon yellow. At this stage the flesh is succulent and very juicy. Although still apple-like in flavour, when dead-ripe a faint, typically "guava" flavour does come through. Fruiting is prompt. Seedlings can begin cropping in as little as 10 to 12 months and, of course,

cuttings and marcotts are correspondingly faster. Four or five flowerings with fruit set are common and our best tree (as far as flowering goes) is seldom without crop all year round.

'Green Jade', our select clone, has much larger fruit than the selection, but produces fewer at each flowering. The fruit does not change colour when ripe (except during the cold, dry season crops in June and July) when a faint colour change is observed. In addition to the large size, the skin is heavily warted and deep emerald green — both features making it an interesting table fruit. The flesh is firm, even when ripe, yet it is every bit as lucious and juicy as fruit from seedling-grown plants of the green apple selection.

Plant size for both the selection and the select cultivar is similar. In all cases, a compact, round crowned tree has developed with thick; blunt ended leaves. The plant is evergreen, or barely deciduous, unlike the species, which has a pronounced leafless period under our conditions. Growth rate is rapid, and mature size (2 to 2.5m usually, and under exceptionally good conditions to 3m) is reached within 12 months.

The other chosen selection of *Psidium guajava* we call "pear guava" — again a reference to the fruit form. This selection is also at odds with the species, but to date no clonal selection has been made. Fruiting occurs in 12 to 18 months from seed and the fruit resembles a large, very juicy 'Packham' pear. It is virtually seedless with as little as 10 seeds or as many as 30 seeds per fruit (the species has hundreds). Ripe fruit colour is a good bright yellow and flesh is creamy white. It is juicier than the green apple selection and larger again. Being pear-shaped the fruit length is in the order of 10 to 12cm. with a base diameter of 6 to 8cm. To date there has been only 2 fruitings per year but this may improve as the plants age.

Instead of the dense, round crown of the green apple selection, or the straggly "no shape" of the species, the pear guava is a tall upright, poplar-like plant. To date, our few (5) specimens have reached 3m and show no sign of slowing down in growth.

With the rising popularity of guava for juice, and to a lesser extent, for canning and in jam making, these two selections and their selected cultivars will create an industry in their own right.

Another species fruiting for the first time since introduction 18 months ago is the bilimbi (*Averrhoa bilimbi*). This fruit is incredibly sour, yet after the initial shock, is very tasty. The aftertaste is reminiscent of the Chinese gooseberry, or Kiwi fruit (*Actinidia chinensis*). The fruit resembles small translucent yellowish-green gerkhins, and are almost all juice. In Sarawak and Malasia they are used in cooking fish, and in some areas

the ripe fruit is added to drinks. I find it an excellent alternative to lime juice. Under our conditions fruiting is continuous and plentiful, even on young plants only 1m high. The plant is evergreen and compact and a very attractive addition to the garden.

Buah kedongdong (*Spondias cytherea*) is fruiting for the first time in Darwin since its introduction just over 2 years ago and, if current indications are correct, crop yields are going to equal, or better those in Asia. Like bilimbi, no active selection has been made, but I feel sure that enormous potential exists for a horticulturist to visit all the fruit growing areas in search of good clones.

One of our more outstanding successes was the jambu ayer, the so-called water apple, *Eugenia aquea*. After sampling the fruit in Java, I was of two minds as to the worth of introducing the species. Fruits were brightly coloured, to be sure, but had no real flavour or, at best, a vague resin-like taste and were very dry textured. I did eventually collect seeds, some from a Denpassar market in Bali and also some from a vendor at Borobodur in Java.

The subsequent plants were not really looked after for as far as I was concerned it was "just" a fruit. Imagine our surprise then, 11 months later, when one tree began cropping. And what a crop! A tree only 1.5m high and every branch had to be propped to prevent breakage under the weight of fruit! The ripe fruit were large for the species, about 4 to 5cm across the base and 3 to 4cm long. They were pear shaped, with a hollow at the base formed by the thickened remains of the sepals. Skin colour is a glossy, brilliant lacquer red, flesh is crisp, juicy, and glistening white. The flavour changes with the season and dry season crops do have the better flavour. In any case, the fruit is far superior to anything I tasted (or have tasted since) in Asia. We describe this jambu as a "kids fruit". The colour is so enticing and the fruit is borne almost continuously, so that it becomes a perfect home garden plant. I doubt if the fruit will keep or carry well so its use may well be limited to home garden and local market distribution. To date all fruit examined (many thousands) have been seedless. Obviously this plant should be the subject of further examination.

The Barbados cherry (*Malpighia glabra*) is another species that has performed extremely well under Darwin conditions, with the dry season flowering giving very large crops of exceptionally fine flavoured fruit. After examination of the many cultivars of this species in the Philippines, however I am convinced that it could become a major plantation fruit in the Northern Territory, where conditions are obviously so good for

growth. Irregular cropping takes place all year round, but the main crop (with all fruit ripening virtually at the one time) does occur from March to June. Interestingly enough, although the seeds are large and well formed, none have ever germinated for us. Unfortunately lack of time has prevented us from researching this phenomenon.

There are other species growing well which give promise of great things to come but have not yet given assessable crops. These include Nanche (*Byrsonema crassifolia*) which fruits exceptionally well in the Kununurra region of Western Australia, the jambolana plum (*Syzigium cumini, syn.: Eugenia jambolana*) and the Bangkok santol (*Sandoricum koetjape*). Nanche is fruiting for the first time in Darwin following its introduction 12 months ago from the Kimberley Research Station, and I am indebted to Allan Skeats for the seed. The present indications are that it will be a worthwhile plant — certainly in flower it is an asset to any garden.

Jambolana plum has shown enormous potential for a shade tree. Growth is dense and rapid and our test plants at age 11 months are already 4.5m high with a similar spread. Some confusion exists as to whether this species is synonymous with *Syzigium cumini*. However I have seen and tasted both, and think the differences are too great for mere varietal variation. The former has large (egg-sized or larger) sweet, juicy fruit in Southern India, where I obtained the seed. The seed source for the latter was from a tall tree; the fruit resembled a peanut pod, (only slightly larger) and the flavour was inferior and sour. To avoid confusion, in our area at least, where both types are available we have utilised the two specific names.

Bangkok santol is a selected clone of *Sandoricum koetjape* (syn. *Sandoricum indicum*). The fruit is 3 to 4 times larger than that of the species and the outer rind is often 1 to 1.5 cm thick. The fruit is in two parts, each complementing the other, and is best eaten in cross-section, so both parts can be taken together. There is a tough yellow skin that is removed before eating, then a pithy, cream coloured rind, that turns pinkish after exposure to the air. This pith has a piercing sour flavour that really sets the palate tingling. The inner, segmented pulp is a translucent grey-white and is almost too sweet, thus off-setting the sourness of the outer portion of the fruit.

The species is extremely variable from seed and obviously any clonal selection must be made by marcott or grafting. Marcotts take easily and are ready for separation in 6 to 8 weeks. To my knowledge, my plant is the only select clone of this species in the Northern Territory and at the time of writing has not yet fruited. Age is just under 4 years and tree height about 5m. The

tree colours up during the dry season and old leaves turn a brilliant liquidamber red before falling. New leaves appear as the old ones fall so the species could be nominally called "evergreen".

In conclusion of this brief list of species I should like to mention the 5 corner or star apple, *Averrhoa carambola*. Seedling variations abound in Darwin and but little selection has occured. There are at least 2 variations of the so-called cultivar 'Siam White' that I know of. Here the fruit is up to 10 times larger than that of the species plants, far less acid in taste and, at maturity, has a creamy-white flesh rather than green or yellow as is more common.

Like its cousin, bilimbi, this fruit needs to be recognised. It travels well, can be ripened after green picking and has a long shelf life. Furthermore, it can be propagated by marcotts (slow, 3 to 4 months) and be in crop in as little as 12 months after establishment.

The scope for the establishment of an exotic fruit industry in the top end of the Northern Territory is enormous. In these days of back loading air freight we are only hours away from enormous markets and freight costs are well within normal consideration.

The greatest problems standing in the way are:

(1) lack of knowledge of the various species and their performance under our conditions, and

(2) lack of suitable, tested clonal material at any price.

We are trying to alleviate problem (1) by active distribution of all new plants as we obtain them. This is not done through official organisations, but rather a loose collective of interested amateurs. While this means that information received may not be 100% accurate it, at least, provides indications of performance under a wide variety of conditions.

Problem (2) is more difficult — while our organisation spends literally thousands of dollars each year in searching out and purchasing new seed we are virtually restricted to seed introduction.

Plant quarantine is strict and it seems that the officers of the department are dedicated to the premise that no plant shall come in alive. I acknowledge the vital necessity of screening and treating incoming plants, but I disagree totally with the techniques currently in use. Few plants, and particularly the exotic fruits, seem able to tolerate methyl bromide fumigation. Until this is changed the introduction of select clonal material from overseas sources remains an expensive and time wasting process.

Table 1. Fruit species currently growing in Darwin, Northern Territory, Australia

Aegle marmelos
Anacardium occidentale
Annona cherimola
Annona glabra
Annona muricata
Annona reticulata
Annona squamosa
Artocarpus heterophyllus
Artocarpus altilis (syn.: *A. incisus*)
Artocarpus integer (syn.: *A.chempeden*)
Averrhoa bilimbi
Averrhoa carambola
Blighia sapida
Borassus flabellifer
Byrsonima crassifolia
Carica papaya
Chrysophyllum cainito
Citrus aurantium
Citrus limon
Citrus maxima (syn.: *C grandis*)
Citrus × *paradisi*
Citrus reticulata
Citrus sinensis
Clausena lansium (syn.: *C wampi*)
Cocos nucifera
Coffea arabica
Coffea liberica
Diospyros discolor
Durio zibethinus
Eugenia aquea
Eugenia grasiliensis (syn.: *E dombeyii*)
Eugenia suborbicularis
Eugenia tierniana
Eugenia uniflora
Euphoria longan (syn.: *Nephelium longan*)
Ficus carica
Garcinia livingstonei
Garcinia mangostana
Garcinia xanthochymus
Litchi chinensis (syn.: *Nephelium litchii*)
Malpighia glabra
Mangifera indica
Manilkara zapota (syn.: *Achras zapota*)
Mimusops brownii
Mimusops elengii
Morus alba
Morus nigra
Murraya koenigii
Musa spp. (several)
Nephelium lappacium
Passiflora edulis (var. flavicarpa)
Passiflora laurifolia
Passiflora quadrangularis
Passiflora seemanii
Persea americana
Phyllanthus acidus
Pithecellobium dulce
Pouteria campechiana
Psidium guajava
Punica granatum
Salacca edulis
Salacca walachiana
Sandorium koetjape
Schleichera oleosa
Solarium hyphorodicum
Spondias cythera
Syzygium cumini (syn.: *Eugenia cumini, E. jambolana*)
Syzygium jambos (syn.: *Eugenia jambos*)
Syzygium malaccensis (syn.: *Eugenia malaccensis*)
Terminalia catappa
Terminalia okari
Ziziphus mauritiana

TECHNICAL SESSIONS

Tuesday Morning, November 28, 1978

The twenty-eighth annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:30 a.m. in the Ballroom of the Royal York Hotel, Toronto, Ontario, Canada.

PRESIDENT McGUIRE: Welcome to the twenty-eighth annual meeting of the Eastern Region of the International Plant Propagators' Society. The weather notwithstanding we have a good crowd this morning. I wish to welcome those members from the Western Region, the Southern Region, the Great Britain and Ireland Region, and the Australian Region who are with us. At this time I would also like to introduce Ray Halward, who is the program chairman for this meeting. Also with us is Mr. Ken Lance, the Deputy Minister of Agriculture and Food.

KEN LANCE: Thank you, President McGuire. It is a real pleasure for me to welcome you to Canada and the city of Toronto. From the looks of your program I am sure you will have a most successful meeting.

PRESIDENT McGUIRE: Thank you Mr. Lance. We have one minor change this morning. Ralph Shugert will be the moderator of the morning program.

RALPH SHUGERT: I am pinch hitting for Jim Wells and I am pleased to report that he is not as ill as last year. He has a leg in a cast which makes getting around difficult. Jim assures us that he will be with us next year.

PROPAGATION BY GRAFTING UNDER GLASS AT HILLIERS NURSERY

BRIAN HUMPHREY

Hillier Nurseries Ltd.
Ampfield, Hampshire, England

Approximately 60,000 plants are grafted under glass each year at our nursery. The species involved cover 126 genera and to achieve compatible stock-scion combinations, approximately 140 different species of rootstock must be established in pots before grafting can commence. The number of plants used in a species varies from as few as 15 to several hundred. This production cycle involves a degree of administrative organisation which may be of interest.

ORGANISATION AND PLANNING

As rootstocks are potted for 6 to 12 months before grafting, any significant increase in production levels must be considered in the season before grafting is to take place. Where this is not possible, bare-root bench grafting must be the technique used.

At Hilliers all plants grown are coded and listed in a master stock book. The code consists of the letter S, C, C.G., R.C.G., or B according to the method of propagation (seed, cutting, cutting graft, root cutting graft, or bud) followed by a number 1 to 52, which represents the week of the year in which propagation is to take place. All species with the same letter prefix and number code are printed out by our computer for the relevant week.

Within each week the plants are arranged in batches according to the understock required or, as in the case of cuttings, particular conditions preferred. Batches may also comprise only types which are produced in large quantities or, conversely, those which are required only in small numbers.

Production requirements are filled in on the blank sheets by the Marketing Division. Where grafting is involved, the number of available rootstocks is checked against the number of grafts required. Finally, the information is fed back into the computer which then prints out Production Target Sheets for the Propagating Units.

As results are known, completed Target Sheets are returned from the Units and filled in on a Master Print-Out for the year. This provides information for Management concerning stock availability, potential shortages or excesses, etc. No close monitoring of progress for grafting is undertaken, although weekly progress sheets are completed by the foreman responsible for a given batch.

Compatibility. Little is understood about compatibility, particularly for the long term, in many genera. Many years of trial and error have provided us with some information on compatibility and information on those combinations which will or will not make a successful union, at least in the short term.

Rootstocks. We generally prefer to use rootstocks which are well established in a pot. The normal size used for broadleaved species is a 4½ inch diameter pot. Its cubic capacity is approximately 1 litre. Conifer rootstocks and a few broadleaved plants (e.g. *Daphne*) may be grown in a smaller pot with a 3 inch diameter.

We prefer to use clay pots if time, handling and general costs would permit but generally the clay pot is now replaced

by a rigid plastic type. After potting in early spring, the pots are placed on sand or gravel beds. Clay pots need to be plunged to the rim in sand or weathered boiler ash.

One or two-year old seedlings are generally selected for potting as they usually provide the required pencil thickness at the collar. Some rootstocks are used for top working; these obviously need to be much larger and are either balled from the field and placed under glass for grafting or potted into much larger containers for subsequent working.

Time of Grafting. Normally grafting occurs either during the winter months or during summer up to early autumn (Table 1). The reasons for the times selected are often rather obscure. Experience is said to have shown the best time for a given species but these conclusions are often drawn from only a single or very few observations and are sometimes colored by prejudice. These comments are by no means aimed only at the Hillier methods. Provided the necessary physiological and environmental conditions are available, it can be said that most species would succeed well during either period.

Carpentry of Grafting. With very few exceptions, the graft used is the side veneer graft in two forms, either (1) unmodified with a short lip at the base, or (2) an elongated lip or flap of rind retained on the rootstock. The latter method is used for species such as the conifers which have a flexible rind likely to survive displacement from the normal position. The advantage of the technique is that it gives an opportunity for more cambial contact between stock and scion than the conventional side veneer. As implied, the top of the stock is more or less completely retained with this graft.

Other grafts less frequently used are the simple splice or whip and an inlay type of graft which is in effect the conventional side veneer with the rootstock cut right back to the point of grafting. In both cases the easier species are chosen, the former method applicable where stock and scion are of similar diameter, the latter where there is some disparity in size between the two.

PHYSIOLOGY AND ENVIRONMENT

Essential points to bear in mind are as follows:

Rootstock. Usually the age of wood of the rootstock at the point of grafting is more than that of the scion wood by at least one year. Rootstock wood is therefore less responsive, slower to form callus, etc. The usual method to overcome this problem is to either graft in the summer when the rootstock is active, or to graft in winter or spring, to ensure the rootstock is in a more advanced stage of growth than the scion.

Table 1. Hillier Nurseries grafting calendar.

Time	Species	Comments
November-December	*Rhododendron* (also cutting-grafts) *Kalmia*	Early bud break of the scion is a danger and this is most delayed at this time of the year. Comparatively cool top conditions can be maintained despite supplying bottom heat. Tolerant of poor light conditions. These can also be done without artificial heat in April.
January-March	Main deciduous species: *Betula* *Fagus* *Juglans* *Fraxinus* Prunus *Sorbus*, etc.	Scions are leafless. Birch tend to take slightly longer to callus than most other species and are done early. Once growth starts after a successful union, light conditions are improving and top growth can proceed normally.
Febuary-March- April	Deciduous conifers: *Larix* *Taxodium* *Gingko*, etc.	
March-April	Evergreen conifers: *Picea* *Junipers*, etc.	Leafy scions.
June-July	Deciduous azalea *Rosa* spp. and some hybrids	The former species appears to do best at this time of the year. *Rosa* spp. break into growth rapidly when grafted in the spring and this can cause difficulties in management to avoid foliar disease.
July-August	*Acer* *Hamamelis* *Sinowilsonia* *Parrotiopsis* *Citrus*	Scions with leaves removed. Removal of leaves enhances survival of scion, reduces disease incidence in grafting cases.
August-September	*Carpinus*	Leaves retained. This particularly easy species responds to splice or inlay grafting with rootstock top removed.
August	Conifers	Usually the union is plunged in slightly moistened peat.
September-October	Quercus	Leaves removed. This slow callusing genus at this season remains dormant for a considerable time after grafting giving the union sufficient opportunity to form. Meristematic activity is higher than it would be in October - November.

Scions. Scions react physiologically in a very similar way to cuttings in the early stages of grafting. Leafy scions must be prevented from desiccation; leafless scions are much more capable of survival.

Sap flow and drowning of grafts and buds. A feature of grafting is that the rootstock is frequently grafted while it is relatively undisturbed and actively extracting moisture from the soil. Moisture in the form of sap passes up the rootstock until it

reaches the point of the union where only a small proportion is able to pass into the scion in the early stages after grafting has taken place. If there is a substantial sap flow the excess sap oozes out at the point of the union, sometimes with such force as to push its way through the protective coating of wax which may have been applied by the grafter. The presence of such quantities of sap at this point adversely affects callus formation and wound healing.

To avoid copious sap-flow it is essential in the operation of spring grafting under glass to dry the understock off before carrying out the grafting operation. This is normally best achieved by withholding water during the warm period under glass when bud activity is being encouraged by temperature.

In the case of summer grafting and budding where the top of the stock is normally retained, "drowning" is less of a problem since the presence of leaves ensures that the surplus sap is removed by transpiration.

Environment During Grafting. For grafting under glass, particularly where leafy scions are used, the grafts are normally protected under double glass, a closed case or polythene tent (Table 2). In conditions of high humidity drying out of the unions is not a problem and it may be merely tied with waxed cotton or rubber strip. The unions of grafts which are placed on the open bench must be prevented from drying out by waxing or plunging them in a moistened medium such as peat or sawdust. Some species tolerant of low temperatures or subject to damping off are normally grafted on the open bench. The easiest species are grafted in the open field.

The majority of the more difficult species and most summer grafts are placed under close conditions where temperatures and humidity can be better controlled.

Practical aspects of environmental control.

a) *Close case/polythene conditions:*

1. Peat layer in base of case should be moist, not soaking.
2. Polythene sheet cover, if used, should be turned before water droplets get too large and drip back on grafts.
3. Grafts are not watered until extensive callus formation is visible and airing becomes necessary.
4. Height of polythene cover above grafts should be adjusted to ensure callus formation is healthy, not excessive or too 'soft'.
5. Heavy shading should be used to keep temperatures cool and prevent scions from being water stressed.

b) *Open bench:*

1. Dry understocks are normally plunged into moistened peat; watering is more critical.
2. Graft union must be protected by waxing or plunging.
3. Shading is very critical and must be liberally used as scion breaks into growth.

Table 2. Environmental conditions for grafts at Hillier Nurseries.

Field Grafting	Close Bench or Frame (Cold)	Open Bench (Heated)	Close case frame or Polythene tent (Heated)
Ailanthus	*Carpinus*	*Aralia*	*Aesculus*
Fraxinus	*Rhododendron*	*Magnolia*	*Acer* sp.
Laburnum	*Chamaecyparis*	*Gingko*	*Alnus*
Malus		*Larix*	*Amelanchier*
Prunus		*Taxodium*	*Aralia*
Pyrus		*Rhododendron*	*Betula*
Robinia			*Camellia*
			Castanea
			Catalpa
			Cornus
			Daphne
			Fagus
			Fraxinus
			Hamamelis
			Juglans
			Ligustrum
			Liquidambar
			Magnolia
			Prunus
			Quercus
			Rhododendron
			Rosa
			Sorbus
			Tilia
			Ulmus
			Vitis
			Wisteria
			Cedrus
			Chamaecyparis
			Cupressus
			Juniperus
			Picea
			Pinus
			Pseudotsuga
			Taxus
			Tsuga

After-care. Once the union has established, the grafts are gradually aired and hardened off. For side grafts the top of the rootstock above the union is reduced by more than half, this operation taking place five to eight weeks after grafting. "Snagging back" to the union occurs at some convenient handling stage afterwards, often the following spring or at bedding-out or potting-on stage.

Subsequent Handling. With slow-growing genera (*Quercus*,

etc.) it is important to bear in mind that the union may be a point of weakness for a considerable period and the graft should be handled carefully.

After the rigours of drying off and confinement in a pot, the young grafts may require high fertility and liberal water to promote vigorous growth. Some species, particularly the forest tree category should be checked for root curling which can cause, in the long term, poor health or death of the specimen. Severely curled roots should be unwound or, if this is impossible, cut off.

MICHAEL DIRR: Is there a universal understock for grafting the trifoliate maples?

BRIAN HUMPHREY: No. We use about six species of maple to cover the whole genera. *Acer triflorum*, *A. maximowiczianum* (syn.: *A. nikoense*), *A. griseum* and *A. mandshuricum* can only be grafted on their own rootstock.

LARRY CARVILLE: Brian, would you comment on the economics of grafting vs. rooting of deciduous azaleas.

BRIAN HUMPHREY: Well, it's not economical at all to graft. In fact, we don't graft them except for a few notable exceptions, such as *Rhododendron weyrichii*.

JOE CESARINI: Do you know if *Magnolia* × *soulangiana* is compatible with *M. grandiflora*?

BRIAN HUMPHREY: I would think so. For magnolia grafting we grow three species: *M.* × *soulangiana*, *M. kobus*, and one of the large leaf types. We do not graft any of the *M. grandiflora* group; that would be *M. virginiana*, *M. grandiflora* and *M. nitida*. All of those we root.

JOE CESARINI: Is wisteria compatible with *Albizia julibrissin*?

BRIAN HUMPHREY: I don't know.

JOE CESARINI: Did you say one grafter does 200 grafts per hour?

BRIAN HUMPHREY: Yes. In fact we have some who do 220 per hour.

MAT ZACK: Do you graft larch at lower or higher temperatures?

BRIAN HUMPHREY: Lower temperatures.

MAT ZACK: In poly tent or open bench?

BRIAN HUMPHREY: We only graft our larch in an open bench with a waxed graft union. Larch, like many of the deciduous conifers, does not grow well at high temperatures. If

you get a combination of high temperature and humidity they "damp-off" so we try to bring them along naturally in an open bench with a waxed union.

MAT ZACK: How about *Cornus* cultivars?

BRIAN HUMPHREY: We side graft *Cornus florida* in February and March under low temperatures in a poly tent.

MIKE LEE: For someone starting out new, would you recommend one year potted material or bare root?

BRIAN HUMPHREY: I would recommend one year potted stock.

MIKE LEE: Particularly, I am interested in *Fagus sylvatica* cultivars.

BRIAN HUMPHREY: Well, you are onto a good one there because *F. sylvatica* is very easy to graft. If you can get the stock dry and do a reasonably competent job with the knife I am sure you will get a high percentage take.

FRANK GOUIN: Have you done any grafting or budding of 'Bradford' pear?

BRIAN HUMPHREY: Yes, we used to grow it in England. We have stopped growing it because our climate is so mild in the autumn, and cool and moist in summer, that the plant gets frosted in winter. The selection 'Chanticleer' is proving to be a better plant. We bud on *Pyrus communis* seedlings but get 1 to 5% incompatibility.

FRANK GOUIN: At what age does the incompatibility appear?

BRIAN HUMPHREY: Immediately.

FRANK GOUIN: In some of the original plantings of 'Bradford' pear in Maryland we are noticing some incompatibility showing up after 20 years.

BRIAN HUMPHREY: I am not surprised to hear that. The Rosaceae, in general, have a very complex incompatibility structure.

CASE HOOGENDOORN: You don't have to graft or bud 'Bradford' pear, you can root cuttings.

BRIAN HUMPHREY: We like to get a 6 foot whip the first year. You won't get that with a cutting.

CASE HOOGENDOORN: No, not in one year.

JACK ALEXANDER: Do you ever cover your graft unions with peat and then poly?

BRIAN HUMPHREY: No, that is not necessary. Perhaps I did not explain it to you well enough. The real purpose of poly for dormant scions is that it simply maintains humidity around

the cut surface of the graft union until they can form callus. You could cover the union with wax or plunge the graft in moist peat moss, both of which require a lot of materials and handling. We like to cover the grafts with poly because it saves us that labor.

ED MEZITT: Is the dryness of the root as important with evergreen conifers as deciduous conifers? The reason I am asking this is because we have observed with blue spruce a quick death of many of the roots and are wondering if they are too wet.

BRIAN HUMPHREY: I cannot give you a precise answer. My suspicion is that it is as important. My advice is that for any plant you are grafting, try to keep the rootstock on the dry side.

VEGETATIVE PROPAGATION OF ELMS BY GREEN CUTTINGS

G.H. SAUL and L. ZSUFFA

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Abstract. Semi-lignified green stem cuttings of several elm clones were successfully rooted in containers under specially prepared tented frames, without a misting system and chemical treatments. The cuttings were collected from vigorous sprouts produced on grafted stools. Clonal variation in rooting was observed.

In the early 1930's, when Dutch elm disease (*Ceratocystis ulmi* (Buism.) C. Mor.) was discovered in North America, programs were initiated to develop resistant elms for future use. American elm (*Ulmus americana* L.) was the most extensively planted species and tree selections of disease resistant individuals were made throughout North America. In Holland, where the disease appeared earlier, disease resistant hybrid elms were developed and released for planting and testing to several European countries as well as to North America. The vegetative propagation of these trees was necessary to raise stock for breeding arboreta, plantation trials and for resistance-testing.

Elms can be propagated by cuttings, but results vary. The propagation of dormant root cuttings can be satisfactory with some elm species (1,5). Experiments with rooting stem cuttings were carried out in different countries (2,3,4). The rooting of semi-lignified and softwood stem cuttings appeared to be more

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successful than the rooting of lignified cuttings (5,6,8,9). Chemical treatments of cuttings and of rooting media improved root development (7). In most cases mist was required for successful rooting.

Following is a method for rooting semi-lignified green cuttings of elms without a misting system and without chemical treatments.

MATERIALS AND METHODS

Semi-lignified green cuttings of several elm species and hybrids (Table 1) were vegetatively propagated in containers under specially prepared tented frames both in the nursery and in the greenhouse. The trials were conducted at the experimental grounds of the Ontario Forest Research Centre, Maple, Ontario, Canada.

Table 1. Percent rooting of selected *Ulmus* clones.

Clone No.	Origin*	No. of Cuttings Planted in Trials 1	2	Percent Rooted
U 3	*U.* × *hollandica* Klemmer	32		78
U 6	*U.* (*U. glabra* 'Exoniensis' × *U. wallichiana*) × (*U. hollandica* 'Vegeta' × *U. carpinifolia*) - complex Dutch hybrid.	32		78
U 7	*U. japonica*, Japan	32	51	52
U 8	*U. japonica*, Japan	32	21	41
U 9	*U. japonica*, Japan	32		28
U 10	*U. pumila*, Japan	32		43
U 11	*U. pumila*, Japan	32		59
U 13	*U. americana*, Minn.		13	62
U 14	*U. americana*, Iowa	32		50
U 15	*U. americana*, Iowa	32	39	70
U 17	*U. americana*, Iowa	32	40	54
U 19	*U. americana*, Iowa		28	56
U 20	*U. americana*, Iowa		79	46
U 22	*U. americana*, Wisconsin		31	55
U 22	*U. americana*, Wisconsin		31	55
U 23	*U. americana*, L-235		13	30
U 24	*U. americana*, Wingham		10	0

* Clone U-24 is from Ontario, U-23 from Quebec (source G. Ouellet). The rest of the clones were obtained from the D. Lester, Madison, Wisconsin collection.

The cuttings were collected from vigorously growing grafted stools. The grafts were made by cleft grafting scions of selected elms on the stock of chinese elm (*U. parvifolia* Jacq.) seedlings. Stools, exhibiting vigorous sprouting, were created by cutting back the well established scion grown to just above the grafting level.

The cuttings consisted of the current year's growth and were of semi-mature wood. If soft, unlignified cuttings were taken, they sometimes wilted and decayed. The cuttings were

5-10 cm (2-4 inches) in length, with one or more leaves attached. The large leaves (5 cm or more in diameter) on the cuttings were cut in half, primarily to make planting easier in a confined area.

The soil medium was relatively coarse to enable good drainage. The styrene tubes[1] contained a 1:1 mixture of medium grade vermiculite and peat moss. The Jiffy pots[2] (No. 7) contained peat.

The cuttings were rooted in a protected environment under tented rooting frames. The tent was made of a plastic cover, placed on a quonset type wood frame, approximately 50 cm (20 inches) high, 90 cm (3 ft.) wide and 1.8 m (6 ft.) long. Wood was preferred for the frame, because of its moisture holding qualities. No artificial lights were used.

The leaves were kept moist by watering manually with a fine mist nozzle on a hose. The watering was done occasionally and very lightly, as required (once daily or less). The sterilized sand, on which the containers were placed, was kept continuously moist by bottom watering thus keeping the air humidity within the tent at a high level.

The first of two rooting trials was conducted in the summer of 1977. The cuttings were placed in 2.5 × 7.5 cm (1 × 3 inches) tube-type styrene containers and kept in the tent in a protected shaded area in the nursery. Half of the cuttings were placed on heated soil, the other half on unheated soil. The heating cables were covered with about 7.5 cm (3 inches) of sand and maintained a soil temperature from about 19°C (65°F) to 29°C (85°F); the air temperature inside the tent was similar or slightly higher. On unheated soil the temperatures were 9°C (15°F) cooler. Thirty-two cuttings per clone were planted (Table 1).

The second trial was established in the winter of 1977/78. A tented rooting bed, with soil-heating cables (covered with 5 cm (2 inches) of sand) was built on a bench in the greenhouse. The floor consisted of 7.5 cm (3 inches) of sterilized sand over a plastic sheet or metal pan. The air temperature varied from 18°C (65°F) to 32°C (90°F), and the soil temperature from 16°C (60°F) to 30°C (85°F). The cuttings were placed either in Jiffy pots or in the styrene containers. Thirteen to 79 cuttings per clone were planted (Table 1).

RESULTS

Cuttings rooted in both trials. In all cases (nursery and

[1] Ray Leach Containers, 1787 North Pine, Canby, Oregon 97013, U.S.A.
[2] Stokes Limited, 2729 Jane Street, P.O. Box 10, St. Catherines, Ontario L2R 6R6.

greenhouse, heated and unheated soils, containers and Jiffy pots) similar results were obtained, and the average rooting for all clones and trials was approximately 50%.

The clonal variation in rooting was significant (Table 1). The poorest rooters were clones U-24 (0%), U-9 (28%) and U-23 (30%). The best were clones U-3, U-6 and U-15 (rooting 70 to 78%).

In both trials rooting started approximately 4 weeks after planting and continued for about 8 weeks. The growth of stem buds was a good sign of rooting. Roots developed mostly from the callus formed at the bottom of the cuttings. The one-year-old rooted cuttings showed regular growth without signs of topophysis.

DISCUSSION

The method of vegetative propagation of elms by rooting stem cuttings described in this paper gave good results with most of the clones tested.

The method is simple, it does not require either mist or chemical treatments, and lends itself to large scale application. Good results were obtained even with cuttings originating from mature trees. Possibly the grafting of mature tree scions on young seedling stock and the subsequent management of grafts for vigorous sprouting resulted in producing juvenile cutting propagules.

In the system of stool-sprouting, new green cuttings can be taken from the same stools continuously, as they are produced, throughout the season. Thus, a large number of cuttings can be taken from very few stools in a short time.

The desirable conditions for rooting were with soil and air temperatures from 24°C (75°F) to 29°C (85°F) and with air humidity from 90% to 100%. It was noted that ideal conditions were obtained when the outside temperatures were cooler than inside the tent, as this maintained under the tent a constant high level of humidity without excessive heat.

Elm cuttings were easier to root in the greenhouse, because of the better control of conditions. The hardening-off of greenhouse-rooted cuttings presents no problem. In the greenhouse the growing of potted stools and new grafts for cutting collection is also easier and faster.

Rooting trials indicated the necessity for better media drainage. For future trials either sand and vermiculite, or sand and peat mixtures might be recommended. A bottom layer of a usual growing soil in the container may further facilitate the growth of the rooted plant. Such a plant could then be readily

transferred to either a larger-size pot or to a transplant bed until it has reached outplanting size.

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PROPAGATION BY CUTTINGS OF LILACS AND OTHER HARD-TO-ROOT SPECIES BY THE SUB-IRRIGATION METHOD

EDMUND V. MEZITT

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At Weston Nurseries we have been rooting cuttings of lilacs for over 40 years — even before mist systems, polyethylene or rooting hormones were introduced. Our early lilac propagation was done in a pit greenhouse shaded with lath several feet above the glass. With careful supervision and occasional hand watering the cuttings rooted quite satisfactorily, particularly the deeper colored cultivars. In more recent years, we have been rooting lilacs in poly tents or with mist. None of these methods have proven reliably satisfactory for many cultivars, particularly the white ones. Today I would like to explain our sub-irrigation method. This is simply applying water to the cuttings from beneath the rooting medium. Metal pans are the only equipment we use at the end of a greenhouse shaded with 60% saran cloth and shielded from direct sunlight with white polyethylene. The pans (8 ft. × 3 ft. × 6 in.) are filled with ¾ inch stone to a depth of 2 inches and the rest with horticultural-grade perlite.

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Hopkinton, Massachusetts 01748

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The stones are separated from the perlite with a fine-sized plastic mesh screen. We insert a 4-inch perforated drain tile in each corner of the pan. With this set-up we can fill the pan by pouring water into the tiles, thus letting the water run through the stones and gradually rise uniformly in the perlite as high as we wish. The pan is filled with water the day before the cuttings are stuck. The perlite is thus saturated and when the water is siphoned out prior to cutting insertion, the perlite becomes naturally compacted.

We take the lilac cuttings at flowering time and try to finish before the flowers fade. This assures us a uniformly-developed cutting each year and true-to-name cultivars, as we cut only from flowering plants. Cuttings are gathered early or late in the day and refrigerated overnight. We heavily wound one side before applying Hormoroot C. The cuttings are stuck close together in a three-inch-deep slit cut with a label. After sticking the cuttings the pan is again flooded with water until the cuttings are turgid. This may be for several hours or overnight, depending on weather conditions.

The normal operation of the rest of the greenhouse is maintained without particular regard to the cuttings in the pans. The pans seldom need to be refilled with water again before the cuttings are rooted. Occasionally, due to unusual heat and ventilation requirements, the cuttings may wilt and require a few hours of water until they recover turgidity.

Cuttings begin rooting in a month and most of them are ready for potting in about 6 weeks. After potting, normal watering is all that is necessary. Roots grow rapidly and the plants can be put in cold frames or even planted out in several weeks.

The rooting percentage is over 90% for all cultivars, except *Syringa vulgaris* 'Primrose', which has been about 60%. Cuttings that do not root fall into two categories. The majority remain green but do not callus and gradually become weaker. They may be weaker cuttings to begin with and could possibly be selected out before they are made. The other loss occurs when cuttings dry up completely. This happens on individual random cuttings and could be from mechanical or physiological causes. The key to the success of this method of propagation lies in the fact that dead and dying cuttings do not contaminate other cuttings. No further losses occur as conditions for spreading disease are greatly reduced. The cuttings are never watered from the top, misted or covered with poly; the well ventilated greenhouse conditions keep the leaves dry at all times.

This simple sub-irrigation method seems to be the best way to root plants that do not tolerate excess water on the foliage or are susceptible to diseases in humid conditions.

It seems that almost all cuttings will root satisfactorily with this method and we have had good success with *Hamamelis*, *Prunus*, *Viburnum*, *Cornus* and *Magnolia* species. After four years of production we can recommend sub-irrigation as certainly being the most reliable way to root white lilacs.

PROPAGATION OF NAMED DELPHINIUM CULTIVARS

MICHAEL DODGE
White Flower Farm
Litchfield, Connecticut 06759

In *Plant Propagation: Principles and Practices*, 2nd ed., Hartmann and Kester say that "Delphiniums can be propagated easily by softwood cuttings taken in the spring." Unfortunately, they omit to say how. After struggling for five years with a variety of techniques, we finally came up with a system which is a combination of several ideas gleaned from the *Journal of Delphinium Society*.

Stock plants are dug out of the fields in the fall and all leaf and stem remains cleaned off. They are packed in wooden crates with slightly moistened shingle-tow around their roots and crowns, leaving their tops exposed. The crates are stored at 36°F and brought into a cool greenhouse in mid-January to promote new growth. The greenhouse night temperature is set at 45°F and the house is well ventilated on sunny days to prevent the shoots from becoming too soft. They are left in the shingle-tow to facilitate easy removal of the cuttings. Shoots appear in about two weeks and the first cuttings are ready for removal by mid-February. We usually take just the sturdiest shoots for they produce the most vigorous plants in the shortest time. The stock plants are either put back in the crates to get more cuttings, or are potted into 2 qt. pots using a peat-sand-vermiculite mix. When they have recovered, these plants are sold at our sales center with 2 to 3 vigorous shoots.

Cuttings are taken with a very sharp, pointed knife. It is essential to remove the cutting exactly at the interface of the old stem and the new shoot. This point can be identified by the swollen area at the base of the new shoot. If any part of the old stem is attached to the cutting it should be trimmed off for it will cause the cutting to rot. If the cut is made above the swollen area it will expose soft, pithy tissue or even the hollow area in the stem; this also causes rotting and removes buds which normally develop at the base of each stem.

To increase cultivars quickly we sacrifice stock plants and

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take every available shoot. Sometimes these shoots are only ½ inch long and ¼ inch across at the base. Although they take longer to root, they will produce 1 or 2 vigorous shoots for propagation during the first growing season.

The cuttings are stuck in moistened #2 vermiculite in plastic flats previously rinsed with LF-10. We have found it unnecessary to use any rooting compounds. The flats are set in water to a depth of ¼ - ½ inches, on benches lined with polyethylene. This procedure keeps the vermiculite constantly moist (but not too wet). We are trying to eliminate this last step by using slow-release water in the form of Viterra-2 Hydrogel mixed with vermiculite. Fifty cuttings are stuck in an 11 by 22 in. flat just deep enough so that they stand upright and the flats are covered with newspaper for 10 days to prevent wilting from the bright winter sun.

The cuttings are checked daily for fungal infections, especially black-rot which is caused by *Rhizoctonia*. Immediate removal of diseased cuttings is essential. Shoots that rot are usually ones that were infected or damaged before insertion. Fungicidal drenches have not helped to prevent or cure this problem.

The first roots appear in about 21 days. At this time the water level in the benches is allowed to drop gradually through pin-holes in the plastic until the flats are no longer standing in water. After this the flats have to be checked daily for watering. When the roots are 2 to 3 in. long they are ready for potting into a peat-sand-vermiculite mix in 3 in. peat pots. They are well watered and covered with newspaper for a week to reduce wilting. Their growing points are pinched out as soon as the shoots develop to inhibit flowering of the primary shoot and to induce development of basal buds.

Nine weeks after striking, the cuttings will have rooted through the peat pots and usually have 3 to 4 shoots emerging from below soil level. At this stage they are either sold by mail-order or planted in the field as stock plants. They are planted with a mechanical planter of our own design and during the summer months are kept well fertilized, watered and sprayed. The tall flower spikes are tied up to a single string to prevent them from snapping off at the base in strong winds. We encourage flowering of stock plants to ascertain if they are true to cultivar name and also to inhibit the flowering of basal buds. The basal buds develop in the fall and provide us with propagation material for the following year.

Why is it necessary to propagate delphiniums by cuttings? There are over 120 named cultivars currently available in England; they are superior in every way to seed strains although

they are still not as perennial as we would like them to be in the hot humid eastern climate. However, I have had some in my own garden for five years so, with care, longevity can be induced. In the future there will be both red and yellow flowered delphiniums available; the best of these will have to be propagated by cuttings in order to maintain true stock.

PROPAGATION OF PERENNIALS USING KYES-KUBES

RICK R. ALLRED
Spring Hill Nurseries Company, Inc.
Tipp City, Ohio 45371

In my talk I hope to show how we, at Spring Hill Nursery, use Kyes Kubes to advantage in the propagation of quality perennials for mail order shipment. The process of producing perennials with Kyes Kubes is not difficult and increases profits through reduced labor costs.

The K-4 Kyes Kube is a blend of natural peat moss with minor trace elements, wetting agent and starter fertilizer. It measures approximately 1¾ inches in diameter and 2 inches in height with a prepunched hole of ¼ in. diameter and ½ in. deep.

We start by setting out the desired number of Kyes Kubes to be seeded and then water them in. During the process of watering we inject Banrot at 200 ppm. to kill any soil-born diseases; wetting agent is added to speed up the process. It normally takes 3 hours to water in 10,000 kubes. To fill in void areas between the kubes and aid in expanding root growth we peat down the kubes with Canadian peat so that the kubes have approximately ¼ inch of peat between them. The kubes are again watered to wet the peat and wash it down between the kubes, followed by a quick run over each flat with a pencil to repunch any filled holes.

The flats are now ready for seeding. We need basically two tools for seeding; a water fountain cup and pencil. Twice a year, winter and summer, we test our seed for viability and germination percentage. Depending on the perennial species and germination test results we decide how many seeds will be dropped into each kube. Normally 2 or 3 seeds are planted. The seeds are then covered with #4 vermiculite; normally the rule of thumb we use is to cover to a depth of ½ the size of the seed. Exceptions are that we do not cover *Campanula* 'Blue Chip' or 'Crimson Coralbells'.

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After sowing, the seeds are watered in and excess vermiculite is washed down between the kubes with a fine mist nozzle.

We germinate our perennials at 74° to 76°F on racks that are inside polyhouses. The racks are 5 ft. high and run the length of the 196 feet poly houses on each side with both racks holding 15,000 Kyes Kubes. Following germination and after the seedlings have their first true leaves they are moved to the floor and grown at 60°F to promote compact growth and harden off the foliage somewhat. Also, at this stage, they are fertilized with a 100 ppm solution of Peters 9-45-15 and Sequestrene 330 FE, followed up with an application of Osmocote 19-6-12 approximately two weeks later. This application of Osmocote carries us through the shipping season and assures us that our customer is receiving a well fertilized perennial.

QUESTION AND ANSWER PERIOD

RALPH SHUGERT: Brian Humphrey, in your talk this morning on the computer printout, does your computer also have the capability of costing each of the functions whether it be grafting, seeding, etc.?

BRIAN HUMPHREY: No.

RALPH SHUGERT: How then are you tracking costs on grafting?

BRIAN HUMPHREY: We do a manual costing system by recording time.

BILL FLEMER: Ed Mezitt, how does *Hamamelis* 'Arnold Promise' overwinter after you have rooted it?

ED MEZITT: We have had trouble with it but I think we have solved it. We have overwintered it satisfactorily, planted it out but lost it the following year. This year we are going to keep them in the greenhouse all winter and keep them growing with no rest period and that might be the answer.

RALPH SHUGERT: We produce a few plants. We root, pot and carry them the next winter in frames with standby heat that comes on at 30°F. In April we go to the field with the potted plants.

CARMINE RAGONESE: Michael Dodge, is there any breeding in the area of heat resistance with *Delphinium*?

MICHAEL DODGE: I really do not know. The species that are being used are annuals from warm climatic regions. They should bring heat resistance but I do not know if anyone is specifically breeding for heat resistance.

CARMINE RAGONESE: Mr. Mezitt, do you think you might have better results with propagation if you had a lower cubic volume greenhouse? It would help you to maintain turgidity better.

ED MEZITT: I think that would help.

MAT ZACK: Ed Mezitt, would your subirrigation method work with *Syringa* × *prestoniae* 'James McFarland'?

ED MEZITT: Yes. 'James McFarland' also roots well under mist.

GIL VASTINE: Ed Mezitt, with enough shade do you feel that your subirrigation method could be used outdoors?

ED MEZITT: Yes, give them enough to keep direct sunlight off. It is the hot sun that causes wilting.

VOICE: Ed Mezitt, I would like to ask you about the length of the cutting, hormone used, and if the crushed rock is sterilized.

ED MEZITT: We use Hormodin 3 and the crushed rock is not sterilized. The cuttings are selected at flowering.

DAVE TYZNIK: Ed Mezitt, what level of water do you maintain or how frequently do you irrigate?

ED MEZITT: We fill the pan the preceding day and then siphon it out before we stick the cuttings. After sticking we flood the cuttings overnight. We do not subirrigate again unless the cuttings wilt. Cuttings will not wilt for several weeks after the first subirrigation. We only leave 2 leaves and this may account for the low water loss.

STEVE STILL: You mentioned 3 genera in your talk that you have propagated. Are there others?

ED MEZITT: Yes, *Chaenomeles* and *Wisteria*. I think most anything will root.

VOICE: Ed Mezitt, you had lights over the cuttings, are they necessary?

ED MEZITT: We can find no advantage from their use.

VOICE: What type of container do you use to pot your lilacs?

ED MEZITT: A poly pot 3 × 5 inches.

VOICE: Richard Allred. When are you seeding your perennials in the Kyes Kubes?

RICHARD ALLRED: The slow growing types are seeded in mid-October to early November. Major part is seeded in late November to early December.

VOICE: You then have to go through the colder months and

use fuel. Could you start the plants earlier and carry them over at a colder temperature? If so, how would you do it?

RICHARD ALLRED: I have not tried that. I might store them at 35°F and then jump the temperature up in January.

VOICE: We germinate about 300,000 perennials in flats and transfer to 2¼ inch pots in the summer. In the fall we put them in cold storage and take them out for shipment in the spring.

DICK CROSS: Brian Humphrey, do you keep your *Juniperus* and *Picea* understocks on the dry side?

BRIAN HUMPHREY: Yes.

VOICE: We do it just the opposite. We wet the understock before placing them in the grafting case.

BRIAN HUMPHREY: That just shows that we must not be dogmatic when talking about propagation.

VOICE: What is the optimum temperature for spruce or pine graft callus formation?

BRIAN HUMPHREY: I would guess that they are low temperature response plants.

Tuesday Afternoon, November 28, 1978

The afternoon sessions convened at 1:30 p.m. with Joerg Leiss serving as moderator.

THE TREE FRUIT VIRUS-TESTED STOCK PROGRAM IN ONTARIO, CANADA

T.R. DAVIDSON

Agriculture Canada, Research Station
Vineland Station, Ontario, L0R 2E0, Canada

Virus diseases of fruit crops are worldwide in distribution. Some of these diseases cause great reduction in yield and/or fruit quality. Others result in a rapid decline and death of plants; still others are much less dramatic in their effects but over a period of time take a steady toll. Because of this most of the major fruit producing countries in the world now have virus-tested stock programs.

In Ontario the first attempts at setting up a special block of virus-tested trees for budwood purposes was made in the late 1940's by Dr. G.H. Berkeley of the Plant Pathology Laboratory in St. Catharines and Dr. W.H. Upshall of the Horticultural Re-

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search Institute of Ontario at Vineland. They were interested in sweet and sour cherries that were free of Necrotic Ringspot and Sour Cherry Yellows. These were the first virus diseases observed in *Prunus* in Ontario. The first budwood was distributed to Ontario growers about 1952.

WHY VIRUS INDEX

Since 1952 we have learned that virus diseases are much more common than originally thought, that a given virus can infect a much wider range of plants than was originally thought possible, and that some of them can be present without producing dramatic symptoms. Those viruses that induce no recognizable symptoms in our commercial cultivars are generally referred to as "latents". Actually they do reduce growth and yield to a degree and over the life of a tree can result in considerable loss. However, if you do not have a "healthy" tree for comparison you may never realize that the growth or yield is subnormal.

Since these latent virus diseases do not attract attention, infected trees remain in the orchards and natural spread from one tree to another occurs. Also, as an infected symptomless tree is often used as a budwood source, these latent viruses become more and more prevalent over the years. On the other hand, those viruses that kill trees or deform fruit soon have the growers calling for help and steps are immediately taken to eradicate them. The reservoirs of such viruses are usually quickly recognized and appropriate steps are taken to eliminate them. Hence diseases with recognizable symptoms are less common.

There are then two main reasons for virus indexing. One is to detect those viruses that are known to occur in Ontario. The establishment and use of budwood trees free of these diseases will gradually improve the tree fruit industry in Ontario. The second, and equally important, reason is to prevent the introduction of serious virus diseases known to be present in other parts of the world. This is the reason for restrictions on the importation of stock from outside Ontario.

ONTARIO'S PRESENT BUDWOOD PROGRAM

The present virus-tested budwood program was prompted by our increasing awareness of the number and severity of virus diseases that affect tree fruits throughout the world. In 1969 it was agreed that the Agriculture Canada Research Station at Vineland Station would establish a block of thoroughly indexed *Prunus*, *Malus* and *Pyrus* stock which would contain 2 to 3 trees of each commercial cultivar and important breeding lines. Budwood was to be distributed only in small quantities for research purposes for the establishment of budwood blocks by re-

search stations and reliable nursery organizations and to accredited research institutions or nurseries in foreign countries. The Horticultural Research Institute of Ontario at Vineland Station would maintain larger budwood blocks of all major cultivars for distribution in larger quantities to nurseries. All budwood trees would be periodically re-indexed for possible virus contamination.

THE VIRUS INDEXING METHOD

Initially we collected samples of all the *Prunus*, *Malus* and *Pyrus* cultivars grown in southern Ontario. Then we "indexed" these selections. What is indexing? Indexing is the technique used to test a cultivar selection for the presence or absence of viruses. The process is dependent on two factors. First, that the virus can be transferred from one plant to another. Usually T-budding is used. Second, every virus that we are concerned with produces distinct, easily recognizable symptoms in some hosts. Host plants that react with specific symptoms we call "indicators". So, for our program, we selected a group of indicators that would detect all the viruses that concern us (Table 1). Naturally this list changes from time to time as more sensitive indicators are found and also when previously unknown viruses are detected. For each crop type the indicators are divided into two groups. The basic group of indicators detects those viruses most commonly encountered in Ontario and some of the more serious ones from a production standpoint. The secondary indicators are used to detect less common viruses. These indicators are capable of detecting at least 16 *Prunus* viruses, 19 *Malus* viruses and 8 *Pyrus* viruses.

Table 1. Virus indicator plants.

Prunus	**Malus**	**Pyrus**
Basic	*Basic*	*Basic*
'Shirofugen' cherry	'Virginia Crab' apple	'Bosc' pear
'Kwanzan' cherry	'Spy 227' apple	Pyrus communis
Sam cherry	*M.* × *platycarpa*	'Virginia crab' apple
Italian plum	'Lord Lambourne' apple	*Pyronia vietchii*
Pozegaca plum	'R 12740-7A' apple	'Spy 227' apple
Secondary	*Secondary*	*Secondary*
'Bing' cherry	'Gravenstein' apple	'Hardy' pear
'Shiro' plum	'Golden Delicious' apple	'Lord Lambourne' apple
Peach sdlg.	'Cox's Orange' apple	'Golden Delicious' apple
'Wenatchee' apricot	'Boskoop' apple	quince

To index any selection we take buds from that selection and by normal methods insert these into one-year-old whips of the indicator. We use two or three indicator trees and insert three buds into each.

VIRUSES DETECTED IN ONTARIO

Some of the reactions induced by viruses that we have detected are as follows:

Green Ring Mottle Virus. This virus is most often found in peach selections. In *Prunus serrulata* 'Kwanzan' this virus produces a very marked leaf epinasty; that is, backward rolling of leaves accompanied by vein necroses and mottling. Growth is much reduced.

Necrotic Ringspot Virus. This virus is common in all *Prunus* species, particularly cherry. It can be readily recognized by its localized reaction in *Prunus serrulata* 'Shirofugen'. Three or four weeks after the insertion of diseased buds into this indicator a severe gumming develops around the buds. When the bark is removed a severe necrosis of the wood is seen.

Peach Rosette Mosaic Virus. Peach seedlings inoculated with buds carrying this virus develop a very rosetted (bunched-up) growth caused by extreme reduction in twig growth (elongation). A faint mottle can be seen on the leaves in the spring.

Prunus Stem Pitting Virus. In peach seedlings this virus induces extensive pitting in the wood under the bark.

Apple Chlorotic Leaf Spot Virus. This is the most common virus in apple selections that we have tested. It induces a very sparce, much delayed development of the indicator in the spring. Leaves of infected trees are rolled, mottled and may have distinct chlorotic rings and lines. The indicators, Russian seedling ('R 12740-7A'), *Malus* × *platycarpa* and 'Spy 227', all react much the same to this particular virus. Affected trees are very stunted.

Apple Stem Pitting Virus. It is detected by 'Virginia Crab'. Small distinct pits develop in the wood with corresponding pegs in the inner bark. This virus also induces an uneven, lopsided development of the fruits of 'Virginia Crab'. This is not the same virus that produces stem pitting in *Prunus*.

Apple Stem Grooving Virus. This virus is also detected in 'Virginia Crab' but here the symptom is an elongated groove quite distinct from the small pits of apple stem pitting. There is no fruit deformity.

Ring Russet Virus. Symptoms develop on the fruits of a number of indicators such as *Malus sylvestris* 'Golden Delicious' and 'Cortland'. We have seen beautiful symptoms on 'Cortland' and on *M.* × *platycarpa*.

Scaly Bark Virus. This apple virus has been reported only from Europe but we recently detected it in the cultivar 'Raritan'.

Blisters develop on one-year-old wood of *M.* × *platycarpa*. The cracking and scaling becomes more and more pronounced in older wood. Normal bark, of course, is smooth and a light yellow-brown.

Stony Pit Virus. This common virus in pear produces a very distorted fruit in susceptible cultivars. Below the pits are extensive stone-cell areas. *Pyrus communis* 'Bosc' is the most sensitive cultivar.

Pear Vein Yellows Virus. This is the most common virus in pear. In *Pyrus communis* 'LA62' it produces a marked yellow banding of leaf veins. Later red flecks develop along the veins.

By careful indexing we hopefully can prevent the importation of serious virus diseases that we know occur elsewhere. A few examples of these are: Peach Wart Virus, which produces a severe raised warty growth on the surface of fruits making them very unattractive. Necrotic Rusty Mottle of cherry is a very severe disease that kills trees in a very short time. Apricot Ring Pox results in unsalable fruit. The Little Cherry Virus has nearly wiped out the cherry industry in some parts of British Columbia.

HEAT TREATMENT

When all sources of a particular cultivar are found to carry one or more viruses we have to try to eliminate the viruses by a process called "Heat Treatment". To date, our work has been mainly with apple. We grow healthy apple seedlings in 5" clay pots. We select strong, well rooted year-old seedlings that are growing vigorously. Buds of the diseased cultivar are chip budded into the lower stem of the seedling. We usually put three buds on each. After one week in the greenhouse these budded trees are placed in a special treatment room under 24 hr light and low humidity (25 to 40% RH). The starting temperature is 22°C (72°F). Over a period of 10 days the temperature is raised to 37.5°C (100°F). This temperature is maintained for at least 30 days, then the seedling stock is cut back to the inserted buds to force growth. As soon as new growth is ¾" long it is cut off and cleft grafted into a small vigorously growing seedling rootstock. The hope is that the new growth produced under conditions of high temperature will be free of viruses. We have had very good success in getting these little grafts to grow. We do not know yet if we have any clean plants. Trees produced in this way must index negative for virus over the next two years before they can be declared free of known viruses.

VIRUS-INDEXED STOCK ON HAND

At the present time we can offer Ontario nurserymen small

amounts of material from 168 named cultivars or species. This includes 37 apple, 6 apple rootstocks, 16 ornamental *Malus*, 4 pear, 9 tart cherry, 18 sweet cherry, 17 plum, 4 plum rootstocks, 6 apricot, 4 nectarine, 30 peach, 3 peach rootstocks and 15 ornamental *Prunus*. It is available for the asking and free of charge.

MYCORRHIZAL FUNGI IN RELATION TO SOME ASPECTS OF PLANT PROPAGATION

DALE M. MARONEK and JAMES W. HENDRIX[1]
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The symbiotic association between a plant root and a mycorrhizal fungus is termed mycorrhiza. The specific types of mycorrhizal associations have been described in previous issues of the IPPS Proceedings (2,4). Mycorrhizal fungi are naturally occurring organisms in over 80% of the plant taxa. The vast majority of vascular plants have evolved to a dependency on mycorrhizae either for survival or to flourish. In many instances, mycorrhizal fungi facilitate increased growth and/or selective nutrient uptake and accumulation; tolerance to environmental stresses, such as drought, temperature extremes and soil acidity, and function in protecting roots from pathogenic infection. In addition, mycorrhizal fungi are also known to produce enzymes, vitamins and growth hormones that increase root size and longevity as well as rooting of cuttings.

Because the mycorrhizal state is a universal, natural association, its importance in nursery crop production may only become apparent when we disrupt the natural soil environment. Advances in the use of fertilizers, pesticides, steam sterilization or fumigation, soilless mixes, etc. to increase crop productivity have simultaneously diminished or eliminated the indigenous beneficial soil-borne mycorrhizal fungi. Consequently, severe stunting, special nutritional requirements, poor survival and/or growth, and increased disease susceptibility are often attributed to deleterious characteristics of a plant species or a failure of cultural practice, rather than absence of mycorrhizal fungi.

In order to benefit from mycorrhizal fungi in the nursery industry, we must be concerned with plant-fungus specificity, differences among fungal isolates producing specific effects

[1] Department of Horticulture and Landscape Architecture, and Department of Plant Pathology, respectively.

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under different cultural conditions, the economics of producing mycorrhizal inoculum and inoculating nursery crops.

In this study we would like to demonstrate some of the benefits one may obtain by incorporating mycorrhizal inoculum into seedbeds and container media during propagation of nursery crops.

MATERIALS AND METHODS

Isolate M3 of the ectomycorrhizal fungus (*Pisolithus tinctorius*) was obtained from sporocarp tissue collected in Laurel County, Kentucky. *P. tinctorius* isolate M1 (original no. 138) originally isolated in Georgia, was obtained from D.H. Marx, Institute for Mycorrhizal Research and Development, Athens, Georgia. Vegetative mycorrhizal inoculum of both isolates was produced by procedures of Marx and Bryan (5). After 3 months, the inoculum was washed and stored at 3°C for 24 hours before use. Inoculum of *Glomus fasiculatus* was prepared and added to the medium following procedures of Bryan and Kormanik (1).

All plants grown in the greenhouse were under an extended 18 hour photoperiod and prevailing greenhouse temperatures of 20 to 28°C day/20°C night (70° to 82°F/70°F night), and were watered with a complete minor element solution once a month (3).

Field Experiments with Ecto- and Endomycorrhizal Fungi. In the fall, 1977, seedbeds were prepared and fumigated with 67% methyl bromide — 33% chloropicrin at 397 kg/hectare and covered with 2 mil plastic. The following spring the land was rotovated and plots were boxed. Plot size was 0.84 m^2. Seed of each species was tested for viability and stratified. Planting density was 222 plants/m^2.

Pine species used were loblolly (*Pinus taeda*), Virginia (*P. virginiana*), pitch (*P. rigida*), shortleaf (*P. enchinata*) and Scotch (*P. sylvestris*). Before seeding, plots were inoculated with *Pisolithus tinctorius* isolate M3 at a rate of 1.1 l/m^2. Redbud (*Cercis canadensis*) seed were planted as above except that plots were inoculated with inoculum of the endomycorrhizal fungus *G. fasiculatus* (6.2 l/m^2).

Seeding was done on June 23, 1978. Each microplot was fertilized with 170 kg/hectare of a commercial 10-10-10 fertilizer. On July 16, 30 and August 13, 1978, 37.4 kg/hectare N was applied as NH_4NO_3.

Fertilizer/*Glomus fasiculatus* Interactions in Growth of Containerized Southern Magnolia (*Magnolia grandiflora*) Seedlings. Two month-old southern magnolia seedlings grow-

ing in flats containing sterilized peat:perlite (1:1 V/V) were transplanted on March 3, 1978, to 7.6 cm (3 inches) pots containing a sterilized mixture of composted hardwood bark and expanded shale (2:1 V/V) and 1.1 kg or 4.5 kg of 18-6-12 Osmocote/m^3. Thirty-six seedlings were planted at each fertility rate and one half of each group were inoculated with *G. fasiculatus* inoculum incorporated at a rate of 1:8 (V/V) into the container medium. Plants were grown in the greenhouse.

Fertilizer/*Pisolitus tinctorius* Interactions in Growth of Containerized Oak Seedlings. In the fall, 1977, red oak (*Quercus rubra*), swamp chestnut (*Q. Prinus*, Syn.: *Q. michauxii*) and pin oak (*Q. palustris*) acorns were collected, screened for viability and stratified at 5°C until used. Quart milk cartons were filled with steamed, composted, hardwood bark and expanded shale (2:1 V/V), half containing inoculum of *P. tinctorius* isolate M1 (1:15 V/V). On February 3, 1978, red and swamp chestnut oak acorns were planted in the containers, grown for 2 months and fertilized with 18-6-12 Osmocote at 1.1 kg/m^3. Pin oak seeds were also planted at the same time in Leach "Super Cell" containers. The potting medium was steamed peat:perlite (1:1 V/V), inoculated with *P. tinctorius* (isolates M1 or M3, 1:8 V/V), or not inoculated. The medium contained various rates of Osmocote 14-14-14. Plants were grown in the greenhouse.

On May 18, 1978, all oak seedlings were transplanted to 15 cm (1 gallon) pots containing composted hardwood bark and expanded shale (2:1 V/V). The mix was amended with 108.5/m^3 of Peter's fritted trace elements and various rates of Sierrablen 19-6-10 + Fe. Plants were grown outdoors in a container nursery until fall, 1978.

RESULTS

Field Experiments with Ecto- and Endomycorrhizal Fungi. Inoculating fumigated seedbeds with *Pisolithus tinctorius* inoculum substantially increased stem diameters and height growth of all 5 conifer species (Table 1). Stem diameters of inoculated plants were 50 to 150% greater than non-inoculated plants while plant heights were 60 to 125% greater. The uninoculated plants were stunted and slightly chlorotic. The apical foliage of uninoculated plants of most species was purple in color, characteristic of a phosphorus deficiency.

The endomycorrhizal fungus *Glomus fasiculatus* increased growth of redbud seedlings in the field. After 3 and 5 months, redbud seedlings growing in soil inoculated with *G. fasiculatus* were 92 and 72%, respectively, taller than noninoculated plants (Table 2). Stem diameters were also 20% larger on plants growing in inoculated soil. No nutrient deficiency symptoms were

Table 1. Effect of ectomycorrhizal fungus *Pisolithus tinctorius* on growth of pine seedlings 5 months after planting.[1]

	Stem Diameter		Height	
	mm		cm	
Species	Inoculated	Control	Inoculated	Control
Loblolly	2.4±.2	1.6±.03	14.9±1.2	7.7±.6
Virginia	1.9±.2	1.2±.1	7.5±0.5	4.7±.3
Shortleaf	2.3±.2	0.9±.1	7.2±.6	3.2±.2
Pitch	2.0±.2	1.2±.1	7.8±.7	3.7±.4
Scotch	1.8±.1	1.1±.1	4.1±.2	2.5±.1

[1] *P. tinctorius* isolate M3, Laurel Co., Ky. Means of 20 seedlings.

apparent on redbud seedlings in inoculated or uninoculated control plots.

Table 2. *Effect of endomycorrhizal fungus Glomus fasiculatus on growth of* redbud seedlings in field beds 3 and 5 months after planting.[1]

	Height (cm)		Stem diameter (mm)
	3 mo.	5 mo.	5 mo.
Control	11.5±0.8	26.1±2.8	3.4±0.3
Glomus fasiculatus	22.1±1.0	45.0±2.8	4.2±0.3

[1] Means of 20 to 41 seedlings.

Fertilizer/*Glomus fasiculatus* Interactions in Growth of Containerized Southern Magnolia Seedlings. Inoculation of container media with *G. fasiculatus* in combination with the recommended rate of 18-6-12 Osmocote (4.5 kg/m^3) produced the largest magnolia seedlings (Table 3). Inoculated seedlings at this rate were twice as large as the noninoculated controls at the full fertilizer rate. Inoculated seedlings grown with one-fourth the recommended fertilizer were also nearly twice as large as noninoculated control seedlings after 7 mo.

Table 3. Endomycorrhizal *Glomus fasiculatus*/fertilizer interactions in height growth of containerized southern magnolia seedlings.[1]

	Fertilizer rates[2]			
	1.1 kg/m^3		4.5 kg/m^3	
	6 mo.	7 mo.	6 mo.	7 mo.
Control	4.0±0.2	4.2±0.3	5.5±0.4	5.8±0.4
Glomus fasiculatus	7.5±0.8	8.2±0.9	10.2±0.8	11.8±0.7

[1] Two-mo.-old plants transplanted into 7.6 cm pots. Means of 18 seedlings.
[2] 18-6-12 Osmocote.

Fertilizer/*Pisolithus tinctorius* Interactions in Growth of Containerized Oak Seedlings. Fertilizer increased height growth of pin oak seedlings grown in Leach 'Super Cells' (Table 4) Plants fertilized at the manufacturer's recommended rate (4.5 kg/m^3) produced the best growth while plants fertilized with one-fourth the recommended rate (1.1 kg/m^3) were intermediate in size between plants receiving no fertilizer and those fertilized at the recommended rate. At the recommended fertilizer

rate, isolate M3 of *P. tinctorius* produced significantly more growth than plants inoculated with isolate M1.

Table 4. *Pisolithus tinctorius*/fertilizer interactions in height growth of pin oak seedlings grown in Leach 'Super Cells' 18 weeks.

	Fertilizer[1] rate		
	none	1.1 kg/m³	4.5 kg/m³
	Height (cm)		
Control	8.2a	10.2a	13.6b
P. tinctorius (M1)	8.5a	9.9a	14.2b
P. tinctorius (M3)	9.0a	10.6a	18.3c

[1] 14-14-14 Osmocote. Means followed by different letters significantly different (Duncan's multiple range test, 5% level).

In outdoor container nursery experiments, the largest red, pin, and swamp chestnut oak seedlings grown in 15 cm containers were those receiving recommended fertilization (4.5 kg/m³) and inoculated with *P. tinctorius* (Tables 5,6,7). After 9 mo. these plants were 20 to 60% larger than noninoculated plants fertilized at the same fertilization rate. Also the inoculated plants at the recommended fertilizer rate grew substantially more (84 to 115%) between the 5 and 9 mo. measurement dates than noninoculated controls (26 to 62%) at the same fertility level. At the low rate of fertilization, growth of all three oak species was poor during the 5 to 9 mo. interval. However, inoculated plants fertilized at the one fourth rate did grow slightly more (1 to 3 cm) than noninoculated control plants fertilized at the same rate.

Table 6. *Pisolithus tinctorius*/fertilizer interactions in growth of red oak seedlings grown in 15 cm pots in the outdoor container nursery.[1]

	Height (cm)			
	1.1 kg fertilizer/m³		4.5 kg fertilizer/m³	
	5 mo.	9 mo.	5 mo.	9 mo.
Control	4.3±1.0	4.6±1.0	8.8±0.9	11.1±1.2
P. tinctorius (M1)	6.4±0.7	7.4±0.5	9.6±1.3	17.7±3.5

[1] 19-6-10 + Fe Sierrablen. Means of 10 plants. Seedlings were transplanted from quart milk cartons to 15 cm (1 gallon) containers.

Table 7. *Pisolithus tinctorius*/fertilizer interactions in height growth of swamp chestnut oak seedlings grown in 15 cm pots.[1]

	Height (cm)	
	5 mo.	9 mo.
Control	15.9±2.7	22.1±3.0
P. tinctorius (M1)	14.6±2.1	31.4±4.6

[1] 19-6-10 + Fe Sierrablen, 4.5 kg/m³ Means of 12 plants.

Pin oak seedlings responded differently to the two isolates of *Pisolithus tinctorius* under differing experimental conditions. In the greenhouse — Leach tube experiment, isolate M3 pro-

Table 5. *Pisolithus tinctorius*/fertilizer interactions in growth of pin oak seedlings grown in 15-cm containers in the outdoor container nursery.[1]

	Height (cm)				*Stem diameter (mm)*			
	1.1 kg fertilizer/m³		4.5 kg fertilizer/m³		1.1 kg fertilizer/m³		4.5 kg fertilizer/m³	
	5 mo.	9 mo.	5 mo.	9 mo.	5 mo.	9 mo.	5 mo.	9 mo.
Control	10.1±0.7	11.2±0.7	12.3±0.6	20.0±1.0	3.5±.1	3.7±.2	4.2±.1	6.3±.3
P. tinctorius (M1)	11.9±0.8	15.3±1.7	16.3±1.3	33.0±2.2	4.4±.2	5.6±.5	4.8±.2	8.9±.6
P. tinctorius (M3)	11.3±0.9	14.5±1.6	12.5±1.4	24.4±2.1	4.2±.2	5.3±.3	4.4±.2	6.9±.9

[1] 19-6-10 + Fe Sierrablen. Seedlings were transplanted from Leach 'Super Cells' when 4-mo-old into 15 cm containers. Means of 10 to 25 seedlings.

duced superior growth (Table 4) while in the outdoor container experiment, isolate M1 produced superior growth (Table 5).

DISCUSSION

These studies indicate mycorrhizal fungi may be beneficial to plant growers in a number of ways: maximizing plant growth and producing salable plants in a minimum time resulting in more efficient greenhouse utilization, reduced labor costs, and greater production turnover; improving plant appearance due to decreased nutrient deficiency symptoms; improving fertilizer utilization or decreasing fertilizer needed to produce plants the same size as nonmycorrhizal plants; and the opportunity to produce "super seedlings", plants specifically infected with a mycorrhizal fungus ecologically adapted to adverse conditions frequently encountered by consumers.

Invariably, we obtained superior growth of seedlings by inoculation with mycorrhizal fungi. Conifers and oaks grew better when inoculated with *Pisolithus tinctorius*, and redbud and magnolia grew better when inoculated with *Glomus fasiculatus*. Obtaining a growth response to mycorrhizal fungi depends upon at least two factors: the rate at which land or media become reinfected with natural mycorrhizal fungal inoculum, and the degree of dependency of a plant species on mycorrhizal fungi for growth. In Lexington, we apparently have little air-borne ectomycorrhizal inoculum so that land or media in greenhouse experiments seldom become infected; other geographical regions apparently have abundant air-borne ectomycorrhizal inoculum so that growth benefits of artificial inoculation may not be realized. Endomycorrhizal fungi are not air-borne; therefore, artificial media devoid of soil will always be deficient and the degree of endomycorrhizal deficiency observed in field production will depend on the efficiency of soil fumigation. Apparently, endomycorrhizal fungi are seldom eliminated but reduction of inoculum may produce an early lag in growth. At 3 months, inoculated redbud plants were 92% larger than uninoculated plants, while at 5 months, they were only 72% larger. The "catching up" of uninoculated plants late in the growing season may be due to an increase in indigenous endomycorrhizal inoculum or a lag in time of infection by indigenous propagules compared to the inoculated plots.

Conifers produced in mycorrhizal-deficient nurseries often have foliar discolorations typical of nutrient deficiencies, especially of phosphorus. Similar conditions may be found with endo mycorrhizal plants, such as sweet gum. While plants may be large enough to sell, they are not appealing to consumers. We noticed this particularly in Scotch pine, inoculated plants being a healthy green color while uninoculated plants were an

unthrifty chlorotic to purple color. Suitable mycorrhizal fungi yield plants with greater visual appeal than mycorrhizal-deficient plants.

Fertilizer is a significant cost item to nurserymen, especially those who use expensive slow-release types. These studies demonstrated that mycorrhizal fungi produced a better growth response when fertilizer was supplied at the recommended rate. Such a response was not obtained at one-fourth the recommended rate; however, in the event a grower was not interested in maximum size but rather desired maximum return on his fertilizer investment, a suitable rate between the two levels used here could probably be found. With a mycorrhizal plant, it should take less fertilizer to produce the same size non-mycorrhizal plant.

Ecologically-adapted mycorrhizal fungi show much potential for allowing superior growth of trees on such adverse sites as strip mine spoils. It appears probable that for any given set of soil conditions, mycorrhizal fungi adapted to those conditions can be found. Homeowners often must contend with adverse soil conditions, such as scalping and removal of top soil by builders, and alkaline soil conditions around building foundations due to mortar. Cost of plants is often not a factor to consumers if fail-safe plants can be obtained. The use of ecologically-adapted mycorrhizal fungi to meet such a demand has not been attempted, but probably mycorrhizal fungi more than any other factor offers potential for producing a fail-safe plant. It seems certain that there will soon be a market for specifically-infected seedlings.

In our studies, adequate fertilization was essential for obtaining growth responses to mycorrhizal fungi. Especially with endomycorrhizal fungi, high fertilization has been reported to inhibit infection and annul growth responses. We found no such effects with either ecto- or endomycorrhizal associations. Probably magnolia and redbud are species with high dependencies for endomycorrhizal fungi.

The two isolates of *P. tinctorius* we studied produced differing responses with pin oak under differing conditions. One isolate was superior with plants growing on peat-perlite in the greenhouse, the other being superior with plants growing on composted hardwood bark-shale in large containers outdoors. Definite conclusions cannot be made with regard to these differences; however, it seems probable that fungal isolates will have to be screened and selected for precisely defined production conditions in order to select isolates which produce the desired plant responses.

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BRUCE BRIGGS: We know that with high fertility it is hard to get a mycorrhizal infection. You appear not to have had this problem. Do you think it is related to your use of encapsulated fertilizer?

DALE MARONEK: You are right about high fertilizer levels inhibiting mycorrhizal establishment. We are presently examining the influence of encapsulated fertilizers on mycorrhizal infection. You may be right that the slow release types are not inhibiting.

MIKE DIRR: Can you compensate for the lack of growth in your pines, which looks like phosphorus deficiency, by adding additional phosphorus?

DALE MARONEK: In some cases, yes and in other cases, no.

MIKE DIRR: How host specific are the mycorrhizal fungi?

DALE MARONEK: Some are very broad and others are quite species specific.

ROOTING *TAXUS* CUTTINGS WITH NO HEAT

EVERETT VAN HOF

Van Hof Nurseries, Inc.
Portsmouth, Rhode Island 02871

We first started propagating *Taxus* with no heat in the 1950's, but like all nurserymen, we had to build a greenhouse to root our *Taxus* cuttings. This gave us something to worry about in the winter — the snow, cold, wind, and filling the oil tank. Three years ago we returned to our original method for two reasons: the rising cost of fuel, and expanding our production would mean another greenhouse.

LITERATURE CITED

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PREPARATION AND PROCEDURES

The propagation frame is constructed so that it is 12 in. high on one side and 8 in. on the other. Three inches of sand is spread on the ground and tilled in to provide good drainage and aeration.

Cuttings are taken in mid-September because this allows them to callus before the weather becomes too cold. Thin cuttings from 2 yr bedded plants are best. A hormone treatment was not used until the fall of 1977 when some of the poorer rooting *Taxus* cultivars, such as *T.* × *media* 'Brownii' and *T. cuspidata* 'Nigra', were shown to produce better rooting percentages with the hormone. This fall we have, therefore, switched over to using Hormex 45 on cuttings of all *Taxus* cultivars except *T. cuspidata* 'Densiformis' which roots with 98% success. The cuttings are spaced using 1×2 in. furring strips between the lines and 1½ in. on the line.

After sticking, the cuttings are well watered and covered with sash and 50% lath shade. A shading compound is applied in May. The frame is aired about the first week of August for 10 to 14 days, after which the sash is removed and cuttings are covered with lath shade.

The cuttings are lifted about the first week of September, bedded out, mulched and covered with lath shade. New root growth is evident in 2 to 3 weeks.

We are also now using a deep, double frame. Twelve inches of sand was used in this frame. Cuttings root equally well in sand or soil. Sand, however, needs closer attention than the soil frame, as it dries out faster. The sand frame needs watering twice during the winter.

SUMMARY

There are several reasons why we like taking cuttings in the fall of the year:

1. No fuel means low cost.
2. Aids in getting our spring planting done on time.
3. Cuttings planted in the fall put on good growth the first year.
4. September is much warmer for taking the cuttings than is December.

RAY MALEIKE: The cuttings were essentially 1 year old and then they were put out in a lath frame?

EVERETT VAN HOF: No, the cuttings were taken about

mid-September and they stayed in the frame for 1 year, after which they go directly to the field.

TOM McCLOUD: Was it just straight top soil that you used?

EVERETT VAN HOF: Yes, but we mix 3 inches of sand into the top soil.

TOM McCLOUD: Do you fumigate the medium or use any fungicides before you close the frames?

EVERETT VAN HOF: No.

VOICE: This method also works for junipers and spruce.

HANS HESS: Do you have sash bars for support or do you just butt them?

EVERETT VAN HOF: Just butt them against each other.

OIL SAVINGS IN PITHOUSE ROOTING OF RHODODENDRON AND LAUREL CUTTINGS

ADRIAN J. KNUTTEL

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Five years ago, when the price of heating oil was only 17.9 cents per gal., fuel costs were not a major consideration in designing propagation facilities. Now that the cost of oil is almost 50 cents per gal., and is expected to go much higher, it seems appropriate to optimize designs for fuel economy. At our nursery, we have had good results with a pithouse. Ours is an H-shaped building constructed of cement blocks at a cost of approximately $9000. The legs of the H are 96 × 11 ft. and 16 ft. apart. The connector between the legs is 12×16 ft. The walls of the connector and the inner walls of the legs are 7½ ft. high, and the outer walls are 6 ft. high. Soil is backfilled to about 10 in. from the top of the walls. The rafters are 2×6 spruce 3 ft. on center. There are 3 layers of plastic on the roof. We have 0.004 clear plastić on the underside of the rafters, 0.006 "602" on top cleated with 2×3's, and another layer of 0.006 "602" over the 2×3's. The connector contains a propagation work table, two oil heaters, and a wood stove for emergency heating. The oil heaters are 140,000 BTU hot air counter-flow furnaces with a one gallon per hour nozzle, and distribute heat by air ducts under the benches. The benches are 4 ft. wide with wire mesh bottoms and they are placed against the walls with a 30 in. wide concrete path between them. The floors under the benches are sand.

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Five years ago, when the price of heating oil was only 17.9 cents per gal., fuel costs were not a major consideration in designing propagation facilities. Now that the cost of oil is almost 50 cents per gal., and is expected to go much higher, it seems appropriate to optimize designs for fuel economy. At our nursery, we have had good results with a pithouse. Ours is an H-shaped building constructed of cement blocks at a cost of approximately $9000. The legs of the H are 96 × 11 ft. and 16 ft. apart. The connector between the legs is 12×16 ft. The walls of the connector and the inner walls of the legs are 7½ ft. high, and the outer walls are 6 ft. high. Soil is backfilled to about 10 in. from the top of the walls. The rafters are 2×6 spruce 3 ft. on center. There are 3 layers of plastic on the roof. We have 0.004 clear plastić on the underside of the rafters, 0.006 "602" on top cleated with 2×3's, and another layer of 0.006 "602" over the 2×3's. The connector contains a propagation work table, two oil heaters, and a wood stove for emergency heating. The oil heaters are 140,000 BTU hot air counter-flow furnaces with a one gallon per hour nozzle, and distribute heat by air ducts under the benches. The benches are 4 ft. wide with wire mesh bottoms and they are placed against the walls with a 30 in. wide concrete path between them. The floors under the benches are sand.

To look at the economics of the design, we will compare it with a conventional 30×96 foot double plastic walled propagation house. Bench space in both houses is the same. The conventional propagation house has 5400 sq. ft. of double layer plastic exposed, including an inflated roof. The pithouse has 2200 sq. ft. of triple plastic exposed, or 40.7% of the exposure of a conventional propagation house. The oil consumption in the winter of 1977-1978 amounted to 4860 gal. of #2 fuel in the conventional house, and 980 gal. of the same fuel in the pithouse, a savings of nearly 80%. Apparently the heat contributed by sub-frostline earth aids in maintaining proper temperatures.

In the pithouse, temperatures in spring and summer are easily controlled by fan and simple shading. For this we use 0.004 and 0.006 translucent white plastic left over from winter storage hoophouses. Because the temperature is so easy to control in the pithouse, we are able to have three crops of cuttings a year, whereas in the conventional propagation house, high temperatures make summer propagation impossible. Since it is so easy to keep the house cool, we have had excellent results propagating deciduous azaleas.

CHEMICAL AIDS IN ROOTING RHODODENDRON AND ILEX CUTTINGS

HARVEY GRAY[1]

State University of New York
Farmingdale, New York

After making and observing the rooting of *Rhododendron* cuttings for 30 years, it appears that cuttings made during the November-December period produce a better percentage of good rooted cuttings than to those taken at other times. It now also appears that soaking the cuttings in a sodium hydroxide (NaOH) solution at a pH of 10.5 for 20 to 30 minutes before sticking in the rooting medium, gives much better rooting and higher percentages. This concept was developed by C.I. Lee, J.L. Paul, and W.P. Hackett and presented at the Western Region IPPS meeting in 1975 (1).

After reading this paper, I decided to run a few tests on the value of soaking wounded cuttings of *Rhododendron* and *Ilex* in NaOH solutions at pH 10.5. Trials with *Rhododendron* cuttings were made November 11, 1977 using cuttings formed during the August growth period of 1977. The *Rhododendron* cuttings were double wounded and soaked for 20 minutes in the

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NaOH solution. The cuttings were next washed in tap water (pH 6.5) and treated with IBA in talc or isopropyl alcohol. No attempt was made to treat the cuttings with a fungicide.

The rooting medium consisted of a mix of Canadian sphagnum peat and propagation grade perlite (1:1). The mix was properly moistened, placed in a vapor proof case, and maintained at 72° to 75°F.

The NaOH increased the rooting percentage and quality with both talc and alcohol methods of auxin application (Table 1).

A second trial, not reported on here, was made in mid-July, 1978, using cuttings formed during June, 1978, and showed that fall cuttings respond better to NaOH then did spring cuttings.

Table 1. Rooting percentage of *Rhododendron* 'Nova Zembla' cuttings with and without NaOH pretreatment.[1]

IBA ppm	Percent Rooted	Quality of Roots
No NaOH Treatment		
15,000 (in talc)	60	just acceptable
20,000 (in talc)	90	good, average
7,000 (in alcohol)	90	good, average
10,000 (in alcohol)	90	good, average
NaOH Pre-treatment — pH 10.5		
7,500 (in talc)	90	abundant, strong
10,000 (in talc)	90	abundant, strong
5,000 (in alcohol)	100	abundant, strong
7,500 (in alcohol)	100	abundant, strong

[1] Date of sticking, 11/9/77; potting, 1/2/78.

Ilex species, like most broad-leaved evergreens, do not produce multiple surges of growth in the same growing season. After most *Ilex* species have completed their season's growth and that growth has matured, they are ready to produce root initals when made into stem cuttings. The cuttings are quite difficult to root if they are not wounded and treated with IBA. When the *Ilex* 'San Jose' and 'James Esson' cuttings were treated in a 30 minute NaOH soak they rooted and had a rapidly growing root system in eight weeks.

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VOICE: How long do you predip with sodium hydroxide?

HARVEY GRAY: I can see no difference between 20 or 30 minutes.

ETHYLENE AND ADVENTITIOUS ROOT FORMATION

RAY MALEIKE

Dept. of Plant and Soil Science
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Abstract. *Pelargonium peltatum* 'Galilee' and a cultivar of *Coleus blumei* were treated with ethephon at 0, 100, 400, and 800 ppm. Treatment effects on number and length of roots and changes in endogenous levels of root promoting and root inhibiting substances were determined. Rooting was stimulated in both species at most ethephon levels, but 400 ppm seemed to be best. Increased rooting corresponded with increased levels of endogenous rooting promoters and/or decreased levels of inhibitors.

Ethylene, structurally the simplest of plant hormones, is primarily associated with metabolic activity which is inhibitory to growth. These include diminished internode length (15), suppression of bud growth in some cases (4,5), abscision of leaves and fruit (1,5), and flower induction of bromeliads (6).

Ethylene has been tied to endogenous levels of indole-3-acetic acid (IAA) (15). Increased levels of IAA usually lead to increased levels of ethylene which then may diminish the concentration and effectiveness of IAA. The response of a plant to ethephon, (2-chloroethyl) phosphonic acid, is dependent on chemical, physical and environmental conditions. A higher concentration of ethylene was released in plant tissue at higher pH's and higher temperatures (9,10). Duration of the effect of ethylene from an exogenously applied ethylene compound may be as brief as 4 to 24 hours (13) or much longer (5).

The formation of adventitious roots on cuttings is a complex procedure. It involves a synergism and/or direct combination of various root promoting substances (cofactors) with auxin (7,8). This complex then aids in cell division and differentiation into root tissue. Problems which may arise are insufficient quantities of IAA due to lack of synthesis and/or catabolism, lack of one or more of the essential cofactors or other root promoting substances, presence of inhibitors to root initiation, presence of gibberellic acid (GA) which may inhibit cell division (8,15) or a combination of any of the above factors. Some of these problems may be overcome as follows:

1. The catabolic effect of IAA oxidase may be overcome by application of IBA, NAA or a phenoxy-compound, which are not rapidly degraded by IAA oxidase.
2. The phenolic fraction of the rooting promoters (cofactors) may be added exogenously by compounds such as catechol or rutin.
3. The inhibitory effect of GA may be lessened by application of ABA or suitable anti-GA compound such as

Cycocel, B-9 or Phosphon, if GA is a problem. The area which is seemingly uncontrollable is increasing the concentration of the other root initiation promoters (cofactors) and/or decreasing the inhibitors of root initiation.

The role of ethylene in adventitious root formation is little understood and contradictory reports are common. Kawase (8) found ethylene applications would stimulate adventitious root formation in willow and tomato cuttings. Swanson (4) found that adventitious root formation was increased in softwood cuttings of 6 different species of woody plants with treatments of ethephon alone or in combinations with IBA and NAA. Ethephon works independently of IBA or NAA (10). Carpenter (3) succeeded in rooting hardwood cuttings of *Juglans nigra* after soaking in solutions of ethephon. Ethylene has also shown promise in the rooting of azaleas (11).

METHODS AND MATERIALS

Cuttings. Uniform cuttings of *Coleus blumei* or *Pelargonium peltatum* 'Galilee' (4-5 nodes) were rooted under intermittent mist in sand, with 26°C bottom heat. Ethrel[1] (ethephon), 21.3% 2-chloroethyl phosphonic acid, previously adjusted to pH 4.5 with 1 *N* NaOH was sprayed on the cuttings foliage (both sides) until drip, at the rate of 0, 100, 400 or 800 ppm. A spreader-sticker, Triton B-1956, was added at the rate of 1 drop to 300 ml of solution. Root number and average root length were noted at the end of 7 days for coleus and 12 days for geraniums. There were 3 replications of 5 cuttings for the coleus and 4 replications of 5 cuttings for the geranium. Mean separation was by Duncan's Multiple Range Test after analysis of variance.

Mung Bean Bioassay. Leaf tissue (1.5g) was boiled in 80% ethanol (6 hours after spraying the geranium and 4 hours for the coleus), macerated in a blender, filtered through Whatman No. 1 filter paper and washed with two 30-ml portions of 80% ethanol. The filtrate was concentrated at 40°C to 5 ml under reduced pressure. A 0.25 ml aliquot of this resultant slurry was streaked across the 5 cm width of Whatman No. 3 chromatographic paper which was 45 cm long. After a 6 to 8 hour equilibration in an atmosphere of 100% ethanol, the strips were developed in 80% 2-propanol for 30 cm by descending paper chromatography. The dried strips were then cut widthwise into seventeen 2 cm segments, each of which was equilibrated for 1 hour in a 10 ml vial containing a 4ml solution of 5×10^{-6}M in IAA and 9.4×10^{-7}M in H_3Bo_3. The extra two strips from above the origin and from below the solvent front served as controls.

[1] Amchem Products, Ambler, PA.

Five uniform mung bean (*Phaseolus aureus* Roxb.) cuttings, sown in vermiculite and grown for 7 days under a 16 hour day at 8.3 klx, 30°C day temperature and 26°C night temperature, were inserted into each vial. There were 3 replications of each treatment. Adventitious roots were counted after 6 days and plotted on histograms according to strip number or Rf value.

RESULTS

Ethephon treatment of geranium at the rate of 400 ppm stimulated the greatest number of roots (Table 1). This was reduced at 100 ppm and further reduced at 0 and 800 ppm. The greatest root length was on the 0 ppm treatment, the least on the 800 ppm, with the 100 and 400 not different than the 0 or 800 ppm treatments. The percent rooting was reduced to 85% at the 0 and 800 ppm levels. The cuttings that did not root would probably have rooted if given sufficient time. There was some leaf abscission at 800 ppm. This data indicates that the ethylene releasing compound, ethephon, will stimulate the formation of a greater number of roots in the 100 to 400 ppm range as compared to the control. The 800 ppm treatment reduced root number, root length and rooting percentage, indicating this concentration was too great for ivy geranium 'Galilee'. The histogram from the mung bean bioassay showed that there was a change in the levels of the various root inducing substances (Figure 1). The highest levels were recorded at the 400 ppm treatment, the lowest levels were recorded at 0 and 800 ppm. These histograms do correspond closely with the rooting study, where the best rooting was at the 400 ppm treatment.

Table 1. The effect of ethephon concentration on the rooting of *Pelargonium peltatum* 'Galilee' stem cuttings.

Ethephon Concn. (ppm)	Average Root Number	Root Length (mm)	Percent Rooting
0	6.5 c[z]	11.0 a	85
100	9.0 b	9.9 ab	100
400	12.2 a	10.4 ab	100
800[y]	5.0 c	7.7 b	85

[z] Mean separation by Duncan's Multiple Range test at the 5% level.
[y] Some leaf abscission of cuttings.

Ethephon treatment of coleus stimulated the greatest number of roots at 400 ppm when compared to the control (Table 2). This was not different than the 100 and 800 ppm treatments. The shortest roots were found on the 800 ppm treatment. A differential rooting pattern between the ethephon-treated plants and the control was noted. The control cuttings only rooted at the basal node, while the treated plants rooted at the basal node and the internodal region between the bottom nodes. The mung bean bioassay histograms showed an increase in root

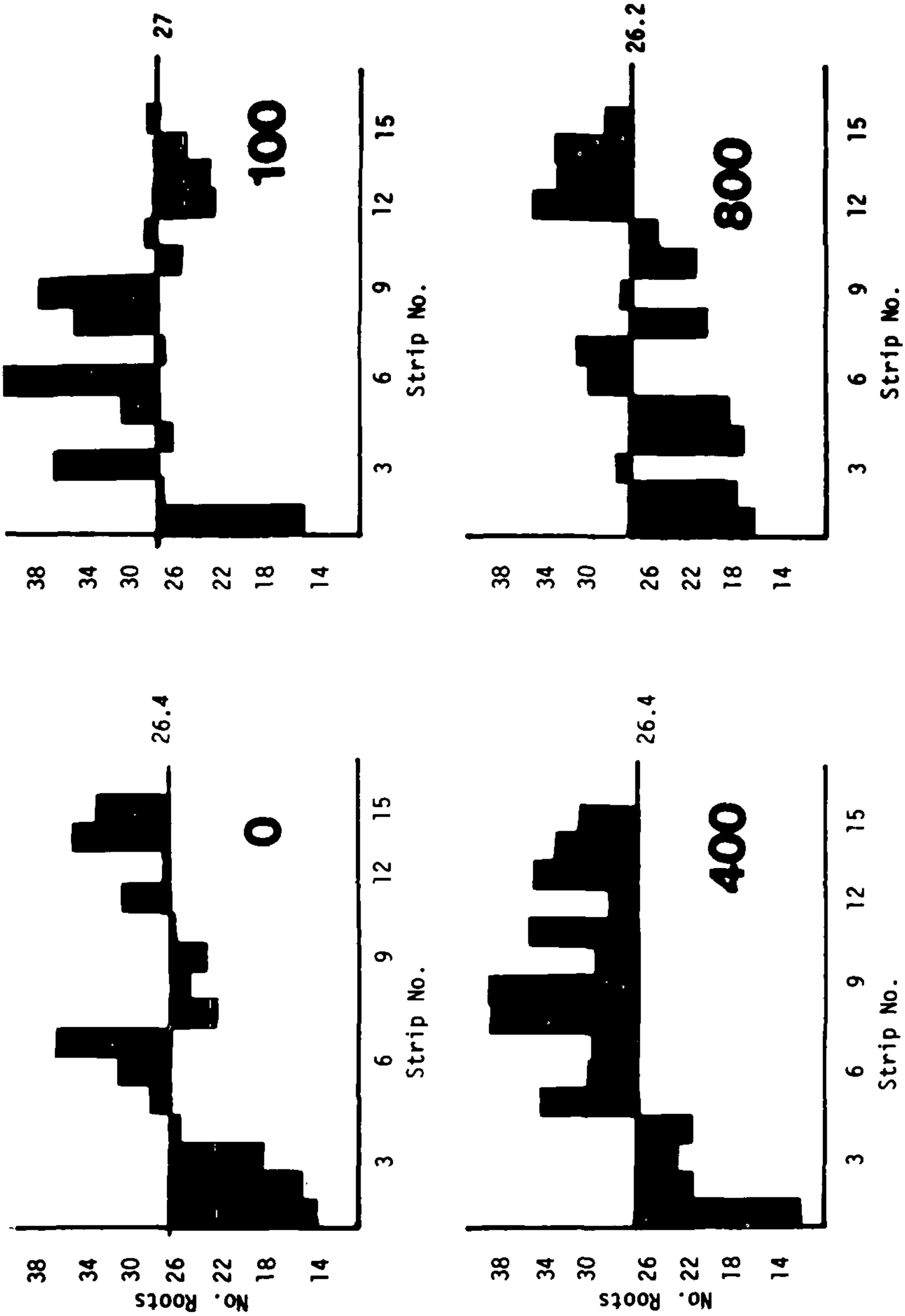

Figure 1. Histograms showing the effect of ethephon at 0, 100, 400 and 800 ppm on the biological activity of *Pelargonium peltatum* 'Galilee', as determined by the mung bean bioassay.

promoting substances, particularly in the 400 and 800 ppm treatments (Figure 2). This also corresponded with the increase in rooting of the cuttings at these levels of ethephon.

Table 2. Effect of ethephon concentration on the rooting of *Coleus blumei* cuttings.

Ethephon Treatment (ppm)	Average Number of Roots	Average Length of Roots (mm)
0	16.3 b[z]	15.4 a
100	30.1 ab	12.6 a
400	35.5 a	13.1 a
800	32.4 ab	9.0 b

[z] Mean separation by Duncan's Multiple Range Test at the 5% level.

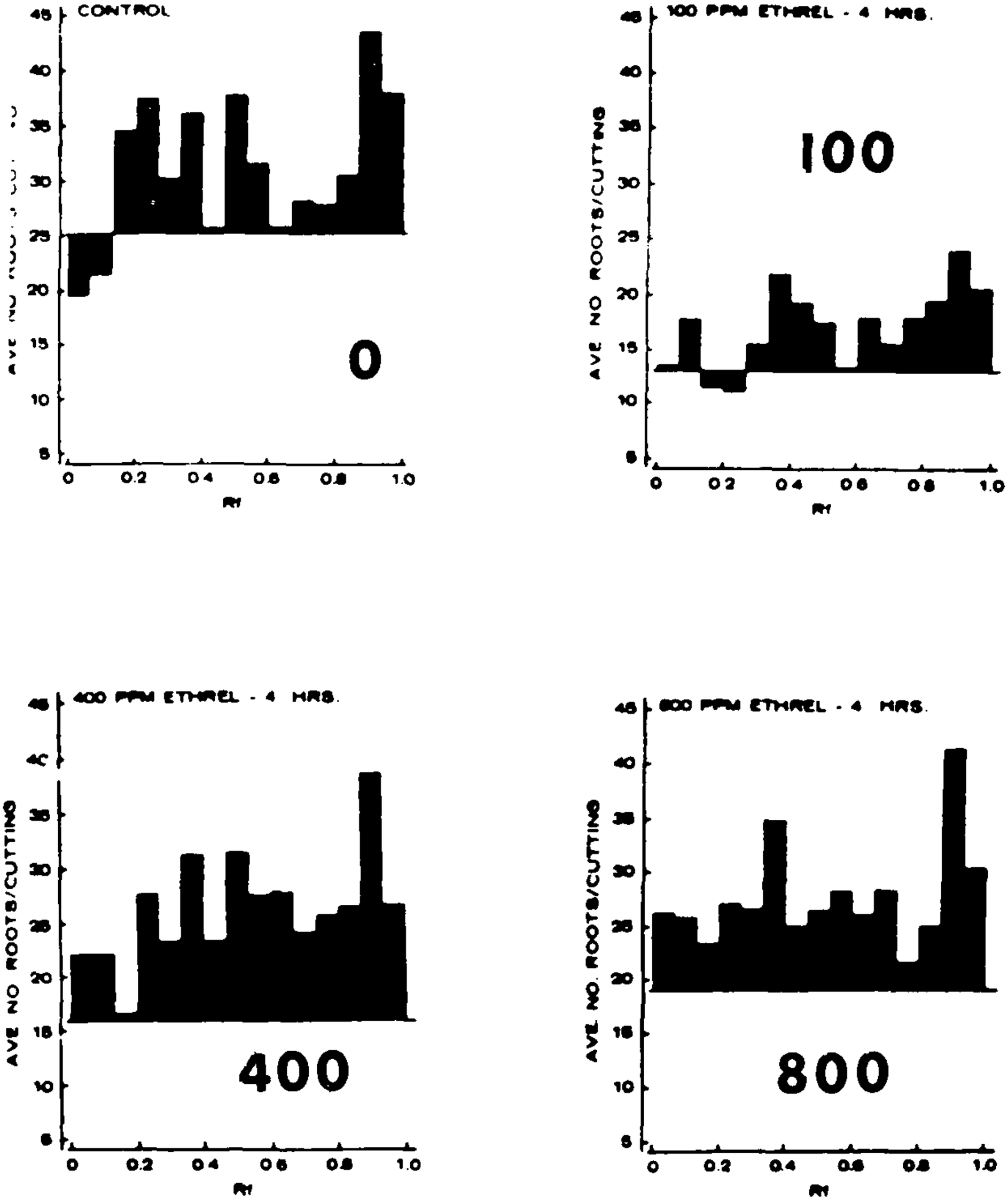

Figure 2. Histograms showing the effect of ethephon at 0, 100, 400 and 800 ppm on the biological activity of *Coleus blumei*, as determined by the mung bean bioassay.

DISCUSSION

The mode of action of ethylene in the stimulation of adventitious root formation on stem cuttings seems to be a manipulation of various plant metabolites which may induce rooting. This is a concept set forth by Swanson (14) and has been little studied. Ethylene, and ethylene-releasing compounds, may increase the number of endogenous root inducing substances and/or decrease the number of root inhibiting substances. Some of these rooting promoters may be the classical cofactors. The increase in rooting of coleus and ivy geranium 'Galilee' cuttings did correspond very closely with the increase of the various rooting promoting substances as determined by the mung bean bioassay.

The optimum concentration of ethylene for the stimulation of rooting is likely to vary with the species, as well as with other environmental and chemical characteristics. Both temperature and pH play an important role in the release of ethylene from ethephon. More ethylene is released at elevated temperatures and higher pH levels. The ultimate effect on future plant growth, flowering, and fruiting is not known. The increase in the levels of endogenous root promoting substances after treatment with ethylene, may rise and fall within a short period of time. The two species reported on here root very easily and quickly. A more difficult to root species, or one that takes a long time to root, e.g. *Taxus* sp., may need a delayed application or multiple applications.

In the mass production of easy-to-root plants, ethylene may stimulate quicker rooting, so that plants can be moved faster. Plants which are difficult or impossible to root may be able to be rooted with the proper application of ethylene.

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QUESTION BOX

The question box session was convened at 8:00 pm with Mr. Ralph Shugert and Mr. Ben Minamoto serving as moderators.

MODERATOR SHUGERT: Has anyone propagated *Viburnum nudum* from seed? If so, what seed treatments were used?

DON SHADOW: The seed, unless picked a little green, will take 2 years to germinate. If picked green and planted in the fall it will often germinate the following spring.

MODERATOR SHUGERT: What is the most successful method of growing *Taxus cuspidata* (Syn.: *T. cuspidata* 'Capitata') from seed and how important is the seed source?

ED MEZITT: I collect and clean my own seed, plant them out the same fall, and cover the beds with hay. The seed germinates the second year. We have been using lead arsenate for rodent control.

CASE HOOGENDOORN: Put the seed in sand for one year and then sow it. The seed will germinate the next year. If it is dead it will never come up.

RALPH SHUGERT: Mr. Hoogendoorn hit a very salient point in this matter. It is very important to take a cutting test on any seed. For *Taxus, Seeds of Woody Plants in the U.S.* states: 90-100 days of warm, 100-120 days of cold; sow it in the spring and maybe the seeds will germinate the next year.

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MODERATOR SHUGERT: If you propagate *Stewartia pseudo-camellia* 'Korean Splendor' from seed what do the seedlings look like, the species or the cultivar?

CASE HOOGENDOORN: It will not come true from seed.

MODERATOR SHUGERT: How does the germination rate of fall-seeded Canadian hemlock compare to the germination rate of cold stratified seed planted in the spring? Do 1-0 hemlock seedlings require shade? If so, how much and for how long?

BRUCE BRIGGS: I can only comment on the western hemlock. The forestry industry grows a tremendous amount for reforestation. They shade the 1-0 seedlings because of the large growth they get. We grow ours in plastic houses in tubes with heat and obtain twice the plant in the same length of time.

FRANK GOUIN: We have just started to work with hemlock in our sludge project and we find that fall-sown seed have fewer weed problems. Germination is the same for both methods, however, we lose many seedlings during weeding of spring-sown beds.

RALPH SHUGERT: I might add that my experience has been, that if the seed viability is there, there is no difference in stands between fall and spring sown. Most nurseries in the Midwest do not shade 1-0 seedlings.

MODERATOR BEN MINAMOTO: What species of *Juniperus* are graft compatible with *Platycladus orientalis* (Syn.: *Thuja orientalis*)?

RICHARD CROSS: In the latest IPPS Proceedings (1977), Philip Hall addressed that subject.

MODERATOR BEN MINAMOTO: What is the best rootstock for cultivars of Japanese black pine?

ED MEZITT: Japanese black pine seedlings.

MODERATOR BEN MINAMOTO: Can *Chamaecyparis nootkatensis* 'Pendula' be grafted on *Thuja occidentalis*?

VOICE: In Europe and Canada *Platycladus orientalis* is used.

MODERATOR BEN MINAMOTO: Can *Fagus sylvatica* cultivars be successfully grafted on *F. grandifolia* rootstock? If so, what are the procedures?

CASE HOOGENDOORN: No. You must use *F. sylvatica* seedlings.

LEONARD SAVELLA: You can graft *F. sylvatica* 'Pendula' on *F. grandifolia* with good results. It is the only one we have grafted successfully.

MODERATOR BEN MINAMOTO: Do genetic dwarf crabapples need grafting? If so, what would be the understock?

BILL FLEMER: Probably *Malus sargentii* would be the best to keep them dwarf.

BRUCE BRIGGS: I would recommend that the individual both root cuttings and graft the crabapples to determine what happens.

MODERATOR SHUGERT: Mr. Maronek would you explain how to find the mycorrhizal fungi, how to incorporate the fungi into the soil and how a small nursery would increase it.

DALE MARONEK: The ectomycorrhizal fungi produce aerial fruiting structures, such as "puffballs". If you find these structures in a forest situation they may be mycorrhizal fungi. With endomycorrhizal fungi types it is a little different. You will have difficulty finding and collecting them. We use a series of techniques including staining to see if the spores are present in the plant tissues in combination with sieving and centrifugation to isolate the spores. We have tried broadcasting on the soil surface and mixing it into the upper 4 to 6 inches and that has worked well. In our container mixes, we treat it like any other component in the mix. With our ectomycorrihizal fungi, we are mixing in vegetative inoculum that we grow in our lab.

MODERATOR SHUGERT: Where does one obtain inoculum for mycorrihizal infection? Is it available commercially or does one collect it from the wilds? How does one prepare inoculum?

DALE MARONEK: When we do it ourselves, we collect fruiting bodies and grow the material as you would callus on agar in tissue culture. After establishing a colony of the fungal material, we then transfer some to a peat-perlite medium containing the necessary growth factors for inoculum production. The fungus actually grows into the vermiculite and we simply use this material as you would fertilizer. Mycorrihizal material is available from Abbott Laboratories, Chicago, Illinois.

MODERATOR SHUGERT: Do broadleaf plants, such as rhododendrons, have mycorrihizal fungi on their roots? Does high pH or calcium have any effect?

DALE MARONEK: There is a select group of mycorrihizal fungi that work with the Ericaceae. I have not worked with this group but Dr. Linderman at Oregon State University has and could better answer that question. Depending on the fungal isolate, pH does affect the fungal isolates ability to function. There is a great deal of variation.

CARMINE RAGONESE: If you incorporate generous amounts of organic material, especially with rhododendrons, the fungi are present.

MODERATOR BEN MINAMOTO: I've rooted softwood cuttings of *Ulmus villosa* under mist. The new growth was horizontal and no amount of staking would induce apical dominance. Late the following winter, the growth was cut back to just above the soil line and the new spring growth showed apical dominance. Unfortunately, I have lost one year's growth. How can I get apical dominance to assert itself?

VOICE: There is a report that gibberellic acid will correct that problem.

MODERATOR BEN MINAMOTO: In the interest of energy conservation, what is the coolest house temperatures that one can successfully root *Thuja*, *Picea* and *Juniperus* species if you use bottom heat?

LARRY CARVILLE: We have found with all three of them that you can maintain a top temperature as low as 30°F and get good root formation with bottom heat.

DICK CROSS: We have had success rooting those species. In our area it is quite cold in December and January when we are doing it and, to conserve heat, we start them out at a top temperature of 50 to 55°F. When spring comes we gradually increase the night temperature to 60°F and finish them off at 65°F. The bench temperature runs a little higher than the air temperature because the heat pipes are under the benches.

RALPH SHUGERT: When I propagated in Nebraska in a structure similar to a pit house, the top heat was set to come on at 34°F. The bottom heat in the ground beds was electric cable and carried at 70°F. Under those conditions, I felt that the top heat was not important. You would have a well rooted cutting by June that could be potted and carried till the following spring and lined out.

DAVE BAKKER: I want to caution you a little bit. First, it is a known fact that when the rooting medium temperature gets below 55°F, hormone activity decreases greatly. One should, therefore, be between 60-70°F with the bottom heat. Secondly, if the temperature differences between the top and bottom is too great you force water by vapor pressure into the cuttings because of the high humidity. This may cause a lot of basal decay on your cuttings. You can be too cheap with the use of bottom heat.

CARMINE RAGONESE: Regarding the manipulation of bottom heat, with rhododendrons a bottom heat of 70°F in combination with a dull overcast day will cause defoliation of the cuttings. You must lower the bottom heat. If there is full sun leave the temperature at 70°F.

MODERATOR BEN MINAMOTO: Poly tents do not keep

the tops cool when rooting cuttings. Therefore, is the old saying "warm bottoms and cool heads" out of date?

CASE HOOGENDOORN: The reason for following that procedure was to stop the cutting from initiating top growth. If you keep the house cool you will root the cuttings and not force growth.

BRUCE BRIGGS: In summer propagation, we are reversing the temperatures. We close the house up and cause high air and cooler soil temperatures.

FRANK GOUIN: We should go back and look at Dr. Milbocker's paper in last years' IPPS *Proceedings* (1977). He has also reversed the temperatures with accelerated rooting.

MODERATOR BEN MINAMOTO: What kind of woody plants are being worked on in tissue culture?

LEN STOLTZ: I am currently working with *Ficus elastica* 'Decora' and 'M-26' apple understock. There is other work being done on elm and poplar.

MARK ZILIS: I have worked on *Prunus*, *Hamamalis*, and *Viburnum* species.

VOICE: Flow Laboratories is providing an abstracting service in the tissue culture area.

BRUCE BRIGGS: Rhododendrons are on the way. There is, however, a problem with rooting the plants in tissue culture. You can take the plants out of tissue culture and root them. We have just finished spending a year researching how to grow the little plants after you get them out of culture.

MODERATOR SHUGERT: Has anyone had success in rooting *Chionanthus virginicus* and *C. retusus* cuttings?

DON SHADOW: I have successfully rooted *C. retusus* from softwood cuttings stuck just as they began to harden. The cuttings are also wounded and treated with Hormodin #2. There appears to be a juvenility factor in the rooting ability. The first cuttings I obtained from old trees rooted very poorly. Cuttings from the rooted cuttings in subsequent years rooted without any problem. We grow *C. virginicus* from seed.

MODERATOR SHUGERT: How much Benlate or Captan should we be using in rooting powders?

CARMINE RAGONESE: You should use 1/16 of the total bulk as the desired fungicide.

BRIAN HUMPHREY: At Hillier's we were unable to duplicate the good results reported for Captan addition to rooting powders. In general we feel, in the case of Captan, if one is applying artificial bottom heat, Captan is of no advantage, or is detrimental. Captan, it is thought, is of advantage only when

you are trying to root plants cold without bottom heat. Commercial Benlate is 10% active ingredient. When mixing it with auxin you take double strength auxin and combine it with an equal part of Benlate and you end up with the recommended 5% Benlate.

DAVE BARKER: Captan in our rooting powders caused stunting of certain plants. We have found that you should stick your cuttings with the normal auxin treatment and then drench them in with the wettable Captan powder. Use a real heavy drench so you don't have to water the greenhouse for a week. Although Captan in the rooting powders appears to be inhibitory with most plants, *Prunus triloba* 'Multiplex' benefits from Captan incorporation into the rooting powder.

CARMINE RAGONESE: Don't worry about incorporating a fungicide into your rooting powder. I dip my rhododendron cuttings in one tablespoon of Terraclor/2 gal of water with good results.

VOICE: I am using Fermate in a 10:1 ratio and obtain excellent results with herbaceous and softwood cuttings in the summer.

RALPH SHUGERT: Research work on the use of fungicides as rooting aids is currently being conducted at Ohio State. I think they are going to recommend the auxin treatment, stick it and apply the fungicide over the top. They are not going to recommend blending with auxin.

FRANK GOUIN: Poinsettia growers are currently applying Benlate to the stock plants 10 days before taking cuttings. This allows the Benlate to get into the cuttings and start to work.

MODERATOR BEN MINAMOTO: Mr. Mezitt, would you give the address for the 3 inch wide by 5 inch deep pots you mentioned.

ED MEZITT: I will be glad to send the address to anyone who wants it.

DICK CROSS: There is a manufacturer of clay pots in Jackson, MS, Cermo Inc., who still makes similar clay pots.

VOICE: Syracuse Clay Pottery Inc. in Syracuse, N.Y. makes clay rose pots.

MODERATOR BEN MINAMOTO: Does anyone know the reason for sparse and crooked growth of pine and spruce in cans? The plants are in 1, 2 and 5 gallon cans.

ED MEZITT: Unless you have a good container program and know your mixes nothing is going to grow as well in containers as in the field. Grow the pines in the field and plunge them into pots in August and reestablish root growth.

MODERATOR BEN MINAMOTO: Mr. Van Hof, is any mist used when propagating your *Taxus* with little or no heat? What is the temperature of the frames in winter?

EVERETT VAN HOF: No mist is used. The cuttings are just watered in. I am not sure what the temperature is, however, it does freeze in the frames.

MODERATOR BEN MINAMOTO: Can anyone tell me the correct method for propagating 'P.J.M.' rhododendron?

KATHY FREELAND: We have found that you can take cuttings from August to December. The cuttings should be 6 inches long, with all flower buds removed, wounded and given a hormone treatment. Our medium is a peat-perlite mix and bottom heat (75°F) is used. The minimum air temperature is 55°F and mist is used on bright sunny days.

MODERATOR BEN MINAMOTO: I would like to know the spacing for cuttings in the accelerated growth method of Knox Henry.

VOICE: It depends on the size of the leaves. For example, *Forsythia* is spaced 3 inches and *Ribes* is spaced 1 inch.

MODERATOR BEN MINAMOTO: Does anyone know of an electronic tree grader for use in a commercial nursery?

BRIAN HUMPHREY: Hillier's Nursery has developed what we call the Hillier Electronic Tree Grader which both counts and sizes trees.

MODERATOR BEN MINAMOTO: What does anyone know about chlorinating pond water for watering plants?

VOICE: *Ornamentals NorthWest* just presented a complete article on that subject.

BRIAN HUMPHREY: You must have reasonably clean water to chlorinate. If it is cloudy with clay deposits the whole idea of chlorination is questionable. The clay absorbs the chlorine and any change in clay content could cause you to be over or under your chlorine content. A filter is necessary for cloudy water.

MODERATOR BEN MINAMOTO: Has anyone used a chemical to remove snow from plastic houses and is it toxic to plants?

FRANK GOUIN: You might try urea. It will melt snow down to 23°F. Calcium chloride is safer than sodium chloride because it does not dissociate as rapidly and will cause less plant damage. I do not know what any of them will do to plastic.

MODERATOR BEN MINAMOTO: Can anyone comment on hot sauce as a repellent?

FRANK GOUIN: We have had some good and bad results. Some growers swear by it, however, we found in one test plot that if the deer are hungry enough they will eat the plants with hot sauce. Some deer also like the sauce better than others. With rabbits we have had a higher degree of success with the oil extract, 4 oz/100 gallons of water, in 7 different test areas. However, it does not work with woodchucks.

VOICE: At our nursery I use Thiram, at the rate of 1 lb Thiram in 4 gallons of water and 1 gallon of latex paint. The deer hate the smell of Thiram. The mixture is my own recipe.

MODERATOR SHUGERT: Where does one obtain Clormone?

DAN STUDEBAKER: We get it from the Clormone Co., Upper Montclar, N.J.

VOICE: I purchase it from Good-Prod., Co., Livingston, N.J.

MODERATOR SHUGERT: Can NAA be used as effectively as IBA for a rooting hormone?

DAVE BAKKER: We have run a large number of tests with IBA and NAA and found for all *Taxus* cuttings that NAA (0.2%) is superior.

MODERATOR SHUGERT: Is IBA necessary for root production in certain plants?

VOICE: At Purdue University root regeneration research with black walnut has shown that IBA is better than NAA. So, IBA may be better with certain species.

BRUCE BRIGGS: On filberts, NAA will not work at all but IBA is very effective.

MODERATOR SHUGERT: That completes all the questions in the Question Box. I thank every one of you for your cooperation and kind attention.

Tuesday Evening, November 29, 1978

The twenty-eighth annual banquet was held in the Concert Hall of the Royal York Hotel, Toronto, Canada.

On behalf of the Society, awards were presented to Mr. Barry A. Eisenberg for the best graduate student award paper and to Dr. Thomas A. Fretz who was the advisor for the work presented in the paper by Mr. Eisenberg.

Two papers received awards for the best undergraduate paper. The awards were presented to Mr. John Frett and Dr.

Tuesday Morning, November 30, 1978

The Thursday morning session convened at 8:15 a.m. with Judith Shirley serving as moderator.

PROPAGATION BY CUTTINGS AT HILLIERS NURSERY

BRIAN HUMPHREY
Hillier Nurseries Ltd.
Ampfield, Hampshire, England

At present some 1,200,000 cuttings are inserted annually but expansion is being planned which will significantly increase this figure. Preparation and insertion of cuttings occurs every month of the year. March and April are the least important for woody plants but at this time propagation space is utilized for the production of herbaceous perennials. Nearly every genus listed by Hillier Nurseries has at least one species which may be propagated by stem cuttings. Where possible, propagation by cuttings has replaced grafting.

Organization and Planning. In general, this follows the same pattern as for grafting. Output is monitored weekly with occasional daily checks. Weekly meetings are held between executive and departmental management to review progress and highlight special problems such as shortage of material, etc. Progress is monitored by the use of graphs for quick appraisal.

Stock Plants. For many years the Hillier Arboretum, supplemented by local sources and stock on the nursery, provided most of the material requested.

Recently, the increasing emphasis placed on the value of selected stock plants, stock plant manipulation and the convenience of collection has meant that the provision of stock plant areas has become imperative.

It seems very likely that new facts will shortly emerge which make pre-treatment of stock mother plants by etiolation or similar techniques a matter of routine for the more difficult species.

Propagation by Mist. The first mist system was installed at Hillier Nurseries in 1959 and quickly established itself as an aid to propagation which had never previously been equalled. From the start we installed MacPenny equipment and found it to be extremely reliable and very good quality.

Mist House Design. The new generation houses were still designed with benches but instead of the traditional mist pipe

lay-out, pipes were suspended above the benches on adjustable 'T' irons. This gave an unimpeded working surface to the benches. The other major change in bench design was to construct some form of free-draining porous concrete surface beneath which was placed electrical heating cable. This concept worked well though burnt-out heating cables could not be replaced.

Later houses have been built without benches with mist lines suspended above head height. Porous, no fines concrete floors are used and, to avoid the problem of burnt out electric cable, bottom heat is provided by hot water (100°F mean) circulated through polythene water pipe.

The concrete floor is made from ½" diameter aggregate with no-fine material included. ½" diameter polythene water-pipes are spaced at 6" centres and cast 4" deep in the 6" thick floor. The no-fines concrete requires skill to lay and must be pressed rather than trowelled to ensure the open, porous structure is maintained.

Drainage is so good in this floor that it has been necessary to cover the surface with an inch deep ⅛" grit to maintain sufficient humidity in the house. The porosity of the floor is protected by covering it with an industrial fabric (I.C.I. Cambrelle) known as Terram before the 1" deep layer of grit is placed.

The high level mist lines are designed to completely cover the floor area in mist.

The advantages of this system are:

1. Unimpeded floor space
2. Flexibility in use and layout
3. Minimum loss of propagating area, up to 100% of floor area can be used.
4. Possibility of using mechanical handling (fork-lifts, pallets, etc.) inside the house.

Mist versus Polythene. Recent work at the Glasshouse Crops Research Institute in England has indicated that during the winter months cuttings under polythene are likely to be more successful than those under mist.

At Hillier's it has been standard practice to line a number of mist houses with polythene. This has been found to be a particular advantage with certain genera including many of the evergreens normally propagated during the autumn and winter months.

It may well be that the combination of mist inside a polythene house or polythene lined mist house has many of the advantages of both systems.

Preparation of Cuttings. Large cuttings are preferred since it is cheaper to grow plant material on the mother plant than on the cutting. Where material is scarce, small cuttings or leaf-bud cuttings can be successful on a surprising range of species. In some cases (e.g. *Mahonia japonica*) it is our standard method of propagation.

Wounding. Most cuttings prepared by us are wounded for it has been shown to consistently enhance results. The reason for this is not understood and various theories have been put forward including better uptake of water and rooting hormone. In some species removal of the pericycle fibre or primary phloem fibres may remove an anatomical barrier to rooting. Anatomical investigation shows that a very shallow wound is preferable to a deep one, the latter mainly exposing tissues incapable of regenerating roots.

Rooting Hormones. The value of rooting hormones or growth substances is long established. The basic range of main chemicals has not change since the 1930's and 40's but it is to be hoped that new and more potent materials may be available in the reasonably near future. IBA is generally acknowledged to be the most satisfactory material. Where extra activity is required, the chemical is normally used in the quick-dip formulation. It is well known that different species respond differently to high and low concentrations. Those in the high response group may be given "super optimum" doses which produce a basal inhibition of rooting or scorch, the roots arising above this area. High concentrations may occasionally inhibit or distort root growth (fused double roots etc.) but this usually returns to normal later.

Fungicidal applications. For some years, the use of fungicides, mainly as basal dips, has been advocated as an aid to rooting. Work, particularly at the Boskoop Experimental Station, has shown the value of Captan mainly when used on cuttings inserted into rooting media which did not receive artificial bottom heat.

More recently, systemic fungicides, notably benomyl, have shown considerable advantages when applied to cuttings. Other fungicides, particularly systemic chemicals such as furalaxyl will further enhance rooting results.

Bottom Heat. The switch from electricity to oil to provide the energy for heating the rooting medium resulted in a cost saving. Further savings were achieved by fitting electronic sensors to replace the rod type thermostats for temperature control. New houses built in the future will incorporate floor insulation using polystyrene blocks on the edges of the house and polys-

tyrene blocks or empty glass bottles laid under the no-fines concrete floor.

Some work in England has shown that continuous bottom heat may not be necessary for successful rooting of at least some species and the possibility of periodic heating offers further opportunities for cost saving.

Work at the Glasshouse Crops Research Institute indicates that, with rhododendron, the advantages of a high bottom heat temperature of 77°F may be offset by a greater incidence of disease. Although rooting is less pronounced at 59°F, more cuttings survived at this temperature and the overall percentage of rooted cuttings was higher than at 68°F or 77°F.

There can be no doubt that, properly used, stimulation of the cutting by controlled basal temperatures is a very potent aid to rooting. This is particularly evident in the comparatively unresponsive hardwood cutting where some species (e.g. *Platanus* or *Malus*) can only be guaranteed to root well if subjected to a pre-conditioning treatment of heat applied in conjunction with rooting hormones to the base of the cutting. In common with many other growers, we have at Hillier's a set of Garner Bins constructed in a cool shed for the pre-treatment of hardwood cuttings. This provides the ideal conditions of warm base and cold tops, with adequate moisture control.

Sun-Frame Cuttings. The original system was based on the old hand-sprayed frame normally placed in full sun and unshaded to build up high temperatures. The "boy" in the propagation department was responsible for keeping the cuttings sprayed over as much as was necessary to keep them turgid. With the advent of mist and polythene the old system, which had fallen into disuse, was revitalized and many nurserymen in Europe and America (notably Templeton with the Phytotektor at Winchester, Tennessee) transformed the old system by using a polythene tunnel equipped with a mist system. We took this up ourselves in the early 1960's and have used it with good success ever since.

A few years ago concern was expressed at the considerable labour content involved in moving and re-building the polythene tunnels and installing the mist lines. It was decided to attempt to build a mobile 'walk-in' polythene tunnel, 20 feet wide by 120 feet long with a maximum height of approximately 10 feet, into which was permanently installed mist propagation water lines and jets. Each tunnel was piped into a solenoid valve controlled water supply. This system has proved very successful enabling the polythene propagation tunnel to be moved from one site to another by a single tractor in a matter of 30 minutes.

Weaning and Over-wintering. The MacPenny weaning unit which is used to provide reduced misting cycles of 1 in 3, 1 in 6 or 1 in 12 has generally been found unnecessary to ensure successful weaning. Well rooted cuttings are normally taken directly from the mist and placed in humid, shady conditions, such as polythene tunnel, glasshouse with closed ventilators, or a cold frame. Under these conditions, we have rarely experienced significant loss at this stage. For over-wintering we like to provide sufficient heat to maintain 40°F but in Southern England many species will overwinter successfully in unheated glasshouses or polythene tunnels.

We do not generally pot off rooted cuttings of deciduous species until the spring after they have been rooted. This simple rule avoids the heavy losses of deciduous plants which, after rooting in mid-summer, are potted off in late summer or early autumn. These often die during the winter unless they can be induced to produce a new flush of growth after potting.

Special techniques, including provision of supplementary light and CO_2 enrichment, are being used by some growers to induce a flush of growth after potting. So far we have not needed to use these techniques. We are interested in the use of growth stimulants, such as gibberellin, to induce secondary growth.

One problem with overwintering cuttings in the rooting boxes is that the more vigorous species are liable to root through the box into the medium below. This results in considerable root damage and consequent loss of vigour when the plants are handled the following spring. At Efford Experimental Station trials are in progress with Gloquat applied to the surface of the standing down medium (normally sand). This chemical kills the root tip and consequently prevents rooting through.

VOICE: With the *Mahonia* cuttings, was that a compound leaf with a piece of stem?

BRIAN HUMPHREY: Yes, with *Mahonia* cuttings, we simply make leaf-bud cuttings with a wound on the back side of the stem. The cuttings are stuck so that the bud and stem are below the surface of the medium. Seradex 2 or 3 is used as the rooting hormone.

VOICE: Why do you object to a solid concrete floor with some water on it?

BRIAN HUMPHREY: Because I believe we need to set up a water tension in the rooting medium to suck air into it. You can only do that with a deep column of water moving through. A solid floor would inhibit this free drainage and put a thin film of capillary water on the bottom of the cutting.

VOICE: Do you have an algae problem in the porous concrete?

BRIAN HUMPHREY: No.

VOICE: How do you root apple rootstock cuttings?

BRIAN HUMPHREY: We only root apple rootstock from hardwood cuttings. We can root MM.111 and MM.106 reasonably well but M.7 is very difficult.

VOICE: Can *Acer griseum* hardwood cuttings be rooted?

BRIAN HUMPHREY: *A. griseum* is extremely difficult, if not impossible, to root from any type of cutting.

CARMINE RAGONESE: Have you run into any problems with an excessive amount of callus on rhododendrons.

BRIAN HUMPHREY: The sure sign of too much callus on any cutting is either that you have an extremely difficult plant to root or that you have used too weak an auxin.

TISSUE CULTURE OF FRUIT TREES AND OTHER FRUIT PLANTS

RICHARD H. ZIMMERMAN

Fruit Laboratory
Agricultural Research, Science and Education Administration
U.S. Department of Agriculture
Beltsville, Maryland 20705

The uses of tissue culture in plant propagation have been amply reviewed in the IPPS Proceedings of the past several years. In the Fruit Laboratory, we are interested in (a) rapid propagation of new selections from our breeding programs, (b) rapid increase of plants that have been indexed for freedom from known viruses, (c) preservation of germplasm, and, in the future, (d) production of haploids for plant breeding. The crops with which we are working are apple (*Malus sylvestris* Mill.), thornless blackberry (*Rubus* sp.), strawberry (*Fragaria* × *ananassa* Duch.) and blueberry (*Vaccinium* sp.). We also have four peach (*Prunus* sp.) understocks in culture but in the future Dr. Hammerschlag of the Cell Culture and Nitrogen Fixation Laboratory will be doing most of the work on peaches at Beltsville.

Tissue culture of fruit crops is underway at numerous locations around the world. In the United States, most such work is in state or federal research stations although several nurseries are now beginning to join in. In Europe, and possibly elsewhere, both commercial laboratories and nurseries are using

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tissue culture for production of strawberries and of apple, plum (*Prunus domestica* L.) and cherry [*Prunus avium* (L.) L.], rootstocks.

In this paper, I will discuss tissue-culture propagation of apple, thornless blackberry, strawberry, and blueberry, as done both in our laboratory and elsewhere.

Apple. Research on growing apples through tissue culture is underway at numerous laboratories in more than 10 countries. The chief goal is development of a rapid propagation technique, particularly for certain of the clonal rootstocks, but development of virus-indexed plants is also a goal in many of these laboratories. Our goal is a rapid propagation technique for apple cultivars because we want to investigate the potential of own-rooted trees in high-density plantings.

Cultures are established using either actively growing shoot tips 5 to 20 mm long or apical meristems 0.2 to 0.5 mm high dissected from buds. Establishing cultures from meristems is more difficult but the technique can rid clones of viruses and is suitable for mass multiplication.

Apples have generally been cultured on variants of the Murashige and Skoog (MS) medium (10); the addition of phloridzin or phloroglucinol, as suggested by Jones (7), is the best-known modification. A somewhat different chloride-free salt mixture has been developed and used in P. Boxus's laboratory at Gembloux, Belgium, and W.C. Anderson has used his rhododendron medium (1) successfully with apples (personal communication). We have used only the MS medium, originally with phloroglucinol. Since we found no particular benefit to using phloroglucinol, we have eliminated it from our medium. The medium we use for culture establishment and shoot proliferation has been detailed elsewhere (4). Often the inclusion of 1 mg/liter indolebutyric acid (IBA) produces too much callus on apple shoot cultures so we now reduce IBA content to 0.5 or 0.1 mg/liter. As a general rule, we establish the shoot tips in a liquid medium and after 2 to 3 days transfer them to a solid medium for shoot proliferation.

For rooting, we have tried both an agar medium and a liquid medium saturating a sterile 1:1 mixture of perlite and vermiculite. Rooting has been better with the latter support medium. The nutrient medium mentioned above is modified by halving the salt concentration and eliminating the benzyladenine (BA) and gibberellic acid (GA_3). We have tested IBA at concentrations ranging from 0.01 to 5 mg/liter; the optimum concentration depends on the cultivar and the support medium. Results to date indicate that IBA concentrations higher than 2 to 3 mg/liter inhibit rooting. In contrast, Huth (5) reported that

rooting of 'Jonathan' shoots was best with 10 mg/liter of either IBA or napthaleneacetic acid (NAA).

Cultures on agar media are grown at 25°C. Light during the 16-hr photoperiod is provided by deluxe warm white fluorescent tubes (40 watt) giving 2.2-4.3 klux (200-400 ft-c) at the culture jar. Light for liquid cultures is provided by high-output cool-white fluorescent tubes (Power Groove[1]) giving about the same intensity at the culture flasks.

Rooted plantlets are removed from the culture tubes, the agar (when present) is washed from the roots, and the plantlets are planted under mist. We have used 1:1 peat-perlite as a planting medium but other media could serve as well. After 7 to 10 days, the plants are removed from mist and transferred to a greenhouse bench. If the plantlets are well rooted in the culture tube, they are easily acclimated under mist. Losses after that stage have been very infrequent.

Using this technique, we have produced plants of 'Spartan', 'Ozark Gold' and 'MM 106'. Shoot proliferation of 'Golden Delicious', 'Summer Rambo', 'York Imperial', 'Stayman', and 'Northern Spy' is progressing well, and we will start rooting experiments with these cultivars soon. Plants of some of these and other cultivars and rootstocks, e.g., 'Golden Delicious', 'McIntosh', 'Cox's Orange Pippin', 'M 26', 'M 27', 'MM 106', and 'MM 111', have been produced in other laboratories. Large-scale production of 'M 26' and 'M 27' is beginning in some commercial laboratories and nurseries.

The main problem now is to refine the conditions necessary for obtaining consistently high rooting percentages of apple shoots. Improving the shoot proliferation rate is necessary for some cultivars, but this seems to be less of a problem than rooting. Acclimating plants from tissue culture to greenhouse conditions may require additional study but it has not been a major problem in our research.

Thornless blackberry. Rapid propagation of genetically thornless cultivars of blackberry has been the goal of our program with this crop. Similar work is underway at the University of Illinois, whereas the USDA program at Oregon State University has the goals of obtaining plants free of viruses and developing completely thornless plants from cultivars that are chimeral for this condition. Such cultivars have thornless shoots but produce thorny adventive suckers from the roots.

The details of our technique have been published (4). Ac-

[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

tively growing shoot tips 10 to 20 mm long are established in a modified MS liquid medium. After 2 or 3 weeks, the explants are transferred to the same medium with added agar for shoot proliferation. Cultures are grown under the light and temperature conditions described above for apple. Cuttings have been rooted in an agar medium but we prefer to take the small (7 to 15 mm long) cuttings and root them directly under mist in the greenhouse. This is quicker, requires less labor and is more effective. We have used the technique successfully on 'Smoothstem', 'Thornfree', 'Black Satin', 'Dirksen Thornless' and several advanced selections that may be introduced soon.

We have also successfully stored rooted plants of 'Smoothstem' at 4°C. These plants were produced by rooting cuttings directly in peat pellets. The well-rooted plants in pellets were sealed in plastic bags and placed in a refrigerator. They receive low intensity light for 16 hours per day to prevent etiolation. The plants have been stored for 14 months now with losses of less than 5 percent; the experiment is continuing.

Strawberry. Production of strawberry plants by tissue culture is rapidly becoming an established procedure. Freeing plants of viruses was the first goal of strawberry tissue-culture research. Once this was accomplished, development of rapid propagation techniques followed (2,3,8). In addition, long-term storage of tissue-cultured strawberries is feasible (9), and some attempts have been made to develop haploid plants for breeding purposes (12). In the Fruit Laboratory, the research objectives are those just outlined. Since 1962, Dr. John McGrew of the Fruit Laboratory has demonstrated freedom from known viruses by indexing of more than 100 cultivars and selections following tissue culture; he has also been testing the long-term storage of strawberry cultures at low temperature for several years. We began our work on rapid propagation of strawberry earlier this year to determine the usefulness of the technique for the strawberry breeding program in the Fruit Laboratory. Research on this crop has been carried out at a number of laboratories around the world. The techniques have been developed enough that large-scale production of strawberries is underway in commercial laboratories and nurseries in several European countries.

Cultures are established using apical meristems 0.1 to 1.5 mm high dissected from actively growing runner tips. The plants from which the runners are obtained are usually grown at 38°C for some weeks before the meristems are excised to increase the probability that the meristems will be free of virus.

A number of different media have been used for growing strawberries in culture (3) but most workers now use either a

modified Knop's solution (2) or the MS salts (3,6). Meristems are established on an agar medium containing no or a very low level of BA. For shoot proliferation, the cytokinin level is increased, the concentration varying according to the laboratory. Although Boxus (2) uses 1 mg/liter BA, other researchers have reported that lower levels are better (6). It appears that the cytokinin level interacts with the mixture and concentration of salts, the type and amount of sugar used, or both. We have been using the technique described by Boxus (2,3) and it works quite well with the cultivars we have tried. We achieved proliferation rates of 3:1 to 4:1 within 3 weeks in our first attempts, and somewhat better proliferation rates have been obtained more recently. The proliferation rates vary among cultivars, so the composition of the medium may need modification for maximum proliferation of each cultivar. We observed that proliferation rates are better if we transfer clumps containing several crowns rather than transferring individual crowns. Separating the clumps into individual crowns may damage the crowns slightly, thus reducing the proliferation rate or delaying the growth of axillary buds.

Rooting is achieved by transferring clumps containing several to many crowns to a medium containing no BA or GA_3. After 4 to 6 weeks, rooting is sufficient to permit transfer of the plantlets to the greenhouse. This is done by washing the agar from the roots, separating the clumps by hand into individual rooted crowns, and planting these in pots. The young plants are placed under mist or a plastic tent for a few days until they have become acclimated to the greenhouse environment. Boxus (personal communication) takes unrooted and small crowns and scatters them on sphagnum peat under mist. These crowns root readily providing additional plants to those rooted in the culture jars. We have done this also, with good success. We have also taken unrooted crowns directly from the proliferation medium and rooted these in peat pots under mist. Rooting percentages of 60 to 80% in 4 weeks were obtained in our first trial but these were reduced to 50 to 70% when lightly rooted crowns were excluded. I am confident that a better mist control and a longer rooting period would improve these results appreciably.

Since March of this year, we have proliferated and rooted several thousand plants of four cultivars and now have proliferated cultures of an additional 10 cultivars ready for rooting. Boxus has used the technique for more than 150 cultivars and selections and has found none for which the method failed to work (personal communication).

Long-term storage of strawberry plantlets *in vitro* has been

accomplished by Mullin and Schlegel (9) and McGrew (personal communication). Boxus (3, personal communication) stores proliferating or rooting cultures in jars for 4 to 6 months at 4°C when necessary; rooted plants in plastic containers can be stored for 3 to 4 months. This storage capability is useful for adjusting production schedules to meet needs for shipping or planting.

Blueberry. Propagation of blueberries by tissue culture is being studied at several laboratories in the United States and Canada in addition to our own. Our goal is to develop a rapid propagation technique to speed the testing and introduction of new cultivars.

Cultures have been established from rapidly growing shoot tips 5 to 20 mm long or from parts of germinating seedlings (11). An agar medium is used for establishing the cultures.

The culture media used have been those developed by Anderson (1) for rhododendron and similar media developed by us which contain neither the sodium nor the chloride ions found in Anderson's. We have tested the combination of indoleacetic acid (IAA) and 6-ς-dimethylallylaminopurine (2iP) used by Anderson as well as IBA plus BA. The IAA plus 2iP have been superior in tests to date.

Both axillary shoots arising from buds and adventitious shoots arising directly from leaves have been produced on cultures of lowbush blueberry (11) and of a number of highbush, rabbiteye and other hybrid blueberries (unpublished results from our laboratory). We are now working on techniques to maximize shoot proliferation rates and are just beginning rooting studies. One problem has been the very small size of the proliferating shoots, which makes separating and transferring them tedious. We anticipate good progress with this crop in the coming year.

This has been a brief overview of work in progress and the present status of research on tissue culture of four fruit crops. Work has been done or is underway on several other fruit crops. I think that tissue culture has a definite role in production of fruit plants in the future and the foundation for this role is now being laid. Tissue culture is not the answer to all production problems but it is an extremely useful tool when applied in the proper situations.

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JOERG LEISS: Do you have an open house at Beltsville?

RICHARD ZIMMERMAN: Yes, in January but I am not sure when exactly it is. You are welcome to come by and we will show you what we are doing.

LARRY CARVILLE: How susceptible to pathogens are the transplants when you take them out of the sterile environment into an open environment?

RICHARD ZIMMERMAN: We have had no problem with pathogens.

LARRY CARVILLE: Do you use any sterilants?

RICHARD ZIMMERMAN: No. The only problem is mildew and we have that anyway.

RICHARD ZIMMERMAN: I missed the question box last night and understand that there was a question on what woody plants were being tissue cultured. There is a lot of woody plant culture being done in Europe. At a research station in France I saw work on ornamental woody shrubs with something like 26 different genera.

BILL FLEMER: What type of roots do you get on your tissue cultured apples? Are they satisfactory?

RICHARD ZIMMERMAN: So far they have been satisfactory. The first had an enormous amount of callus and we thought that this was what we did not want. As it turned out those were the only cuttings that rooted. Those were the tallest apple plants that I showed in the talk.

VOICE: Could you review how long it took you to get the 1800 strawberry plants mentioned in your talk?

RICHARD ZIMMERMAN: It takes 8 to 9 weeks from the initial meristem isolation to have material ready to go into the multiplication stage. At that point you have a culture that can be divided into 2 pieces; you would then subculture at 3 week intervals. Rooting requires 4 weeks and this is followed with a growing on period of 4 weeks. Starting in April with well established cultures, 1800 strawberry plants were produced by September.

Thursday Afternoon, November 30, 1978

The Thursday afternoon session convened at 2:00 p.m. with Burke McNeil serving as moderator.

PROPAGATION OF UMBRELLA PINE — CLONAL DIFFERENCES IN ROOT INITIATION[1]

SIDNEY WAXMAN

University of Connecticut
Storrs, Connecticut 06268

The Japanese umbrella pine, *Sciadopitys verticillata*, has long been considered extremely difficult to propagate by cuttings (4). Lowry (2), reported rooting less than 14 cuttings out of a total of 1100 taken. DeFrance (1) was more successful and obtained 50% rooting in 1938. Waxman (4) reported a relationship between the stage of plant development and the ease of root initiation. Cuttings taken after the chilling requirements were partially or completely satisfied had the highest rooting percentage. The recommended period for taking cuttings was from January through March.

Subsequent attempts to root Sciadopitys cuttings have given highly variable results even though the cuttings were taken during the recommended period. A considerable number

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of tests were carried out using a wide range of rooting hormones, concentrations and methods of applying them. The treatments found to be most effective were those in which the bases of the cuttings were submerged in dilute IBA aqueous solutions for periods ranging from 24 to 72 hours (Table 1). Treatments in which the base of the cuttings was given a brief concentrated dip (2000 ppm IBA) or dusted with 8000 ppm IBA in talc were not as effective. These results (Table 1), and others that followed, gave evidence that it was the method of application rather than the concentration of rooting hormones that was crucial to root initiation.

Table 1. Effect of IBA concentration and methods of application on the rooting of *Sciadopitys verticillata* cuttings.[1]

Treatment	Percent Rooted	Average No. Roots per Rooted Cutting
Control	20	1.0
8000 ppm IBA in talc	20	4.0
200 ppm IBA dilute submergence (24 hours)	80	17.1
2000 ppm IBA dip	10	4.0

[1] 10 cuttings/treatment, wounded and placed under mist.

In almost all instances, those cuttings in which the bases had been submerged in a dilute solution of IBA for 24 to 72 hours invariably had higher rooting percentages, and the greatest numbers of roots, compared to cuttings treated with concentrated dips or with talc preparations. Also, control cuttings, whose bases were submerged in water (without hormones) often had higher percentages than the various hormone-treated cuttings that were not submerged.

Immediately upon the severing of an umbrella pine cutting there is a discharge of white resin oozing out of the 13 resin ducts located in the phloem. A relatively large amount of resin emerges in hair-like strands when the cuttings are immersed in water. Under these conditions the resin falls away from the cut surface and drops to the bottom of the container. The exudation of resin can go on for several days, emerging rapidly during the first three minutes and slowly thereafter. If the freshly-made cuttings are not submerged, the emerging, sticky resin will gradually accumulate and adhere to the cut surface of the cutting.

It is conceivable that this substance may inhibit the rooting possibly by physically blocking movement of water, oxygen, and carbon dioxide.

The purpose of the present research, therefore, was to determine: if there are differences in rooting among clones; if

resin is associated with rooting; if there are seasonal differences in rooting and in resin production; and if there is a correlation between them.

MATERIALS AND METHODS

Root Initiation. Ten cuttings were taken at monthly intervals from each of ten 15-year-old umbrella pines. Five cuttings from each clone were wounded with the point of a knife, treated with 3000 ppm IBA (Hormodin No. 2) and Captan (10%) and placed directly into a peat moss and perlite (1:1) medium. The remaining five cuttings were wounded as above but were then suspended for 48 hours in a pan of water (under mist) in which only the lower two inches of the stems were submerged. Upon removal from the water, the cuttings were allowed to dry and were then treated with IBA and Captan as above. All cuttings were maintained under a mist system that was operated by a light-intensity-activated controller. A minimum temperature of 22°C (71.6°F) was maintained in the rooting medium throughout the study. Data on root initiation was taken approximately six months after insertion.

Resin Weight Determination. At monthly intervals five cuttings of uniform length (3 inches) were taken from each clone and immediately inserted into vials of water and then placed under a mist system. After 18 hours, the resin exudate that had fallen from the cuttings to the bottom of the vials was placed on previously weighed filter papers. The filter papers were then dried and the differences in weights between filter paper and filter paper plus resin were recorded.

RESULTS AND DISCUSSION

Clonal Variation in Rooting. There was a wide range in rooting response among the ten clones (Table 2). Differences in rooting percentages ranged from 0 to 100% among the control group. Clones 6 and 9 were difficult to root, not only in this test but in all the others taken throughout the year.

Differences in numbers of roots per cutting ranged from 0.2 for clone No. 9 to 12.0 for clone No. 8. Clones 1 and 8 consistently produced the greatest numbers of roots in this experiment as well as in all the others. Mean root lengths ranged from 0.3 to 6.4 cm, with clones 1, 2, and 8 among the highest.

Resin Removal and Rooting. The removal of resin, by submerging the bases of the cuttings in water, significantly improved all three aspects of rooting. Rooting percentages, root numbers and root lengths were all increased as a consequence of the removal of the resin.

Seasonal Aspects of Rooting in Relation to Resin Exudation.

Table 2. Clonal variation and effect of resin removal on rooting cuttings of *Sciadopitys verticillata*[1].

	Percent Rooted									
Clone:	1	2	3	4	5	6	7	8	9	10
48 hr. Submergence -	100	100	80	100	100	100	100	100	40	80
Control -	60	100	40	40	40	0	60	80	20	60

	Average Number Roots/Cutting									
Clone:	1	2	3	4	5	6	7	8	9	10
48 hr. Submergence -	24.6	16.0	10.0	20.2	21.0	14.6	23.0	20.6	1.8	9.4
Control -	7.8	7.2	2.4	3.2	0.8	0.0	6.8	12.0	0.2	3.0

	Average Root Length (cm)									
Clone:	1	2	3	4	5	6	7	8	9	10
48 hr. Submergence -	7.9	7.9	4.4	7.0	9.4	8.2	10.9	8.4	2.0	5.2
Control -	4.2	5.9	2.2	2.3	0.3	0.0	4.7	6.4	1.4	3.0

[1] 2/4/76 - 8/11/76 5 cuttings/treatment.

The highest levels in rooting occurred in February and March and again in July and August (Table 3). Associated with high rooting levels were low resin levels. Also, on those dates during which rooting was poorest, resin levels were highest. There is a significant negative correlation between resin exudate and rooting percentages at the 5% level.

Table 3. Seasonal aspects of rooting cuttings of *Sciadopitys verticilliata* in relation to resin exudation.

Date	Percent Rooted[1]	Resin[2]	
		Date	Weight/Cutting (gr)
2/11/76	50		
2/24/76	90	2/24/78	.0981
3/16/76	86	—	—
3/31/76	80	3/31/78	.1363
4/13/76	42	5/ 5/78	.4064
6/ 2/76	55	6/13/78	.3316
7/12/76	88	7/21/78	.1054
8/28/76	80	8/25/78	.1266
9/15/76	64	—	—
10/13/76	50	10/19/78	.1054
11/ 9/76	68	11/19/78	.2394
12/14/76	34		
1/21/77	68		

[1] Average of 10 clones, 50 cuttings/date
Treatment: Hormodin No. 2 and Captan (not submerged) mist.

[2] Average weight in resin exudate/cutting from the above clones.

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4. Waxman, Sidney, 1960. Propagation of *Sciadopitys verticillata*. *Proc. Inter. Plant Prop. Soc.* 10:178-181.

PETER ORUM: Are the cuttings completely submerged or are only the cutting bases?

SYDNEY WAXMAN: Only 2 inches of the stem are submerged.

BILL FLEMER: Do the rooted cuttings reproduce the original plant form?

SYDNEY WAXMAN: They reproduce the parent form. There is no need to stake them.

CARMINE RAGONESE: Is there any special position on the plant that you take cuttings from?

SYDNEY WAXMAN: We take them from all areas with no problems.

VOICE: Do you have any problem breaking dormancy in the spring?

SYDNEY WAXMAN: None. We pot the cuttings up after they are rooted and put them in a cold frame after a short stay in the greenhouse.

JOERG LEISS: Does the cutting location have any influence on resin production?

SYDNEY WAXMAN: No, it is the cultivar.

RICHARD FENICCHIA: Are the cuttings from current season's growth?

SYDNEY WAXMAN: Yes. Two-year cutting wood will also root.

VOICE: What type of auxin treatment do you give the cuttings?

SYDNEY WAXMAN: We treat the cuttings with Hormodin 2.

PROPAGATION OF RHODODENDRONS FOR SOUTHERN ONTARIO

A. W. SMITH

Horticultural Research Institute of Ontario
Vineland Station, Ontario, Canada

The program for the development of hardy rhododendrons for southern Ontario had its beginning in 1958 at the Horticultural Research Institute of Ontario, Vineland Station, Ontario.

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Seed was obtained from various sources, as well as plants of various species and cultivars. As hybridizing took place it naturally followed that propagation by seed and cuttings of selected plant material was of prime importance.

Seed Propagation. Propagation by seed using various peat and peat-perlite mixtures has met with a varied degree of success. The use of long fibered sphagnum moss has given the best results during the past three seasons.

Seed is gathered the last week in August or early September depending on the season. The seed pods are dried in an oven at 100°F (37.8°C) for 3 days and prepared for sowing about the 5th to the 10th of September. Long fibered sphagnum moss is thoroughly soaked in pails of water, wrung out as you would a sponge, and firmly packed in plastic trays or seed flats. Holes for drainage are essential. Dividers can be used depending upon the number of crosses and amount of seed to be sown. The seed is sown directly on the moss and lightly watered. The flats are placed on a propagating bench which maintains a temperature of 22-24°C (72-75°F) by use of fin type steam pipes located under the bench. The seeds are misted by a time clock control 24 hr a day. Depending on weather conditions, 5 sec every 30 min has proven satisfactory.

Germination is evident after 16 days. When seedlings are large enough to handle, they are transplanted into flats containing a medium of 6 parts peat, 4 parts perlite and 2 parts shredded sphagnum moss. Seedlings are fertilized with Peter's rhododendron special 15-45-5 diluted to half strength (1 tbsp per gal) every 4 weeks. The seedling flats are transferred to a shadehouse when all danger of frost is over, approximately the first week in June.

Propagation by Cuttings. Rhododendrons can be divided into three groups: deciduous azaleas, evergreen azaleas and lepidote rhododendrons, and elipidote rhododendrons. The propagating season begins with deciduous azaleas, primarily Exbury and Knaphill hybrids and a few azalea species. In the Vineland area cutting propagation of the deciduous types usually takes place the last week of May until the second week of June, depending on weather conditions.

As deciduous azalea cuttings must be soft and pliant, most cuttings can be obtained while plants are in bloom and producing new growth. It is advisable to select cuttings on a day to day basis as rooting ability diminishes as cutting material becomes firmer. As the cuttings are gathered they are immediately immersed in water in labeled beakers or jars and carried back to the work area. The cuttings are then given a quick dip in a Benlate solution and trimmed below a node leaving a cutting 6 to

10 cm long. They are then treated with Seradix #1 rooting hormone powder (0.1% IBA). The cuttings are then stuck in "Kadon flats" 2-½ inches deep containing a medium made up of 60% peat and 40% perlite. The Kadon flats afford perfect drainage and eliminate any risk of water build-up.

Approximately 40 cuttings are stuck in each flat. The cuttings, after watering in, are placed in the propagating house. An automatic mist timer is set for 5 seconds every 8 minutes. The setting can be decreased on dull days and increased during extra hot weather conditions. Shade must be given at all times as any direct sunlight will prove fatal. No bottom heat is necessary at this time as greenhouse temperatures are quite satisfactory (70°F-80°F, 22-25°C).

Supplemental lighting from the middle of August is essential to give the cuttings 14 to 16 hours of daylight. Most cuttings should be rooted in 14 weeks, some will take longer. The cuttings, after rooting, are transplanted to Kadon flats 4" deep containing a medium composed of one 6 cu. ft. bale of peat, one bag perlite, 1 cu. ft. long-fibered sphagnum moss and 2 lbs of regular Magamp fertilizer. The flats are transferred to a cool greenhouse for growing on. Supplemental lighting is given until the end of the year.

In early January the flats are placed in a plastic greenhouse with a minimum temperature of 35°F (3°C). The plants continue their growth cycle in the spring, and are then transplanted to the shadehouse area after all danger of frost is over.

Cuttings of evergreen azaleas and lepidote type rhododendrons are usually taken between August 15 and October 15. Cuttings are approximately 5 to 7 cm in length. Both types are treated with Seradix or Stimroot rooting powder #2 and stuck in a propagating bench containing a medium made up of 60% peat and 40% perlite. Cuttings are misted 5 seconds every 20 minutes by a time clock control. Most cuttings will be ready for transplanting into flats in 8 weeks time. The flats are then transferred to a cool house until spring.

Propagation of elepidote rhododendron hybrids has been undertaken from August to January with a variety of results. The optimum time appears to be between October 15 and November 15. Cuttings are gathered, rinsed in a solution of Benlate (1 tbsp./gal) and then shortened to 8 cm (shorter cuttings will root just as easily). Large leaves are trimmed back about ⅓ to avoid overlap in the propagating bench and terminal buds are removed.

Cuttings are wounded approximately 2 cm on both sides. Cuttings appear to develop a more balanced root system with this procedure. Cuttings are then dipped in Seradix #3 or simi-

lar hormone and stuck in a propagating bench containing a medium of peat and perlite (60/40 mix). Bottom heat is maintained at 72 to 75°F (22 to 24°C) supplied by fin type steam pipes directly below the bench. A time clock controls the misting which is set at 8 seconds every 20 minutes. This can be adjusted as weather conditions change.

Most cuttings will have rooted in 10 to 12 weeks. If they are not rooted in 17 weeks time, cuttings are discarded. Unrooted hybrids or cultivars are recorded for future trials using different hormone strengths and times of year cuttings are taken.

Rooted cuttings are transplanted into Kadon flats (4" deep) containing a medium of 6 parts peat, 4 parts perlite and 2 parts shredded sphagnum moss. The addition of sphagnum moss to the medium has produced a better root system and diminishes transplanting losses. Plants are then grown on in a cool greenhouse and transplanted into a shadehouse area about the first of June.

Over a 3 year period using the same 60 cultivars, rooting percentages averaged 72% in a 12 week period, 78% in 15 weeks, and 81% in 17 weeks. Using 30 Vineland hybrids in similar trials, rooting averaged 56% in a 12 week period, 70% in 15 weeks and 77% in 17 weeks.

PROPAGATION OF HOLLY IN SOUTHERN ONTARIO

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Good, broadleaved evergreens for northern gardens are not plentiful and selection of suitable species which will survive even the reasonably mild winters of Southern Ontario is difficult. The area of interest in establishing additional broadleaved evergreens is that bordering the Great Lakes from, roughly, Toronto west to Windsor and Sarnia in the area of Detroit. This is within the area defined as Zone 6B or 7A on the Canadian Hardiness Zone Map.

The small leaved hollies, *Ilex crenata* and its cultivars, have been grown with moderate success for many years, but have never become popular. No studies have been undertaken by Canadian institutions to determine the adaptability of any or all of the species of *Ilex* which might succeed under the climatic extremes suggested.

In 1958 the Horticultural Research Institute of Ontario

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Most cuttings will have rooted in 10 to 12 weeks. If they are not rooted in 17 weeks time, cuttings are discarded. Unrooted hybrids or cultivars are recorded for future trials using different hormone strengths and times of year cuttings are taken.

Rooted cuttings are transplanted into Kadon flats (4" deep) containing a medium of 6 parts peat, 4 parts perlite and 2 parts shredded sphagnum moss. The addition of sphagnum moss to the medium has produced a better root system and diminishes transplanting losses. Plants are then grown on in a cool greenhouse and transplanted into a shadehouse area about the first of June.

Over a 3 year period using the same 60 cultivars, rooting percentages averaged 72% in a 12 week period, 78% in 15 weeks, and 81% in 17 weeks. Using 30 Vineland hybrids in similar trials, rooting averaged 56% in a 12 week period, 70% in 15 weeks and 77% in 17 weeks.

PROPAGATION OF HOLLY IN SOUTHERN ONTARIO

R. A. FLEMING

Horticultural Research Institute of Ontario
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Good, broadleaved evergreens for northern gardens are not plentiful and selection of suitable species which will survive even the reasonably mild winters of Southern Ontario is difficult. The area of interest in establishing additional broadleaved evergreens is that bordering the Great Lakes from, roughly, Toronto west to Windsor and Sarnia in the area of Detroit. This is within the area defined as Zone 6B or 7A on the Canadian Hardiness Zone Map.

The small leaved hollies, *Ilex crenata* and its cultivars, have been grown with moderate success for many years, but have never become popular. No studies have been undertaken by Canadian institutions to determine the adaptability of any or all of the species of *Ilex* which might succeed under the climatic extremes suggested.

In 1958 the Horticultural Research Institute of Ontario

undertook a breeding, selection and cultivar trials project with the genus *Ilex*. This project was to include all known species, hybrids and cultivars which might show adaptibility to the existing climatic conditions. The two most popular species were, of course, *Ilex opaca* and *I. aquifolium* and, initially, a number of cultivars were obtained from several American nurseries from as far south as Indiana and west to Oregon. Seed was also obtained from Holly-by-Golly nursery on Long Island, which has since introduced the blue hollies to commerce and which are, at present, under trial at the Horticultural Research Institute, Vineland Station, Ontario.

A number of hybrids also have been tested at the Horticultural Research Institute. The most successful has been the male form of *Ilex aquipernyi*. Of the two female forms 'Brilliant' and 'Elegance', neither has survived the winters without serious dieback. Two other *Ilex* hybrids, 'John T. Morris', and 'Lydia Morris' have survived the two severe winters of 1976-77 and 1977-78 with minimal injury. A third hybrid, 'Nellie Stevens' does well except under extreme conditions of exposure. Few cultivars of *Ilex aquifolium* survived more than 5 or 6 years. Of those that did survive, Brownell's 'Winter Queen' and 'Green Maid' are still growing after 18 years. Of the *Ilex opaca* cultivars, 'Arden', 'Cardinal', 'Farage', 'Margaret' and 'Hedge Holly' are doing quite well though they suffered quite extensive leaf and twig injury in the winter of 1976-77. Of the deciduous forms of holly, *I. verticillata* and *I. decidua* are performing well. Other species and cultivars which have grown successfully over the past 15 to 20 years are *I. pernyi*, *I. cornuta*, 'Dr. Kassab', *I. aquifolium*, 'Jan C. VanTol' (syn. 'J.C. Van Tol'), and *I. ciliospinosa*.

Seed Propagation. The initial seed lot received from Mrs. Kathleen Meserve was sown in the fall of 1958. The first seedling emerged in 1960 and germination continued through 1961 and 1962, after which time, the seed flats were dumped. Succeeding lots of seed, collected from the cultivar trials, were treated in several ways. After the pulp was removed in a Waring blender, floating-seeds were removed and the heavy seeds dried for 24 to 48 hours.

After cleaning, the seed was treated as follows:

1. Directly seeded in flats.
2. Held in cold storage, and sown the following fall.
3. Kept warm 21°C (70°F) for 10 months, then cold 2 to 4°C (35 to 40°F) for 10 months and then sown in flats.

Direct sowing after collection meant flats that had to be

cared for at least 2 years before seed germination. The alternating hot, cold treatment did not appear to give any better or more rapid germination. The present method of placing the seed in cold storage for 12 months and then sowing in flats in October or November, usually results in up to 25% germination the following spring. Seed flats are held for 3 years with maximum germination the second year after seeding. With this method, there is a succession of seedlings from 3 year's collection germinating each year. The seed flats are wintered in unheated cold frames, brought into a heated greenhouse in late March or early April and germination usually begins in 4 to 5 weeks. When seedlings have attained 2 to 4 true leaves they are pricked off into 1-pint plastic pots using a soil-sand-peat moss potting soil, and grown on in the greenhouse until late September when they are placed in an overwintering plastic structure with a minimum temperature of 2°C (35°F). As the days lengthen in late February and March and daytime temperatures rise in the plastic structure, new growth soon develops. By early May the seedlings are transplanted to one quart or one gallon plastic containers using an artificial soil mix. The holly mix is used for all *Ilex* once they have reached a size suitable for a 1-quart or larger container.

Propagation by Cuttings. Cuttings are generally taken from mid-October to mid-November, with preference given to the earlier date. At this time the wood has matured, and the plants usually have been subjected to at least one hard frost. Cuttings will range in size from 4 to 8 inches (10 to 20 centimeters) and may be tip growth, branched, or include a portion of old wood. After removing the lower leaves, a fresh cut is made below a leaf scar and the base of the cutting is dipped in water and then in #2 Seradix or Stimroot rooting powder. Soft growth at the tip of a cutting is cut off because soft tissue usually wilts and decays during propagation.

The cuttings are stuck in a bench 6 inches deep constructed with an expanded metal bottom to allow better heat distribution by fin type steam pipes, located under the bench. A medium temperature of 22 to 24°C (72 to 75°F) is maintained at all times. An attempt is made to keep the air temperature at about 18°C (65°F).

The cuttings are misted by a time clock control 24 hours a day. The setting of the clock is determined by weather conditions, though generally about 5 seconds misting every 15 to 20 minutes has proved satisfactory. The medium in the bench must be well drained. Our present medium consists of 55 to 60% perlite/turface mixture and 40 to 45% fibrous peat. Usually this particular medium is good for two rooting seasons before the

peat breaks down and drainage and aeration are impaired. The cuttings are usually wounded on one side prior to dipping in the rooting hormone though this is not a routine procedure. Rooting appears most commonly at the base of the cutting, not necessarily along the wound.

Rooting usually takes 6 to 10 weeks. Cuttings are checked in early December and again early in January. Most species and cultivars will be well rooted at this time. Those which have failed to root but appear sound, are restuck; all others are discarded. The cuttings are immediately potted in pint or quart plastic containers, depending on the size of the cutting. The medium used is one prepared for container nursery stock and is used for all evergreen rooted cuttings. After potting, plants are grown on a greenhouse bench at 18 to 21°C (65 to 70°F) for approximately 3 weeks, or until new root growth is evident on the outside of the soil ball. At this time, the plants are placed in a cool plastic greenhouse held at a minimum temperature of 2 to 3°C (35°F). By mid-March daytime temperatures in the plastic greenhouse will reach 7°C (45°F) or more, and new top growth of the cuttings will begin.

Root growth is usually sufficient by early May to repot in gallon containers. The gallon containers are grouped together either in cold frame space or some other area convenient to a water supply. In addition to the fertilizer included in the artificial mix, regular bi-weekly feeding with a soluble 20-20-20 fertilizer solution is given at the rate of 200 ppm. By the end of the growing season many cuttings will be 18-24 inches in height and often berried.

Overwintering. Because of the apparent susceptibility to winter injury in the area of southwestern Ontario, young plants are overwintered under heated plastic for the following winter. In late fall or early spring, they may be transplanted to 2 gal. containers in which they will be grown until final distribution.

Success in overwintering in ordinary unheated plastic overwintering structures has proved quite variable. Good results were obtained when the containers were sunk in a narrow trench dug the length of the structure and the containers mulched heavily with wood chips. A similar experiment, used outside without plastic protection, also gave good results, but mouse injury in late winter almost completely eliminated the test material.

In the Niagara Peninsula, the Asiatic and English holly cultivars appear to adapt readily to any reasonably good, adequately drained soil. The *I. opaca* cultivars are difficult to establish. A site protected from prevailing winds, and a heavy mulch

around the base of the plant for the first 4 or 5 growing seasons is strongly recommended.

The artificial mix used in the container production of holly and other evergreens is as follows:

12 cubic feet sphagnum peat (two 6-cu. ft. bails)

12 cubic feet red wood waste (approx. two 6-cu. ft. bails)

8 cubic feet Turface (or Perlite) (four 2-cu. ft. bags)

4 cubic feet greenhouse potting soil: 1 sand, 1 soil, 1 peat

To this is added approximately 6 cubic feet of well rotted manure, 15 lbs of regular Magamp and 8 lbs of agricultural limestone. The ingredients are thoroughly moistened while being mixed by hand and through a Royer shredder. There appears to be no necessity to allow this mix to age or cure. Often rooted cuttings or transplants are potted in the material on the day of mixing without apparent ill effect.

DEVELOPMENT OF A PRODUCTION CONCEPT FOR HANDLING PRE-GERMINATED SEED

D.A. SKEATES AND V.H.H. WILLIAMSON

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Abstract. A high degree of utilization is essential when genetically improved seed is used for nursery stock production. This can be achieved in systems which provide improved environmental conditions for germination and early growth. Steps in the development of a pregermination technique are described, utilizing sphagnum moss cigarette plugs for germination and the handling of black spruce germinants. After initial growth in heated greenhouses, seedlings were transplanted into standard nursery beds. Two-year-old transplants were grown, comparable to conventional three to four-year-old bare root nursery stock. Concepts are presented for automating the technique as a possible basis for development of a viable modified stock production system.

A major concern in stock production has been seed efficiency, defined as the proportion of stock shipped from the nursery relative to the number of viable seed sown. For most major reforestation species, i.e. white pine (*Pinus strobus*, L.), red pine (*Pinus resinosa*, Ait.) and white spruce (*Picea glauca* (Moench) Voss), seed efficiency averages about 25%. However, for black spruce (*Picea mariana* (Mill) B.S.P.) this is only 15%. Nature has little concern for seed loss. For example, a mature white spruce in a good seed year should produce 100,000 viable seed, probably repeated 15 to 20 times during a rotation. Yet

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this tree is replaced by only one or two trees in the natural successional process. Man has embarked on tree improvement programs to increase the potential for growth. Limited quantities of costly high quality seed are produced. The valuable genetically improved seed must be used wisely to regenerate as much area as possible with faster growing trees to meet forecast increases in industrial need.

To achieve a seed efficiency close to the germinative potential, suitable environmental conditions must be provided. Under the optimum conditions defined by Fraser (2) the germinative capacity of most provincial black spruce seed is in excess of 95%, achieved in 8 to 10 days. Under conventional seed bed conditions, especially in northern nurseries, only a small proportion of seed germinates, with emergence extending from spring to early August.

In evaluating modified stock production systems, three major factors must be considered. Quality of stock at time of planting, in terms of top length and stem diameter affect plantation survival and early performance (5). Current information estimates overall mean survival of conventional nursery stock of 58% to 64% across Ontario five years after planting, depending on species (3). Optimum germination conditions, in addition to ensuring a high degree of seed utilization, provide good quality, vigorous germinants which contribute to the uniformly high quality shipping stock necessary to meet competitive situations on outplanting.

Increased needs for planting stock are forecast. Annual planting of 66,000 hectares of the major coniferous species is predicted by 1987 (6). Current planting is reported at 19,300 hectares (1). The black spruce component is expected to rise from 7.6 million (15.8%) of the 48,292 million trees planted in 1977 (1) to 27.4 million (29.8%) of the estimated 92,000,000 trees, bare root and container stock for planting in 1983-84 (Reese, personal communication).[1] Such increases will severely tax labour resources and facilities unless shorter rotations and high speed automation are employed.

Changes in technique to achieve these goals must be accomplished in time of economic restraint. For modified germination conditions, facilities such as germination rooms and greenhouses are needed. Full utilization of greenhouses, using only established germinants, and reduced production time help minimize this cost. Only one set of conditions need be maintained in the greenhouse as germination is completed elsewhere. Culling costs relate to uniformity of stock in the nur-

[1] Derived from personal communication with K.R. Reese, Stock Production Specialist, Ontario Ministry of Natural Resources, Toronto.

sery bed. With all greenhouse stock starting from germinants at the same stage of development, and with early culling at time of transplanting, these costs will be minimized.

SYSTEM DEVELOPMENT

A technique has been developed for the production of high quality two-year-old black spruce transplants as an alternative to current three and four-year systems. This involves pregermination of seed, early development under greenhouse conditions and subsequent transplanting and shipping as bare root nursery stock.

Pregermination plugs. The planting of germinants by hand is used in research with valuable seed lots and in developing countries with labour intensive production systems. However, with the high labour costs in Ontario, automation is essential. This necessitates a device for handling the germinant while protecting its delicate radicle.

The use of a small container seems obvious. The Ontario tube was pioneered by the Ministry of Natural Resources for the tubed seedling program (4). The technology developed in that program provided a starting point for smaller containers for germination only. Waxed paper straws were investigated and found to be too difficult to fill and seed. Dental cotton rolls presented an excellent germination medium but proved to be difficult for black spruce root penetration and for maintenance of optimum moisture conditions. Nonetheless this might still be a valuable technique for some horticultural species. A satisfactory solution was found in sphagnum moss. Using a standard hand cigarette roller with 4 cm gauze bandage, peat moss cigarettes were formed and cut into 1.5 cm long germination plugs.

Containers to hold the germination plugs were made by drilling 200 holes in 2.5 cm styrofoam plates, 30 × 15 cm, in a 10 × 20 configuration to facilitate seeding on a standard tubed seedling vacuum seeder (7). Dental cotton rolls were inserted in the bottom of each hole to serve as a base for germination plugs and to act as a wick.

The system, though adequate for small research trials, was not suited for larger projects. A cigarette machine, Molin Mark VI provided by Imperial Tobacco, was assembled at the Ministry of Natural Resources Kemptville provincial nursery. A cleaning tower to eliminate coarse materials from the peat moss was built by Imperial Tobacco staff at Aylmer, Ontario. The research staff of Johnson and Johnson Ltd. provided a gauze type, nonwoven cellulose used in tea bags as a cigarette covering material. Cigarettes, from which germination plugs could be cut, were produced in an afternoon in sufficient quantity to meet re-

search needs over a three year period. Production was about 600 cigarettes per minute, or the equivalent of 3000 germination plugs.

Cigarettes, placed in a hopper which released a single 30 cm long row of cigarettes, side by side, were picked up in a clamp. A second clamp was used to hold the other end of the cigarettes so that they could be cut into 1.5 cm lengths on a paper cutter. A plastic trough (Figure 1) was designed to hold a row of plugs on which seed was sown on a single line vacuum seeder head. A standard tubed seedling tray, 30 cm × 15 cm, held 12 troughs or approximately 450 germination plugs. A germination cabinet with a capacity of 20,000 plugs was used to provide optimum conditions for germination.

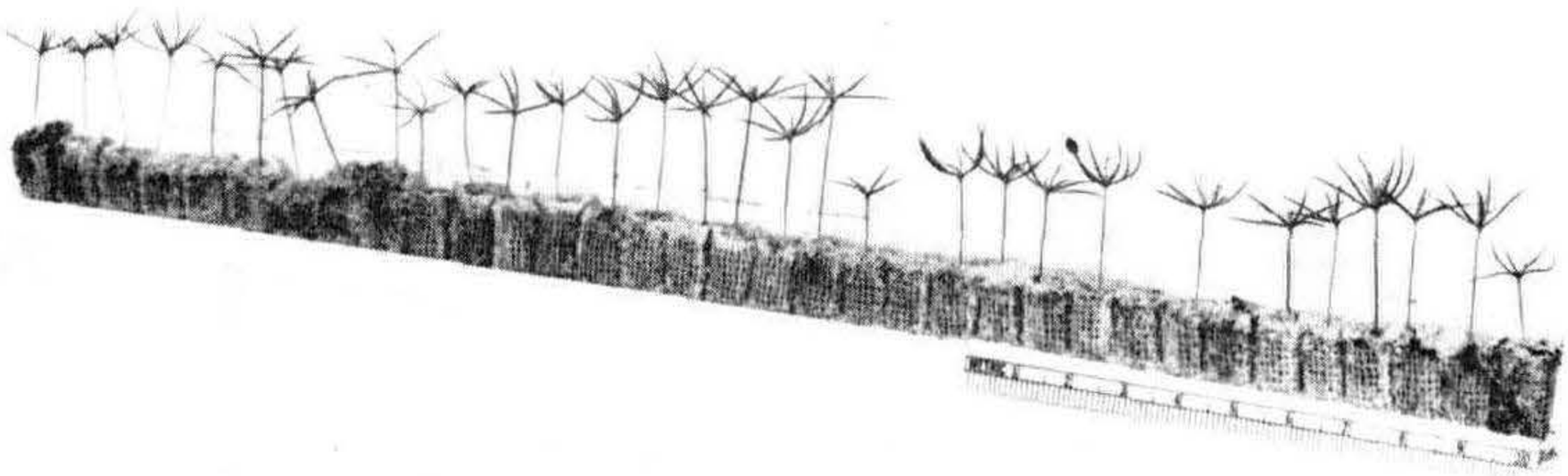

Figure 1. A trough of germination plugs with germinants.

Soil Blocks. A system was required in which the germinants could develop further in the greenhouse to a size sufficient for transplanting into the nursery. A soil block making machine was used to produce 2.5 cm cubes or a line of 12 across a continuous 30 cm conveyor belt (Figure 2). This machine appeared to have potential for production of either "containerless" containers or greenhouse transplants. The machine was modified so as to provide a hole in each cube to accommodate a germination plug. The holes replaced the shallow depressions normally provided for seeding. To overcome the difficulty of cubes breaking across the dibble holes, further modifications were made to recut the original fault lines between cubes.

Various soil media were tried. Muck, so successful in the production of vegetables in Holland Marsh, was of poor structure and its pH was too high for production of coniferous seedlings. Screened organic peat from a bog in Dunmore Township

in northern Ontario and commercial peat moss with additions of 10% sand and 5% clay worked well on the machine.

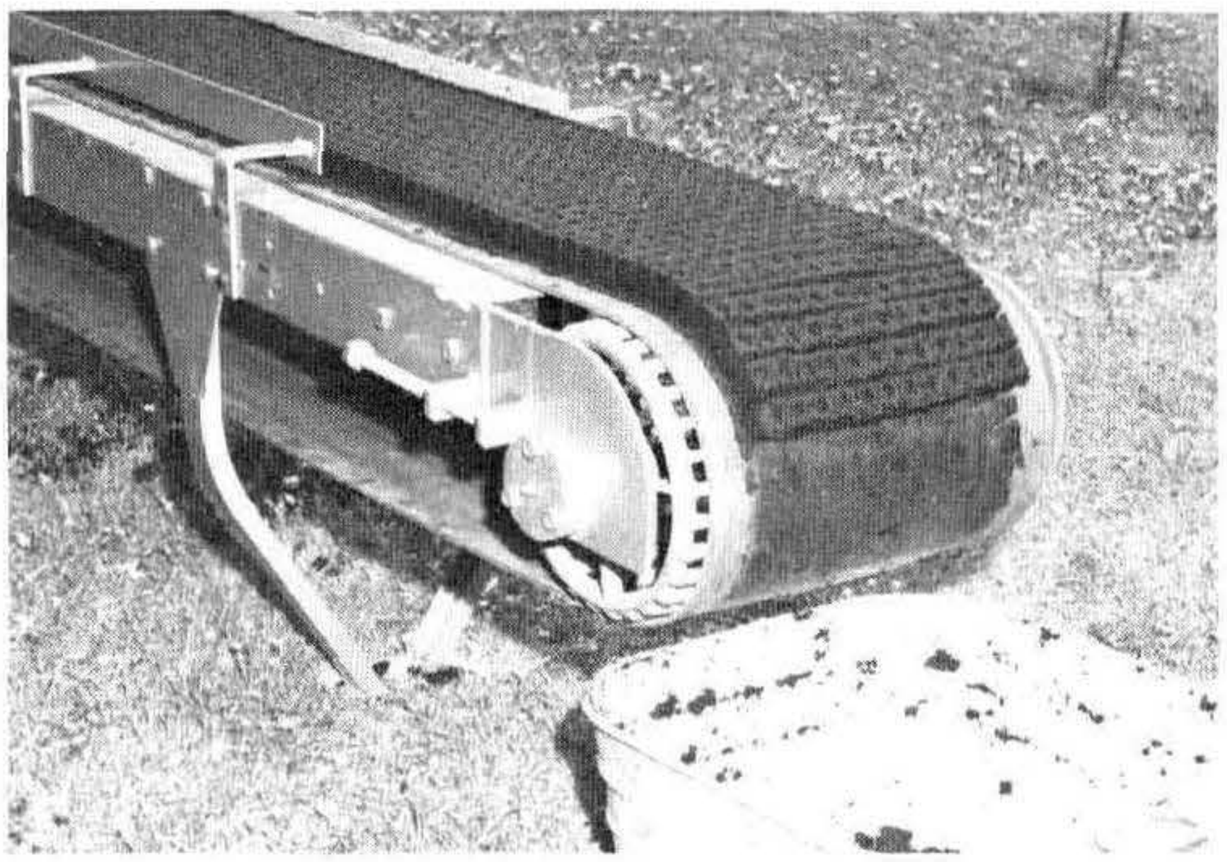

Figure 2. Dewa soil block machine delivering cubes of organic peat.

FIELD TRIALS

Orono Nursery 1975. A study of time of sowing was initiated at the Ontario Forest Research Centre at Maple and seedlings transplanted manually at the Ministry of Natural Resources nursery, Orono, Ontario. Plugs were sown at approximate monthly intervals from mid-February to early June. Germinants were planted in cubes as soon as cotyledons were fully formed and seed coats had dropped. Planting was by hand, using forceps to handle the plugs. The results are in process of publication by the authors.

Plants, sown in February and sampled after the second season in the nursery bed attained an average height of 27 cm and a dry weight of 5.3 g. Ministry shipping standards of 15 cm and 2.5 g plants were achieved by sowings up to May 1st though with considerable variability between plants. Shoot/root ratios, based on dry weight, were about 2:1, indicating a well balanced plant.

Swastika Nursery 1976. A pilot operation was conducted at Swastika, a northern Ministry of Natural Resources nursery near Kirkland Lake, Ontario. Seed was sown April 1st and planted into cubes April 20th. Seedlings were grown in a heated greenhouse for eight weeks, moved to a shaded area and finally transplanted July 5th to a standard nursery bed.

A subjective assessment by the nursery superintendent indicated stock could be shipped without culling. Mean height of 28 cm and 7 g dry weight far exceeded the minimum Ministry shipping standards. Shoot/root ratios of 2.7:1 were satisfactory. Trees grown in cubes of peat from Dunmore Township consistently outperformed those grown in cubes of commercial peat.

Swastika Nursery 1977. A second pilot operation, sampled in October, 1978, showed considerably more variation among plants. Germination was slow and irregular due to inability to maintain optimum germination conditions in the early weeks of opening the greenhouse in February. Mean height of 25 cm and dry weight of 6.5 g were still well above the minimum criteria. However it was estimated that 15-20% of the trees would not be shippable after two growing seasons. Shoot/root ratios averaged 2.3:1.

PRODUCTION CONCEPTS

The feasibility of growing two-year-old greenhouse transplants of acceptable shipping standards has been demonstrated. Some of the production steps have been worked out, but to date most developments have been to facilitate a manual operation. With automation, the number of steps can be reduced. The stage has now been reached where it is necessary to visualize the overall system in an operational setting.

Production and Handling of Germination Plugs. The Molin Mark VI cigarette machine is fully mechanized. By removing the indexed cutter, the cigarette machine will produce a continuous cigarette rope which can be stored on large reels.

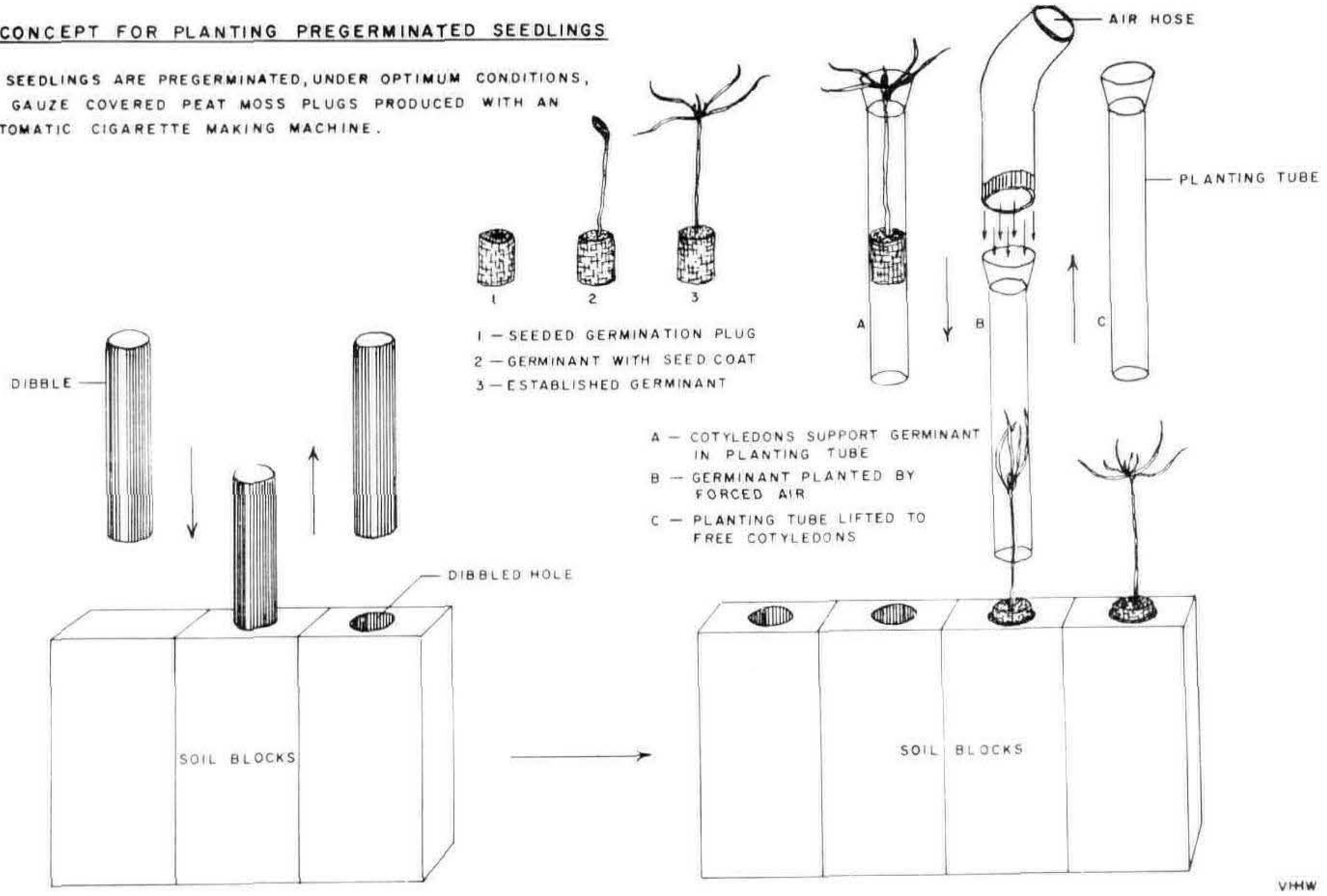

Figure 3. Assembly concept for production and handling plugs.

Through a series of guides, wheels and an indexed cutter, plugs can be produced and placed vertically in a line between horizontal guide rails (Figure 3). The line will move forward by means of a conveyor wheel onto a feeder conveyor into handling troughs. Once in the troughs, they will be moved into trays where other steps such as seeding, moistening and germinating can easily be automated on a production scale.

Planting in Soil Blocks. Some modifications to the soil block machine are complete. The cylindrical dibbles open a cavity adequate to hold the germination plug. A germinant planting device is currently being designed.

A culling step will be in place to allow selection of fully developed germinants between the germination and planting stages. This will be in a transfer system, where lines of germinating plugs will be scanned and accepted germinants of adequate height will be gathered into units of 12 for delivery to the planting system.

A system delivering 12 stocked germination plugs into the seeding tubes (Figure 4) will be installed on the soil block machine. Plugs drop easily into the tubes but are stopped by the cotyledons, holding the germinant suspended at the top of the tube. A pressure release at the appropriate time for a short period of time will send the plug and germinant down the tube into the dibble hole in the cube.

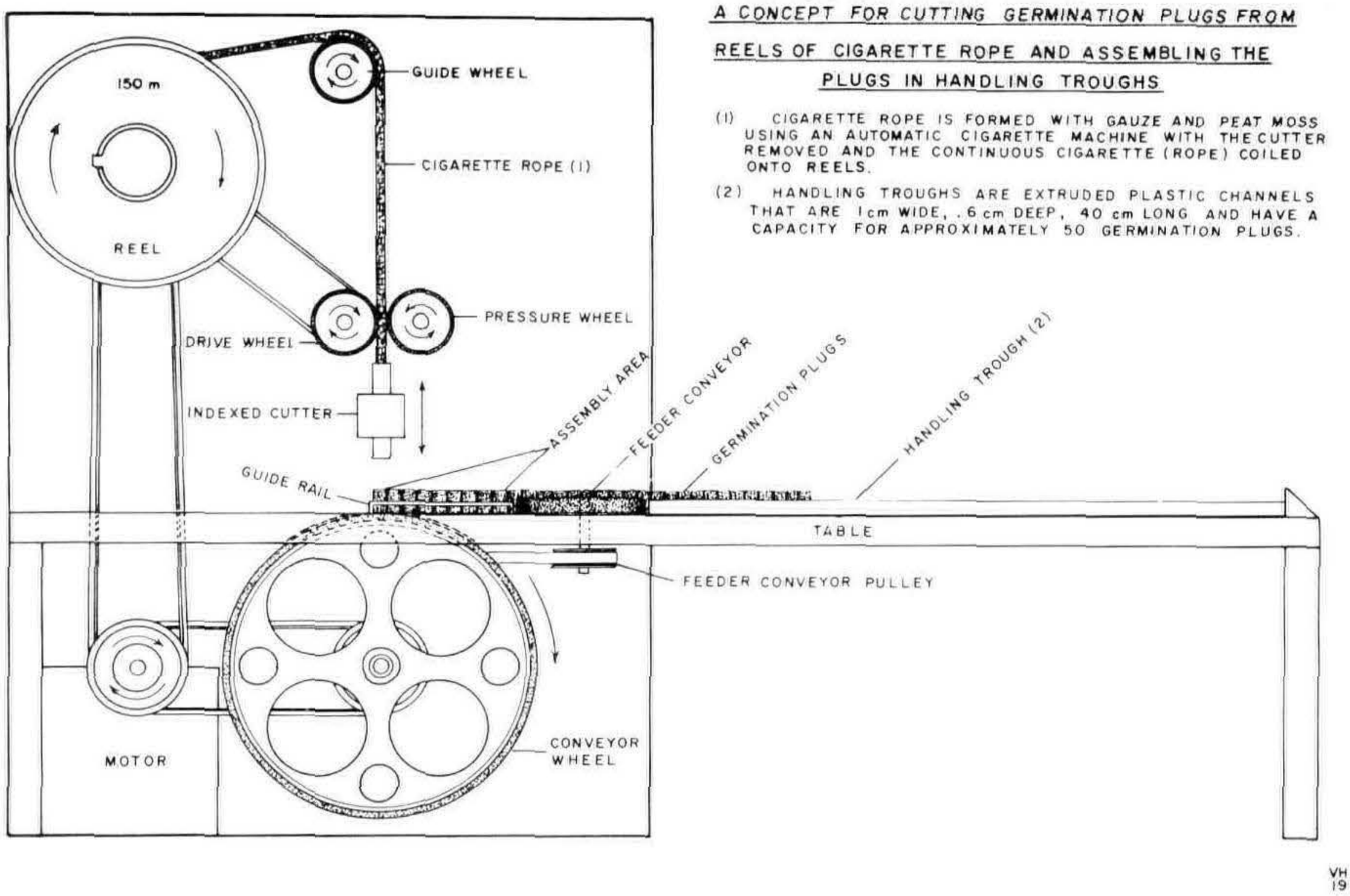

Figure 4. Assembly concept for planting pregerminated seedlings.

Transport of Cubes with Germinants to Greenhouse. Continuous lines of cubes from the conveyor belt will be fed directly into pallets (Figure 5). The pallets will be moved to the greenhouse by forklift whenever transfer is necessary.

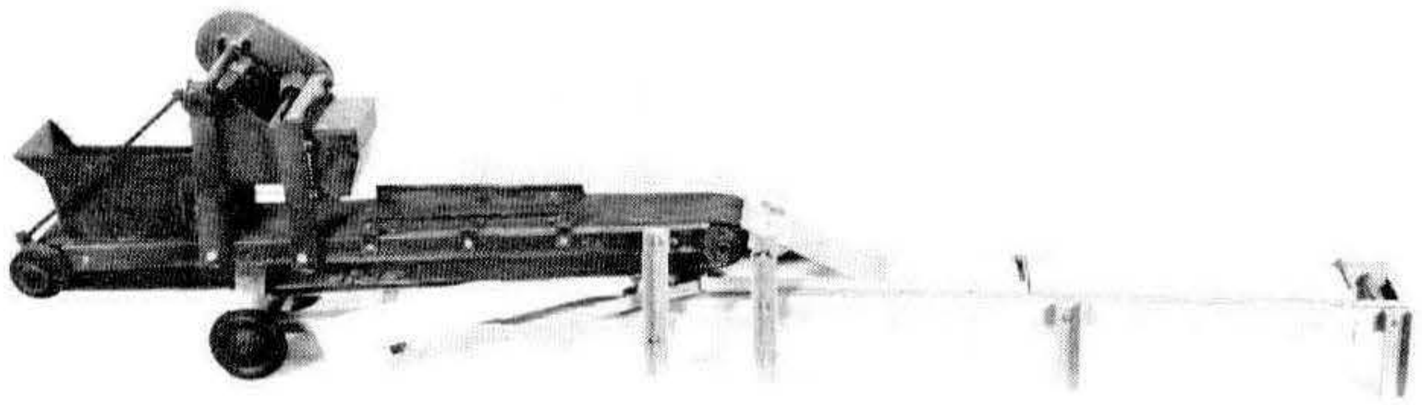

Figure 5. Model of soil block machine.

Transport of Cubes with Seedlings to Nursery. Pallets of seedlings will be moved to holding areas for hardening off before transplanting. Subsequently they will be transported to nursery compartments and transferred to a transplanting vehicle (Figure 6). A device on the vehicle will remove the pallet frame and the cubes will be moved forward by a conveyor. At the end of the conveyor, pallet bottoms will be separated from the cubes. The cubes will then pass through rolling coulters and be guided in lines into the nursery bed at whatever desired configuration.

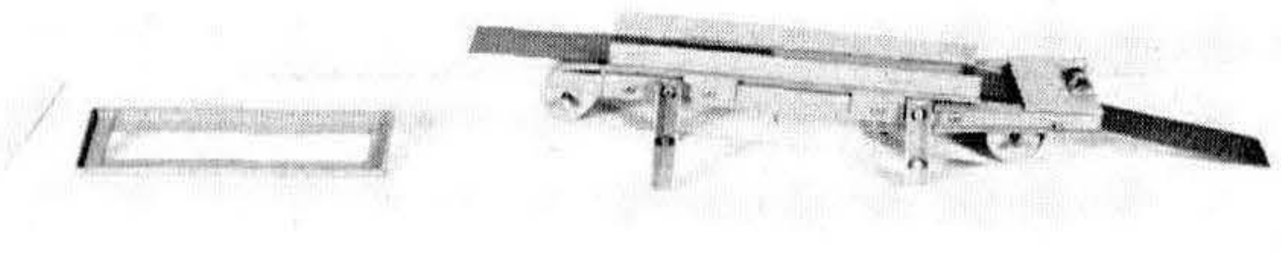

Figure 6. Model of transplanting vehicle.

CONCLUSION

A system has been developed for growing a crop of coniferous seedlings using germination plugs, peat cubes and various handling devices. Most of these developments have facilitated manual operations though some highly mechanized steps

have been completed. The goals in terms of growth objectives have been shown to be feasible.

A need remains to produce optimum schedules for greenhouse growth and to produce the necessary germination facilities in order to improve quality of stock. The concepts presented here form a basis for automating the mechanical operations from pregerminated seed to production of bare root nursery transplants.

Acknowledgement. Photographs were taken by Miss Jean Robinson, Ontario Forest Research Centre, Maple, Ontario.

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BILL FLEMER: Why not sow directly on the soil blocks instead of on the cigarette process first?

VICK WILLIAMSON: We find that by growing on the cigarette process first, we can germinate under optimum conditions. We are able to get the root radicle down into the medium with the least expense of energy. After it starts to produce its own food it can branch out into the soil.

VOICE: How do you get each individual seed into the cigarette plugs?

VICK WILLIAMSON: We use a vacuum seeder.

BASSWOOD (*TILIA AMERICANA L.*) SEED GERMINATION

DAVID E. VANSTONE

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Research Station, Morden, Manitoba, Canada

Basswood seed has held the interest and caused the frustration of plant propagators for many years (1,2,4). This presentation is limited to American basswood (*Tilia americana* L.) seed. The seed is borne within a tough indehiscent pericarp and has a crustaceous testa, a fleshy, yellowish endosperm, and a well-developed embryo. The seed normally matures in mid to late September, but may hang on the tree into winter. Since basswood seed persists on the tree, seed collection is often postponed until long after maturity.

It was reported about basswood seed nearly 50 years ago (3) that "the germ must have a year at least on the ground among the leaves and damp mold to ripen. In planting them it is, therefore, necessary to wait until the second spring for their germination." More recently, the summary of basswood germination in *Seeds of Woody Plants in the United States* (5) stated that "seed treatments that consistently result in good germination have not been developed." Certainly these reports document the problem of basswood seed germination and reflect past results obtained from my own Institute.

The first step in our investigation of the basswood seed germination problem was to determine the effect of seed maturity at harvest on subsequent germination of seed from a tree of local source. Seed was harvested weekly (Table 1) beginning while the pericarp was still green, the endosperm was milky and the embryo was immature. As the season progressed, ontogenetic changes occurred. The pericarp became grayish-brown and woody, the endosperm became dry and yellowish, and the embryo grew and became differentiated. Some of this seed was sown outdoors as soon as it was harvested. Germination was recorded the first spring and the results are presented in Table 1. Germination from the August 12, 19, and 26 harvest dates was 10%, 8% and 12%, respectively. Germination from September 2 improved to 21%; 51% germination was obtained from September 9 harvest date and, thereafter, germination was extremely poor. Similar seed lots were sown in the greenhouse and there, too, best germination was obtained from seed which had been harvested and sown on September 9. It may be asked, "is there something special about the date, September 9?" Of course not. These results indicate, however, that some special physiological state favouring germination existed in seed harvested at that stage of maturity.

Table 1. Spring germination of fall-sown American basswood seed.

Date of Harvest and Sowing	Germination Percentage	Seed Moisture (Percent Dry Weight)	Pericarp Colour (Percent Grayish-Brown)
August 12, 1977	10	61	0
August 19, 1977	8	60	0
August 26, 1977	12	57	44
September 2, 1977	21	27	94
September 9, 1977	51	16	100
September 16, 1977	6	7	100
September 23, 1977	1	9	100

Our next step was to record the moisture content of the seed and the colour of the pericarp during the consecutive weeks of harvest. These factors were evaluated for usefulness in indicating the ideal harvest date. The moisture content remained nearly constant at 60% for the first three harvests. It then dropped rapidly to below 10% during the next three weeks and remained at that level. The ideal stage of maturity occurred during the time when moisture was being lost rapidly from the seed. The actual seed moisture content on September 9 was 16%. This indicator could be used to measure maturity. Unfortunately it would take a considerable effort and require an expensive balance for measuring the weights. Alternatively, the colour of the pericarp is easily and inexpensively observed. It also appears to be a definitive characteristic. Once the color change of a pericarp began it proceeded very quickly, so that green pericarps were easily distinguished from grayish-brown pericarps. The ideal date of harvest occurred at the time when 100% of the pericarps had turned grayish-brown. There is good uniformity of ripening on any individual tree. The exact date of ripening may vary by several weeks among trees.

Having established that there is a very specific stage at which basswood seed should be harvested for subsequent ease of germination and that the colour of the pericarp indicates that stage, one might ask what part of the seed structure promotes or permits germination at that stage and not at some other stage of maturity. There are really two possible causes of dormancy. One cause is from a physical restriction such as might be imposed by the pericarp or the testa. The other possible cause of dormancy lies physiologically within the endosperm or the embryo.

The possibility of the pericarp causing restriction to germination was tested by comparing germination of whole versus de-pericarped seed in the greenhouse. The results, shown in Table 2, indicate that the whole seed germinated just as well as the de-pericarped. It would seem then that the pericarp did not restrict germination despite its woody structure. The effect of

the testa on germination has been evaluated on the basis of a simple observation. Seeds were placed in water at each harvest date. The seeds harvested August 12 through September 9 imbibed completely within 24 hours. Seeds harvested September 16 and 23 did not imbibe even after being in water for one week. Since the date when seeds failed to imbibe coincided with the date when germination became poor, it would seem that the testa was restricting germination. Undoubtedly there is another barrier to germination as well because prompt germination of basswood seed did not occur when it was harvested and sown at a stage of maturity when the testa was not restrictive.

Table 2. Germination of greenhouse-sown American basswood seed.

Date of Collection and Sowing	Percent of Germination	
	Whole	De-pericarped
August 12, 1977	—	12
August 19, 1977	9	11
August 26, 1977	28	47
September 2, 1977	32	23
September 9, 1977	53	32
September 16, 1977	—	29
September 23, 1977	8	5

Internal barriers to seed germination were examined by aseptically removing embryos from the testa and endosperm and placing these on agar culture medium containing nutrients but no hormones. At each harvest date the embryos promptly began growing and developed as normal seedlings. If the endosperm, or even a part of the endosperm, was left around the embryo, no growth took place. These tests indicate an apparent lack of embryo dormancy since the naked embryo will grow when it is separated from other components of the seed. Some factor restricting germination seems to be present in the endosperm which must be overcome before germination of an intact seed can occur. That factor would normally be overcome through stratification.

How then should basswood seed be handled in nursery practice? The most reliable procedure for propagators who collect their own seed is to monitor the pericarp color as the seeds are maturing and collect the seed when nearly all of the pericarps have turned from green to grayish-brown. The freshly harvested seed should be sown promptly into a well-prepared seed bed. The seed bed should be mulched well, protected from rodent damage and kept moist until germination begins in the spring.

Late-harvested seed may also be germinated the first season but it requires more treatment than seed harvested at the ideal stage of maturity. Good germination (68%) was obtained in one

of our studies but the pre-germination treatments involved pericarp removal, scarification and stratification (Table 3). The seed was first de-pericarped mechanically using a modified buckwheat de-huller. Removal of the pericarp exposed the testa. The exposed testa was scarified using concentrated sulfuric acid for 20, 30 or 45 minutes. Following scarification, the seed was stratified at 5°C for 7½ months in peat moss/sand (1:1) containing 30% moisture by weight. Stratified seed was beginning to germinate when it was sown on May 25. Further studies are underway to establish the consistency of that treatment.

Table 3. Germination of de-pericarped American basswood seed.

Pre-germination Treatments		Sowing Time	Germination Percentage
H_2SO_4	Stratification		
1. none	none	fall	—
2. 20 min.	none	fall	6±1
3. 30 min.	none	fall	5±1
4. 45 min.	none	fall	2±1
5. none	Oct. 5-May 25	spring	—
6. 20 min.	Oct. 5-May 25	spring	68±6
7. 30 min.	Oct. 5-May 25	spring	68±2
8. 45 min.	Oct. 5-May 25	spring	56±3
9. none	Dec. 5-May 5	spring	—
10. 20 min.	Dec. 5-May 25	spring	10±1
11. 30 min.	Dec. 5-May 25	spring	12±3
12. 45 min.	Dec. 5-May 25	spring	7±2

Much more is yet to be learned about American basswood seed germination. The potential is exciting — the unanticipated problems are frustrating. The net result of such endeavours will hopefully be a more consistent supply of American basswood seedlings and trees.

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4. Heit, C.E. 1977. Propagation from seed, Part 27, *Amer. Nurseryman* 145(7):10-11, 100-110.
5. Schopmeyer, C.S. 1974. Seeds of Woody Plants in the United States. Agriculture Handbook #450. Forest Service, U.S. Department of Agriculture, Washington, D.C.

RALPH SHUGERT: Do you feel that there are differences in seed germination with seeds taken from different trees?

DAVID VANSTONE: Yes. We used 2 seed sources in the

experiments. Although both showed similar results, one source was better than the other.

EDITOR'S NOTE: Jack Alexander, Arnold Arboretum, showed a film: *Plant Propagation – A Tribute to Alfred Fordham*. The film is available from McMillan Films, MacQuesten Parkway, Mount Vernon, N.Y.

Friday Morning, December 1, 1978

Dr. Harrison Flint served as moderator of the morning session with Mr. Alfred Fordham serving as moderator for the New Plant Forum.

PROPAGATION OF MAGNOLIAS BY SOFTWOOD CUTTINGS

RICHARD A. FENICCHIA
Department of Parks
Rochester, New York 14620

Magnolias can be propagated from soft, succulent shoots and from semihardened cuttings providing rigid sanitation procedures are followed. We have used the method described below on a small scale at our park. The outdoor propagating frames are constructed in a shady area and covered with sash. We do not use mist in the outdoor beds; however, one could use mist in a greenhouse. Sand and sand-peat mixtures are satisfactory rooting media. Following bed preparation, I apply a Benlate drench at the rate of 1 teaspoon per gallon of water.

Cuttings should be 3 to 6 inches long with the soft terminal bud removed and the leaves cut in half. The cuttings should be wounded on one side. I have observed that when magnolias are wounded, many roots will be initiated along the side opposite the wound.

Before sticking, the cuttings are dipped in Hormodin 3, containing Benlate. The cuttings should then be stuck 2 inches deep. A groove is made in the medium before sticking, so as not to brush the hormone off. After sticking, the cuttings are well watered, and covered with sash and lath. The cutting bed should be kept well watered for the first 2 weeks. A weekly

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spray with a mixture of Benlate (1 teaspoon/gal) and 20-20-20 soluble fertilizer (1 teaspoon/gal) is applied.

The rooted cuttings in the outdoor frames are not dug until they have received a natural cold period to break their dormancy. In February, we pot and set the rooted cuttings in a greenhouse to establish a good root system before lining out in the nursery.

I have had similar good success this year, on an experimental basis, rooting *Magnolia* 'R.A. Fenicchia' in a greenhouse with bottom heat at 70°F. Cuttings were stuck on July 21, August 16, and September 8. Most of the cuttings were well rooted in 3 to 4 weeks at all time periods.

In conclusion, I would like to say that the overall percentage of cuttings rooted with both techniques is very good. With some *Magnolia* cultivars the rooting percentage was 100%. I have found that *M.* × *soulangiana* and *M. quinquepeta* (Syn.: *M. liliflora*) cultivars root readily.

HOW THE COMMERCIAL PROPAGATOR MIGHT BEST USE THE RESOURCES OF AN ARBORETUM OR BOTANICAL GARDEN

JOHN H. ALEXANDER, III

Arnold Arboretum
Jamaica Plain, Massachusetts 02130

Prior to becoming an Arnold Arboretum staff member, I worked for a small family owned nursery. I occasionally visited the Arboretum and, once in a while, I requested and received propagating material from them. But not until I became an Arboretum staff member did I become fully aware of the many ways a commercial propagator might make use of an arboretum. Some of the resources available from an arboretum are plants, seeds, cuttings and a myriad of information relating to them. One can also obtain help in identifying, locating and propagating plants. One can even get help in selling plants.

The Brooklyn Botanic Garden (BBG) Handbook, *American Gardens – A Traveler's Guide*, lists the names and addresses of over 100 arboreta and botanic gardens in North America. It also includes many other gardens that are open to the public. Many botanic gardens regularly publish booklets that are helpful and educational. Another BBG handbook that I often find useful is the *Nursery Source Guide*. It lists wholesale and retail sources of plant materials. To take advantage of this and similar free

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advertising, one should add arboreta and botanic gardens to his company's mailing lists.

Nursery catalogues, horticultural periodicals and an abundance of botanical and horticultural books may be found in the libraries of botanic gardens. Some winter day you could look through *Horticultural Abstracts*, available in many garden libraries, and find what has been written about your areas of interest. It is a great aid in keeping up on the changes and new ideas which can help keep one ahead of the competition.

If you are searching for a plant that you have read about, but for which you cannot locate a source, check with your nearest arboretum, and if they don't have it, ask if their library has the microfiche published by the American Horticultural Society Plant Sciences Data Center. It is a combined inventory of some of the major plant collections on this continent. By using it or the individual inventories made available by some gardens, you may find a possible source. Then a polite request will usually obtain propagating material for you. When you do make a request, don't expect hundreds of cuttings or pounds of seeds, because most arboretum collections include only one or two plants of their more unusual taxa. Gardens are also limited by the staff available to make collections for you and the length of your request list should be limited accordingly. Another use for plant inventories is to indicate the relative hardiness of a plant. But this information alone can be misleading because the plant may actually be in a protected site.

You and your customers can use an arboretum collection to compare what you are growing with what you could be growing. Mature specimens of plants you offer can be compared with other possibilities and may be photographed for use in your catalogue.

In the past year, two east coast arboreta have offered walks for propagators. While touring the collections, participants were encouraged to take cuttings of interesting plant materials. Following is a list of arboreta and botanic gardens that have traditionally been active in collecting and introducing new plants to cultivation: Arnold Arboretum, Brooklyn Botanic Garden, Cary Arboretum, Los Angeles State and County Arboretum, the Royal Botanical Gardens-Hamilton, University of British Columbia Botanic Garden and the University of Washington Botanic Garden. If you are interested in trying new plant material, many gardens publish an index seminum from which you may request seeds. The U.S. National Arboretum has a very active breeding program and they have also collected and distributed many interesting plants from foreign nurseries.

Last year the Arnold Arboretum sent two staff members to

Japan and Korea to collect seeds of species growing in the coldest habitats in which they were known to occur. Plants from these seeds are now being tested and, if they prove to be superior to what is now available, they will be offered to the trade. If you would like to test your own selections, why not send propagules to several arboreta to see how the plants perform under different conditions.

Just as nurseries have specialties, so do arboreta. An arboretum with a very complete collection of the cultivars of a genus may be designated by an International Horticultural Congress to be the registration authority for that genus. The Royal Botanical Garden at Hamilton is, for example, the registration authority for the genus *Syringa*. Cultivar registration protects the use of the name and provides official record of the introduction.

When an arboretum does have a very large special collection they frequently have one or more staff members who are experts in that subject and, if you have a problem in that area, they may be able to help you. Or they may undertake a research project designed to study your question. Another arboretum expert you may wish to consult is the horticultural taxonomist who, with the help of an herbarium collection, can identify an unknown plant for you or your customers.

If you have further interests in the functions and resources of arboreta and botanic gardens, why not join the American Association of Botanical Gardens and Arboreta, an organization dedicated to research and education as they relate to botanical gardens. Now that you are aware of the multiple uses of an arboretum or botanical garden, I urge you to use and support them for our mutual benefit.

INFORMATION RESOURCES

American Association of Botanical Gardens and Arboreta. Dr. Mildred E. Mathias, Department of Biology, 124 Botany Building, University of California, Los Angeles, CA 90024.

American Horticultural Society, Plant Sciences Data Center, Mount Vernon, VA 22121.

Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn, NY 11225.

Horticultural Abstracts, Commonwealth Bureau of Horticulture and Plantation Crops, East Malling Research Station, Maidstone ME19 6BJ, Kent, U.K.

PROPAGATION OF WOODY ORNAMENTALS USING FLOOR HEAT

WILLIAM VANDERKRUK

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Waterdown, Ontario, Canada

The purpose of this paper is to show that floor heat in propagating ornamentals can be advantageous in several ways. First of all, let me point out that nearly all our propagation is done indoors in fiberglass quonset greenhouses. The reason for this is that during the early summer months, and again in the fall, the temperature fluctuates rapidly and can cause damage to the young crops. We use quonset fiberglass houses because these endure more severe weather than either glass or plastic. In the quonset houses we grow two crops per year: a summer crop consisting of deciduous shrub and perennial cuttings and a winter crop of coniferous evergreen cuttings.

Until last year these crops were rooted on raised benches. We, too, have been looking for ways to cut our fuel consumption and construction costs so we decided to use floor heat in our next house. Let me emphasize that this project is not a new thing in horticulture but I think that we have gained a few insights that I would like to pass on to you.

All our houses are heated by hot water which is circulated from a boiler by a circulating pump in each house. This enables each house to operate at a different temperature.

The greenhouse is a tedlar-coated fiberglass clad quonset type, 30 × 100 ft., and the sub-floor was tile drained and leveled before construction began. A 4 in. layer of ¾″ crushed stone was spread to form the base for the heating pipes. The heating pipes (1″ galvanized steel to ensure longevity) were laid 15 in. apart throughout the entire length of the greenhouse. Each set of 8 pipes were connected to a 3 in. header and a 3 in. return line, thus dividing the floor area into 3 beds. The importance of having 3 separate sections is to ensure an even heat distribution to all areas of the house. An Armstrong 3 in pump was situated in the return line to the boiler. The circulator is activated by a thermostat, the probe of which is inserted in the rooting medium.

After the pipes were leveled and secured another 4 in. of crushed ¾ in. stone was spread and leveled over the 1″ pipes. Concrete was then poured over the entire floor in sections in such a manner as to leave three 7 foot beds sloping on each side to a path. The paths which act as drainage gutters and walks at the same time are sloped to one end of the house. The

slope of the beds from the centre to the sides is approximately 3 degrees.

The edges of the beds have a 4" high plank to keep the medium from spilling on the walks and are slightly raised to allow for drainage.

The following are some observations that we have made during the first two crops in this house:

1. The temperature is remarkably stable in the floor heated beds. The mass of crushed stone and concrete give it the ability to retain heat for a long time. Very little boiler heat is needed to keep the mass at the required temperature.

2. The floor heated beds are easier to wash and clean and need practically no maintenance, except for the 4" board along the edges, perhaps every five years.

3. There is very little waste of space using this type of bed.

4. The floor beds seem to have a cooling effect during the hot summer months. Deciduous shrub cuttings have more top and root growth than similar cuttings on raised beds.

5. Construction of the floor beds is easier than the raised beds and somewhat less costly.

There are also a few disadvantages with floor heat. The heat loss from the beds is so little that we had to install one heating line above ground to keep our mist lines from freezing during the coldest nights. Also, it is much more difficult to plant the cuttings sitting down than standing by a raised bed.

We have rooted quite a variety of plants using floor heat during the first year. Plants rooted by this method include: *Juniperus scopulorum* 'Wichita Blue', *J. scopulorum* 'Admiral', *J. chinensis* 'Mountbatten', *J. virginiana* 'Skyrocket', *J. chinensis* 'Spartan', *Mahonia, Ilex opaca* and *Thuja occidentalis* 'Spiralis'. From the experience we have had with floor heat, we think it has a lot of merit.

LOW PRESSURE AND REFRIGERATED STORAGE OF ROOTED AND UNROOTED ORNAMENTAL CUTTINGS[1]

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Abstract. Rooted and unrooted cuttings of geranium (*Pelargonium* × *hortorum*, Bailey 'Irene'), poinsettia (*Euphorbia pulcherrima*, Wild. 'Annette Hegg Dark Red'), tallhedge buckthorn (*Rhamnus frangula* L. 'Columnaris'), Regel's privet (*Ligustrum obtusifolium* Sieb. & Zucc. var. *regelianum* (Koehne) Rehd.), and compact European cranberry bush viburnum (*Viburnum opulus* L. 'Compactum'), were stored up to 9 weeks using low pressure (LP) and refrigerated (RF) storage systems. Low pressure storage extended the storage life of rooted geranium and poinsettia cuttings 2 weeks beyond that achieved with RF storage. Unrooted geranium and poinsettia cuttings had 2 week and 4 day longer storage periods with LP than RF storage, respectively. Unrooted compact European cranberrybush viburnum, Regel's privet, and tallhedge buckthorn cuttings stored 6 weeks using LP storage were superior to RF storage. Regardless of treatment, quality of all plant materials stored decreased with each progressive removal date.

INTRODUCTION

Extended refrigerated (RF) storage of rooted and unrooted cuttings is often limited by loss of pigmentation (4,17), defoliation (5,22), pathogen invasion (13,16,23,25), high rates of transpiration (14,17,23), excessive respiration (17,20), and the condition of the plant material at the time of placement into storage (4,13,20,24). Refrigerated storage is useful in extending the storage life of cuttings (10,25) by retarding both respiration and the growth of pathogens (15,17). Experiments utilizing LP storage have shown that this system can extend the storage life of cuttings beyond periods achieved with RF storage (2,3).

Low pressure (LP) storage reduces the partial pressure of gases that compose the storage atmosphere (oxygen, CO_2, etc.) which retards respiration to a greater degree than RF storage (2,6,11). Also, gases that normally accumulate in the commodity diffuse at a faster rate since the atmosphere is less dense (11). Gases that normally accumulate in the storage chamber are exchanged with uncontaminated incoming humidified air (2,6,11). An additional benefit of the LP storage system when compared

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[1] This investigation is part of a thesis submitted by the senior author in partial fulfillment of the MS degree. This paper also received the Eastern Region's Graduate Student Award for 1978.

[2] Graduate Research Associate and Associate Professors of Horticulture, respectively.

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to RF storage systems is a retardation of pathogen growth (26).

Refrigerated storage of cuttings is limited to rooted material (10,14,18,19,22,23,24,25) and to a lesser extent to the storage of unrooted cuttings (1,13,16,19,21). Low temperatures (0 and 4.4°C) and the use of fungicides prolonged the storage of rooted cuttings for periods up to 180 days (10). Storage periods for unrooted cuttings have generally been shorter than for rooted cuttings (1). Unrooted softwood azalea (21) and rhododendron (13) cuttings have been successfully stored for 70 days. In general, the more succulent the material the shorter the storage period (16).

Using LP storage, carnations, chrysanthemums and some foliage plant cuttings can be stored successfully for periods at least twice as long when compared to RF storage systems (2,3).

If rooted and unrooted cuttings could be stored for extended periods, it would free production area and subsequently increase productive capacity since a greater number of cuttings could be stored in anticipation of peak sales. In addition, cutting material in the proper condition for propagation could be stored and removed when labor and space were available. The producer with an overabundance of stock could benefit by storing cuttings, thereby preventing liners from becoming overgrown. Thus, studies were initiated to investigate the use of LP and RF storage systems in extending the storage life of rooted and unrooted cuttings. Partial results of this work have been reported previously (8,9).

MATERIALS AND METHODS

Uniform cuttings of 'Irene' geranium, Regel's privet, 'Annette Hegg Dark Red' poinsettia, tallhedge buckthorn and compact European cranberrybush viburnum were obtained from commercial sources and placed in storage the same day. Prior to storage, unrooted cuttings were immersed or sprayed to run-off with Bravo 6F (tetrachloroisophtolonitrile), 1.3 ml/liter, allowed to dry, wrapped and loosely tied with 1.9^2 cm. plastic netting.

Cuttings were placed vertically in 40 liter stainless steel milkcans. Treatments consisted of LP (35mm. Hg) and RF storage (atmospheric pressure) with storage periods of unrooted geranium, poinsettia and woody ornamental cuttings, being no longer than 6, 3, and 9 weeks, respectively. Each treatment had a control group which was directly rooted, or with rooted cuttings, placed into a greenhouse after receiving the initial 4.4°C. treatment for 3 hours.

The storage system utilized in these experiments was similar to LP systems outlined previously (6,8,9). Woody ornamental

cuttings were maintained at 2°C while poinsettia and geranium cuttings were stored at 5°C.

Upon removal from storage, the foliage of all unrooted and rooted cuttings was visually evaluated (Figure 1). In addition, supplemental foliage evaluations were obtained on days 1 and 7 following removal from storage, using the same rating scale.

Following removal from either the LP or RF storage system, unrooted cuttings were placed in a 1:1:1 peat-perlite-sand medium (by volume) after recutting the basal end. Tallhedge buckthorn cuttings received a basal dip of 0.1% IBA powder hormone application prior to being placed in rooting medium. Poinsettia, geranium and woody ornamental cuttings remained in the propagation bed for 21, 26, and 42 days, respectively. A 6 min/6 sec mist cycle was employed in all experiments. Temperature of the propagation medium was maintained at 25° ± 2°C. After rooting, cuttings were evaluated using a visual rating scale where 1.0 indicated a dead cutting and 6.0 indicated a heavily rooted cutting.

At removal rooted cuttings were placed under mist for 1 day then transferred to a 20°C greenhouse for 13 additional days prior to recording the final foliage evaluation. Intermediate evaluations on days 1 and 7 following removal from storage were also obtained with rooted cuttings.

Unrooted cuttings used as controls were evaluated after 26 days in the propagation house using the previously outlined visual evaluation scales for foliage and rooting characteristics. Rooted cuttings used for controls were placed under mist for 1 day and then were placed in a 20°C greenhouse for 13 days before final foliage characteristics were evaluated.

Unless otherwise stated, all experiments consists of 4 replications with 5 observations per replicate for each storage treatment. Data were analyzed using Tukey's omega procedure (hsd) at the 1% level (23).

RESULTS

Woody Ornamentals. Cuttings from 3, 6 and 9 week LP storage had survival percentages of 50% or greater while only the 3 and 6 week RF storage showed similar trends. A significant treatment × week interaction was apparent when unrooted cuttings were removed from storage (Figure 1). Cuttings from LP storage showed a decline in quality with each progressive removal period while cuttings from RF storage deteriorated at a faster rate. The quality of Regel's privet and tallhedge buckthorn cuttings from the 3 and 6 week LP or RF storage treatments were not significantly different, while compact

European cranberrybush viburnum cuttings were similar only at the 3 week treatment. After 9 weeks of storage all treatments in LP storage were superior to RF storage.

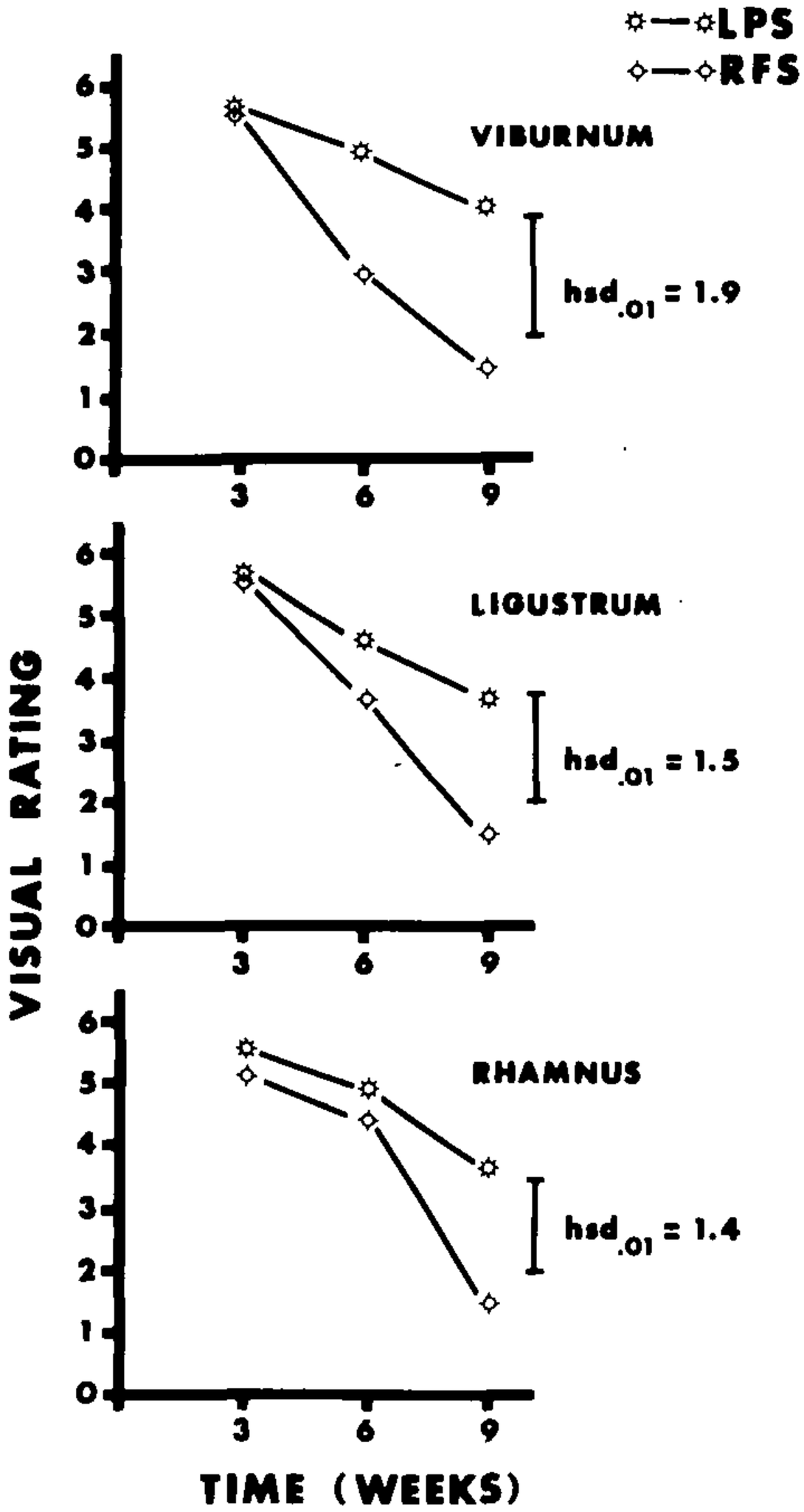


Figure 1. Visual evaluation of the foliage of unrooted *Viburnum*, *Ligustrum* and *Rhamnus* cuttings at removal after 3, 6, or 9 weeks LP or RF storage. (1- cutting dead, 2- leaves completedly deteriorated (defined as the loss of tugor, yellowing, defoliation or the appearance of neucrotic leaf tissue) 3- more than ½ the leaves deteriorated, 4- less than ½ the leaves deteriorated, 5- 1 or 2 leaves deteriorated, 6- leaves in good condition no loss of tugor).

Cuttings evaluated after 42 days in the propagation bed exhibited nearly identical foliage and root evaluations, but only foliage evaluations will be presented. Cuttings stored for 3 and 6 weeks in the chambers were comparable to control cuttings (Figure 2). Compact European cranberrybush viburnum cuttings from the 3 week RF storage treatment were comparable in quality to similar material from LP, however, as the storage period

increased, the differences in quality between the RF and LP systems became greater. All woody cuttings from the 9 week treatment regardless of the storage facility were not comparable to controls (Figure 2).

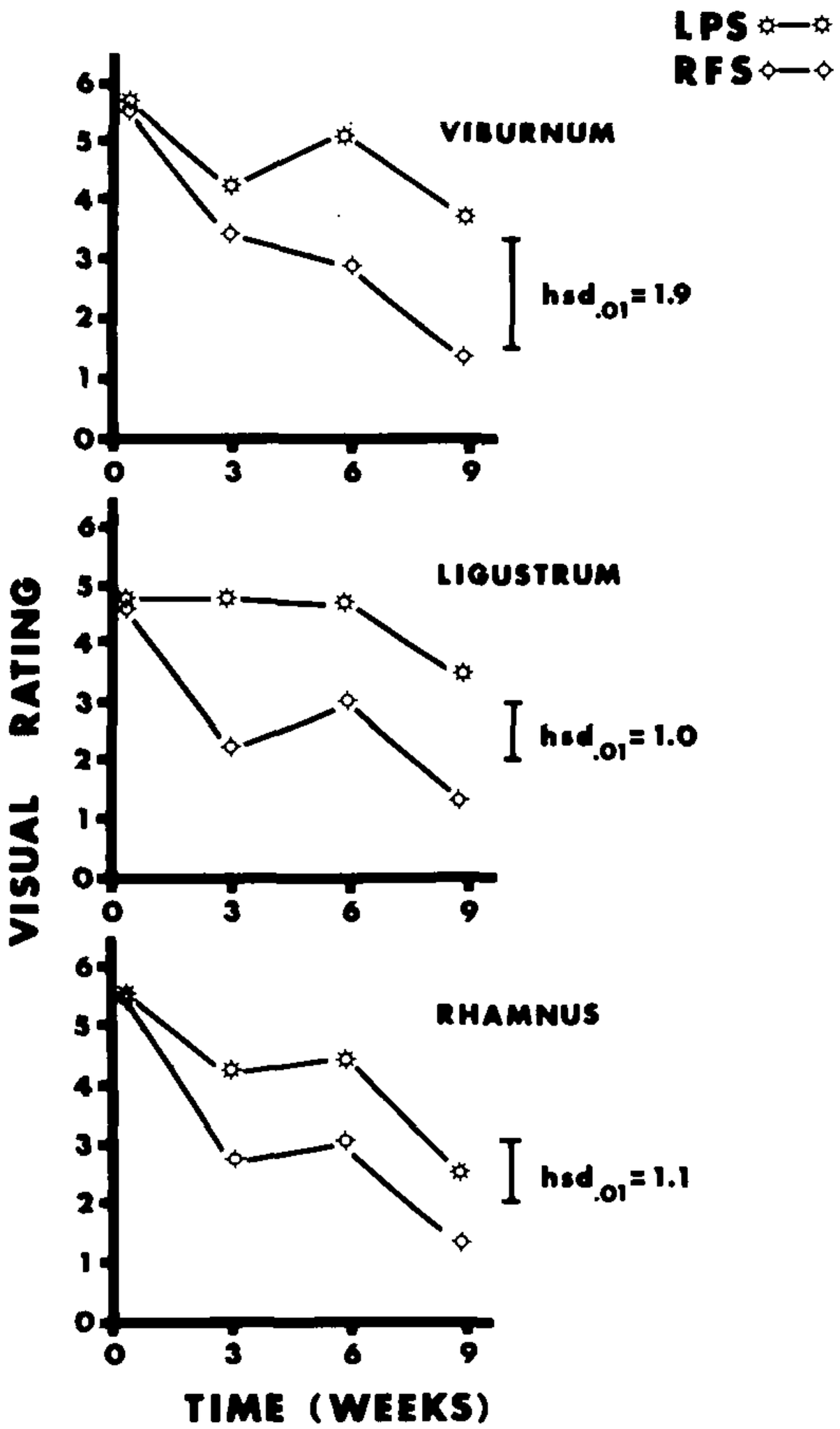


Figure 2. Visual evaluation of the foliage (See Figure 1) of unrooted *Viburnum*, *Ligustrum* and *Rhamnus* cuttings after 6 weeks in the propagation bed following 3, 6, or 9 weeks LP or RF storage.

Poinsettias. Unrooted poinsettia cuttings showed a significant treatment × week interaction regardless of the parameter measured. Only the 1 week LP storage cuttings were of acceptable quality at removal, 1 day and 7 days after removal (Figure 3). Unrooted cuttings from the 1 week RF storage treatment were of acceptable condition only at removal, but did not compare in quality with similar cuttings from LP. Cuttings from 3 week RF storage were totally deteriorated and were not placed in the mist bed for rooting. Though poinsettia cuttings stored

for 3 weeks in the LP chambers were of acceptable condition at removal, the tissue collapsed and was unacceptable 1 day after removal from storage.

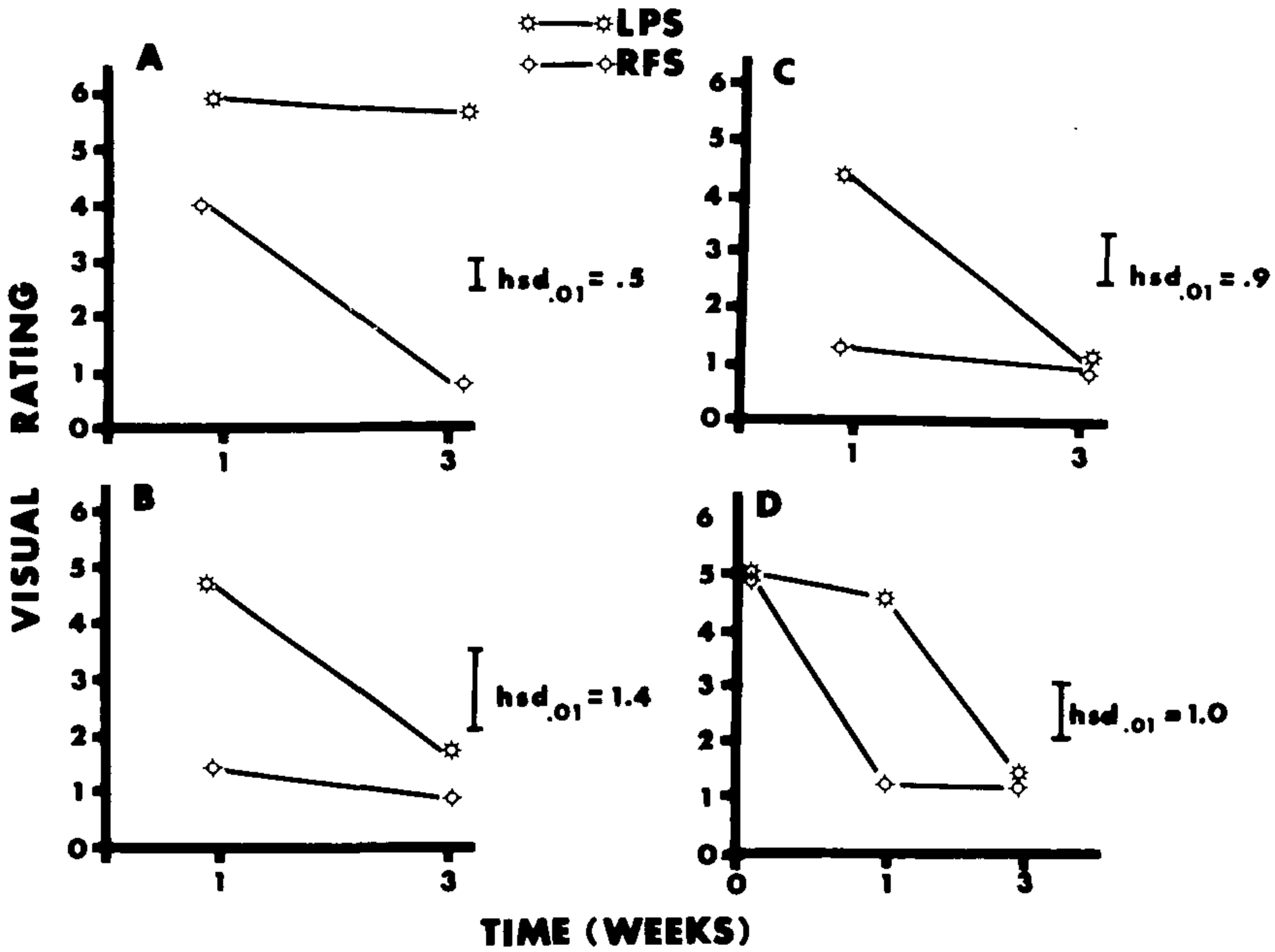


Figure 3. Visual evaluation of the foliage of unrooted poinsettia cuttings (See Figure 1) following 1 and 3 weeks LP or RF storage (A- at removal from storage, B- after 1 day in the propagation bed, C- after 7 days in the propagation bed, D- after 21 days in the propagation bed).

Unrooted poinsettia cuttings were placed in rooting media and evaluated after 21 days in the propagation bed. Again, root and shoot evaluations were similar and only data from shoots will be presented (Figure 3D). Cuttings from the 1 week LP treatment were comparable to control cuttings while all other cuttings from the RF storage treatment were completely deteriorated.

Rooted poinsettia cuttings exhibited a different trend than unrooted cuttings when they were removed from storage. At removal from storage, all treatments were in excellent condition and only those cuttings from the 3 week RF storage treatment showed gradual decline in quality upon evaluation 7 days after removal (Figure 4). Cuttings when evaluated 14 days after removal from storage, were all comparable to control cuttings except the 3 week RF storage treatment (Figure 4).

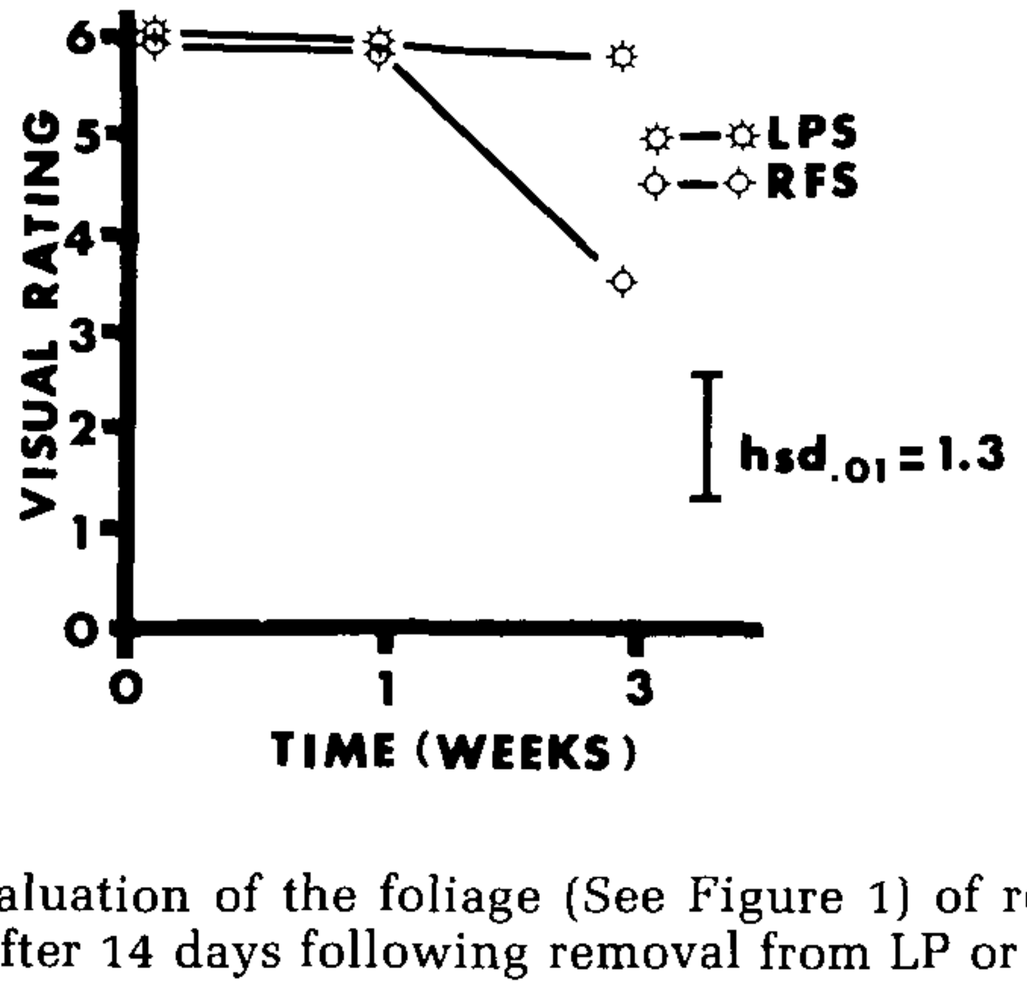
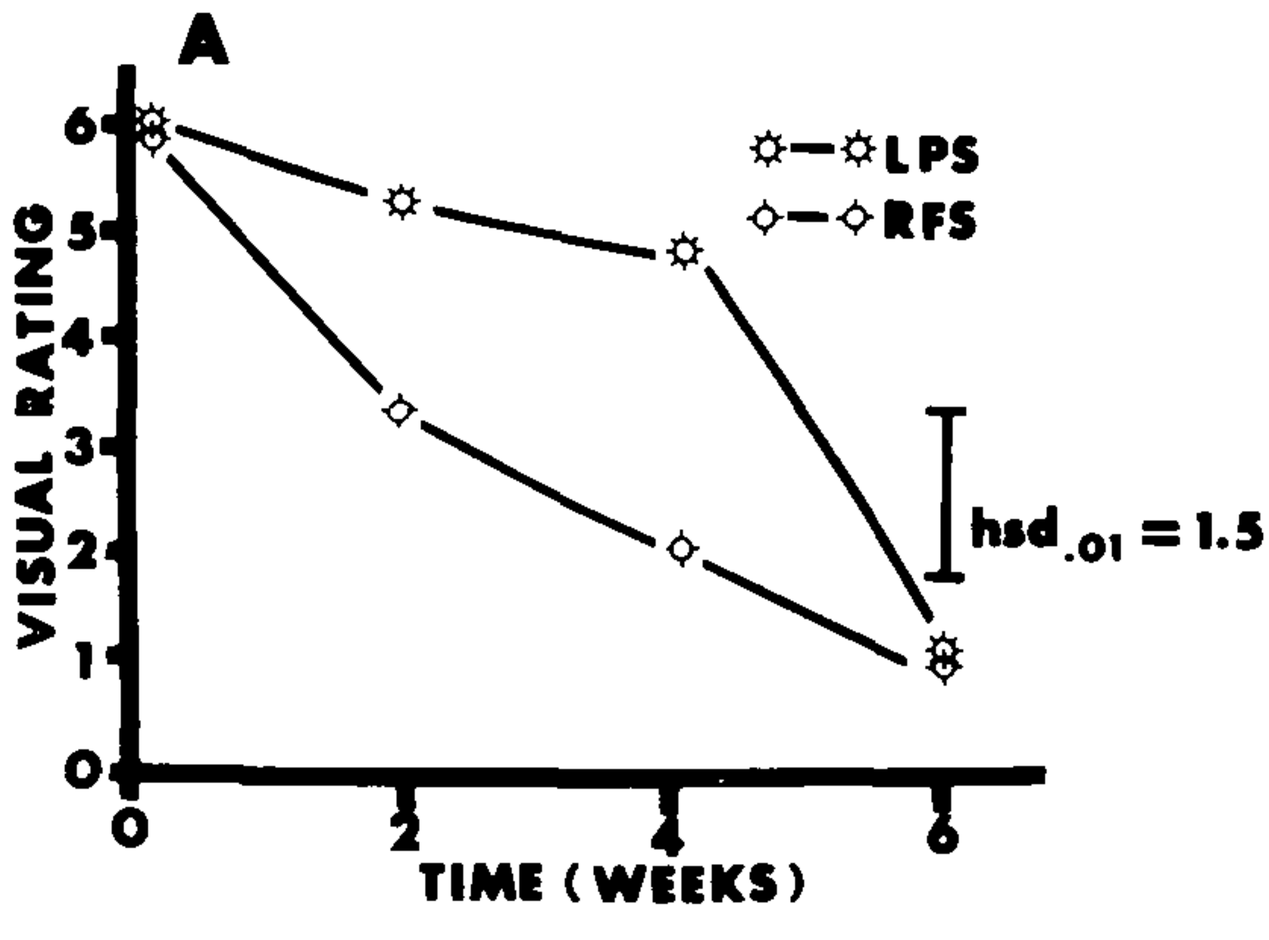


Figure 4. Visual evaluation of the foliage (See Figure 1) of rooted poinsettia cuttings after 14 days following removal from LP or RF storage.



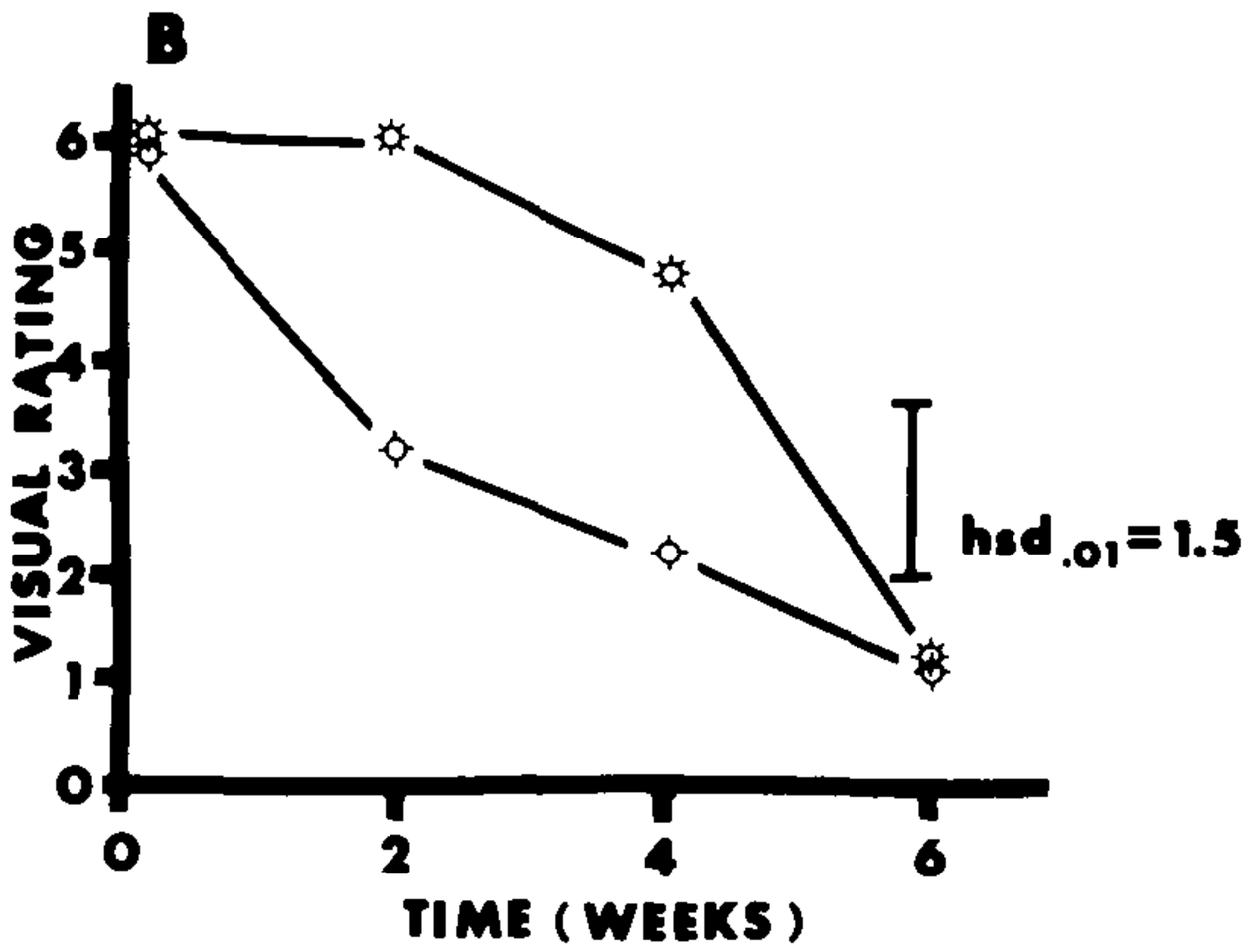


Figure 5. Visual evaluation of unrooted geranium cuttings after 26 days in the propagation bed following 2, 4, and 6 week LP or RF storage (A- foliage evaluation, see Figure 1, B- root evaluation, see text).

Figure 6. A comparison of unrooted geranium cuttings after 4-week LP or RF storage following 26 days in the propagation bed. (In the picture, CCS should be interpreted as RFS).

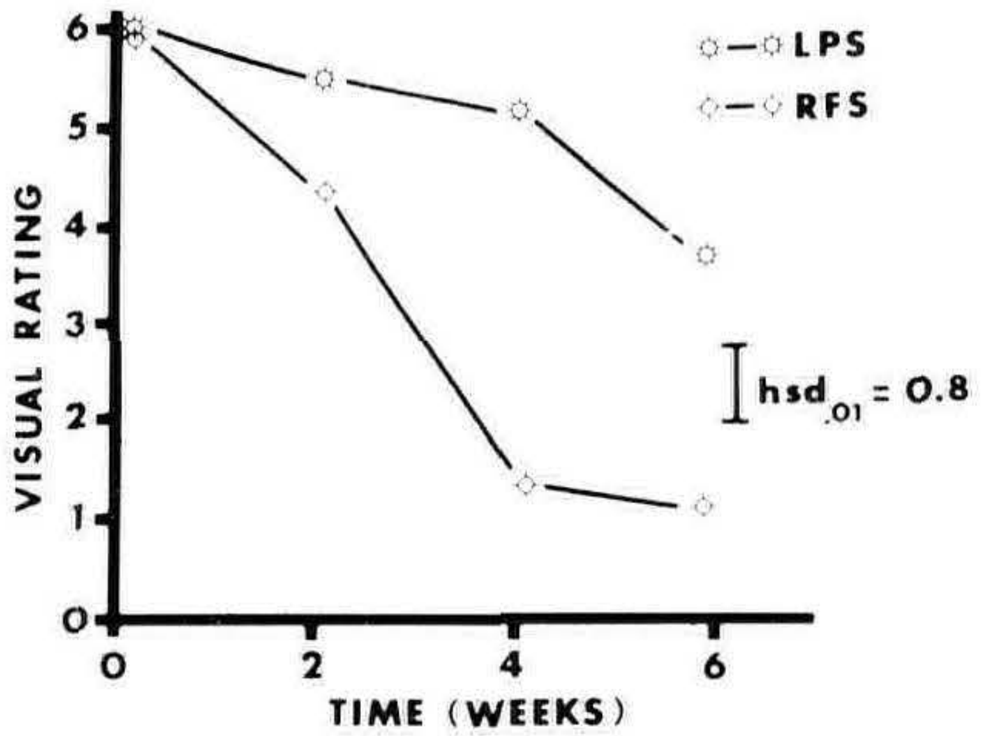


Figure 7. Visual evaluation of the foliage (See Figure 1) of rooted geranium cuttings after 14 days following removal from 2, 4, or 6 week LP or RF storage.

Geraniums. Upon removal from storage, unrooted geranium cuttings exhibited a significant treatment × week interaction. As the length of the storage period increased, the quality of the cuttings decreased (Figure 5), but reduction in plant quality occurred gradually with each progressive removal date from LP while similar cuttings from RF storage showed a more rapid decline in quality. In general, cuttings stored in LP for 2 or 4

weeks were of acceptable quality at removal while only the 2 week RF storage treatment were acceptable at removal.

When cuttings were evaluated after 26 days in the propagation bed, root and shoot evaluations were similar and thus only shoot evaluations will be presented (Figure 5). Cuttings from the 2 week LP or RF storage treatments were of acceptable quality, but only the cuttings from the 2 week LP treatment were comparable to control cuttings. As the storage period increased, only those cuttings from the 4 week LP treatments were of acceptable quality. Differences between the storage systems were evident after the 4 week treatment (Figure 6) with good foliage and root development on cuttings stored under LP.

Rooted geranium cuttings exhibited nearly identical patterns to those of unrooted geranium cuttings at removal from storage and when final evaluations were taken, rooted cuttings were in better condition than unrooted cuttings from the LP storage systems (Figure 7). Also, rooted cuttings from the 6 week LP storage were not completely deteriorated whereas unrooted cuttings from the LP treatment were.

DISCUSSION

Generally, storage of both rooted and unrooted materials in the LP system was superior to the storage of similar material in the RF system. The deterioration of stored unrooted cuttings as characterized by foliar chlorosis and/or necrosis, yellowing or loss of chlorophyll was found to be the limiting factor in our studies, as well as in other studies (4,17). Depletion of carbohydrates with high rates of respiration enhance foliar yellowing (20) and could be the limiting factor in our storage experiment. One of the principles of LP storage that extends the storage life of various crops is the ease in which the system reduces the partial pressures of the gases in the storage chamber (2,6). Since oxygen is one of the substrates for respiration, a low O_2 tension would lower the respiratory rate. Thus, if the respiration of a commodity is reduced, then carbohydrate levels would not decrease as rapidly and a better quality crop may result at removal from storage. This could be the factor which sustained LP stored cuttings for longer periods than those in RF storage in good condition.

Low temperatures will slow respiration (2,17) but our results indicated that lower temperatures alone were inadequate. In many experiments this was evidenced by the treatment × week interactions (Figure 5). Essentially these interactions indicated that if short term storage (2 weeks) were desired, either LP or RF storage would be adequate. However, if a longer stor-

age period were desired, then the LP storage system was clearly advantageous.

Ethylene causes leaf abscission, and/or yellowing of plant material that has been stored for extended periods (5,22). Another principle of LP storage that extends the storage life of crops is the rapid removal of ethylene and CO_2 from within the commodity and the storage atmosphere (2,6). Defoliation of Regel's privet and tallhedge buckthorn cuttings was observed when they were removed from RF and not from LP storage. Ethylene levels were not monitored, but Regel's privet and tallhedge buckthorn cuttings may be susceptible to ethylene damage.

Leaves are known to produce auxins and rooting cofactors as well as being a site of carbohydrate synthesis which interact to enhance rooting. Cuttings stored in the LP system consistently exhibited better root development when compared to RF storage (Figure 6), which can be correlated to greater leaf number at removal from storage.

Diseases play a role in limiting the storage of cuttings (16,22). Low pressure storage limits the growth of pathogens (25); however, low temperatures and the use of fungicides also reduce pathogen growth (16,22). With rooted and unrooted geranium and poinsettia cuttings, diseases were noted only on the material stored in the RF storage system, while material stored in the LP storage system appeared disease-free. Diseased tissue was not observed on the geranium cuttings until the plant material had been in storage for 4 weeks or more.

When poinsettia cuttings were stored, differences were noted in the length of successful storage achieved using rooted and unrooted cuttings (Figure 3 and 4). Storage of unrooted poinsettia cuttings was successful with LP for 1 week and for 3 days with RF storage (7), while rooted material could be successfully stored for 1 week with RF storage and for 3 weeks with the LP storage system. Possibly because poinsettia plants have thin, delicate leaves, they lose excess amounts of water after storage and unless roots are present this lost water cannot be fully replenished before dessication occurs.

The results presented here do not differ from previous LP work with cuttings (2,3). Storage times with LP were doubled when comparing LP to RF storage, thus indicating the possibilities of using a LP storage system for extending the storage of cuttings. However, controlled atmosphere storage using the same partial pressure achieved at LP were not used as controls in our first experiments. Since the writing of this manuscript, further research has been conducted using controlled atmospheric (CA) storage. It appears from our first experiments that

CA storage (1% O_2, 99% N_2) can extend the storage of unrooted geranium cutting for periods similar to LP storage. Controlled atmospheric storage with 5% and 10% O_2 extended the storage period when compared to RF storage, but did not equal storage periods achieved with 1% O_2 or LP (Unpublished data).

Mention must be made concerning some inconsistencies in our results with geranium cuttings. In some instances, the day following removal from storage, regardless of treatment, cuttings appeared wilted. The older leaves soon abscised while the newer leaves recovered. Cuttings from LP and CA chambers recovered sooner than cuttings in RF storage.

The factors involved with this problem are unknown at present, but it is highly probable that the condition of the material at time of entry into storage had a major influence on its condition at the completion of the storage period. Since cuttings for a great many of our experiments came from greenhouses where plants were being forced, high nutrient levels leading to excessive succulence may have been one of the factors. Research in this area will give us a better understanding of the factors involved in the proper storage of rooted and unrooted cuttings.

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Friday Morning, December 1, 1978

NEW PLANT FORUM

Alfred Fordham served as moderator.

MODERATOR FORDHAM: Our first speaker on this portion of the program will be Tom McCloud who has four plants which he would like to discuss.

TOM McCLOUD: The four plants I would like to tell you

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NEW PLANT FORUM

Alfred Fordham served as moderator.

MODERATOR FORDHAM: Our first speaker on this portion of the program will be Tom McCloud who has four plants which he would like to discuss.

TOM McCLOUD: The four plants I would like to tell you

about today are releases from the U.S. Department of Agriculture.

Lagerstroemia 'Muskogee' is a multiple-stemmed, large shrub or small tree with exfoliating bark. The heavy, glossy, dark green leaves turn good shades of reds and yellows in the autumn. The abundant inflorescences are a light lavender. Under field conditions the plant is highly mildew tolerant.

Lagerstroemia 'Natchez' is a multistemmed, large shrub or small tree. The most outstanding characteristic is the dark cinnamon brown exfoliating trunk bark that remains spectacular all year. The foliage turns orange and red in the autumn. Under field conditions the plant is highly mildew resistant.

Both cultivars are reliably hardy to Zone 7b.

Pyracanta × 'Navaho' has a low dense branching habit. It is a semi-evergreen to evergreen shrub with dark green leaves. The abundant white inflorescences in May are followed by a spectacular fruit display. The fruit clusters are 4-5 cm in diameter. The fruit ripens to a luminescent orange red and persists throughout most of the winter. The plant is scab resistant, highly fire blight tolerant, and hardy to Zone 7.

Pyracanta × 'Teton' has a distinct upright growth habit. The semi-persistent leaves are a medium green. The abundant white flowers in May are followed by 4-6 cm clusters of yellow-orange fruit that persists until January. The plant is scab resistant, highly fire blight tolerant and hardy to Zone 6b.

MODERATOR FORDHAM: Paul Meyer has two plants to present.

PAUL MEYER: *Prunus* 'Okame' has several features that make this cherry valuable for landscape purposes. Most cherries flower for only a short time in the spring (5-7 days). *P.* 'Okame' has an effective color period of three weeks. The buds are a maroon color and open to a bright pink. After the petals fall the stamens give a red color to the plant for another week. The form is upright oval. It can be propagated from softwood cuttings in June.

Clethra barbinervis, the Japanese clethra, is far superior to *C. alnifolia*. It grows to be a large shrub or small tree. The main feature that it has going for it is the flowers in late July and early August. The white flower clusters are 6 to 8 inches long. Another good feature of this plant is the mottled striations of the bark. Softwood cuttings in June, treated with Hormodin 2, root readily.

MODERATOR FORDHAM: Dr. Elwin Orton has two *Pyracantha* selections to show us.

DR. ELWIN ORTON: *Pyracantha* × 'Firey Cascade' is a relatively low growing form. The fruit starts out as more of an orange color that changes to red. Foliage is small and dark green. Although the last two winters have not been kind to it, the cultivar is hardier than most of the red cultivars in the trade. No fire blight or scab has been detected on this plant.

Pyracantha coccinea 'Rutgers' is fully winter hardy. It reaches a maximum height of 24 to 30 inches and has orange fruit. The selection is similar to 'Low Boy', however, it is totally resistant to scab and no trace of fire blight has been detected on the plant.

MODERATOR FORDHAM: Ed Mezitt would like to present a series of azalea hybrids he has made.

ED MEZITT: Rhododendron 'Gibrosea' flowres before any of the Exbury types. It is very floriferous and fragrant. The plant has a compact growth habit and is hardy.

R. 'Circus' has color variation within the flower cluster which makes it more attractive. Pink, yellow and red colors occur.

R. 'Popsicle' has a good clean foliage and flowers after most other rhododendrons. The June flowering date allows extension of the flowering season and the new growth is no problem because it is very floriferous.

MODERATOR FORDHAM: Joerg Leiss has four plants that he would like to tell you about.

JOERG LEISS: *Syringa* 'Slaters Elegance' is a very large flowered hybrid. The flowers are single and white in color.

Syringa 'Agincourt Beauty' is a large single flowered hybrid. The flowers are violet in color.

Syringa reticulata 'Ivory Silk' is a sturdy, compact Japanese tree lilac with an oval growth habit. It flowers when young with large creamy white flower clusters in early July.

The last plant is an American ash we found growing. The main feature of this plant is its growth habit which is narrow like a pool cue. The first year's growth is purple and it has a good purplish color in the fall. It can be grafted on any ash understock. We are calling it *Fraxinus americana* 'Manitoo'.