The Adventitious Rooting of Vegetative Cuttings Using Hydropropagation

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INTRODUCTION

Cuttings need external conditions that will minimise stress, if they are to survive and form roots (Elliot and Jones, 1980). These conditions involve water, temperature, light and oxygen. Protecting the cutting from water stress is usually achieved by misting or fogging. Temperature is often regulated so that the rooting medium is 5 to 10C warmer than the aerial temperature. High light intensity can result in overheating of the cutting and consequently shading is preferable, particularly under glass. Oxygen is essential for root formation (Zimmerman, 1930) and poor aeration conditions due to waterlogging will lead to death of cuttings. Factors such as the use of rooting hormones (auxins) (Thomas, 1982) and slow-release fertiliser in the rooting medium (Carter, 1985) can promote quicker rooting of cuttings.

Boland and Hanger first described the concept of hydroponic propagation (Boland and Hanger, 1991). The system potentially overcame water stress by standing the cuttings in aerated recycling water. The solution could be heated to create a warm rooting zone and the inclusion of a low concentration of IBA in the water for an optimal period accelerated early root development.

This paper describes a series of studies using the hydropropagation methods. The aims were to study a range of test plants:

1) Determine the effects of auxin type, concentration, and exposure time.

2) Determine any benefit of low concentration nutrients being added to the recycling water.

3) Show that hydropropagated cuttings established well in standard potting mix.

4) Determine whether fogging could improve rooting.

MATERIALS AND METHODS

The hydropropagation modules consisted of galvanised powder-coated channels 2.3 m long, 100 mm wide, and 40 mm deep, filled with black polypropylene beads, approximately 4 mm by 3 mm in size. Channels were supported on galvanised iron benches that had a slope of 1 : 11. At the lower end the beads were retained by a wad of foam that allowed water to drain back to the reservoir.

Submersible pumps were used to pump the solutions from 42-litre plastic drums through 13-mm tubes to the upper ends of the channels where plastic jets delivered the solution at approximately 500 ml/min. Solution depth depends on the degree of incline and flow rate but was generally approximately 15 mm. The system was located in a heated glasshouse (minimum air temperature 16 to 18C) that was covered with 60% shade cloth and contained a fogging system that on occasion was used to maintain relative humidity at a minimum of 75%.

When required, solution temperature was raised by heat exchange from coiled 15-mm black irrigation tubing in each reservoir. Water heated to 35C was circulated through the tubing and the flow was controlled by solenoid valves linked to Datataker® and Iopack® control units. Details of the combination of treatments for each species are shown in Table 1.

With some species a second batch of cuttings was propagated in a heated mist bed with bottom heat set at 21C and 8 sec misting at 8 to 10 min intervals. The medium used was 1 sterilized washed sand : 1 perlite : 1 sieved peat moss (by volume). Results obtained in the mist bed could not be compared statistically with hydropropagation but did indicate differences or similarities between the two systems.

Table 1. Summary of hydropropagation treatments, environment, and test plants.

Plant	*Swainsona formosus*	*Daphne odora*	*Rosa banksiae* var. *banksiae*	*Eucalyptus ficifolia*	*Banksia ericifolia*	*Melaleuca gibbosa*
Commenced	13 Jan	31 Jan	13 Mar	6 July	17 Dec	21 Dec
Duration (weeks)	4	4	6	8	6	4
Hormone:						
Auxin (potassium salts)	IBA or NAA	IBA	IBA	IBA	Nil	IBA
Concentration (ppm)	10	10	5	0.2 or 5	"	2 or 10
Exposure time (days)	14	14	12	7 or cont.	"	7
Nutrient:						
Strength [1]	Nil	0.5	0.25	Nil	Nil	Nil
Start @ day	"	16	5 or 10	"	"	"
Renewal (days)	"	14	14	"	"	"
Recycling solution:						
Continuous flow	✓	✓	✓	✓	-	✓
Pulsed flow	-	-	-	-	✓	-
Temperature °C:						
Setpoint	21	-	-	22	23	-
Ambient	-	✓	✓	-	-	✓
Medium:						
Beads (only)	✓	✓	✓	✓	✓	✓
Beads:peat	-	-	-	-	✓	-
Light (µEm-2 s-1 PAR)	390	390	390	860	960	960
Fog (75% RH)	-	-	-	-	✓	✓/-
Cutting:						
Length (cm)	8-14	10-12	6	15	8	7
Node number	2-3	2-3	2-3	2 or 4	50	75
Number (per treatment)	46	45	39	24	45	51

[1] Full strength 2 ds/m; composition after Cooper (1979).

RESULTS

Sturt's Desert Pea (*Swainsona formosus*). Sturt's desert pea terminal cuttings were easy to root using the hydropropagation technique (Table 2a). NAA was toxic when applied at a rate of 10 mg/litre for 14 days. IBA did not increase percentage strike but did promote a larger root mass than cuttings which received no auxin. NAA and IBA used as quick dips (2500 mg/litre for 5 sec) were both beneficial to rooting in the mist bed (Table 2b).

Table 2a. Effect of auxin type on rooting of Sturt's desert pea and the presence of *Botrytis* sp. after 4 weeks hydropropagation.

Hormone	Rating (%)	Botrytis (%)	Strike (%)
Control (zero hormone)	3.08	0	92.9
IBA	3.48	0	98.9
NAA	1.44	0	36
LSD 0.05	0.37	ns	17.9
LSD 0.01	0.49	ns	23.5

Table 2b. Effect of auxin type on the rooting of Sturt's desert pea and on the incidence of *Botrytis* sp. after 4 weeks mist bed propagation.

Hormone	Rating (%)	Botrytis (%)	Strike (%)
Control (zero hormone)	2.52	85.3	77.7
IBA	2.90	59.8	88.8
NAA	3.19	66.3	93.2
LSD 0.05	0.28	20.9	7.8
LSD 0.01	0.37	29.3	11.0

In the hydropropagation system no *Botrytis* was present whereas a high incidence of *Botrytis* was present on cuttings propagated in the mist bed. *Fusarium oxysporum* was isolated from the roots, symptoms being root rot (browning) and wilting of the cutting.

Melaleuca gibbosa. Results in Table 3 show that either 2 ppm or 10 ppm IBA stimulated rooting. However the lower IBA concentration appeared to be the better treatment under nil-fog conditions. The number of roots produced was also greater in the absence of fog.

***Rosa banksiae* var. *banksiae*.** Incorporating IBA into the recycling solution was toxic to *Rosa banksiae* var. *banksiae* [syn. *R. banksiae* 'Alba'] and all cuttings died when IBA was present at a concentration of 5 ppm. Cuttings that were not treated with IBA rooted successfully and the early introduction of quarter-strength nutrient at day 5 to the hydropropagation recycling solution was beneficial to early root development. Cuttings receiving nutrients had increased root number and length compared to nil nutrients after 3 weeks and this was later reflected at week 6, with improved early shoot development (Table 4).

Table 3. Effect of auxin concentration on the rooting of *Melaleuca gibbosa* after 4 weeks hydropropagation in a fogged or nil-fogged environment.

Environment	Hormone (per liter)	Strike (%)	Root length maximum cm.	Total root number
Nil-fog	Control(zero IBA)	28	0.4	6.3
	IBA 2 mg	87	4.4	41.6
	IBA 10 mg	61	4.0	20.0
	LSD 0.05	-	1.4	9.4
	LSD 0.01	-	3.3	12.4
Fog	Control (zero IBA)	4	0.1	0.2
	IBA 2 mg	65	2.2	6.7
	IBA 10 mg	67	4.1	8.4
	LSD 0.05	-	1.2	3.9
	LSD 0.01	-	1.6	5.1

Table 4. Effect of nutrient timing during propagation on root and shoot developement of *Rosa banksiae* var. *banksiae*.

Nutrients started	Root		Shoot	
	number	length maximum (cm)	number	length total (cm)
	3 weeks		6 weeks	
None	0.2	3.9	0.9	2
Day 5	1.8	21.4	1.3	7
Day 10	1.1	9.8	1.7	3
LSD 0.05	0.8	10.1	0.5	2

Cuttings from each treatment were grown on in a standard pine-bark-based potting media and were assessed after 5 and 15 weeks. There was no significant carryover effect of the early nutrient introduction during propagation but hydropropagated cuttings did grow faster than mist-bed propagated cuttings.

Banksia ericifolia. Cuttings of this species swelled at the base, but did not root, when they were placed in plastic beads with continuously recycling water. Intermittent recycling (15 min on/15 min off) did not improve the result. When cuttings were placed in a medium consisting of 5 plastic beads : 1 peat moss (approximately v/v) 62% rooting was achieved in 6 weeks without recycling water. The rooting increased to 82% when intermittent recycling was used in combination with the beads/peat medium (Table 5).

Table 5. Effect of support medium and solution pulsing on the rooting of *Banksia ericifolia* using hydropropagation grown in a fogged environment.

Medium	Flow	Strike (%)		Callused or swelling (%)		Dead (%)	
		4 weeks	6 weeks	4 weeks	6 weeks	4 weeks	6 weeks
Beads	Pulsed	0	0	6	84	0	8
Beads	Continuous	0	0	19	90	0	10
Beads & Peat	Pulsed	60	82	0	15	0	4

Daphne odora. *Daphne odora* is considered to be of moderate difficulty to strike by conventional propagation. Incorporating IBA into the recycling solution at a concentration 10 mg/litre for a period of 14 days significantly advanced root development (Table 6a); 98% of cuttings were struck in 4 weeks compared to 71% for cuttings which received no auxin. Root number, maximum length, and root dry weight were all significantly increased. Incorporating nutrients into the solution at day 16 did not significantly increase root or shoot growth over the next 12 days.

By comparison, cuttings propagated in the mist bed were inferior in development after 4 weeks with only 37% of cuttings struck, fewer roots, and less growth (Table 6b). IBA (2,500 mg/litre for 5 sec) did not significantly improve rooting under mist-bed conditions.

Table 6a. Effect of hydropropagation on root development of *Daphne odora* after 4 weeks.

Treatment	Strike (%)		Root		Dry weight (g)	
			Number	Length (max.) (cm)	Shoot	Root
Control (zero IBA)	70.5	(50.5)	17.8	17.5	16.0	1.3
IBA	98.7	(88.3)	51.7	39.3	14.6	8.5
IBA + Nutrients	97.3	(80.7)	53.3	38.1	15.9	11.3
LSD 0.01	7.9	(15.4)	13.8	7.7	NS	5.1

Table 6b. Effect of mist bed propagation on root development of *Daphne odora* after 4 weeks.

Hormone	Strike (%)		Root	
			Number	Length (max.)(cm)
Control (zero IBA)	37	(16)	5.3	1.0
IBA	35	(16)	6.0	0.9
LSD 0.05	ns	ns	ns	ns

Note: ( ) Percentage of quality cuttings having >10 roots and the shortest root was >1.5 cm.

***Grevillea* Species and Hybrids**. Only limited success was achieved with Grevilleas. Cuttings of 'Poorinda Peter' developed basal callus but had not formed roots within 6 weeks. Nine per cent of Ivanhoe cuttings rooted after treatment with 2 ppm IBA for 7 days. However, if concentration of IBA was increased to 10 ppm, 84% of cuttings died within 6 weeks.

Under fog conditions 23% of *G. rosmarinifolia* cuttings rooted within 6 weeks and this increased to 63% if cuttings were exposed to 2 ppm IBA for 7 days. However, if cuttings were not maintained under fog conditions the IBA was toxic even at the low concentration of 2 ppm.

Eucalyptus ficifolia. The hydropropagation technique did not promote roots on cuttings of adult *Eucalyptus ficifolia*.

Hydropropagation did however stimulate the production of callus which had root-like appearance but lacked organised meristems. This callus developed on approximately 50% of two-leaf cuttings, and cuttings potted into a pine-bark media and held in a fogged environment have remained alive for approximately 11 months and developed new shoot growth up to 4 cm long.

CONCLUSION

For some plants e.g., *D. odora*, incorporating auxin at low concentration for short exposure time (2 to 14 days) can advance root initiation at optimal concentration and promote a high quality root development. However, auxin is not always necessary, and in some cases (e.g. *G. rosmarinifolia*) can be toxic even at low concentrations (2 ppm). The importance of hormone type and toxicity was highlighted by *S. formosus*.

The early addition of low-strength nutrients can be beneficial to advance early root and shoot development. Hydropropagated cuttings (e.g., *R. banksiae* var. *banksiae*) can be successfully grown on using standard pine-based potting media.

The failure of cuttings to root using hydropropagation may, in some instances, be due to inadequate aeration of the recycling solution. The use of aeration stones or intermittent recycling on a short time interval may be beneficial.

Using peat in the recycling solution was beneficial in promoting rooting as shown with *B. ericifolia*. Therefore, investigation of whether this was a pH effect or caused by other factors may prove useful.

Fogging in combination with hydropropagation can be mutually root enhancing for some plants, e.g., *G. rosmarinifolia* but may not be always necessary if the house relative humidity is maintained at a high level. However, fogging delays or reduces the risk of hormone toxicity.

Hydropropagation has potential but requires further experimentation before it could be commercially viable.

Acknowledgments. I wish to thank The Horticultural Research Development Corporation and The Australian Nurseryman's Association for funding the research; Bill Thompson (Industry Manager Fruit, IHD) for his research advice; Philip Moyle for writing computer programs and building of the temperature control system; Michelle Bankier and Fran Richardson for their technical assistance; Pearl Benn for word processing.

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Protea Stock Plant Nutrition

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INTRODUCTION

This paper describes some of the trials carried out at Proteaflora in Monbulk, Victoria. The general aim of the trials was to achieve consistent production of good quality cutting material. The work described in this paper concentrates on the importance of nitrogen and phosphorus in the rooting and subsequent growth of cuttings.

In previous experiments we established that nitrogen and phosphorus were the most critical elements in the fertilization of our stock plants.

In the trial described here two clonal cultivars were used: *Telopea* 'Shady Lady' red and *Leucospermum cordifolium* #27.

THE TRIAL

The stock plants under consideration were potted into 15-cm pots in standard Debco potting mix (pine bark and sand) without nitrogen, phosphorus, or potassium, but including those elements added to the bark during composting.

The plants were liquid fed twice weekly. Potassium, iron, calcium, and magnesium were applied equally to all plants. Nitrogen (applied as ammonium nitrate) and phosphorus (applied as monosodium phosphate) were applied at one of the following levels:

N0 = 0 ppm of nitrogen
N1 = 50 ppm of nitrogen
N2 = 100 ppm of nitrogen
N3 = 160 ppm of nitrogen
P0 = 0 ppm of phosphorus
P1 = 4.5 ppm of phosphorus
P2 = 7.0 ppm of phosphorus
P3 = 9.0 ppm of phosphorus
P4 = 14.0 ppm of phosphorus

After 12 months, 10 cuttings were taken from each group of plants at each fertilizer level. The cuttings were placed under normal propagation conditions (media: peat and perlite; environment: mist, igloo).

At the appropriate time assessments were made of:

- Strike rate
- Quality of the roots
- Vigour of cutting
- Subsequent growth of the cutting

Figure 1. Growth of *Telopea* 'Shady Lady' red stock plants in response to applications of N and P.

RESULTS AND DISCUSSION

***Telopea* 'Shady Lady' red.** Response of the stock plants to the various fertilizer levels is seen in Fig. 1. The stock plants responded to higher fertilizer levels, and generally the higher the level (within the range tested) the greater the number

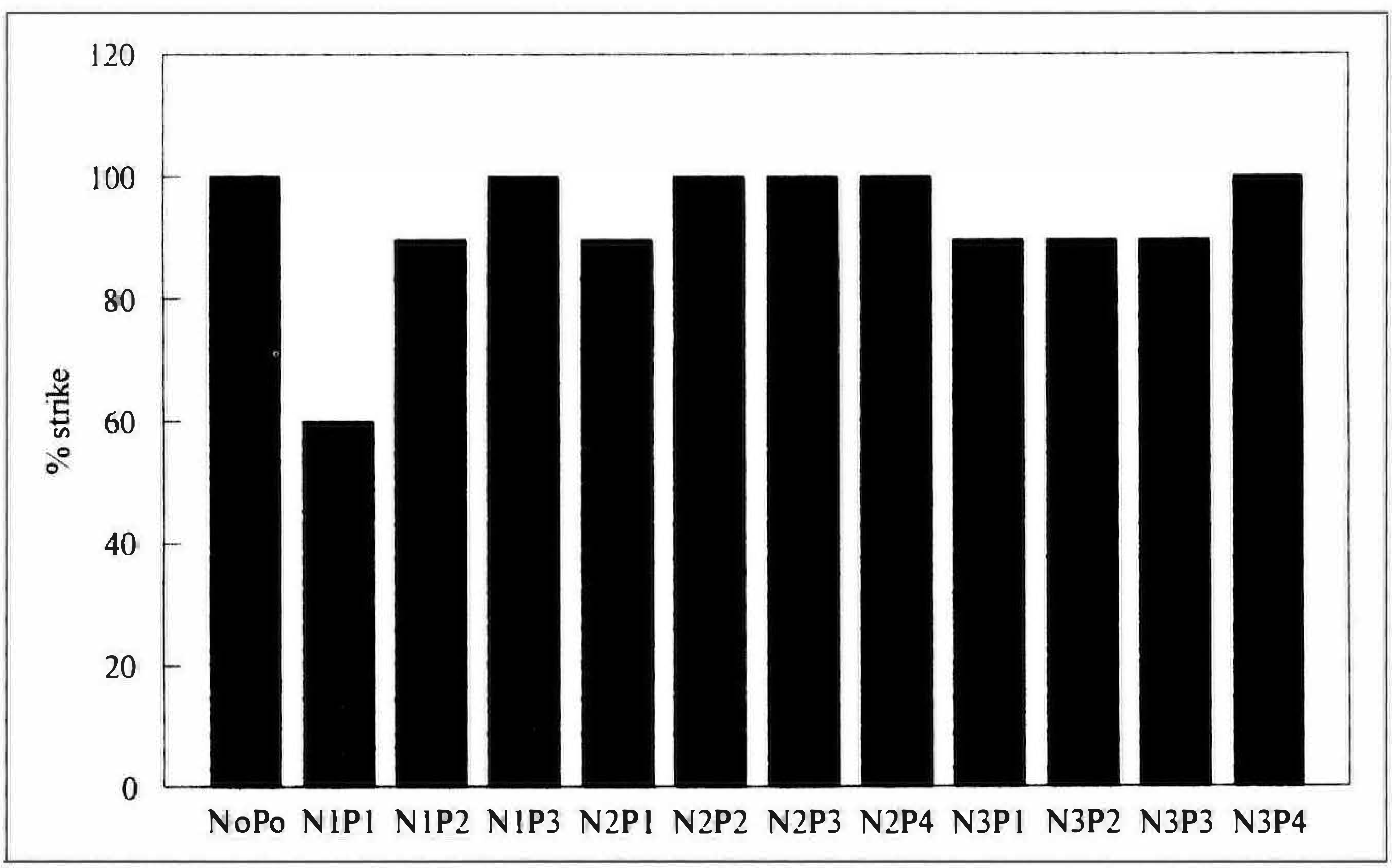

Figure 2. Percentage strike of *Telopea* 'Shady Lady' red as affected by N and P fertilization.

of cuttings that were available. As phosphorus was increased at the N2 and N3 levels of nitrogen, plant growth increased.

Strike rate was generally good at most levels of fertilizer (Fig. 2), but the number of buds increased with increasing fertilizer level (Fig. 3).

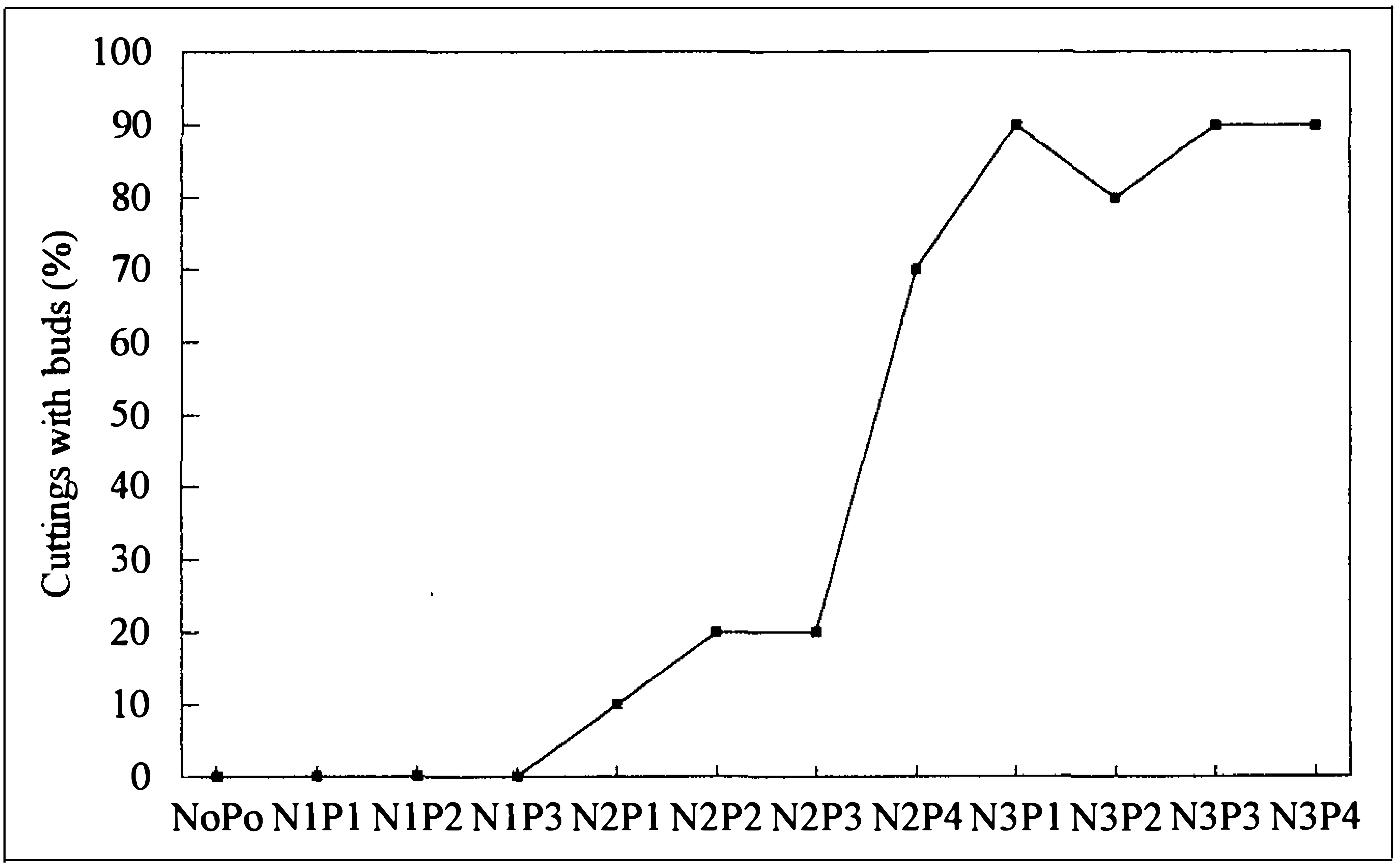

Figure 3. Percent of *Telopea* cuttings with growth buds.

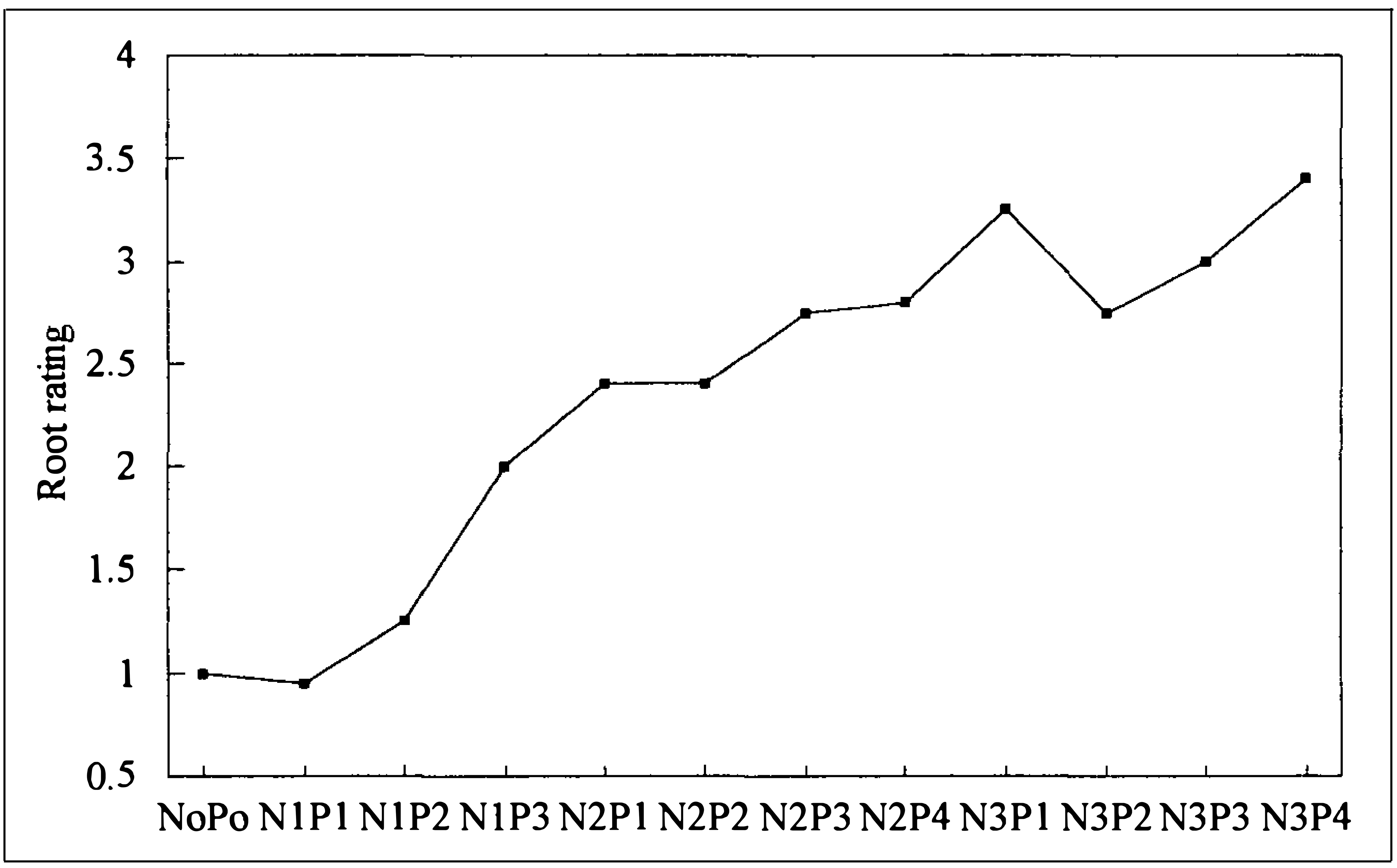

Figure 4. Root rating of *Telopea* cuttings (0 = worst; 4 = best).

A greater difference between the cuttings is seen when we examine the root development (Fig. 4). As phosphorus was increased at the N2 level of nitrogen both the roots and shoots of the cuttings improved.

The plants that grew on from the cuttings initially showed great differences in vigour but after 10 months they had all reached similar heights (Fig. 5).

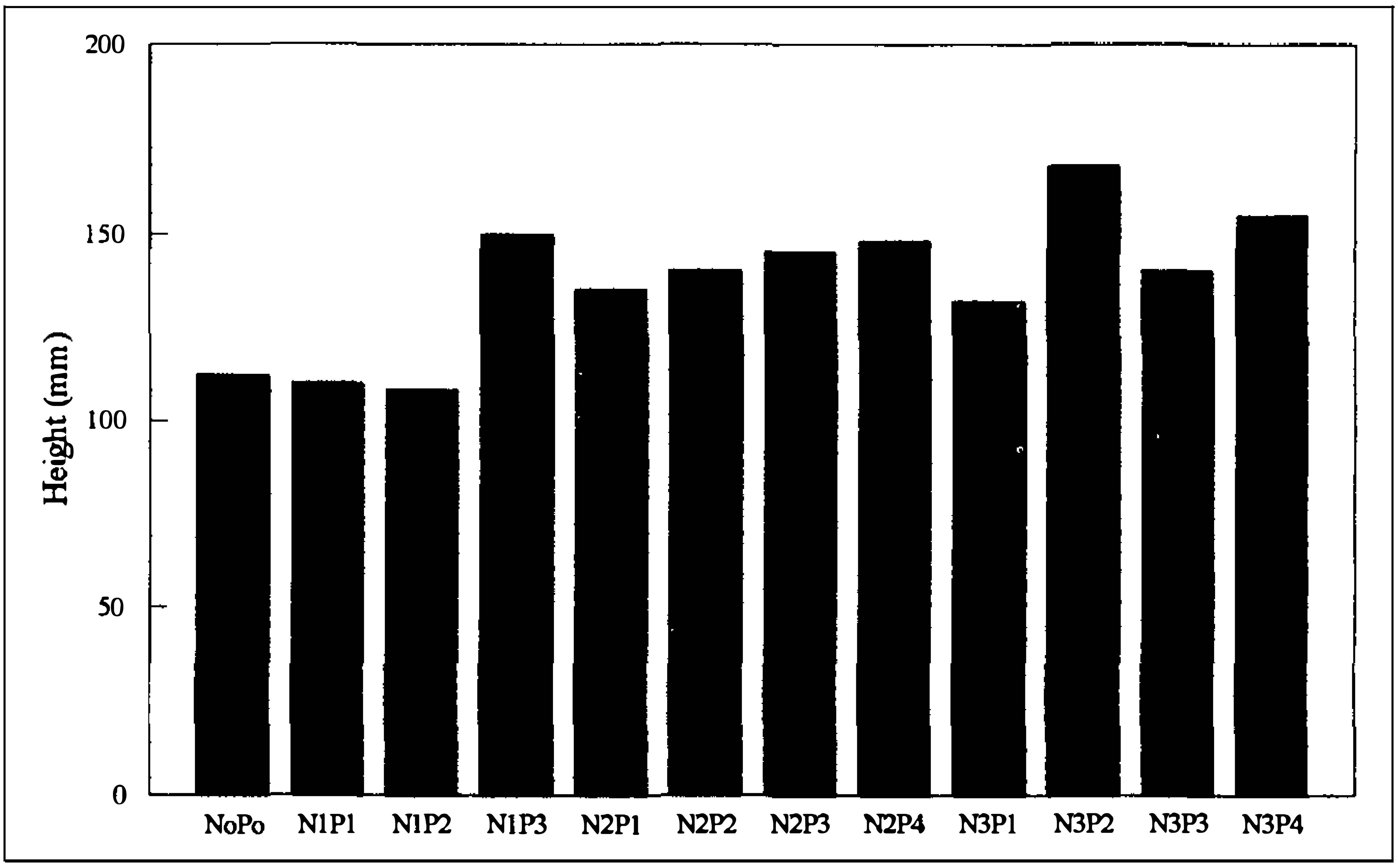

Figure 5. Height of *Telopea* plants 10 months after taking the cuttings.

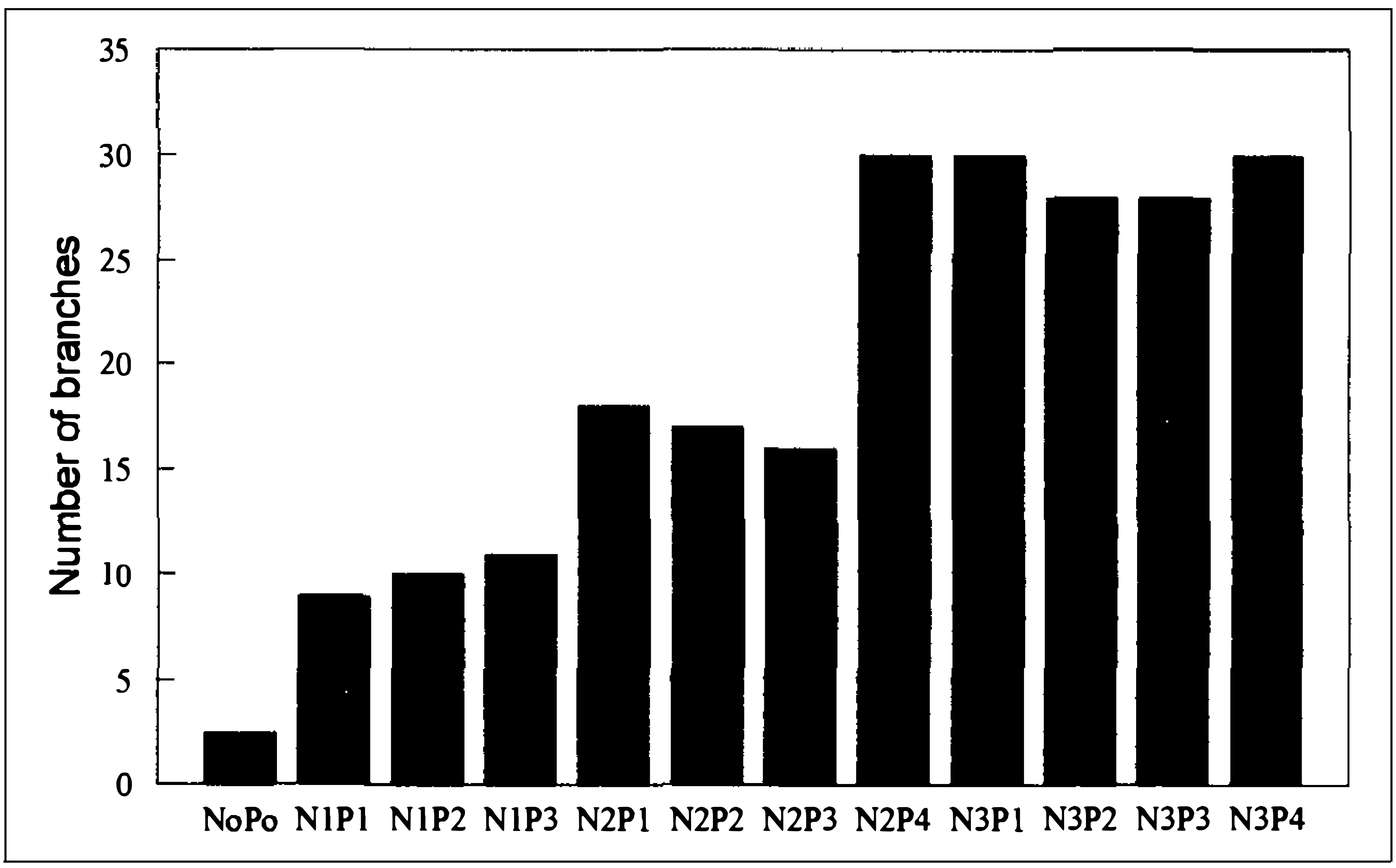

Figure 6. Mean number of branches on *Telopea* plants 10 months after taking the cuttings.

The total number of branches on the plants was clearly influenced by higher fertilzer levels of the stock plants (Fig. 6).

After considering all the factors we aim for a fertilizer level of N3P3.

Figure 7. Growth of *Leucospermum cordifolium* #27 stock plants as affected by applications of N and P.

***Leucospermum cordifolium* #27.** We restricted the fertilizer levels on the stock plants compared with the *Telopea* because earlier trials had indicated that N2P3 was the highest level at which the plants survived. Response in the current trial is shown in Fig. 7.

Early striking of cuttings (6 weeks) was enhanced at the N2P2 level, but the eventual strike rate (after 12 weeks) was similar at various levels (Fig. 8). Whilst the N0P0 level produced a good strike rate, the number of cuttings available per stock plant was very limited.

Root development was enhanced by increased phosphorus levels in the N1 range of nitrogen (Fig. 9). The N2 range was also beneficial until the phosphorus level was too high (N2P3). Good root development was noted also on the zero fertilizer cuttings.

The height at 10 months of plants arising from the propagation trial generally increased in relation to fertilizer level (Fig. 10). However the zero fertilizer level cuttings performed well. A possible explanation for this may be that a low nutrient level in the cutting encouraged the formation of proteoid roots which are very efficient feeding roots. The branchiness of the plants (Fig. 11) followed a similar pattern to the height.

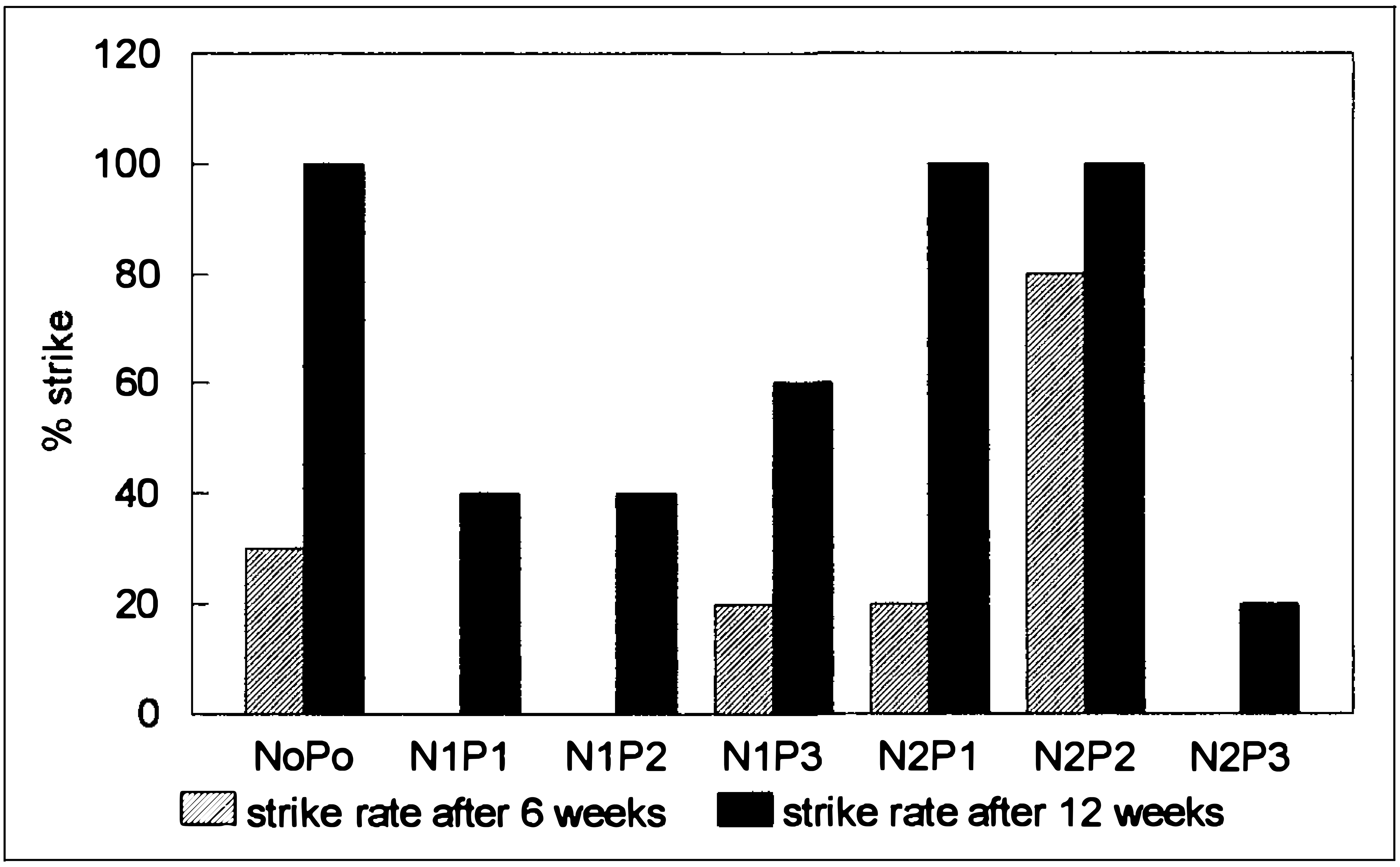

Figure 8. Strike rate of *Leucospermum cordifolium* cuttings at 6 and 12 weeks.

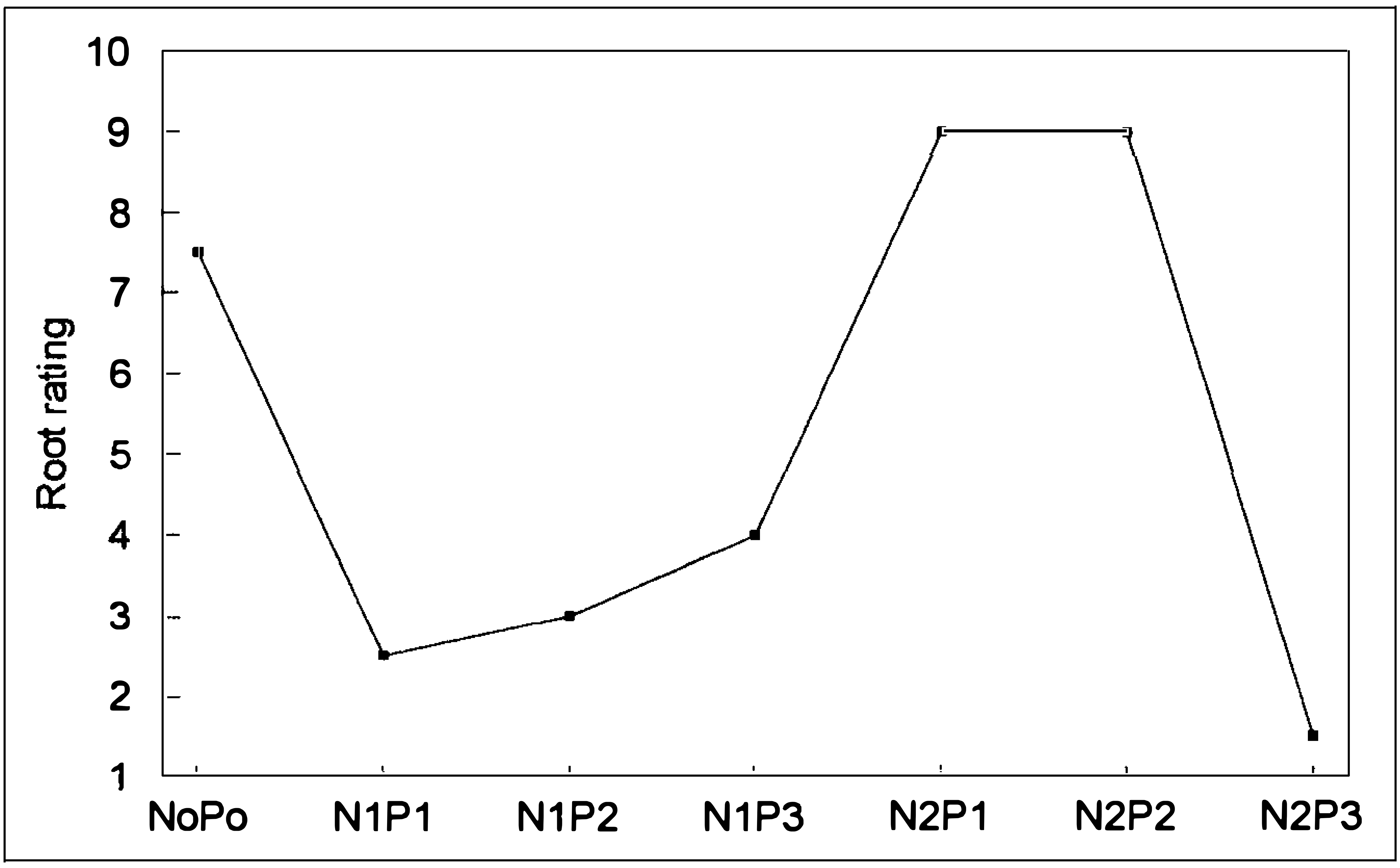

Figure 9. Root rating of *Leucospermum cordifolium* cuttings as affected by stock plant fertilization (0 = worst, 10 = best)

CONCLUSIONS

The nutritional balance in a stock plant influences the subsequent growth of cuttings taken from the plant. Optimum levels of fertilization have to be determined for each cultivar grown. To record strike rate alone as a measure of propagation success is only looking at half the story.

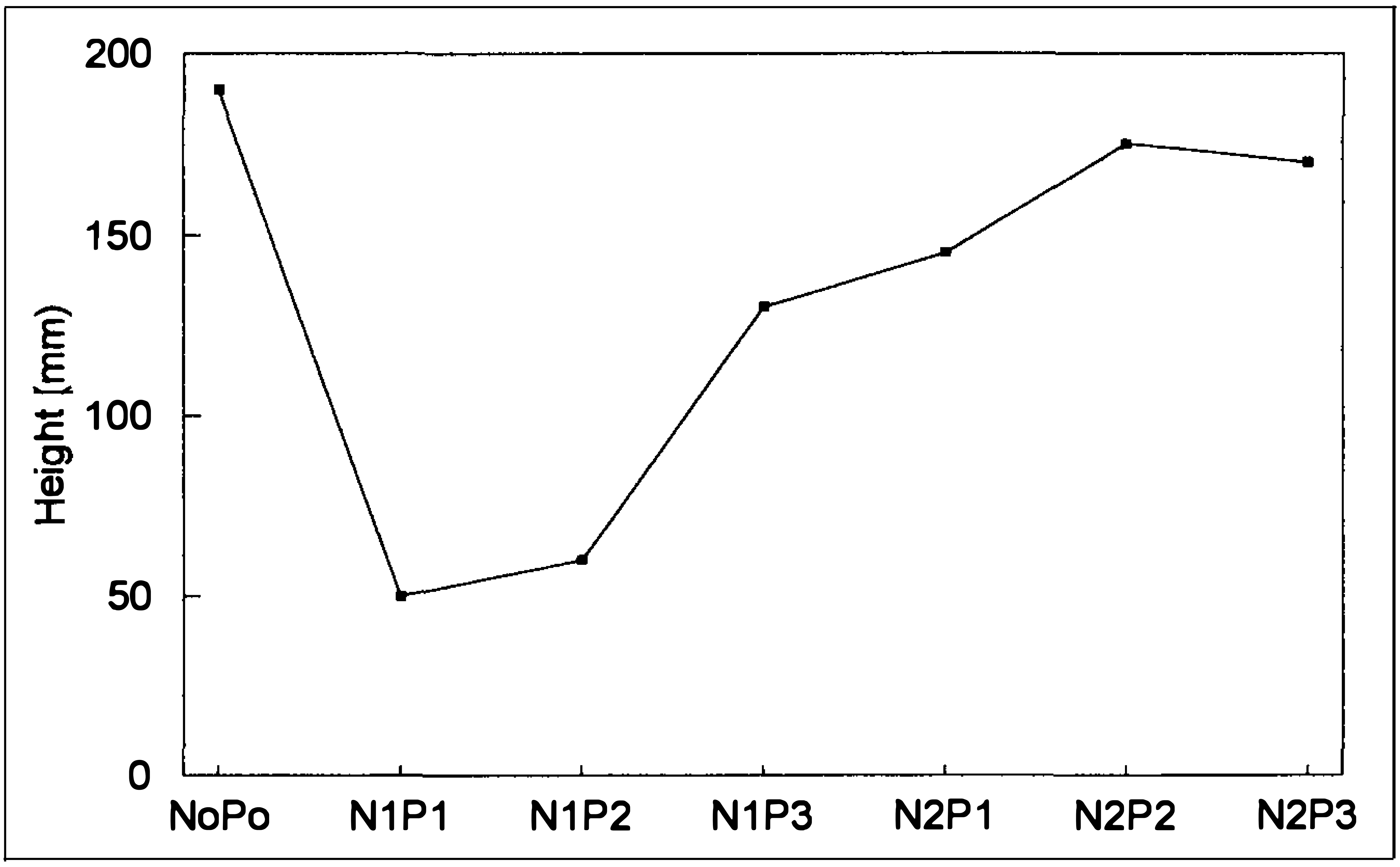

Figure 10. Height of *Leucospermum cordifolium* plants 10 months after propagation.

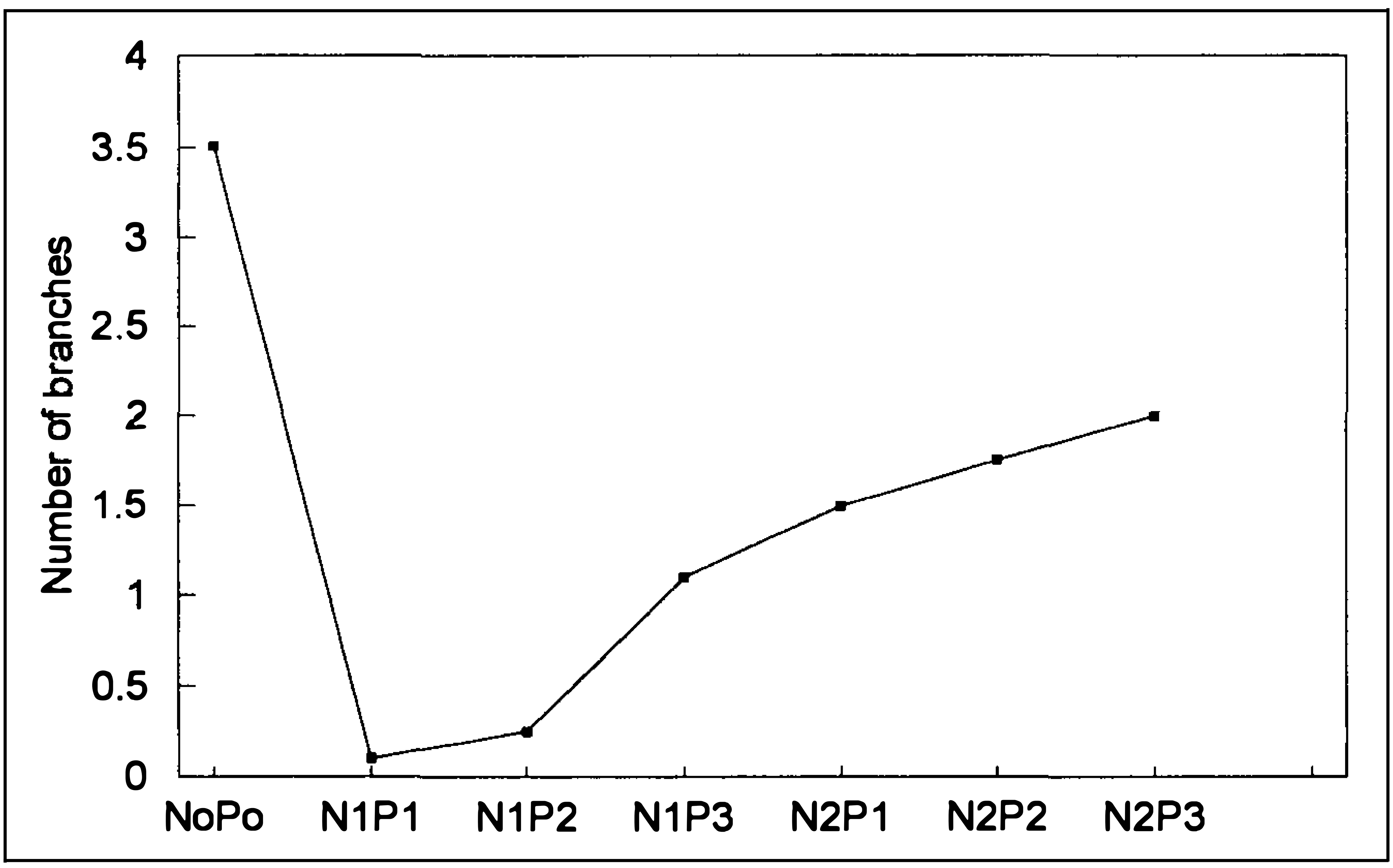

Figure 11. Mean number of branches on *Leucospermum cordifolium* plants 10 months after propagation.

Inspecting a Plant for Problems: What to Look For

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When one is presented with a problem during plant propagation or cultivation, the cause(s) may be known and the problem rectified. Under other circumstances, for example, through lack of knowledge of the environment in which you're working or the plant which you are producing, a remedy may not be as straightforward.

Early diagnosis and the adoption of a holistic attitude to the growing of any crop or line are paramount. Over time, if records are maintained one may learn to predict outbreaks of disease, pests, or other problems, and take precautions against recurrences.

DIAGNOSIS

Obvious Diagnosis. Frequently, the cause of a problem is known—or at least anticipated or prevented (e.g., *Hebe* is susceptible to scale, *Jacaranda* spp. are frost tender when juvenile).

Not-So-Obvious Diagnosis. Pride and professional arrogance are the downfall of many workplaces. It's better to acknowledge that there is a problem and go from there, than to think, "maybe it'll go away", or, "it's my fault so I have to deal with it...even if I don't know what it is." It's better to mention it to someone than pour through libraries of books trying to find an answer.

Within any business there is usually someone who has already done that, or merely has a heightened awareness of the plant or environment and its history.

Haven't Got a Clue. Sometimes the answers are not readily available. Sometimes the perceived or recommended solution isn't successful. This is when a methodical approach is required.

Inspecting a Plant for Problems. Regular inspection of plants and propagules is a must. Accept that any individual may not be superhuman. We can all miss the obvious. Encourage a team approach in the workplace. If someone notices a problem they should mention it. It's far better that the person ultimately responsible is told about something ad nauseam than that a plague infests the entire site. Complacency will only heighten a problem.

Assuming that there are obvious symptoms, grab a pest and disease book; look at the pictures, read what the author has to say. Often a $5.00 magazine or your old edition of Yates Garden Guide will supply the answers. If they're of no use, and you have ready access to texts published specifically for commercial growers, have a quick browse.

The following table may be of assistance with diagnosis. Remember that time is of the essence. If you spend a week trying to discover a remedy, it may be too late.

Table 1. Diagnosis of plant disorders.

Symptom	Possible causes	Treatment
Spindly growth	Low light (i.e., shade), excess water, high temperatures, plants too close together	Improve light, cut watering, reduce night temperature in greenhouse by cooling or ventilation, reduce feeding, increase spacing between plants
Growth reduced	Insufficient nutrients, and/or water	Feed more often, water more often
Old or lower leaves yellowing	Nitrogen deficiency	Increase proportion of nitrogen in your solution; change the form of nitrogen being used to a form which is easier to be taken in by the plant; check solubility of nitrogen in your formula; check pH (this can affect nutrient availability);and adjust if needed
Young leaves yellowing between veins	Iron deficiency	Spray or drench with iron
Purple leaves	Phosphorus deficiency	Apply superphosphate; in crease concentration of phosphorus in fertilizer
Root tips burnt or discoloured	Excess fertilizer or salts, toxic chemicals in medium (sometimes occurs when medium is fresh)	Leach thoroughly to wash away excess nutrient or toxin; check levels with an EC meter
Woody growth	Plants overhardened (i.e., exposed to tough conditions), or slow growing	Increase feeding, if problem is excessive, also prune
Stems very wet and decaying at base of the plant	Damping off disease caused by dirty conditions, high humidity and/or overcrowding	Thin out plants, apply fungicide
Algae, moss, or liverwort on surface of the medium	Excess moisture and nutrient on surface; doesn't harm plant initially but can impair flow of nutrient solution in the long term	Reduce watering, increase ventilation, use better draining medium; some chemicals (such as ferrous sulphate) can be used to kill algae and moss
Poor root growth	Excess nitrogen, poor aeration or drainage in medium, low temperature in medium, toxic chemicals	Determine which of these is the problem and act accordingly

The above disorders will often weaken a plant and increase its susceptibility to a range of more serious disorders. More often than not, more than one factor is involved in a plant's ultimate lack of vigour. Beginning at a base level, potential problems can be systematically considered and a solution will be forthcoming.

The following procedure, as published by The Australian Horticultural Correspondence School is a straightforward checklist for diagnosis.

FIRST

Systematically examine the plant and take note of any abnormalities.

1) Look at the leaves.
   - Are there abnormal markings, swellings, distorted shapes, etc.
   - Is there any discolouration
   - Are there dead patches or holes

2) Look at the fruit and flowers.
   - Are the flowers and fruit developing well
   - Is there any fruit drop
   - Is fruit undersized (this indicates weakness)

3) Look at the stems/branches.
   - Are the growth tips lush and growing fast (a healthy plant will have lush, growing tips. If other parts are damaged but the tips are lush, this can indicate that the plant is recovering from a previous problem)
   - Are there any abnormalities on the stems

4) Look at the roots.
   - Are the root tips lush and healthy or black and rotting
   - Are the roots strong or is the plant loose in the ground
   - Are roots coming out of the surface of the ground (this may indicate soil is frequently infertile or dry deep down—roots are coming up for water and nutrients; or soil has been eroded away)

5) What parts of the plant are most damaged—the parts which are most exposed to the problem will be most affected.
   - Frost damage occurs more on parts most exposed to frost
   - Sunburn occurs more on parts exposed more to the sun
   - Fruit rots may occur on branches close to the ground where disease spores can splash up from the soil
   - Small animals tend to eat lush growth in preference to older tough foliage, while grazing animals will eat lower growth on shrubs and trees that is within their reach

SECOND

Examine the surroundings and note anything which relates to abnormalities noticed when you examined the plant.

1) Soil.
   - Is it wet or dry
   - Is it well drained

2) Surrounding plants.
- Are they healthy or not
- Do they have similar symptoms

3) Environment.
- Consider exposure to wind, frost, sun, etc.
- Has anything been changed since the problem arose (e.g., a building or large tree which provided protection may have been removed)
- Is the plant at the bottom of a hill or slope? Could something have washed down from further up the hill (e.g., herbicide, disease from another plant, etc.)

THIRD
- Decide which group the main problem comes from—pest, disease, nutrition, environment, or weed; decide whether it is likely that there is more than one major problem
- Decide which of the five main groups the problem is most likely to come from
- Eliminate the groups you can
- Identify the groups you consider possible, and those you are sure of

FOURTH

Consult a text, or contact an entomologist, nematologist, field extension officer, or colleague with your deductions/eliminations in mind. Alternatively, cross-reference the genus, species, or cultivar of plant, using a reliable reference with the most likely disorder.

If you are still unsure of an accurate diagnosis, make an educated guess and devise a treatment which could be used. Apply the treatment and monitor the results according to whether or not the plant responds.

Remember that lack of vigour, chlorosis, or necrosis can be the result of more than just 'pests' or 'diseases'. Problems that can be encountered can include:

1) PESTS—ranging from the microscopic to dogs or rabbits

2) DISEASES—commonly fungi, viruses, or bacteria

3) ENVIRONMENTAL DISORDERS—including pollutants, soils, and climatic considerations

4) NUTRITIONAL EXTREMES—in relation to the plant's needs

5) WEEDS: which often harbour pests and diseases and will compete with the desirable plant for its requirements

6) INSECTS—frequently the most common pests experienced. If you conclude that an insect is the causative agent consider the following list, which includes the most common insect pests.
- INSECTS (and other pests) WHICH CHEW ABOVE GROUND: ants, armyworm, bugs, beetles, caterpillars, crickets, cutworm, earwig, flea beetle, grasshopper, leafminer, leafroller, leaf skeletonizer,sawfly, slug, snail, springtail, and weevil.

- INSECTS (and other pests) WHICH SUCK PLANT PARTS ABOVEGROUND: aphid, harlequin bug, lace bug, leafhopper, mealy bug, mite, psyllid, scale, squash bug, thrip, tree hopper, and whitefly.
- INSECTS (and other pests) WHICH FEED BELOW GROUND: root aphid, root nematodes, root borer, rootworm, root weevil, wooly aphid, wireworm, and beetle larvae.
- BORERS (including into fruit): codling moth, bark beetle, corn earworm, white pine weevil, melon worm, longicon beetle, European apple sawfly, etc.

Given that we are all concerned with our health, and that of our staff and families, and money-cum-financial constraints, the remedy you decide to adopt should bear at least these factors in mind. Opt for the least dangerous treatment; it will frequently be the most successful and cheapest!

Research the life cycle of a disease or pest and consider the implementation of biocontrols or integrated pest management techniques. Dare to consult organic or biodynamic growers. It may be that something can be effectively lured from your growing area, and subsequently prevented or at least reduced in its impact.

Consider the overall environment in which your production occurs, and the conditions under which your plants are growing. How closely do they emulate the indigenous environment of the species?

Remember that prevention IS better than cure.

The Propagation of Australian Native Plants from Cuttings at the Australian National Botanic Gardens (ANBG)

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INTRODUCTION

The Australian National Botanic Gardens (ANBG) is a major scientific and educational resource, and has the world's most comprehensive display of living Australian native plants.

The ANBG occupies 90 ha on the lower slopes of Black Mountain in Canberra, together with 80 ha at Jervis Bay (Jervis Bay Botanic Gardens). There are approximately 91,000 plants, representing more than 5,900 taxa, growing at the ANBG. These plants are held in open-ground plantings, permanent pot collections and in glasshouses.

The objectives of the ANBG are to grow, study, and promote Australia's indigenous flora and vegetative propagation plays a major role in the achievement of these objectives.

VEGETATIVE PROPAGATION

A significant function of the ANBG's study and display of the Australian flora is the correct identification of plants. The maintenance of this attribute is guaranteed by vegetative or clonal propagation.

The preferred method of propagation is by the use of cuttings because they are easy to prepare, and are successful with a wide range of species. Grafts have been used when plants have either shown a susceptibility to root fungi or are difficult; however, for long-term clonal continuity, vegetative propagation is essential.

The nursery at the ANBG propagates approximately 500 plant species from cuttings each year and produces more than 12,000 plants.

COLLECTION OF CUTTING MATERIAL

Field Collection. Most of the plant material entering the gardens is collected on field trips, by staff or other authorised collectors.

After collection, cutting material is wrapped in wet newspaper and then placed in plastic bags and kept cool either in an esky or a portable refrigerator. Plant material prepared in this way will keep fresh for several days; this allows time for collection from remote locations.

Collection within the Gardens. Repropagation of existing collections is carried out throughout the year. Lists of the plants required are prepared and staff use reference maps to locate particular stock plants. Clear plastic bags are used to store cutting material, which is collected in the morning to minimise stress. Bags are kept out of direct sunlight whenever possible and a small amount of water is sprayed over cutting material. When the plant material reaches the nursery the bags are placed in a refrigerator and kept at approximately 4C.

PREPARATION OF CUTTING MATERIAL

The cutting material selected is usually semi-firm new growth and cuttings are taken initially at a length of about 150 mm when possible. Preparation involves the retention of two to three sets of leaves at the apical end of the cutting. The other leaves are stripped away, taking care to make sure that the stem is not damaged. The cuttings are then held between the thumb and index finger which are lined up with either the first or second node below the bottom set of leaves. The basal ends of the cuttings are then cut just below the fingers and immediately dipped in the hormone solution for a maximum of 5 sec depending on the softness of the plant material. The purpose of this procedure is:

1) To limit the length of the cutting—especially the distance between where the roots will form and the bottom leaves. This will mean that the cutting will not become top heavy later and be difficult to prune.

2) To make a fresh cut on the cuttings—the removal of at least 3 cm of the stem opens the transpiration stream and allows the cutting to take up the liquid hormone.

3) To make all cuttings the same length so they can be dipped to give uniform uptake of the hormone.

After dipping, the cuttings are put to one side for a minute or two to allow excess liquid to evaporate. They are then placed in punnets of cutting mix so that the bottom leaves of each cutting are just above the surface. The cuttings are then gently firmed down and watered before placing in the propagation house. All cuttings are drenched with an eradicant, systemic fungicide and this is repeated on a weekly basis.

MEDIUM

The cutting propagation medium used at the ANBG is 5 perlite : 1 peat (v/v), which is mixed before being steam sterilised for 15 min. With an air-filled porosity of about 35%, this mix has excellent drainage and supports healthy root growth. It has a number of advantages:

1) Roots form uniformly throughout the mix because the air space is uniformly distributed throughout the mix.

2) It is easy to check whether cuttings are rooted by giving a gentle tug. (Mixes which contain sand tend to be come compacted and tight around the cuttings, making it difficult to tell whether they are rooted or not.)

3) Rooted cuttings are easy to extract without damage—this is especially relevant for cuttings with brittle roots, for example some *Grevillea* spp., *Hakea* spp., and *Acacia* spp.

PROPAGATION STRUCTURE

The ANBG propagation glasshouse uses a fogging system with the fog produced by the compressed air method. This method gives a droplet size of between 10 and 20 microns. Controls are set for 90% relative humidity throughout the year.

The glasshouse is covered with shade cloth which provides a 50% reduction of light. Propagation benches have electric cables for heating and the temperature is maintained at 24C for most of the year but is reduced to 15C during the hotter months.

SELECTION OF TREATMENT

Selection of treatment or hormone is made by the analysis of information provided by the ANBG computer data base (IBIS - Integrated Botanical Information System). This system allows data input and processing for all aspects of the ANBG's operations including the living collections, herbarium, and research.

It is an easily accessible source of information about all plants that have been collected and propagated in the gardens. Propagation history includes the range of hormones used, date of application, number of cuttings made, strike rates, and present location of cuttings or plants.

When propagation has been difficult, unsuccessful, or a new species is being tried, it is treated as a mini trial with 2 or more hormone treatments used. This procedure is continued until all feasible variations are tried or plants are successfully propagated. Analysis of the information stored by IBIS allows accurate assessment of propagation history and the elimination of repetitious treatments.

HORMONES AND OTHER TREATMENTS

Auxins. Indole-3-butyric acid (IBA) has been found to be the most effective rooting hormone for a wide range of Australian native plants at the ANBG. However, combinations of IBA and NAA (naphthaleneacetic acid) are also effective for many taxa. All rooting hormones used at the ANBG are liquid (Ellyard, 1981a) and are made by dissolving pure hormone in a 50% ethanol/water solution. The hormones are stored in light-excluding bottles in a refrigerator and when used, a small quantity is poured into a petrie dish. The petrie dish is kept covered when not in use to minimise evaporation and possible contamination. At the end of each day all used hormone is poured into a jar and kept for safe disposal.

The response to rooting hormone treatments may vary from species to species and at different times of the year. In many cases, cuttings will strike without the use of hormones; however, hormones frequently speed up the process, improve root systems, and provide more uniform results. The list below indicates some treatments which have been found to be consistently successful for the families and genera indicated.

1) 500 ppm IBA / 500 ppm NAA
   Asteraceae: *Brachyscome*, *Cassinia*, *Helichrysum*, *Senecio*
   Chenopodiaceae: *Maireana*, *Rhagodia*, *Atriplex*
   Cunoniaceae: *Bauera*, *Ceratopetalum*
   Epacridaceae: *Epacris*
   Goodeniaceae: *Dampiera*, *Goodenia*, *Lechenaultia*, *Scaevola*
   Fabaceae: *Dillwynia*, *Hardenbergia*, *Pultenaea*
   Myrtaceae: *Calytrix*, *Darwinia*, *Kunzea*, *Leptospermum*
   Rutaceae: *Boronia*, *Crowea*, *Zieria*

2) 1,000 ppm IBA / 250 ppm NAA
   Rutaceae: *Boronia*, *Zieria*

3) 2,000 ppm IBA
   Cunoniaceae: *Bauera*, *Ceratopetalum*
   Dilleniaceae: *Hibbertia*

Fabaceae: *Pultenaea*
Goodeniaceae: *Scaevola*
Lamiaceae: *Prostanthera, Westringia, Hemigenia*
Myrtaceae: *Melaleuca, Baeckea, Darwinia, Kunzea*
Rutaceae: *Eriostemon*
Sapindaceae: *Dodonaea*
Thymelaeaceae: *Pimelea*

4) 4,000 ppm IBA
Araliaceae: *Astrotricha*
Fabaceae: *Bossiaea*
Myrtaceae: *Callistemon, Calothamnus, Eremaea*
Proteaceae: *Telopea, Lambertia, Grevillea, Adenanthos, Isopogon, Petrophile*
Rhamnaceae: *Pomaderris*

5) 4,000 ppm IBA / 2,000 ppm NAA
Rutaceae: *Eriostemon*

6) 6,000 ppm IBA
Mimosaceae: *Acacia*
Proteaceae: *Hakea, Banksia, Persoonia*

7) 1,000 ppm IBA / 200 ppm NAA / 200 ppm 2,4-D (Ellyard, 1981b)
Proteaceae: *Persoonia*

Cytokinins. Some trials have been carried out on those *Acacia* species which have compound leaves and other taxa that have a tendency to drop leaves quickly after cutting. Soaking the basal ends of cuttings in a solution containing kinetin before dipping in an IBA solution has given some encouraging results. (Richmond and Lang, 1957; Mothes and Englebrecht, 1961).

CONCLUSIONS

The propagation system used at the ANBG has produced good results given the wide range of taxa being attempted. Using the methods and the computerised recording techniques outlined above, we are succeeding in propagating difficult and hitherto untried taxa.

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Introduction to Growing Perennials from Seed

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INTRODUCTION

Perennials in the last decade have enjoyed enormous success amongst the gardening public. The movement to a more free-form and care-free style of gardening, and in particular the "cottage gardening" trend has buoyed sales of perennials. They now account for a sizeable but undocumented market share. Nursery persons unfamiliar with perennials have found it necessary to grow them to maintain sales. This has resulted in some cases with inappropriate propagation techniques and has resulted in plants being produced below the growers' usual standard.

WHAT IS A PERENNIAL?

Botanically a perennial is any plant that lives from year to year. Horticulturally the definition is a little stricter and generally refers to any plant that lives for more than a year and is herbaceous. This excludes all woody plants, although some plants with secondary thickening are considered as perennials because of their horticultural use. Examples would include *Artemisia arborescens*, *Romneya coulteri*, and the native *Parahebe perfoliata*. *Echinacea purpurea*, *Thalictrum delavayi*, and *Delphinium* are examples of deciduous perennials which become completely dormant in winter. Others such as *Campanula trachelium*, *Anemone* × *hybrida*, and *Achillea* 'Moonshine' have flowering stems which are deciduous in winter but in our climate have basal growth which is maintained. Evergreen groundcovers such as *Dianthus* 'Doris', *Anthemis tinctoria*, and *Aurina saxatilis* are often categorised as perennials.

PROPAGATION METHODS

The full range of propagating techniques can be applied to perennials. Vegetative propagation is carried out to maintain named cultivars. Softwood tip cuttings are a commonly used method and are the most desirable because it is easy to produce an uniform crop. Other methods include the use of root cuttings and the division of the crown in winter. More recently some genera, *Astilbe* and *Hosta*, are being propagated in tissue culture.

Seed propagation is by far the cheapest method. There is no need to maintain large numbers of stock plants and the actual production of the plant requires fewer labour units per plant. With careful selection of seed sources, variation inherent in propagation by seed can be minimised. Some cultivars come true from seed so evenly that they have been accorded cultivar names, examples would include *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm', *Aubretia* 'Novalis Blue', and *Lobelia* × *speciosa* 'Compliment'.

CHALLENGES

Production of perennials from seed offers some challenges compared to that of annual plant cultivars. Generally the germination rates vary widely between cultivars, and careful year-to-year monitoring is necessary so that enough seed is sown to produce the required number of plants for sale. Not as much work has gone into optimising seed germination as has been carried out on the high volume annual cultivars such as petunias and marigolds.

Germination in genera such as *Campanula* and *Gunnera* can be erratic and uneven. Sometimes it can take 8 weeks from first germination to optimum emergence. This makes production scheduling difficult because the tray may need to be gone over a number of times to obtain the required number of plants. These difficult types should be noted and in subsequent years they should be oversown so that pricking out need only be carried out once.

As a generalisation, the seedlings of perennials tend to be smaller and they are certainly softer than those of woody plants. Techniques need to be modified so as not to damage or check the growth of the resulting plants. Seedlings should be handled only by the cotyledons. This minimises damage to soft stem tissues. It is best to transplant seedlings as soon as practical so growth is not checked, and because transplanting then is fastest. This creates challenges when working with genera such as *Digitalis* and *Trachelium* which have very fine seed. The most skilled transplanter should be used and the seedlings should be inserted into media sieved finer than normal.

TIPS AND TECHNIQUES

Some perennial plants require specialised treatment to ensure germination. The commonest treatment is stratification, designed to replicate the cold or freezing winters of the areas of origin of genera such as *Dicentra* or *Paeonia*. The seed trays are be placed in the refrigerator for usually 8 weeks. There are very few places in Australia where plants that require this treatment will thrive. If seed doesn't germinate when sown in autumn and subjected to your normal winters then it isn't an appropriate species to grow in your area. A good example would be *Helleborus* which germinates readily in spring after an autumn sowing in southern climates, but is progressively more difficult the further north you go.

The exact management techniques are not particularly important as long as they work for you, encompass the basics of propagation and have been modified for the peculiarities of the plants grown. I aim to obtain 1000 seedlings per standard nursery flat. The medium is composed of approximately 4 pounded pine bark : 1 fine sand (v/v), has an air-filled porosity of about 15% and no fertiliser added. This sowing density and low nutrient content is acceptable if the seedlings are transplanted young and pushed on quickly.

Attention to hygiene is important because many perennials are susceptible to damping off diseases. Standard nursery practice of clean media and containers should be sufficient to prevent most infections. I prefer not to incorporate a dry fungicide with the soil medium, or to drench trays after sowing. I now only drench when an infection is apparent. Germination results seem to be improved, which may be due to other reasons, but certainly results are no worse.

Producing a saleable perennial in a pot can take a great deal of skill. Timing of sowing, potting, and stopping are critical in producing a compact flowering plant. An understanding of a plant's life cycle and flowering times is essential. Careful recording of your observations and experimentation will give you the information needed to add new perennials to your nursery plan.

SEED SOURCES

Perennial seed can be obtained from the major Australian and New Zealand seed suppliers. They don't list in their catalogues all the perennials that they can obtain so an enquiry is worthwhile for particular requirements. Some seed merchants in Holland and Germany will handle small orders from nurseries and are reliable suppliers of a wide range of fresh seed.

Specialist overseas garden societies can be rewarding sources of new and unusual perennial plants to those who join them. Many of them have a free seed exchange to which members can subscribe and obtain small packets of seeds. The larger societies can have up to 6000 taxa listed.

One source of seed that should not be ignored is collecting your own. A few plants can provide enough seed for your sowing requirements. Taxa in similar genera should be isolated to prevent any hybridisation. For example, *Digitalis* is very promiscuous. Plant seed stock plants in a place where they are regularly visited because some seed ripens suddenly and then is shed, for example *Euphorbia* and *Geranium*, and protect them from tidy gardeners with secateurs.

CONCLUSION

Attention to detail will result in the successful production of perennials from seed.

The Future—Computer Applications

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INTRODUCTION

In my view, the future will see the use of computer systems within nurseries extending beyond the administrative functions to cover production and operational functions. The question facing nursery managers will change from "What can computers be used for?" to "What should computers be used for?" Table 1 lists some typical computer applications.

Table 1. Typical computer applications.

Market	Function	Application
Horizontal market software	Word processing	Price lists, correspondence, stock lists, instructions
	Spread sheets	Budgets, production schedules, cash flow projections
	Data bases	Mailing lists, plant lists, sales prospects
	Accounting	Accounts receivable, general ledger, cash book bank reconciliation, accounts payable, payroll, finished goods stock
	Project management	Major landscape developments
	Point of sale	Retail stock, management communications, customer stock lists, purchasing, supplier stock lists
Vertical market software	Production stock	Future stock availability, order fulfillment
	Planning, scheduling	Cost efficiency, quality control
	Production costing	Inventory reduction, profitable pricing, market specialisation

In the future businesses will move down through the table (Table 1) of applications. Applications at the lower end of the Table 1 have quite different characteristics from those at the top.

The applications can be broadly categorized as horizontal market software and vertical market software.

Horizontal market software is developed as single products designed to meet the needs of all industries. The software is often sold through retail stores, the price is relatively low, and training can be obtained from a wide variety of institutions.

Vertical market software is developed by small specialist firms selling direct to the end user. The software is designed to meet the specific needs of a single industry. The cost of the software is much higher. Training is often only available from the developer.

Other changes occur as we move down the table: the users become increasingly dependent upon the computer system, the computers are generally larger with multiple terminals, and the installation requires a greater commitment from all staff to ensure the efficient operation of the system.

One of the keys to business success, in general, is to differentiate the products and services offered by the business from competitors products and services. The applications at the lower end of the table must therefore be capable of adapting to the unique characteristics of the business.

The applications will often require "tailor made" modifications to suit each individual user's needs. The software must be capable of continued modification as the business changes in response to new market opportunities. At the top of the table the business must adapt to the software; at the lower end of the table the software must adapt to the business.

Applications at the lower end can achieve much greater returns for the user. These applications can identify the profitable operations within a business and the software itself will often make new customer services possible and open new market opportunities. By achieving more efficient operations these applications have the potential to release large amounts of working capital.

MAKING INVESTMENT DECISIONS

Making decisions about new computer applications can often appear daunting. As with all investment decisions, a methodical and detailed analysis of the advantages and disadvantages is required.

Table 2 lists some of the possible advantages and disadvantages that could flow from a particular installation.

Table 2. Advantages and disadvantages of computer systems.

Advantages of computer systems

Advantage	Typical application
Provide new skills	Word processing
Volume processing	Invoicing
Improved management decisions	Credit control
Detailed interrogation of data	Sales analysis
Reduced operating expenses	Order processing
Reduced capital investment	Stock, debtors
Smaller stock range	Detailed costing
Communication	Product stock lists

Table 2 (Continued). Advantages and disadvantages of computer systems.

Disadvantages of computer systems

New skills to be learned
Investment of time and money
New expenses
Less social contact
Increased vulnerability

In the long run, the only reason to install a computer is to increase the profitability of your business.

Table 3 can be used to determine the initial economic evaluation of a computer system.

Table 3. Economic evaluation chart for proposed computer installation.

Capital costs:

A. Total cost of equipment and installation
B. Total cost of staff training
C. Total cost of all software and installation
D. Cost of entering initial data
E. (A+B+C+D)

Capital savings:

F. Reduction in stock value
G. Reduction in total value of debtors
H. (E-F-G) Proceed if negative
J. (H/100)

New Revenue:

K. Increase in weekly sales
L. % profit on sales
M. (K*L/100)

Expense savings:

N. Number of man hours saved each week
P. Hourly total cost of labour
R. (N*P)
S. Other weekly cost savings
T. (M+R+S)

New expenses:

U. Cost of software maintenance per week
V. (T-U-J) weekly savings, proceed if positive

FUTURE CHANGES IN COMPUTER TECHNOLOGY

The following is a list of some of the recent technological developments that should find useful applications within horticulture over the coming decade.

- Increasing use of communications between computer systems, both suppliers with customers and customers with suppliers.
- New techniques for data collection and data entry, including bar code scanners, voice recognition, touch screens, and hand-write tablets.
- Application of problem-solving software for plant identification, disease diagnosis, and for the selection of plants for specific environments.
- Integration of computer technology with video disks to aid plant identification, disease diagnosis, and plant selection by end users.

SUMMARY

The horticulture industry has been rather slow to accept computer technology to date. This has been in part due to the lack of applications specifically designed to meet the needs of the industry an in part to a natural conservatism within the industry. The future will see a much wider acceptance as new applications and new technology are adapted to the needs of the industry.

Banks and airlines would not be competitive today without their extensive use of computer systems. In a few years time the same may well be said of plant nurseries.

New Alpine Plants to Propagate

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INTRODUCTION

At the Snowline Landscapes Australian alpine wildflower nursery, we have over 100 species in cultivation. Many have perfumed flowers or foliage and most have not been introduced to the horticulture industry.

The nursery is in Alpine Ash Forest at 1000 m altitude, 9 km northwest of Falls Creek, Victoria and is regularly covered by up to 1 m of snow in winter. It covers 1200 m^2 and includes a solar- and gas-powered greenhouse and automatic-watering system.

When the nursery was established in 1983, little was known of the growth patterns of these plants. Initially, plants were collected from the wild and their growth observed. Those species which flourished were selected for propagation and the remainder are at the experimental stage.

Plants are propagated from wild stock by seed, cuttings, or division. Plants are potted into a standard commercially available mix then grown on in polystyrene boxes to protect the roots from freezing.

Many species have a germination success rate of more than 70% with no treatment. Some species require stratification, as do those in the Leguminosae family.

It has been found (Maclurcan, 1992) that most Australian plants have mycorrhizal associations. These improve plant growth and resistance to drought and disease. Inoculation is achieved by incorporating a small quantity of alpine soil into the seed raising mix.

Suitable cutting material is difficult to obtain in the wild as plant growth form varies according to aspect and exposure. Plants propagated by cuttings generally have short, woody branches with little distance between leaf nodes.

Many ground cover type species are easily propagated by division and have a high growth rate.

The native conditions in which a species flourishes must be considered when attempting to cultivate these plants for the horticulture industry.

Plant communities vary according to soil type, aspect or exposure, altitude, and water.

Bogong High Plains is an old uplifted plain with well-weathered, gently undulating landscape. Sphagnum moss beds are found in the base of the saucer-like land form, surrounded by grasslands, then increasingly taller woody shrubs until there are trees at the apex of the small hills. This pattern arises largely from the effect of 'frost hollows' where colder air sinks to the lowest point of the landscape.

Soils are very shallow, stony, sandy, or organic loams that are fine, porous, highly organic, acidic (pH 5.5 in grasslands, 3.5 in mossbeds), strongly leached, and have low availability of nitrogen, calcium, and phosphorus. Mean annual temperature is 5C and mean annual precipitation is 2250 mm, of which 30% to 50% is from snow.

Plant growth is rapid with species found in the relatively deep, well-watered soils of the grasslands. *Craspedia* spp. and *Gentianella diemensis* sprout from tuberous-type roots to flower in 6 to 10 weeks. Where plants must contend with shallow, stony soils and exposure to cold, desiccating winds, growth is slow and often produces bonsai forms with plant age estimated in hundreds of years.

IMPLICATIONS FOR HORTICULTURE INDUSTRY

These alpine plants are "new" and many are easy to propagate. However, little is known about them.

An important consideration is their ability to survive or, preferably, thrive in environments other than alpine. A few species have been available within the horticulture trade for some years e.g., *Scleranthus biflorus*, *Wahlenbergia gloriosa*, *Helipterum anthemoides* (hybrid form marketed as baby's breath), *Prostanthera cuneata*, *Brachycome rigidula*, and *Hovea montana*.

Over the last 10 years we have tested some species in Victorian environments ranging from coastal to city suburban and inland with mixed results. These informal experiments have indicated that with well-drained soil that is mulched to keep the plant roots cool, alpine plants can do well.

The most common problem in both propagation and growing on has been the tendency for roots and plants to rot, presumably from fungal invasion due to excessive water.

Experimentation with propagation methods has been curtailed by lack of available time and reliability of propagation equipment at the nursery.

For those with the resources and interest to improve propagation methods and test plant performance in a variety of environments, here is an opportunity to introduce a range of new plants to the horticulture industry.

There is currently a proposal being discussed to establish an alpine botanic garden in the north east of Victoria. This garden would be part of a national network of Regional Botanic Gardens and would incorporate facilities for botanical research and support the development of the Australian horticultural industry by introducing appropriate native species to cultivation.

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Propagation of Mint (*Mentha*)

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An essential oil industry based on production of high value peppermint oil for export is emerging in the upper reaches of the river valleys of northeast Victoria. Research into essential oil production at the Ovens Research Station (ORS) by the Department of Agriculture, Victoria, commenced in 1976. This paper gives an overview of the production process, including methods of propagation.

TAXONOMY

The genus *Mentha*, in the family Labiatae, contains a large number of species and has a geographic distribution over most continents. Most species are herbs and aromatic. The mints have been known over the centuries for their use in herbal treatments and oil extraction. The first references to the use of mint leaves date from the time of the Pharaohs.

The *Mentha* genus is divided into two subgenera *Pulegium* and *Menthastrum*. *Pulegium* is characterised by poorly developed stolons, reclining habit, and axillary flower spikes. The subgenus *Menthastrum* typically has well developed stolons and is mostly perennial. *Mentha* species most commonly used in steam distilled essential oil extraction in today's essential oil industry are derived from the subgenus *Menthastrum*.

Native Spearmint. *Mentha spicata* (2n=48) which is possibly a hybrid of *M. longifolia* (2n=24) × *M. suaveolens* [syn: *M. rotundifolia*] (2n=24).

Scotch Spearmint. *Mentha cardiaca* (2n=72) a name recently changed to *M.* × *gracilis*. The major spearmint components are carvone (55% to 65%) and limonene (13% to 20%). Spearmints are most often found in chewing gums and other confectionery lines.

Peppermint. *Mentha* × *piperita* (2n=72) is believed by some to be derived from a triple cross between *M. aquatica* (2n=96) and *M. spicata* (2n=48) (itself a possible hybrid). It is important to note that *M.* × *piperita* is sterile. Peppermint oil typically contains menthol (43% to 50%), menthone (15% to 25%), and menthylacetate (2% to 7%) and is the true peppermint of commerce. Main uses for peppermint include confectionery, food flavouring, and pharmaceutical products.

Corn Mint. *Mentha arvensis* (2n=96) produces an oil containing many compounds in common with peppermint oil but with menthol levels much higher at 85%. The oil produced is inferior to peppermint oil but is used in mixtures with peppermint oil to produce a cheaper oil.

COMMERCIAL PRODUCTION

This discussion will focus on peppermint because its value and production is by far the largest of the four species listed above. Peppermint oil production has historically been situated in the USA with the main producing states Wisconsin, Michigan, Washington, Oregon, and Idaho. These states have a latitude above 40°N. This fact provides an insight into one of the conditions necessary to produce high quality peppermint oil. The peppermint plant uses daylength to determine its flowering time and hence foliage maturity. Broadly speaking, oil quality can be tied to the flowering stage of the plant.

Another determinant which controls oil quality is diurnal temperature fluctuation in the month preceding harvest (January-February in Australia). In Australia the production of peppermint is restricted to two regions: Tasmania, which offers daylengths similar to production areas in the U.S.A.; and the upper reaches of the river valleys in north eastern Victoria, which have clear hot days and clear cool nights, due to their proximity to mountain ranges.

If either of the two above conditions are not met, it is virtually impossible to produce an oil which has the correct balance of components. The normal chemical pathway involves the reduction of pulegone to menthyl acetate, through the intermediates menthone and menthol. Production of menthofuran, an undesirable compound, from pulegone occurs in plants which are not grown under the proper climatic conditions.

PRODUCTION CYCLE

Planting. The peppermint plant being a sterile hybrid must be propagated vegetatively. This has a negative side because the entire commercial crop in a region could possess the same genotype. Such a monoculture has inherent problems with disease susceptibility.

Field propagation of peppermint is relatively easy due to the stoloniferous habit of the peppermint plant. Stolons can be broken up and spread over the ground in spring or (for best results) in autumn, lightly incorporated and then irrigated. Commercial planting equipment achieves a multiplication ratio of approximately 1 : 7. This equipment consists of modified double-row potato digger which lifts the plants or stolons into either a truck or directly into a mint root planter. The planter flails or strips the stolons into short segments containing both roots and leaves. The segments are then dropped down hoppers into furrows opened and closed by tines. A roller follows to smooth out the soil layer. Irrigation is applied as soon as possible following completion of planting.

A less sophisticated but satisfactory method involves the use of a converted spinning-disc fertiliser spreader to evenly apply the mint stolons, followed by light discing and irrigation.

Growing Stages. Following autumn sowing of mint stolons and proper weed control, the mint shoots appear in September and October. Attention to nutrition, weed, pest, and disease control as well as irrigation are the growers' main activities until harvest approaches in late January to mid February. By this time the plants are approximately 1 m tall and fill all the available space in a field.

Harvest and Distillation. The mint field is mown and windrowed to allow wilting for a 1/2 to 1 day. Wilting provides a means of cost reduction as less water in the plants means lower transport costs and lower fuel costs at distillation time.

The mint herbage is then forage harvested into large enclosed tubs which hold about eight tonnes of herbage and may hold the crop from 1/3 ha. These tubs are transported to the boiler site and become part of the still when steam is connected to one end and a condenser to the other. Peppermint oil is collected in a receiving can. The expected yield of peppermint oil is approximately 70 kg/ha.

New Cultivar Breeding. Gamma-ray irradiation to induced artificial mutations is the main method used to produce new cultivars. Several new strains have been developed using this technique.

The main cultivar released in Victoria is Todd's Mitcham, a cultivar with some tolerance to a specific type of verticillium wilt (*Verticillium dahliae* var. *menthae*)—not identified to date in Australia. This root disease has altered the way mint is grown in the U.S.A. It is spread by soil and water movement and stolon transfer. Soil disturbance has been reduced to a minimum for fear of spreading the disease across fields. Planting material is now produced in certified nurseries geographically remote for the production centres.

MICROPROPAGATION OF *MENTHA* SPECIES

Micropropagation of peppermint is a simple technique using conventional tissue culture methods. Firstly, shoot and shoot tip culture was undertaken using excised plant material imported in tissue culture from the National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon, U.S.A.

Shoot tips are placed on Murashige and Skoog (MS) medium which is commonly used in the micropropagation of herbaceous plants. MS medium contains macro- and micronutrients, vitamins, sucrose, and agar. Other additives can be used but for peppermint propagation the basic MS medium was found to be satisfactory except for several difficult lines requiring added hormones.

The flasks contain 30 ml of medium which provides sufficient nutrient to last the plantlet for up to 6 weeks. In the case of peppermint, turn around time is 3 to 5 weeks between subculturing. Subculturing at 4 weeks typically produces a multiplication rate of four (four new plants from one plant every 4 weeks). NCGR in Oregon uses a very similar protocol with similar results.

Import Procedure. The Department of Agriculture had initial importation problems because of Australia's quarantine regulations relating to the type of container used to maintain sterile conditions. In an attempt to reduce container damage and limit the risk of contamination these regulations state that plants imported via tissue culture must be sent in rigid, clear plastic containers preferably with screw top lids/seals. Unfortunately, the NCGR only sends tissue cultured plants in soft, clear, heat-sealed, plastic containers called STAR-PAK. STAR-PAK is a more suitable method of transportation as it possesses some flexibility and occupies a smaller volume.

Storage. Peppermint plantlets store and travel very well for periods of up to a year under refrigeration at 2 to 4C. Although they can still be successfully propagated after extended storage, some cultivars do show a loss of vigour after such an extended period.

Media. In an attempt to better use the plant material received, and to reduce plant loss in the initial propagation phases, basic research was undertaken into the use of hormones in propagation media. The cytokinin, benzylaminopurine (BAP), was used to increase shoot multiplication from the limited plant material available. A suitable rate for *Mentha* species was found to be 0.1 µM. The auxin, indole-3-butyric acid (IBA), was used at different rates to induce root initiation of plants difficult to propagate. Treatments of 0.1, 1 and 10 µM were tried with 1.0µM found to be most suitable. With the addition of these hormones the general multiplication rate was 4X.

Once in culture the peppermint plants were grown under similar regimes of temperature and daylength as most other herbaceous plants. Temperatures of 20 to 24C and a daylength of 16 h were found to be best for peppermint multiplication.

CONCLUSION

The preceding comments have outlined the growing and propagating requirements for the emerging peppermint oil industry in north east Victoria. The industry is now in its fourth year of exporting to the flavour and fragrance houses around the world. It is anticipated that the industry will continue to evolve and produce a wider range of essential oils and to take its place on the world scene as a producer of essential oil of the highest quality.

Hop Propagation in Australia

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INTRODUCTION

The hop, *Humulus lupulus*, is a dioecious, perennial, climbing vine used as a flavouring in beer. The female hop "cone" contains resins and essential oils that give beer its bitterness and contribute the hop flavour (Neve, 1991).

Hops were originally introduced to Australia by the early settlers and was grown around Sydney. Sydney's climate did not enable the production of high yielding, good quality crops, and hop production soon moved to Victoria and Tasmania where climatic conditions were more favourable (Pearce, 1976).

The Australian hop industry of today is located in north east Victoria and Tasmania. The total commercial area in Australia is at present 1160 hectares, with Victoria growing 330 ha, and Tasmania 830 ha. This area produces annually 3000 tonnes, with a gross value of A $16 million. Australia exports approximately two-thirds of the hop crop to a range of overseas countries. The other third is sold to the Australian domestic breweries. Australian Hop Marketers (A.H.M.), the largest hop grower in Australia, grows 60% of the Australian crop, and markets 80%.

HOP PROPAGATION

Seed. Hops are easily propagated from seed. However, this method is not suitable for commercial purposes, but is used in hop breeding. Hop is a dioecious plant, and seeds produce males and females—usually one third male and two thirds female. Male plants produce no cones, and are of no commercial value. Seedlings lack uniformity, with many having inferior commercial characteristics. Also a seedling takes longer to reach maturity than do plants produced by other methods. Therefore, in order to ensure uniformity of the commercial characteristics like yield and brewing quality, hop plants are always produced by vegetative propagation. A hop field is planted with clonal material of one cultivar (Burgess, 1964).

Strap Cuttings. In Australia the traditional method of propagation is to cover the base of the hop vine with earth towards the middle of the season. This process is called hilling up because the earth mounds look like small hills. Hilling causes the covered bases of the vines to thicken and develop perennial buds. In winter these thickened vine bases are cut off to produce what is called a strap cutting. These are either planted straight into the hop garden, two to three cuttings per hole, or into cool storage for planting at a later date.

Sometimes these strap cuttings are placed into a nursery for one year to produce a "bedded set" or "yearling." Yearlings establish more quickly and have a greater strike rate (Neve, 1991). Hilling is limited by the number of vines produced in the previous season. Hence, the number of strap cuttings produced is low, and the rate of multiplication by this method of hop propagation is slow (Burgess, 1964). The traditional method of hilling up is still used by some growers who just want small amounts of planting material to replace missing plants in existing gardens. Due to the increased demand for large quantities of planting material by the larger growers like A.H.M., new methods of propagation have been developed.

Ground Layering. Ground layering is a quick method of achieving large quantities of planting material. This method can take place in a commercial field but, due to the large loss in yield, this method usually occurs in a nursery. Strap cuttings are planted and grown on for one year to produce nursery yearlings. In the second year, instead of hilling up these hops or removing the yearlings, the whole vine is laid along the ground. The lowered vine is then covered with soil, leaving only the tip exposed. This tip is trained up a string. During the season the covered vine thickens, producing perennial buds and roots at each node along the vine. In winter the thickened vine is dug and cut into single-node sections. Ground layering is an ideal method of producing large quantities of identical clonal hop planting material.

Aerial Layering. An alternative to ground layering is aerial layering. This technique consists of wrapping the lower portion of a vine with black polythene, or a fertiliser bag, and filling this sleeve with either potting mix, soil, or sphagnum moss. The covered section of the vine thickens to produce perennial buds and roots at each node. In winter the sleeve and soil medium are removed to reveal the thickened hop vines. These are cut into single-node sections ready for planting. The advantage of aerial layering is that layering is easily performed in a commercial hop field because only the bottom section of the vine is covered. In aerial layering the top section is harvested as normal and the hop cones collected.

Softwood Cuttings. A more rapid and intensive method of hop propagation is via softwood cuttings. As a mature hop plant grows it produces more than enough shoots needed for commercial hop production. Each year, only nine of the strongest shoots or runners are trained up three strings. This leaves a large amount of unused vegetative material readily available for propagation. Each shoot contains a number of nodes with each node having two axil buds. These extra shoots are collected from the field and cut into single-node cuttings. Each cutting consists of two leaves and two axil buds with a short length of stem 3 to 4 cm in length. The cuttings are stuck into a soilless medium on a mist bench, with the axil buds and the two leaves pointing upwards. After 10 to 14 days the cuttings have rooted and are removed from the bench. They are then potted, hardened off, and allowed to grow for 2 weeks. The whole process takes a minimum of 4 weeks and one hop plant can produce about 200 rooted cuttings in that period. This is a great improvement on the other slower hop propagation techniques.

The advantage of this form of rapid multiplication is that new cultivars can be multiplied quickly for large scale planting. Only a very small initial nuclear stock is required to commence the process each season. It is possible to ensure that each new hop plant is true to type and, more importantly, free from viruses. Due to the large number of parent stock in the older methods of hop propagation, there is no check on the virus status of the propagated material, and viruses easily spread (Neve, 1991).

A minor variation on cutting propagation is used in some countries for hop propagation. Hop cuttings are collected, cut up as in mist propagation, and planted into a soilless medium. Instead of mist, the cuttings are covered with plastic sheeting to control wilting. After two weeks the propagated cuttings have rooted and the buds have started to grow (Legrand, 1988).

Tissue Culture. Another method of rapid propagation is tissue culture. This has not been adopted in Australia, but it has been used in other countries, e.g., South Africa. Tissue culture offers little advantage with hops, because hops can be propagated rapidly and successfully by mist propagation. Shoot-tip culture is used in the United States, and in Australia to a smaller extent, to eliminate viruses from new and old hop cultivars, but only on parent material (Probasco, 1986).

COMMERCIAL HOP PROPAGATION

A.H.M. last year propagated 240,000 hops—mainly new cultivars for its four company farms—by mist propagation. The Victorian Hop Research Station uses the mist propagation technique. Shoots are collected from mother plants in the field, or in pots, and placed into water. Each shoot is cut into single-node sections, with each cutting having one to two leaves and two axillary buds. The cuttings are dipped into a phosphorous acid fungicide to help control fungal outbreaks. After the fungicide dip, the hop cuttings are stuck into Jiffy 517 peat pots. The peat pot contains a soilless medium (peatmoss, fine gravel, lime, and slow-release fertiliser [15N, 4.8P, 10.8K, 1.2Mg, plus trace elements]) which is drenched with a phosphorous acid fungicide. The cuttings are placed under mist for 10 to 14 days. During winter and early spring propagation benches are maintained at 18 to 21C, air temperature at 21C, and daylength 16 h. Summer and late spring propagation occur in two poly tunnels with automatic misting systems. After 14 days, the mist is turned off and the cuttings are hardened. At this stage the shoots are actively growing and the roots are starting to extend out of the peat pot wall. Depending on the use for the new rooted hop cuttings, they will either be planted in a nursery or potted. Rooted cuttings for the nursery are planted close together and the new shoots trained up strings. These are left to grow for one year to develop into yearlings. Yearlings will be left in the nursery for either more propagation (i.e., layering), or planted into the hop garden. The potted cuttings are for planting into the hop garden in the same year that they are propagated. The potting mix used is 3 composted pine bark : 1 coarse sand : 1 peatmoss (by volume) to which lime, and slow-release fertiliser (15N, 4.8P, 10.8K, 1.2Mg, plus trace elements) has been added. The cuttings are potted into 5-in. plastic pots and allowed to grow for 2 weeks before they are available for planting.

The other hop propagation techniques, such as hilling and layering, are used commercially to propagate smaller amounts. This material is mainly used to replace missing and weak plants in the hop garden. These techniques are sometimes used to propagate small quantities of new culitvars. Hilling and layering are popular with many growers, because no special equipment is needed and these methods are cheaper than mist propagation. Prices vary according to the cultivar propagated. Some cultivars are difficult to propagate, because of susceptiblilty to fugal infection. The following prices outline the costs involved in propagating a strong triploid hop:

Type of hop cutting	Cost each
Layered cuttings from a nursery	15¢
Strap cutting from nursery yearlings	20¢
Misted cuttings not potted	40¢
Misted cuttings potted and grown on	65¢
Nursery yearlings	95¢

Propagation by seed is used in hop breeding to develop new cultivars. Female hop plants are selected for their desirable characteristics, including high yield and quality. A paper sleeve is placed over the female flowers to stop open pollination. Selected male pollen is added to the sleeves around early January. At harvest in March the sleeves are collected and the seeds extracted from the cones. The collected seed is labelled and stored in a refrigerator for 8 weeks to overcome dormancy. The seeds are then chemically sterilised and planted into the same soilless medium used for mist propagation. An air temperature of 21 to 23C and a daylength of 16 h are maintained during germination. The seeds quickly germinate and grow into small seedlings. At this stage the seedlings are potted and grown on for planting into a breeding garden. Each year approximately 5000 seeds are sown. About 3000 seedlings are selected and planted into the breeding garden at the Hop Research Station. Hop breeding is a slow process, and a new cultivar takes on average 10 years to develop.

CONCLUSION

Hop propagation is only a small part of the hop industry, but it is essential to the development of high-quality and high-yielding crops. Mist propagation is essential in the production of virus free planting material. Good propagation techniques develop true-to-type, virus-free planting material which gives the Australian hop industry an edge over its competitors.

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Timber Species Propagation

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INTRODUCTION

The propagation of tree species for timber production is governed by the same basic principles and objectives that govern the propagation of tree species for horticultural use. Furthermore, the same methods of propagation are also used. What will vary, however, is the emphasis placed by a nursery on the number of species to be propagated. Forestry nurseries often focus on only one or two species. As timber production enterprises are usually large-scale programs over long rotations, the propagation of a timber species not only must be cost efficient, but at a scale capable of consistently producing large numbers of uniform, high quality propagules able to survive and grow under field conditions.

What, then, are the techniques used to propagate timber species? In a broad sense, they can be grouped under two headings:

1) Natural (or in situ) methods from seed in the soil, seed trees, or direct seeding; and coppice

2) Artificial methods, all of which require transplanting propagules into the field, include: grafting, seedling production, cutting propagation, and micropropagation

While it is important to recognise that extensive forest areas are still established by natural means, this paper will focus only on the artificial methods identified above. Species relevant to Australia and New Zealand will be used as examples wherever possible, with only brief reference being made to other important timber species.

GRAFTING

Although used infrequently as a method of propagation for timber production per se, grafts continue to be used almost exclusively for the production of clonal seed orchards. The major advantage of using grafts in establishing clonal seed orchards is that they can be successfully produced from relatively old parent trees. Often, trees selected for further breeding or seed orchard purposes are so old (often greater than 15 to 20 years) that the production of rooted cuttings is either impossible, or much more costly than the production of grafts. While graft incompatibility can at times be a serious problem, and even a barrier in the production of grafted stock for some species, it remains a quick, straight-forward, and cost effective way of establishing seed orchards where graft incompatibility is not a serious problem.

In Australia, grafted stock has been used for the establishment of seed orchards for radiata pine (*Pinus radiata*), hoop pine (*Araucaria cunninghamii*), slash pine (*P. elliottii*), and Caribbean pine (*P. caribaea* var. *hondurensis*). A number of eucalypt species, including *Eucalyptus nitens* and *E. globulus*, also have been successfully grafted to establish clonal seed orchards.

SEED PROPAGATION

The use of seed to produce nursery-grown plants is still the major method for propagating timber species, and remains the simplest and most cost-effective way of providing large numbers of uniform seedlings (Menzies and Arnott, 1992; Ritchie, 1991). Vincent (1991) maintains that seed has the advantage of being well proven to perform predictably under a wide range of conditions. Importantly, major efficiencies have been achieved through mechanisation, beginning with seed bed preparation, through tending and physiological conditioning to lifting, packaging, and transporting the seedling crop (Duryea and Landis, 1984; Trewin and Cullen, 1985).

There are three plant production systems used to produce seedlings. These are bare-root, container, and transplant systems, the latter being a combination of both containerised and bare-root systems (Menzies and Arnott, 1992). The use of any one of these depends on the species to be propagated and its inherent growth rate, the climate and length of growing season, the size and pre-sowing requirements of the seed, the morphological criteria placed on the crop, and the number of seedlings required.

In Australia and New Zealand, radiata pine is the major plantation species grown. Although rooted cuttings are often used, the production of radiata pine as bare-rooted seedlings continues to be the preferred method of propagation.

The propagation of eucalypt species for timber production in Australia and New Zealand is also predominantly from seed. But, unlike radiata pine, this is often as containerised, rather than bare-rooted stock. The reason for this is twofold. Firstly, the survival of outplanted containerised seedlings is often higher than for bare-rooted seedlings. Secondly, eucalypt seed is very small and expensive to obtain and seed is commonly sown onto germination trays; the seedlings are subsequently pricked out using tweezers and transferred into containers while still at the cotyledon stage.

For the northern hemisphere, propagation of timber species from seed using bare-root, containerised, or transplant production systems is very much dominated by location and species. This is due to the large number of species used, the large differences in environmental conditions, and the variation in facilities available. Excellent reviews on seedling production of both bare-rooted and containerised stock include those by Duryea and Landis (1984), Scarratt et al. (1982), and Tinus and MacDonald (1979).

CUTTING PROPAGATION

The last 15 years have seen a dramatic rise in the use of vegetative propagation for timber species. According to Ritchie (1991), prior to 1974 only three programs existed where more than 100,000 rooted cuttings per year had been produced: in Japan which produced 120 million rooted cuttings of sugi (*Cryptomeria japonica*) in 1966/1967, and in Finland and Lower Saxony where 150,000 and 1 million rooted cuttings respectively of Norway spruce (*Picea abies*) were produced in 1973.

The three reasons most responsible for focusing attention on vegetative propagation since 1974 were:

1) An overall shortage of seed for many commercial plantation species due to the rapid expansion of forest plantations;

2) The limited production of seed orchard seed from superior genotypes identified in breeding programs (Mason, 1989); and

3) The interest in clonal forestry (Carson, 1986; Libby, 1983).

Rooted cuttings have been successfully produced from root sections, for example the black locust (*Robinia pseudoacacia*) (Keresztesi, 1988), from leaf sections in eucalypts, and from needle fascicles in radiata pine.

However, lateral and terminal shoots from stool and hedge plants, and from seedlings remain the most commonly used vegetative material.

In Australia and New Zealand, plantation conifer species including radiata pine, slash pine, Caribbean pine, slash pine × Caribbean pine hybrids, and hoop pine are commonly propagated vegetatively. A number of eucalypt species also are being propagated vegetatively, including *E. nitens*, *E. globulus*, and *E. nitens* × *E. globulus* hybrids.

However, while the interest in and use of vegetative propagation continues to increase, its success remains limited. This is because the importance of the physiological age of the donor plant has resulted in the almost exclusive use of juvenile donor plants for cutting production (Ritchie, 1991). In order to overcome the problems of poor root formation and seedling growth loss that commonly arise due to maturation of the donor plant, plants with a physiological age less than 4 to 5 years are generally used. Two methods that have had some success in maintaining physiological juvenility are the hedging of seedlings and taking cuttings from cuttings (serial propagation). While the latter method is more successful in arresting maturation, it is both costly and laborious. So long as the problem of assessing and maintaining juvenility in donor plants remains unresolved, the use of vegetative propagation will be used mainly to multiply up cuttings from limited amounts of control pollinated seed.

Leaving aside the problem of maintaining juvenility, the cost of producing rooted cuttings can be two to three times greater than for seedlings (Menzies and Arnott, 1992), due largely to the labour intensive nature of collecting and setting cuttings. For the use of vegetative propagation to gain a wider acceptance, production costs will have to approach those achieved in seedlings systems. But for this to occur, most of the labour-intensive steps will need to become automated.

MICROPROPAGATION

The use of micropropagation by organogenesis (tissue culture) and embryogenesis is gaining widespread interest as a method for propagating commercially important timber species. Two reasons in particular make it attractive. Firstly, it allows the maximisation of genetic gain from breeding programs using both juvenile and mature trees. Secondly, it provides a very rapid means of propagating scarce genetic material. This opens up the potential for clonal forestry. Aitken-Christie and Connett (1992) and Dunstan (1988) have reviewed micropropagation of forest trees, viewing it as a delivery system for the clonal propagation of genetically superior and possibly genetically transformed trees.

When considering the use of micropropagation, the differences between organogenesis and embryogenesis need to be understood. In organogenesis adventitious shoots are developed first while roots develop later to form complete plantlets. In embryogenesis, however, somatic embryos (complete with cotyledons and root axes) are formed and these "germinate" to form plantlets (Aitken-Christie and Connett, 1992). Although still in its infancy, embryogenesis does open up the possibility of producing "artificial" seed to further propagate superior genotypes.

Although the use of micropropagation is still largely in the research and development phase, at least one New Zealand forestry company is using organogenesis at an operational scale to establish clonal forests of radiata pine, producing 1.5 million tissue culture seedlings in 1991, and increasing this to 2.5 million in 1992 (Darling, 1991). In both Australia and New Zealand, organogenesis also has been successfully used to propagate a number of eucalypt species and their hybrids, including *E. nitens*, *E. globulus* and *E. regnans*.

However, while delivery systems have been greatly streamlined and automated, production costs of tissue-cultured seedlings remain considerably higher than for seedlings or rooted cuttings. Still, Menzies and Arnott (1992) consider that somatic embryogenesis offers the potential for higher multiplication rates and lower costs relative to organogenesis. While the use of embryogenesis as a method of propagating timber species is still relatively new, somatic seedlings of important timber species have already been planted in field trials, including Norway spruce, Douglas fir (*Pseudotsuga menziesii*), and radiata pine (Aitken-Christie and Connett, 1992; Menzies and Arnott, 1992).

Research into the use of artificial seed as a delivery system for somatic embryos is also under way. However, before embryogenesis is used for the large-scale production of forest trees, considerably more work is required to evaluate the field performance of somatic seedlings, particularly with regard to production costs.

CONCLUSION

For forestry to continue as a sustainable and cost efficient industry, new and harvested forests must be replanted. Because of the need to maximise productivity per unit area of land, relying on the least expensive method of propagation is no longer sufficient. While the production of seedlings from seed of genetically superior genotypes will continue to be the most attractive and cost efficient method of providing planting stock, the use of vegetative propagation as well as micropropagation will increase. This will be inevitable if the gains from tree breeding and genetic engineering are to be realised.

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Crop Scheduling: A Business Practice or a Customer Service?

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To many of us crop scheduling means rotation between a wheat crop, a lucerne hay crop, a barley crop, or something of that nature. In reality it just means planned and/or organised production of your crop.

You are probably aware that in most businesses, whether they are producing nuts, bolts, cars, or aeroplanes, the production is done according to schedule. They work to a plan i.e., a certain number of a certain product is produced at a predetermined time of the year. If you produce suntan lotion then your production is greater just prior to summer. Well, plants are no different—their production also has to be preplanned.

I'll digress a little bit here and talk about customers. One of the current buzz words, favoured by business consultants and financial advisers, is "trading partners." The trading partners are a pair or a set of businesses whose success, productivity, and profit depends on each other. It basically means you the seller depend on your buyer's successful business for your business to be successful and conversely for them to be successful they require you to be successful and have a good efficient business. If you take this to its logical conclusion or to its nth degree, trading partners are not just two businesses. They are a chain, much like in a food chain. In our business there is a primary producer (the plant propagator), a wholesale nursery, a retail nursery, and the end user or consumer—the gardening public.

Now its not hard to see that if the gardening public is happy with the plant then the propagator benefits. This can be illustrated as follows: *Ceanothus papillosus* var. *roweanus* 'Blue Pacific' is an attractive green shrub with prolific blue flowers in spring. At the right time of year it is an extremely eye catching plant. If the plant is potted up too early or held too long in a pot, the dark green lustre of the leaves goes and you are left with a yellow tinge and a leggy sparse plant which is not only very unattractive but is actually very hard to sell. So lets take the case of Mr. & Mrs. Joe Bloggs who walk into Fred Smith's retail garden centre. They don't know what they want to buy and in fact they may not even have in mind a particular spot in the garden. They see a group of 20 or 30 *Ceanothus* 'Blue Pacific' all in full flower—a magnificent sight—and they buy one. During the day a whole group of Mr. & Mrs. Bloggs come and buy all the *Ceanothus* 'Blue Pacific'.

In one Saturday morning the retailer sells his entire stock of 30 *Ceanothus* 'Blue Pacific' and so on Monday morning he is on the phone to his wholesale supplier saying: "Those *Ceanothus* 'Blue Pacific' you delivered on Friday were great, they're all gone. I'll have another 50 of them next Friday, thanks."

He receives these plants on Friday and once again they have all gone by lunch time on Saturday—that's what business is about, buying and selling plants, turning them over quickly and efficiently. He is happy and so is the wholesaler, who has just sold another 50 plants, which in these hard times is a good sale.

The wholesaler is feeling pleased with himself. The *Ceanothus* tubes were only bought in April. A 5-month turn around over winter is pretty good. In fact he probably couldn't have grown them on any quicker and still had them up to size and looking good. So he looks back in his records to find out from whom and when he bought them. He then rings Mr. & Mrs. Jones Propagation Nursery and orders another 1000 for the following April.

So what we have got here is a happy consumer, a happy retailer, a happy wholesaler, and a happy propagator. This is where crop scheduling comes in. Mr. Jim Jones now has an order for 1,000 *Ceanothus* that have to be ready for April. So he looks back in his books and sees that in the previous year he propagated those in December. He then opens his diary to October (or notes on his computerised production schedule) and inserts a reminder to cut back and fertilize the mother stock plants to stimulate growth so they can be cut in December and ready for tubing in February. By April they will be ready for sale to the wholesaler who can then grow them on to sell in September.

In essence the above sequence is what crop scheduling is all about—getting your plants propagated and potted up at the right time so they can be ready for selling in their peak selling condition or when they are wanted. This doesn't sound too difficult, and isn't, when dealing with only one or two taxa. Where it becomes complicated is when you have a broad range of plants. If you have 1000 taxa, crop scheduling not only becomes harder but it also becomes more than just a matter of customer service.

To do crop scheduling efficiently you need detailed, accurate knowledge of the plant and its growth habits, your customer, their customers, your business, and your production methods. All of these are necessary for successful crop scheduling and business management. To do those things efficiently requires records—accurate detailed records on everything you do, from propagation to sale. It also really requires that you go out and talk with your customers—not just send them a list every month, take an order by fax, send them the plants, post them the bill, and take the cheque. That is not really doing business; it is just paper shuffling.

Many of you probably go to a variety of different seminars during the year and just about every seminar has someone talking on business practices, business trends, how to make your business more efficient, etc. At the ones I've been to, two things come through strongly: the first is customer service and the second is information technology. These two areas are what I believe are the most important aspects of business management. They are also the fundamentals of crop scheduling.

With crop scheduling what you are aiming to do is have your plant ready when it is wanted by your customer. This may not sound too profound but for many years the attitude in our industry seems to have been: you will have it when it is ready. With some plants it is a simple procedure to have a plant ready at any given time. It only requires some basic knowledge: when it is wanted, percentage strike rate, time to put on roots, and time to fill the pot. With this information you can calculate when to propagate and how many in excess of what is ordered. You have got to make allowances for external factors, such as the weather. Some people work on a variance of a month either side, others on two weeks either side. I have actually come across some customers who specify the day they want their plants delivered. Even though this level of accuracy is generally for accounting purposes rather than for growing purposes, it does give some idea of how organised some nurseries are. These are the ones you have to cater for because they are the nurseries that are going to be successful, and most likely able to weather the hard times.

However, there are some plants that have a very narrow window for propagation. This can be due to a plant's physiology or perhaps there have to be certain weather conditions. A classic example is *Daphne odora*. The old story is that it should be propagated on Boxing Day, with the tubes generally being ready in late April. This is a problem for customers who want there tubes in January so that they can get some growth on before the winter cold sets in. What the propagator needs to do is to let the customer know that the best time for daphnes is April. If the customer still wants them in January he may have to pay more and they may be slightly over grown. Another choice is a compromise. The customer may be able to take them in September, after the cold of winter has passed. Whatever happens, the propagator should make it the customer's choice. Too often the propagator tells the wholesaler that the plants will be available in April, take it or leave it.

Currently, there are a large number of newcomers in the nursery industry. There are also many nurseries trying new plants. Therefore, I often find that I also have to do a degree of crop scheduling on behalf of my customers. This gets back to my earlier reference to trading partners. It is no good if my customer buys my tubes at a time when they will either die or not be ready for sale when the public wants them. If they do this too often they will go out of business and I will have lost a customer.

So far I have only talked about crop scheduling for the purpose of customer satisfaction. Efficient business procedure is another reason for crop scheduling. There are many propagators who seem never to plan—they just propagate what they think of each day. If you only have a small facility or only do a limited range this method will suffice. If your range is extensive and you do not have a good schedule you will soon find your production in a mess—I speak from experience—and many customers missing out on their orders. You will also find yourself with excess tubes or plants that may have to be disposed of.

Planning for business efficiency involves working out the practicalities. You don't want to get to the stage where your tubers have no work to do, or where there is far too much tubing. It is a matter of mixing slow-striking species with quick-striking ones. Another point to consider is that of propagating difficulty. Our staff are paid a bonus based on production rates. They get a bit upset if they get all hard-to-propagate or unpleasant plants, or if they get lots of small runs. So we plan each week in consultation with one staff member and create an even mix of short and long runs, and easy and difficult plants.

In summary, crop scheduling is a complicated process, although it is not one that requires vast amounts of expertise or intelligence. To do it successfully all that is needed is the desire and information. Information on:

- The plants: strike rates, rooting time, growth rates, flowering time, etc.
- The customer: their customers, growing methods, e.g., machine or hand pot, their general weather patterns, etc.
- Sales: when and how many of each plant, forward orders, etc.
- Production: your staff, your own weather patterns, staff holidays, training, etc.

Finally I urge everyone to try and preschedule their plant production. Don't be discouraged if it doesn't seem to work the first time. It is a continual learning process and no two years will be the same.

The Use of Composted Tree Chippings as a Potting Medium

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INTRODUCTION

Wood wastes are extensively used in potting media, with pine bark and sawdust dominating most types of container mixes in Australia. However, there are other wastes and by-products that, with appropriate treatment, could also be used as media components. In the United States there is a great range of composts available for container mixes, some being derived from construction wood wastes and sewage sludge (Mecklenberg, 1993). This paper discusses the use of one of these materials—composted tree chippings. It looks at both the production and current use of the material, as well as trials to compare and evaluate its performance as a medium.

Currently the Box Hill City Council nursery uses this material extensively in different mixes used in the production of a wide range of species. Its use forms part of an overall strategy at the nursery to minimize the use of non-renewable resources and reduce the use of horticultural chemicals.

The research component of this paper was undertaken during 1992 and 1993 as part of a project conducted by the senior author at the Victorian College of Agriculture and Horticulture, Burnley Campus (V.C.A.H.-Burnley).

PRODUCTION OF COMPOSTED TREE CHIPPINGS

Tree chippings are a relatively plentiful resource within the Box Hill City Council as a result of the council's tree maintenance activities. The fresh chips are held in heaps at the rear of the nursery, then are laid out as a mulch over the ground surface in outdoor pot standing areas and on glasshouse floors.

The chips are effective as a weed suppressant, and assist in drainage of all outdoor areas. They are spread to a depth of between 150 to 200 mm, with 40 m^3 of material covering approximately 200 m^2.

The chips remain as a surface mulch in the standing areas for a minimum of 12 months. Following this period on the ground the chips have undergone considerable decomposition and are much changed. The now dark coloured "compost" ranges from fine particles to larger woody pieces, and has a rich, loamy texture. The material is lifted and placed into heaps for its use as a potting medium. The compost may sit for between 2 to 4 months, depending on potting requirements. Prior to its incorporation into a mix the compost is passed through a mixer with a 10-mm sieve ensuring removal of the larger woody pieces. The sieved compost is then mixed with various aggregates and fertilizers to achieve the composition required. The compost is normally used in the proportion of approximately 80% of each mix by volume.

The most common component additions to the mixes include coir fibre dust, rice hulls, recycled plastic, and polystyrene. Propagation, indoor, and general mixes are all produced at the nursery using the compost as a major component. The range of plants grown at the nursery includes exotic ornamentals, display specimens, potted colour, indigenous plants, and advanced containerized trees.

MATERIALS AND METHODS

Trial # 1. A compost-based mix used at Box Hill Council nursery was compared with two commercial mixes. All three media contained similar supplementary fertilizers, with the nitrogen amount standardised in each mix. In addition, a fortnightly liquid feed of 192N-34P-162K mg/litre was applied to the pots over the first eight weeks. The components of each mix were as follows (per m^3):

Mix A (commercial mix)		
Pine bark (medium)	2	parts
Pine bark (medium/fine blend)	2	parts
Sand	0.5	parts
Osmocote (3/4 month 18N-4.8P-9.1K)	2	kg
Micromax	1	kg
IBDU	800	g
Gypsum	450	g
Dolomite	1	kg

Mix B (commercial mix)		
Pine bark (medium)	7.5	parts
Sand (coarse)	1.5	parts
Rice hulls (sterilized)	0.5	parts
Peat moss	0.5	parts
Osmocote (3-4 months 18N/4.8P/9.1K)	2	kg
Micromax	1	kg
IBDU	800	g

Compost mix		
Composted chippings	8	parts
Plastic pellets (hard)	1	part
Polystyrene	2	parts
Coir fibre dust	1	part
Iron (GU49)	1	kg
Osmocote (3/4 month 18N-2.6P-10K)	2	kg
Micromax	1	kg
IBDU	800	g

Tubestock of *Cytisus* × *racemosus* (Syn. *Genista* sp.), *Escallonia laevis* [syn. *E. organensis*], *Brachycome multifida* fine-leaf form, and *Argyranthemum frutescens* were potted into 140-mm containers of the mixes on the 9 October 1992. There were 10 replicates of each treatment (species/medium). The pots were randomized in outdoor growing areas at the campus nursery, under overhead sprinkler irrigation. The plants were destructively harvested on 10 January 1993 approximately 13 weeks after the commencement date. The stems, shoots, and leaves of each plant were removed at the base, dried at 80C and weighed.

Trial # 2. In this trial, a medium of pure sieved compost and supplementary fertilisers was compared with a commercially produced pine-bark-based medium. Both mixes had similar levels of supplementary fertilizers, with the nitrogen component standardised in each mix. All pots received a fortnightly liquid feed, as in Trial # 1. The mix components per cubic metre were:

Mix X (commercial mix)		
Pine bark (medium)	2	parts
Pine bark (medium/fine blend)	2	parts
Sand (coarse)	0.5	parts
Nutricote (3/4 month 16N-4.4P-8.3K)	2	kg
Micromax	1	kg
Iron (slow-release)	1	kg
IBDU	800	g
Dolomite	1	kg
Gypsum	450	g

Compost mix		
Compost (sieved)	1	m3
Nutricote (3/4 month 16N-4.4P-8.3K))	2	kg
Micromax	1	kg
Iron (slow-release)	1	kg
IBDU	800	g
Gypsum	450	g

Tubestock of *Correa* 'Dusky Bells' and *Verbena* × *hybrida* were used. There were two watering regimes—overhead sprinklers in the outdoor growing area, and capillary sandbed irrigation—with 10 replicates of each treatment (species /mix / irrigation) in a randomized block design.

The trial commenced on 11 March 1993, when the tubes were potted into 140 mm containers of each mix. The trial concluded on 23rd April, 1993, some 6 weeks later, when the plants were destructively harvested as in trial #1.

Selected physical and chemical properties of the media were determined at potting and at harvest. The pH and electrical conductivity (EC) of the media were assessed by the 1 : 1.5 volume method. Measurements of air-filled porosity (AFP) and bulk density (BD) of the media were also taken. The methods used are described in the

Australian Standard for Potting Mixes (Standards Australia, 1989). The harvested plant tops were dried at 80°C and weighed.

RESULTS

Table 1. Some properties of the media in Trial # 1.

	pH		EC (µs/cm)		AFP (%)		BD (g/cm3)	
	Pot.	Har.	Pot.	Har.	Pot.	Har.	Pot.	Har.
Mix A	5.7	5.6	197	103	14	-	0.36	0.30
Mix B	5.7	5.6	355	142	18	-	0.37	0.30
Compost Mix	6.0	6.0	410	281	24	-	0.19	0.18

Table 2. Some properties of the media in Trial # 2.

	pH		EC (µs/cm)		AFP (%)		BD (g/cm3)	
	Pot.	Har.	Pot.	Har.	Pot.	Har.	Pot.	Har.
Mix X	6.0	6.0	937	193	14	-	0.32	0.39
Compost Mix	6.2	6.5	796	615	18	-	0.20	0.25

Table 3. Shoot dry weights (g/pot) - Trial # 1.

	Mix A	Mix B	Compost mix
Cytisus × racemosus	27.9	28.4	21.6
Escallonia laevis	24.3	25.6	17.4
Brachycome multifida	23.6	23.0	18.0
Argyranthemum frutescens	8.8	9.7	6.8

Table 4. Shoot dry weights (g/pot)—Trial # 2.

	Capillary sandbed		Overhead irrigation	
	Mix X	Compost mix	Mix X	Compost mix
Correa 'Dusky Bells'	4.4	4.1	4.0	3.4
Verbena × hybrida	4.5	5.4	5.5	7.2

DISCUSSION

Properties of the Media (Tables 1 and 2).

pH. The pH values of the compost media fell within the range of suitability for most plant species. There were no high pH values recorded, as has been the case with some other wood waste composts (Mecklenberg, 1993). However, for some plants the pH may be too high and adjustment necessary.

Electrical Conductivity. The EC values fell well within the range of being suitable for container growing.

Air-Filled Porosity. This proved to be a problem with the first trial where the AFP of the compost mix was considerably higher compared to the two pine-bark-based mixes. This slightly disadvantaged the compost mix, particularly when coupled with overhead irrigation difficulties as the trial continued into the Christmas / New Year period. The greater pore space of the compost mix in relation the two commercial mixes under the same irrigation frequency meant that the compost mix was drying out more between irrigations, thus placing the plants under greater stress. More frequent irrigation may have reduced the differences between the mixes, however media with similar initial AFP would have been preferable.

Bulk Density. The lower bulk densities of the compost media could be both a benefit and a problem. In some situations it may be necessary to add some ballast to the mix (e.g., sand) to provide some pot stability. However in other situations, such as transport, the comparative lightness of the mix would be a bonus.

Volume Drop. Decomposition of the compost mix caused some shrinkage in the mix volume during trial #1. This was observed to be between 10 to 20 mm from the initial potting height in the container. This was not observed in trial #2. This has been noted as a problem with other wood waste composts (Mecklenberg, 1993).

Variability of the Compost. The compost will always have a level of variability in its composition. This is due to a number of factors including the different species and pruning undertaken, the type and quality of the chipper used to make the chips, and the composting process itself. This variability helps to explain some of the features observed. This may restrict its role in some situations (i.e., specialized propagation mixes). More effective composting of the chips, as is undertaken with pine bark and sawdust, (Bunt, 1988) will reduce variability.

Dry Weight Measurements (Tables 3 and 4). In trial # 1 shoot dry weights of all species were significantly lower for plants in the compost mix than of those in the two commercial mixes (Table 3). Results were different for trial #2. Verbena shoot dry weights were significantly higher in the compost mix compared to the commercial mix, whilst Correa shoot dry weights were not significantly different in either medium (Table 4).

It is difficult to totally explain these differing results. The longer trial # 1 (13 weeks) produced poorer results for the compost medium than in trial # 2 (6 weeks). The higher air-filled porosity (AFP) of the compost mix in the first trial was certainly a factor in these results. In the second trial the AFP of mixes was much the same.

Perhaps a more significant factor involved was nitrogen draw-down of the compost mix, particularly over the latter 5 weeks in trial # 1 when there were no applications of liquid nitrogen fertilizer. Nitrogen draw-down is common to many low-nitrogen organic materials used in potting media, such as barks and sawdusts. Composting of the material and/or the addition of nitrogen fertilizers must be used before some materials can be used in potting mixes (Handreck and Black, 1991). It has also been noted as a problem with other wood waste composts produced in the United States (Gouin, 1992). No assessment of nitrogen draw-down of the compost or other mixes was made during the trials. However the levels of nitrogen in pre-plant and liquid fertilizers applied during both trials were greater in comparison to nitrogen levels in fertilizer "recipes" referenced elsewhere (Handreck and Black, 1991). More effective composting of the chips prior to their incorporation into potting mixes would reduce the problems of nitrogen draw-down.

CONCLUSION

Based on the healthy plants produced at Box Hill Council nursery and the experimental results, composted tree chippings are an effective medium for container crops. With greater compost development and manipulation of ingredients it may prove to be a material that can meet the needs of many growers. Alternatively, there may be a place for production and sale of the compost for the nursery industry. This has proven to be the case in the United States, where patented composts are marketed widely (Gouin, 1992), particularly where the compost has proven benefits to the grower. One of these benefits which has not been discussed in this paper is the ability of composts to biologically suppress pathogens in potting mixes (Mecklenberg, 1993; Handreck and Black, 1991). This feature has certainly been noted at Box Hill Council Nursery, and well documented by others. Given that research on the use of pine bark as a potting material was undertaken over a long period of time (Aaron, 1991), further study on the use and applications of this material would be desirable.

There is increasing concern in the wider community about the use of non-renewable resources and the need to look towards alternatives which are more environmentally friendly. In particular in the nursery industry, where the use of alternatives to peat moss are being evaluated for their effectiveness (Pryce, 1991). It seems appropriate therefore that composts are making a return to use in potting media.

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Using Artificial Light in Plant Propagation

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We are all aware of the importance of light in the growing of plants, of the reaching for light by plants in crowded situations, and of phototropism—the directional attraction to a light source by plants. It has not been my experience, however, to hear much talk of the effects of light on the propagation of plant material.

The light emitted by the sun has many different forms of radiation mixed up in the total product, each characterized by its precise wavelength. Most common amongst these radiations are ultra violet light (UV) at the short wavelength end of the scale, visible light in the middle area, and infra red (IR) emissions of long wavelength producing heat as we know it. UV emissions are of wavelengths of less than 380 nm (1 nm, is one millionth of a mm), while IR is above 780 nm, with visible light being in the area between these two boundaries. It is the energy produced between 380 and 780 nm about which I am referring in this article, and which we call light.

Light provides the energy for photosynthesis, which is the process plants use to produce carbohydrates from carbon dioxide and water. This process together with other chemical reactions within plant cells allows the plant to live and grow through active cell multiplication.

It is fairly generally appreciated by those who do a lot of propagation from seed material that some seeds are blessed with the ability to determine their germination according to the availability and intensity of the light at the time they are sown, or fall on the ground. *Ficus* seeds, for instance, must be fully exposed to light to successfully germinate, while *Cyclamen* seeds require total darkness for successful germination. *Philodendron* seeds will not readily germinate between April and October. However, if the light intensity is considerably increased on the seed during this period, germination can occur reasonably easily, if a little erratically.

The evidence of the effect of light on root formation in vegetative cuttings is not completely understood, and in particular the most beneficial wavelengths to promote rooting are confused by conflicting evidence. Some experimental work suggests that light in the region of 600 to 750 nm encourages root initiation, whereas other research has shown that exposure of cuttings to prolonged treatment by light of wavelengths from 380 to 450 nm encourages fairly rapid formation of roots. It is also known that treatment of the mother plants with light from the blue region of the spectrum produces cutting material which readily forms roots. So it appears that the light of shorter wavelength provides a better quality cutting and consequently more rapid rooting.

Four or five years ago we finally became tired of slow-rooting cuttings—even with the addition of bottom heat and mist—in September/October. Root formation was very slow and frustratingly uncertain.

Finally, we decided to try artificial light. After a discussion with a lighting engineer, we bought a Philips metal halide lamp which looks very much like a mercury vapour lamp but has metal halide additives. The light was suspended over a propagation bench at a height of 1 m. The bench is 1.2 m in width, and the area effectively covered by the light was about 1-1/2 m^2. In the case of *Genista* × *spachiana* [syn. *Cytisus racemosus* 'Nana'] rooting was reduced from 3 to 4 months at that time of the year to 5 to 6 weeks, and since installing this first light the propagation of plants from cutting material has improved markedly.

Having demonstrated the benefit of added light in the propagation of our plants, we decided to expand the lighting regime. We calculated that we would need five lights per 6-m bench. Apart from the cost, five lights also represented a considerable shadowing of the benches during daylight hours. Members of our staff came up with the idea of a mobile light and, with the aid of a considerable length of bicycle chain and a small electric motor geared down to an output of one revolution per min, we built a travelling light which covers one length of the bench in about half an hour. By running the 400 W lights for 12 h each night, sometimes longer during winter, we irradiate the cuttings for the equivalent time of five lights for about 2.25 h.

Plants deflasked from tissue culture are also given the same treatment and under normal circumstances we get a 100% result. Though we are not able to say we obtain the same results with cuttings, we can report that we have more success with the use of lighting.

I am not saying that the same results can not be obtained with other types of lighting, for example, high intensity sodium lights. We have not tried lights other than the metal halide type. If no natural daylight is used during rooting, selected fluorescent tubes would be more economical to install and use.

We have not tried using light without bottom heat. I have a suspicion that light may be of greater significance than bottom heat, and if so, it may be somewhat cheaper to irradiate cuttings than provide them with heat in the rooting zone.

For those interested in trying artificial lighting in propagation, the cost of the metal halide lamps, including the reflectors and chokes, is about A$200 each. When we used lighting on *Philodendron* seeds, we simply used 150 W incandescent domestic flood lights to achieve germination between April and October. We do not know whether metal halide lamps, or lamps with other wavelengths, would be more beneficial than incandescent lamps for seed germination.

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Effects of Reduced Humidity and Paclobutrazol on Acclimatisation of Tissue-Cultured Plants

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INTRODUCTION

Plant tissue culture is now a widely used propagation method. Its main advantage is the ability to rapidly multiply selected cultivars and to produce genetically uniform plants. The techniques range from simple micropropagation using a bud, node or leaf segment, to cell or protoplast culture. Commercial production mainly involves micropropagation. Whatever the technique used, the final step involves the transfer of the cultured plants from the protected environment of the culture vessel to the nursery bench. The process of the plant adapting to this change in environment is known as acclimatization.

Under in vitro conditions of low light intensities and in the presence of carbohydrate in the medium, plants are heterotrophic i.e., they are unable to photosynthesise to meet their carbohydrate requirements. The high humidity in the culture vessel also results in plants unable to control water loss through transpiration (Brainerd and Fuchigami, 1981; Capellades et al., 1990; Grout and Aston, 1978; Smith et al., 1986; Grout and Millam, 1985). During acclimatization, the plants must survive the water stress long enough to re-establish photosynthesis and controlled transpiration.

To maximise the potential of tissue culture applications in the nursery, it is necessary to increase the survival of plants during the acclimatisation procedure and reduce the time that this procedure requires. One approach is to control the humidity either before or after the plants are planted-out (Whish et al., 1992). Another is the use of plant growth retardants (PGR) to reduce the wilting of plants when transferred to the nursery. Increasing the light intensity or reducing the sugar supply in the medium may also promote photosynthesis (Kozai, 1991).

Paclobutrazol (PAC) (PP333, ICI) is a broad spectrum, xylem mobile PGR which reduces growth by inhibiting gibberellin biosynthesis (Lever, 1986). PAC does not block the activity of existing exogenous or endogenous gibberellin (Lever, 1986). The morphological effects of PAC application include reduced leaf size of apples (Curry and Williams, 1983) while the anatomical effects include increased cell thickness, number of mesophyl layers, sunken narrower stomates, increased chloroplast size, and an increase in epicuticular wax deposition (Gao et al., 1987).

The reduction of the humidity in the culture vessel has improved the survival of several species including *Ptilotus* sp. (Whish et al., 1992) and *Allium* sp. (Fari and Nemeth, 1987). It was found that the reduction of humidity in the head space led to increased rooting, higher leaf dry matter, and profuse wax production in onion (Fari and Nemeth, 1987). Survival of *Ptilotus* after deflasking was better if roots were produced in vitro (Whish et al., 1992).

This paper reports the response of two species, *Rosa* 'Red Cascade' and kangaroo paw (*Anigozanthos bicolor*) to reduced humidity or PAC application during the final stage of micropropagation.

MATERIALS AND METHODS

Culture Media. Both species were cultured on de Fossard (1976) medium with high minerals and organic supplements and 30 g/litre^{-1} sucrose. The agar concentration was 8 g/litre^{-1} for kangaroo paw and 6 g/litre^{-1} for rose. The pH was adjusted to approximate 5.8 prior to adding agar and autoclaving in 200 ml aliquots for 25 min at 121C and 103 kPa.

Humidity Treatments. Plants of both species were exposed to four relative humidities (RH), 86%, 90%, 95%, and 100%. The 100% RH was the control simulating a normally sealed culture vessel. Humidity was controlled by placing the open culture vessels over saturated salt solutions within larger chambers. The theory behind this method is that in a confined space, at equilibrium, the atmosphere above a saturated solution will have a particular RH (Table 1). The salt solutions were autoclaved for 15 min at 121C and 103 kPa, then 50 ml dispensed into each sterile Chanrol M30 Polypropylene chamber.

Table 1. Selected salts and the theoretical equilibrium RH.

Humidity	86%	90%	95%	100%
Saturated salt	Potassium chloride	Zinc sulphate	Dibasic sodium phosphate	Deionised water

To prevent water evaporation from the gel, the surface was covered with aluminium foil. Small incisions were made in the aluminium foil and the plants were inserted through to the medium. The culture vessel lid was removed and the open vessel placed into the humidity chamber which was then sealed and kept in a culture room at either 22C for rose or 25C for kangaroo paw, with 16-h day and 8-h night and a light intensity of 25 ìmol m^{-2} sec^{-1}. After 4 weeks in the culture rooms, the humidity in the chambers was recorded using a hand held humidity meter (Hanna, HI 8564, Thermo Hygrometer). This was achieved by partially removing the lid of the chamber and inserting the probe to the level of the plant then wrapping the chamber and the probe with plastic wrap.

Paclobutrazol Treatments. Five concentrations of PAC (0, 1, 2, 3, and 4 mg litre^{-1}) were incorporated after the rooting media had been autoclaved and cooled to 60C. The medium composition and culture room conditions were the same as described above.

Acclimatization. For acclimatization, the plants were removed from the media and the roots washed to remove excess gel. Root length and fresh weight of the plants was recorded before they were planted into a potting mix of 1 vermiculite : 1 perlite : 1 peat (by volume) then subjected to the following regime: 4 days under mist and shade cloth; 3 days under mist only; 4 days in a white washed glasshouse; then 2 weeks in a normal glasshouse.

At the conclusion of acclimatization, the root length, survival index and growth index were recorded. The survival index was a simple ranking of 1 for alive and 0 for dead. The growth index included 5 levels over the range 1= no growth, 3= average growth, and 5= vigorous growth. Plants were then oven dried for 48 h at 80C to determine total dry weight.

RESULTS AND DISCUSSION

Effects of Humidity. At the end of the 4-week culture period the RH in the chambers was around 90% to 95 % irrespective of the humidity treatment applied and there was no difference between species (data not presented).

For kangaroo paw, plant dry weight tended to be greater with the 86% RH treatment (Fig. 1) however the difference between the humidity treatments was small, only 0.22 g between the highest and the lowest. This small response may be due to the stabilising of the RH at approximately 90% to 95% in all chambers by the end of the four weeks in culture. Evaporation of water from the gel and condensation into the salt solutions may have gradually raised the RH and reduced the treatments effect. The aluminium foil did not prevent evaporation from the medium.

Roots on plants kept at 86% RH were, on average, 65 mm long while plants at 100% RH had 30-mm roots. Why is there an increase in root growth at lower humidities? The roots were extensively branched and healthy in all cases. At 86% RH, kangaroo paws were usually well developed with even, dark green leaves and healthy appearance. At higher RH plant growth was less with only a few shoots present.

The reduced humidity in vitro increased the growth of kangaroo paw and improved its overall appearance while not effecting the number surviving; however, the plants could be ready for market after a short time in the glasshouse.

The rose cultivar did not respond to RH in any consistent way. The biomass was greatest at 90% RH but with no difference between the humidity treatments. The reduced humidity allowed the plants to establish ex vitro in shorter time compared to the higher humidities. The 90% RH caused a slight decrease in root length and this was correlated with a reduced growth index. The increase in total biomass was probably due to thickening of the roots since shoot growth and root length were reduced.

Plant Growth Retardant Application. There was a noticeable difference in the height and the habit of the plants when they were removed from culture. Plants treated with the higher concentration of PAC, namely 4 mg/litre^{-1}, leaves were reduced in size and darker green in colour. This was uniform for both species.

After acclimatization, the response of plant dry weight to PAC application rate was inconsistent (Figs. 1 and 2). In both species growth was promoted with 1 mg/litre^{-1} PAC. Kangaroo paw was inhibited by 2 mg/litre^{-1} and rose promoted at 4 mg/litre^{-1}.

Visual ranking of plant growth gave a more consistent response with growth suppressed at 2 mg/litre^{-1}.

There is no obvious explanation for this irregular pattern of response. Root length was not significantly affect by PAC (data not shown) although root systems were seen to be compact and thickened compared to the untreated controls. This thickening of the roots has previously been seen in chrysanthemum treated with PAC in vitro (Smith et al., 1991). It may be that the end results are superimposed on different rates of recovery from the treatments. Plants were initially noticeably

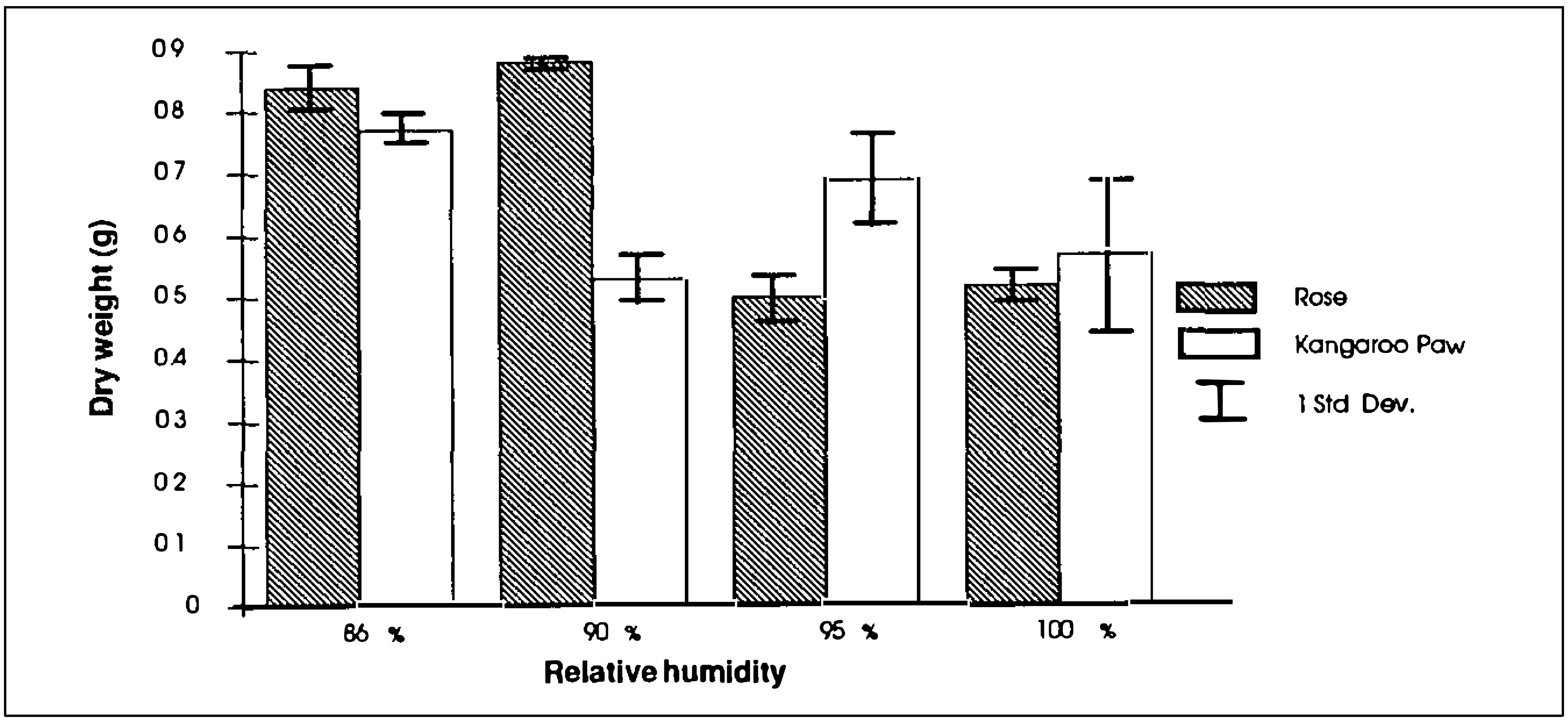

Figure 1. Comparative dry weights of kangaroo paw and *Rosa* 'Red Cascade' under reduced humidity in vitro.

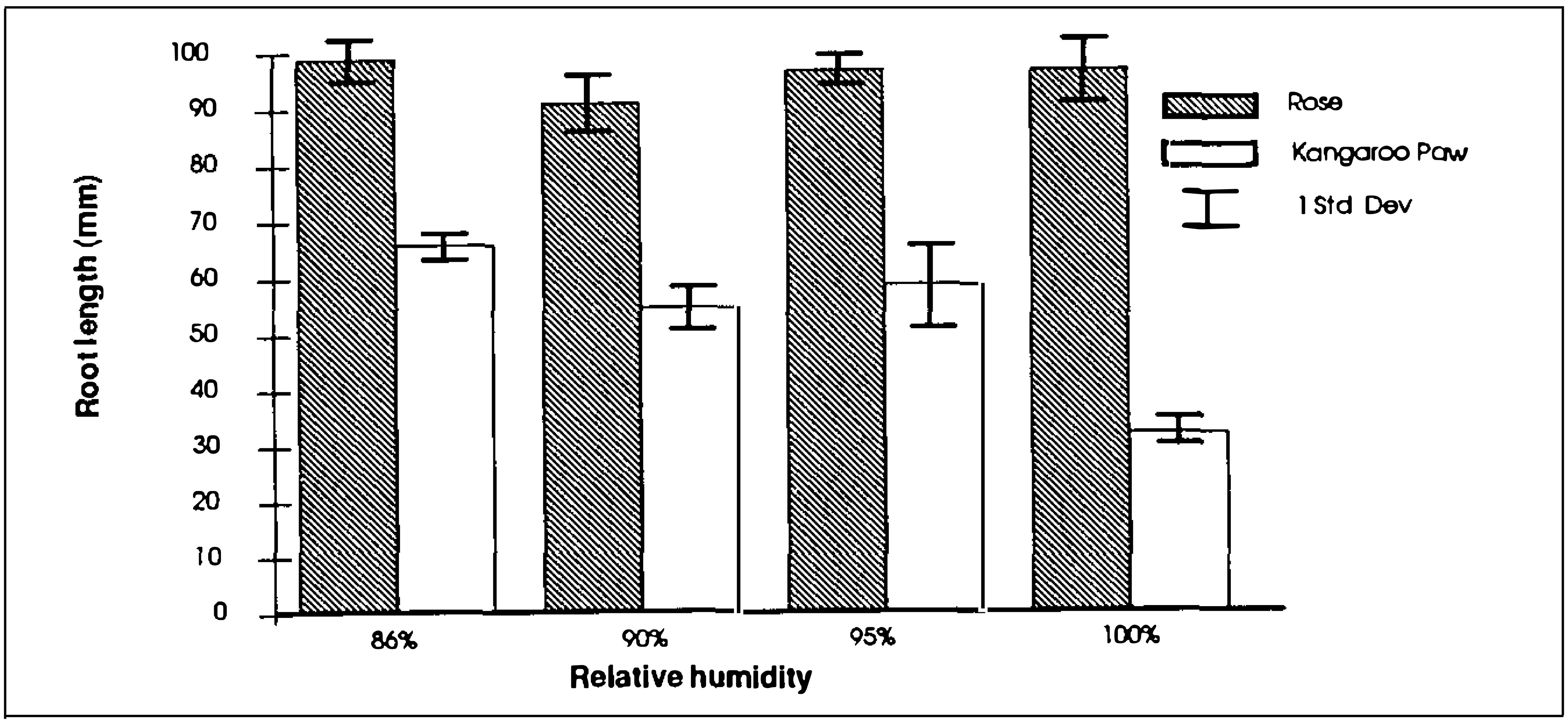

Figure 2. Comparative root lengths of kangaroo paw and *Rosa* 'Red Cascade' under reduced humidity in vitro.

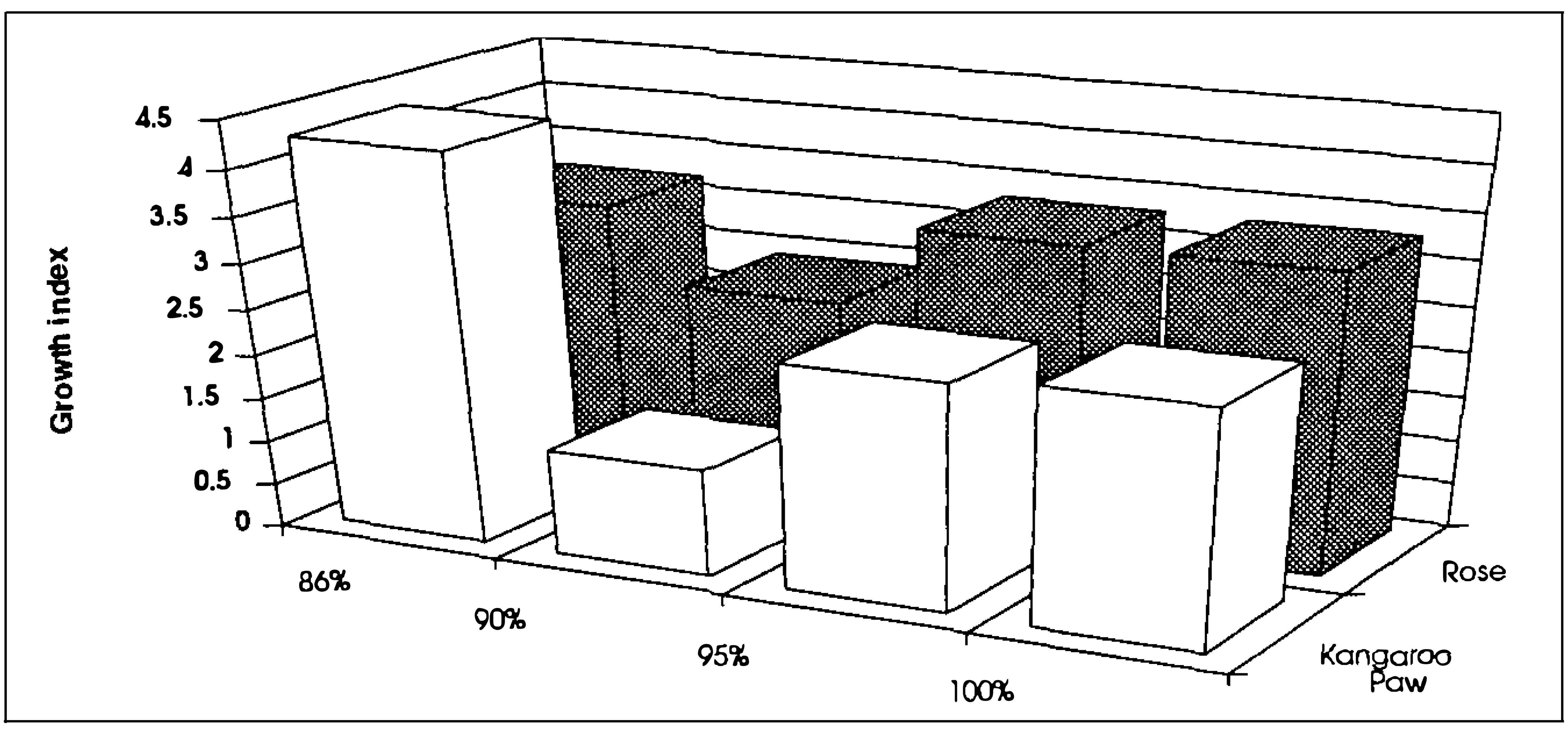

Figure 3. Comparative growth index for kangaroo paw and *Rosa* 'Red Cascade' under reduced humidity in vitro.

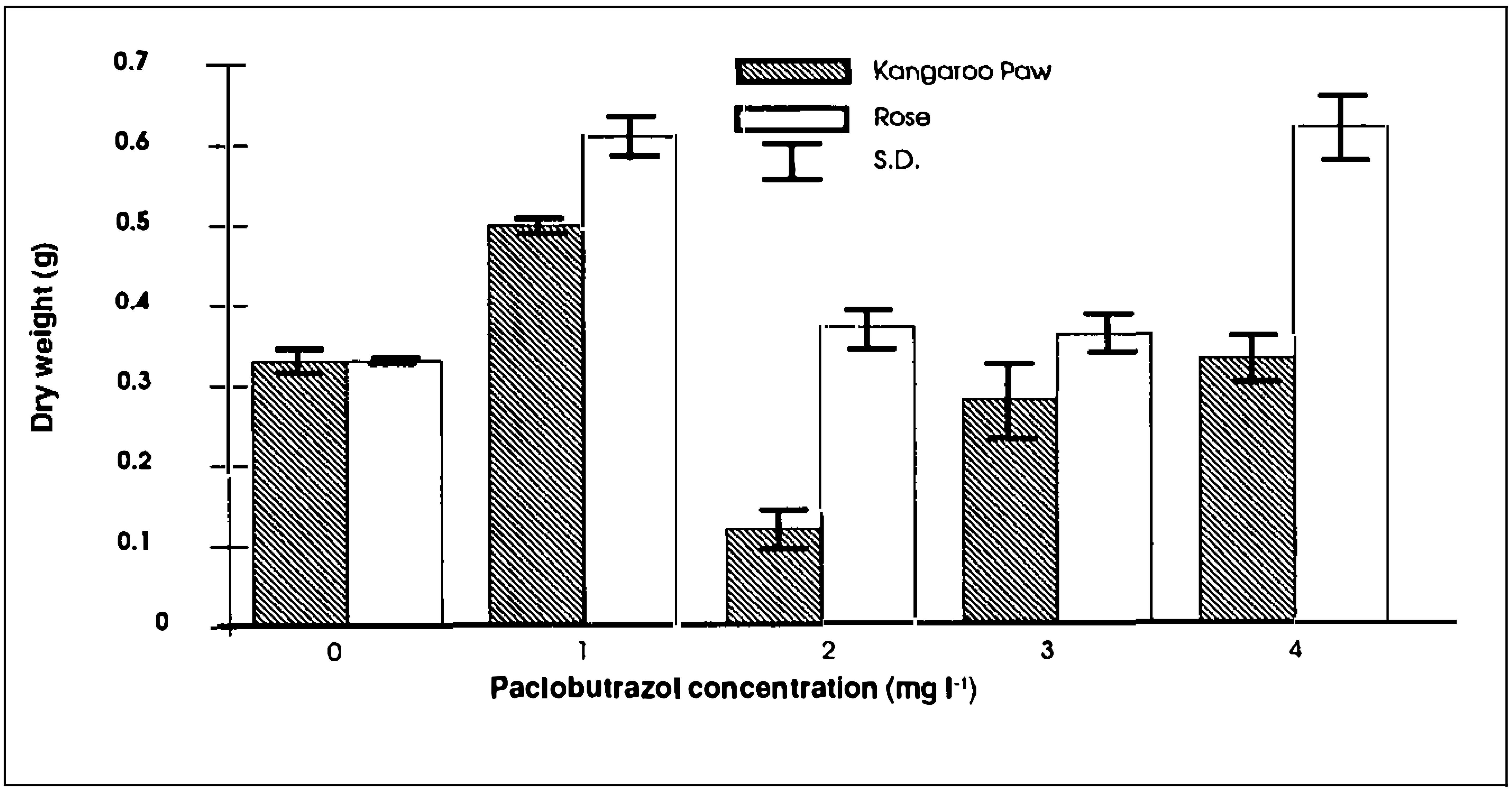

Figure 4. Comparative dry weights of kangaroo paw and *Rosa* 'Red Cascade' under different paclobutrazol concentrations in vitro.

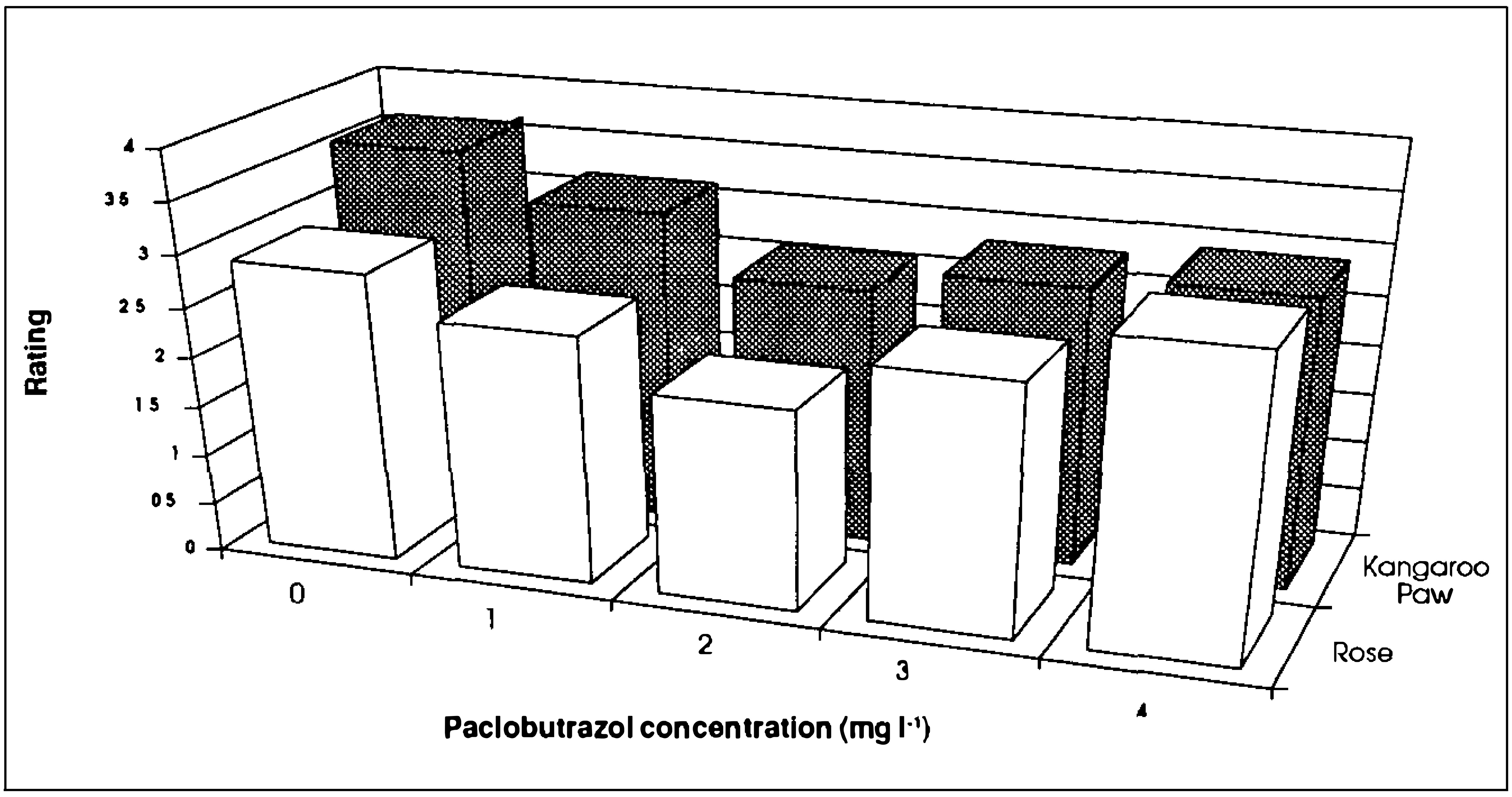

Figure 5. Comparative growth rating index for kangaroo paw and *Rosa* 'Red Cascade' after paclobutrazol treatment in vitro.

bushy at the higher concentrations; however, following 25 days of glasshouse environment, growth had begun to return to normal in all treatments.

CONCLUSIONS

Survival and growth of rose was not improved by the reduction of humidity in vitro. Kangaroo paw growth was increased by reducing in vitro humidity to 86% to 90% RH and root length increased at RH below 100%. Growth responses to PAC were erratic.

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Hostas in Australia

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INTRODUCTION

I first became interested in the genus *Hosta* after I visited England in 1977 and saw large specimen plants displayed at the Chelsea Flower Show and in many gardens that I visited. This interest remained dormant until 1978 when, on becoming a member of the I.P.P.S. at the Hobart conference, I saw a display of *Hosta* plants in the Hobart Botanic Gardens conservatory. This rekindled my interest, and on my return to Melbourne I began searching for hosta plants. I managed to obtain plants from various nurseries and slowly built up a collection of the cultivars then available. These included *H. sieboldiana*, *H. crispula*, *H. ventricosa*, *H. fortunei* var. *albopicta*, *H. fortunei* Aurea, *H. plantaginea* 'Grandiflora', *H. undulata*, *H. ventricosa* 'Aureo-maculata', and *H. undulata* var. *univittata*.

In the beginning, it was difficult to find collectors or growers. In fact, it was even difficult to find people that knew what a hosta was. This dearth of information has been partially overcome by articles in gardening periodicals and by small promotions of hosta by those interested in this genus. It was on meeting Ruth Tindale, who had a collection of hosta in her garden at Sherbrooke, that my collection really began to burgeon. Ruth was a member of the American Hosta Society and was at that stage importing seed from America. As I had access to heated glasshouses and propagation facilities, I was given some of this seed to sow and from the myriad of seedlings I was able to select some hostas with different leaf shapes and some with golden and variegated leaves. These seedlings were an improvement on the available cultivars in that the colour was retained right throughout the growing season.

In recent years a seed firm in Melbourne has been importing flasks of tissue-cultured cultivars from England and this has seen an upsurge in the cultivars available. There are at least two other people importing hosta plants into Australia and these plants are slowly becoming available to the public.

PROPAGATION METHODS

The methods of propagating hosta are: seed, division, and tissue culture. I don't intend to discuss propagation by tissue culture, other than to say, that to the best of my knowledge, there is nobody actually producing them by tissue culture in Australia. The plants that are available for sale in this country are from overseas sources and are only being deflasked here and grown on. This importation has allowed many of the new cultivars to become available in this country.

Seed. Hosta propagation from seed is easy. The seed germinates readily and generally produces an abundance of plants. However, hostas cross breed freely and the resulting plants should be considered hybrids, and should not, even if they appear similar, be labelled with the name of the parent plant. The only species which comes true from seed is *H. ventricosa*.

The breeding of *Hosta* is a fascinating hobby. However, most of the plants produced will not be sufficiently different from existing cultivars and should be ruthlessly rogued out, and the effort channelled into growing on the crosses which have been selected as showing promise. In selecting promising crosses, the grower should consider leaf colour, shape, leaf markings, habit, and vigour. I suggest that all seedlings should be grown for at least two seasons before discarding any of them.

When growing hostas from seed, the seed is collected as the pods start to turn yellow in autumn. The pods should be labelled and left to dry in paper bags until the pods split and shed the seed. The seed is sown immediately after cleaning into trays containing pasteurised potting mix topped with a mix of 1 peat moss : 1 vermiculite (v/v), watered in, placed into a heated glasshouse, and the trays covered with a pane of white painted glass. The seed usually germinates within 3 weeks and germination is generally close to 100%. When the seedlings have reached the four-leaf stage, they are pricked off into 2-in. tubes of a good quality potting mix, and kept growing in the glasshouse during the winter period. They should be fertilised monthly with a liquid fertiliser or alternatively top dressed with a controlled-release fertiliser. In mid-spring the plants should be moved from the glasshouse into a shadehouse and kept growing through until the autumn, when they will go into winter dormancy. The hostas are potted into 6-in. pots in spring of the second year for growing on and assessment. Those seedlings with potential are retained and the rest discarded.

Division. Vegetative propagation of hostas is usually by division in early spring, but they can also be divided when the plant is in full growth.

Hosta plants in the ground can be divided simply by using a sharp spade and cutting a wedge out of the plant. This wedge can either be replanted as a whole or divided into smaller pieces.

Hostas grown in pots are best divided prior to the beginning of growth in spring. The roots of the plants are vigorous and matted and a large knife or even a meat cleaver or tomahawk is needed to divide the plants.

Trying to produce hosta cultivars by division is a slow process and I am now trying the "Ross method" of propagation. This method of propagation is best carried out in spring or even early summer when the plant is in active growth. A thin sharp knife is inserted into the stem just above the basal plate and the knife is pushed down through the plate into the roots. Another cut can be made at right angles to the first cut. The damaged tissue will mend by callousing and a new growth bud should form which will develop into a new division. I feel that this method should only be carried out every second year to allow the plant to recover and build up its reserves of energy.

CONCLUSION

In conclusion, I feel that as hostas provide colour and interest for at least 6 months of the year in the shady areas of the garden, that there will be a growing demand for new *Hosta* cultivars.

Propagation and Growth of the Tree Dahlia—Some Observations

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The giant tree dahlia (*Dahlia imperialis*) has been grown by horticulturists, nursery propagators, and gardeners for about 100 years. A survey of books and literature on propagation shows that very little information is given specifically to tree dahlias apart from the fact that unlike the garden dahlia, they can be propagated by cuttings taken from the cane-like growths after flowering has finished in late autumn.

This paper discusses the propagation of tree dahlia from leaf-bud cuttings, softwood tip cuttings, canes, and single-bud cuttings. Also discussed is the summer pruning of tree dahlia plants to achieve dwarfed forms that will encourage new landscape usage of this plant and may promote pot culture of tree dahlia plants within the nursery trade.

The tree dahlia belongs to the same group of plants as the common garden dahlia. Some botanists consider that modern hybrid garden dahlias and the tree dahlia originated through a common source—a cross between *D. pinnata* and *D. coccinea*. Naturally growing tree dahlia plants have never been found growing in the wild.

The propagation of modern day hybrid dahlias is well documented and includes: propagation by seed, tuber division, repeated removal of new shoots cut from tubers, and chunk grafting into spare tubers of cuttings with some tuber attached. Tree dahlia plants are easily propagated from sections of their cane-like stems. Most references recommend stem sections with two or three nodes.

The results presented in this paper are observations from field trials over a period of two years with only a few plants. Further trials will be needed to replicate the findings and to verify the results.

Summer Pruning of Tree Dahlia Plants. Experimenting with propagation of the tree dahlia was secondary to that of trying summer pruning to produce low-growing, flowering tree dahlia plants. The idea to try pruning came from observation of strong regrowth from an accidently severed tree dahlia clump.

Trial pruning of about one-third of a large clump of tree dahlia shoots was carried out in December 1991. The soft new growth shoots that were 200 to 300 mm long were cut back to 100 mm. Twin new growths arose from the base of each of the opposite leaves directly below the cut. By autumn of the following year these shoots had flowered. The growths were half the height (2 to 3 m) of the parent plant shoots that had received no pruning.

Flowering did not seem to be inhibited by pruning. In fact there were probably more flowers on the twin shoots of the pruned sections than on the unpruned section. The ultimate result was that the plant was reduced in height by half and this allowed the plant to present its flowers at eye level—a very pleasing landscape effect.

Double pruning of the growing shoots would probably result in a bushy flowering plant that only grows to about 1 m. This remains to be demonstrated.

PROPAGATION

Summer (December) pruning produced many fresh softwood cuttings and a decision was made to try propagation using single leafbud cuttings, terminal growing shoots, soft canes, and small regrowth shoots.

Leafbud. a sharp knife was used to cut and scoop a section containing a leaf with an immature leaf axil bud. The base of this cutting was inserted into a palm-peat propagation medium and the leaf area reduced by half.

The resulting growth from this type of cutting produced small tubers at the base and a flowering shoot about 1 m in length. The cuttings received no fertiliser or nutrient supply during the period of the experiment. With further research or trials, a nutrient regime could be formulated. Pruning of the new growth or the application of growth retardants may result in compact flowering potted plants being produced from leaf bud cuttings within one season. The potted plants would need to be transplanted into the garden after flowering.

Soft Tip Cuttings. Soft tip cuttings were removed from the major growing shoots and from the leaf axils where regrowth had appeared.

Two-thirds of the leaves were removed from each cutting, then the cuttings were placed in a pot and watered. A plastic tent was placed over the pot to give extra humidity. Several cuttings rooted but most died due to irregular watering and no fungicide drench being applied.

The initial successful rooting shows propagation using soft tip cuttings is an optional method that can be used to propagate tree dahlia plants.

Propagation by Canes and Single Bud Cuttings. Some of the semi-hard canes that were cut from the plants during the summer pruning were defoliated and the cane sections placed into the palm-peat propagation mixture. The cuttings used contained at least two nodes. Plants grew from these canes and the canes formed miniature tubers around the root area.

Observations of tuber and root formation on the canes and leaf bud cuttings suggest that the cane sections could be cut into tiny one-bud pieces. If single-bud pieces were initially stuck into sterile rooting medium and a high humidity environment with bottom heat, it is likely that these too would quickly produce acceptable saleable plants.

The quick propagation and subsequent production of flowering potted plants of the tree dahlia in one season using the propagation and pruning methods described should be of some use to nurserymen. Summer pruning of tree dahlia plants in the outdoor environment to produce low-growing forms or hedges, should be of interest to plant propagators, home gardeners, and all those involved in landscaping with these plants.

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I.P.P.S. and the Creation of a New Australian Botanic Gardens

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In 1978 the Royal Australian Institute of Parks and Recreation proposed to the Australian Government a proposal to establish a series of regional botanical gardens in which inland regional flora would be exhibited. These gardens would enhance the botanical collections existing in our coastal rim of gardens, which are associated only with our state capital cities and densely populated areas. The proposal was accepted in principle and there are currently six gardens being planned for development. They are: Alice Springs, Port Augusta, Longreach, Mt. Isa, Kununurra, and Sunraysia.

The Sunraysia Oasis Botanical Gardens will be a garden of world significance. It will bring together the plants of the world as the region of Sunraysia has brought together the peoples of the world. European migration to our region, immediately after the second world war, was very large.

The gardens are an expression of our community's horticultural maturity. It is a way of paying homage to our pioneers. It will be a place of tranquil beauty, of eudcation, and of scientific involvement, rather than of harsh commercial survival, which was the lot of our forefathers.

They are gardens built with people power. We have raised over $200,000 by public patronage and subscription. This money is destined for capital works. During this current harsh depression we have received great support from the "Friends of the Gardens", the local service clubs and business houses alike. Labour has been given freely and materials supplied either free or at cost.

The only government assistance we have sought is grant monies for community employment schemes. We are now recognised as part of the local TAFE college campus for horticultural students and as an exhibition facility for our regional scientific institutions.

I.P.P.S. INVOLVEMENT

It is true to say that the gardens would not have been created had it not been for the Australian Region of I.P.P.S.

During a lunch-time discussion, at CSIRO Research Station, Merbein, Victoria, some 40 years ago, three young men decided to build a botanic garden, as it was the one horticultural facility not provided for in the forward planning of our irrigation district, as designed by the Chaffey Bros of Canada, when Mildura was first developed. I was one of those young men.

I.P.P.S. member Lois Smith, an outstanding applied botanist in her own right, and I, in the company of I.P.P.S. members from all over, have visited most of the great gardens of the world. Our first exposure to world horticulture come under the leadership of Ed Bunker, our inaugural Australian chapter at large president. Typical of Edward's sensitivity, he planned a trip which in addition to witnessing plant propagation, also included the end product of great plantsmanship, the fully mature plants exhibited in exciting and marvellous gardens. It was on an I.P.P.S. post conference tour, in 1982, as an International Board member, that the spark ignited for us. We visited the newly established Pacific Botanical Gardens in the Hawaiian Islands. We brought back to our CSIRO colleagues the Pacific Gardens method of finance through patronage. In 1983, a steering committee, consisting of required talents such as legal, engineering, horticultural, etc., was selected from successful people within our community.

The committee of management of Sunraysia Oasis Botanical Gardens has four horticulturists serving on it, of whom three are I.P.P.S. members. They are Lois Smith of Sunraysia Nurseries; Mary-Anne McMillian, a tutor in plant propagation at the Sunraysia College of TAFE; and myself, also of Sunraysia Nurseries. I believe that in the management of Australian Regional Botanic Gardens, this is unique. The committee employed John Wrigley, horticultural consultant and former curator of the Australian National Botanic Gardens, whom we knew through I.P.P.S., to prepare a development plan which we could put to our community to solicit support. Together with John Wrigley, I.P.P.S. member Keith McIntyre assisted us in selection of a site for our gardens. It has not just been I.P.P.S. members, but also contacts made through I.P.P.S. members which have proved invaluable in the formation of our gardens. We had, for instance, the renowned conservationist, Harry Butler, present the keynote address to our first gathering of patrons. This was organised through I.P.P.S. member Ray Aitken of Western Australia. The book "Grow What Where", produced by the Australian Plant Study Group, of which Past President Natalie Peate is a member, has been used extensively in landscape design.

LOCATION AND SITE

The gardens are located 10 km from the heart of Mildura on the New South Wales side of the Murray River. Mildura is the centre of the Sunraysia District, which is in the heart of the great Murray/Darling River Basin. This river system springs to life in southern Queensland, northern NSW, south eastern NSW, and north eastern Victoria to empty into the southern ocean through south Australia.

The gardens site consists of 42 ha (105 acres) Murray River frontage and 110 ha (272 acres) of typical East - West Mallee sand ridge country. We are developing only 50 ha (122 acres) in our generation, leaving 103 ha (256 acres) for future generations to do with what they will. Lois and I were most impressed by the far sightedness of the forefathers of Vancouver, Canada, in setting aside 1000 acres for future generations to develop, within walking distance of the city centre.

The area we are working on will be developed as 26 ha (64 acres) of dryland gardens, exhibiting Australian flora and 23.5 ha (58 acres) of irrigated gardens exhibiting both exotic and Australian flora.

TO SEEK AND TO SHARE

We share our experiences and methodologies with you. We will share the gardens' progress with you. We share the opportunity to be part of it with you. We seek your assistance in supplying plants true to type, for planting in the gardens.

Is IBA an Effective Promoter of Root Formation on Cuttings of *Eucalyptus grandis*?

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Cuttings of a single clone of *Eucalyptus grandis* ex Hill. showed a positive rooting response to the presence of IBA applied as a liquid to the cutting base. The magnitude of the response varied with each of three identical trials conducted during winter, spring, and summer and it was not possible to define any optimal dose rate in the range 0 to 10,000 ppm IBA. A concentration of 2000 ppm was as equally effective as 4000, 6000, 8000, or 10,000 ppm. Root formation on cuttings dipped in IBA for 1 second was no different to that on cuttings dipped for 5 or 10 seconds. No advantage was achieved by allowing the base of treated cuttings to dry before the cuttings were inserted into the propagation mix.

INTRODUCTION

The use of auxins to promote adventitious root formation on cuttings is routine in many production nurseries. It is an easily applied treatment and is effective for many plant species.

Commercially important species of eucalypts are routinely propagated by cuttings in countries including Brazil, Portugal, and South Africa. All the descriptions of propagation techniques used in the nurseries refer to the use of IBA and also indicate that a range of IBA concentrations are used. Cuttings of *Eucalyptus camaldulensis* may be treated with 0.1% IBA (Marien, 1992) or 0.8% (Reuveni et al., 1990) and those of *E. globulus* with no IBA (Wilson, personal communication) or 0.8% (Hetherington and Orme, 1989). A similar range of concentrations has been used for *E. grandis*, for example Geary and Lutz (1985) reported use of 0.3% IBA and Wignall et al. (1991) used 0.8%.

That different nurseries have used different IBA treatments for the same eucalypt species suggests that cuttings may show a positive response to a broad range of IBA concentrations. It may be there is no one optimal IBA concentration and indeed it may also be possible that cuttings prepared without IBA treatment will root just as well as nontreated cuttings. Evidence to clarify these points is required as the auxin treatment adds material and time costs to production of the rooted cuttings.

In the study reported here we investigated a method of applying the IBA to the cutting. This was done as an attempt to clarify two points, firstly to look for time effective methods of applying the auxin and secondly to see if reproducible results could be obtained.

Liquid preparations of IBA are generally applied to each cutting as a quick dip of 5 to 10 sec. The trial investigated whether it was possible to achieve effective root promotion by using shorter insertion times. We also considered whether the cutting base must have dried before it is inserted into the propagation medium. To insert the cutting while still wet may mean some of the IBA solution is lost by absorption to the medium. But to wait for the cutting to dry means extra time is required and this adds to production costs.

We also considered the question of whether a single clone of *E. grandis* will consistently show the same rooting response to a given concentration of IBA. Cuttings of *E. grandis* were treated with IBA solutions in a range of concentrations. Three identical trials were conducted, one each in winter, spring, and summer.

MATERIALS AND METHODS

A single clone of *E. grandis* was used for all trials. Stock plants had been established from rooted cuttings either 2 or 3 years prior to the trials and grown in containers in a greenhouse with an average air temperature of 25C day and 15C night. They received natural radiation and photoperiod.

Cutting preparation was identical in all trials. Eight-week-old shoots were harvested from stockplants and trimmed to four leaf pairs. Leaves were removed from the two basal nodes.

The IBA solutions were made from K-IBA dissolved in ethanol. Unless stated otherwise, a preparation of 8000 ppm was used and the basal 1 cm of the stem was dipped into the solution for 1 sec.

After cuttings were given the specified treatments they were inserted into Kwik® pot trays. The trays contained a mixture of 1 peat, 1 perlite, and 1 sand (by volume). After cuttings insertion the trays were placed on a propagation bench with bottom heat and overhead misting.

For all trials, assessment of the cuttings took place 50 days after the cuttings were inserted. Cuttings were scored for the presence of roots and the number of roots per rooted cutting.

Raw data for percentage rooting was analyzed for variance using a logistic regression. Data for root mass and root number was analyzed for variance using an unbalanced mixed model treated with REML.

Experiment 1 - Trials 1 and 2. These two identical trials, conducted in October 1990 and January 1991, looked at adventitious root formation on cuttings after they were dipped into IBA for 1, 5, or 10 seconds. Pairs of cuttings were treated with IBA. The base of one cutting was immediately inserted into the medium and the other was allowed to dry before insertion. The cuttings were arranged in four randomized blocks. Each block contained 10 pairs of cuttings for each of the three immersion time treatments. Each pair represented a wet and dry insertion.

Experiment 2 - Trials 3, 4, and 5. This series of trials consisted of three identical investigations to find an optimal concentration of IBA to promote root formation on cuttings. The trials were conducted in August and October 1992 and January 1993. Treatments consisted of IBA concentrations of 0, 2000, 4000, 6000, 8000, and 10,000 ppm. The control treatment was ethanol. Cuttings were dipped into the solutions, removed, and to ensure each cutting absorbed the IBA, the stems were allowed to dry before the cuttings were inserted into trays. Cuttings were placed into a randomized block design of six blocks. Each block contained four replicates of each of the six treatments.

RESULTS

The length of time for which the cuttings were held in the IBA solution had no significant effect on root formation (Table 1). For example in trial 1, cuttings given 1-, 5-, or 10-second treatments showed no difference in the number rooted or the number of roots per rooted cutting.

Table 1. The rooting response of *Eucalyptus grandis* cuttings dipped in an IBA solution for 1, 5, or 10 seconds.

Dip time (sec)	Rooting (%) Trial 1	Rooting (%) Trial 2	Root number/cutting Trial 1	Root number/cutting Trial 2
1	66	65	1.6	1.9
5	58	75	1.6	2.1
10	61	83	1.6	1.9
mean value	62	74	1.6	2.0

Allowing the IBA solution to dry on the base of the cutting before it was inserted into the propagation media had no consistent effect on root formation (Table 2). In trial 1, significantly more cuttings rooted if inserted with a dry base, but the number of roots per cutting did not differ from that of cuttings with a wet base. In trial 2 there was no significant difference in treatment effects on the percentage of cuttings to root or the number of roots per cutting.

Table 2. The rooting response of *Eucalyptus grandis* cuttings, treated with IBA and then inserted into the propagation medium with wet or dry stems.

Insertion treatment	Rooting (%) Trial 1*	Rooting (%) Trial 2	Root number/cutting Trial 1	Root number/cutting Trial 2
base wet	49	75	1.4	1.9
base dry	75	72	1.7	1.9
mean value	62	73	1.6	1.9

* Significant difference between treatments within the trial at a probability level of 0.05.

Interactions between the duration of the dip and the method of allowing the stem to dry after the dip, were tested and found to be nonsignificant.

Cuttings treated with different dose rates of IBA showed no consistent response in adventitious root formation (Table 3). In trial 3 there was no evidence of significant treatment effects and although in trials 4 and 5 significant differences did occur, the pattern of difference was unclear. In trial 4 there was a suggestion of inhibition of rooting at the higher levels of IBA whereas in trial 5 all treatments with IBA rooted better than the control that had no IBA.

For both experiments, rooting response changed notably between trials. This variation between trials was often greater than that within a trial. For example, in experiment two, means for all treatments within a trial show that trial four cuttings rooted only half as frequently and had half as many roots as trial five cuttings (Table 3).

Table 3. The effect of variable IBA dose rates on root formation on cuttings of *Eucalyptus grandis*.

Treatment IBA ppm	Rooting (%)			Root number/cutting		
Trials	3	4*	5*	3	4	5
0	67	42	71	1.8	1.4	2.3
2,000	54	75	92	1.9	1.3	2.9
4,000	70	50	96	2.2	1.4	4.3
6,000	71	54	88	2.3	1.5	5.3
8,000	67	38	92	1.7	1.9	2.6
1,0000	75	29	99	2.6	2.0	3.3
mean value	67	48	90	2.1	1.6	3.5

* Significant differences between treatments within trials at a probability level of 0.05.

DISCUSSION

These experiments indicate that within the range of IBA solutions tested there was no evidence of strong root promotion or inhibition on *E. grandis* cuttings. All that can be concluded is that some IBA is probably better than none. It seems likely that a dose rate of 2000 ppm was just as effective as higher concentrations.

The results have also suggested that to apply liquid IBA preparations it is only necessary to dip the cuttings into the solution for sufficient time to wet the stem. A 1-second immersion is just as effective as a 5- or 10-second immersion. There remains the possibility that exposures longer than 10 seconds would allow greater uptake of IBA into stem tissues but such treatment does not seem necessary.

Despite the rigourous approach used in these experiments there were large variations in results between repeat trials. These variations are not consistent with seasonal effects and remain unexplained. However, it is clear that the use of IBA was not able to overcome the effects on rooting of any unknown factors. This is illustrated in trial 5 by the non-IBA-treated controls that rooted as well or better that any IBA-treated cuttings in trials 3 and 4.

The lack of repeatability in experiments of this nature has been previously pointed out by Loach (1988) in a review of the use of auxins as an aid to rooting of cuttings.

Our experiments confirm his conclusions and provide a caution to propagators who may consider adopting the results of non-repeated trials.

We also suggest that use of IBA on naturally poor rooting clones will not significantly improve adventitious root formation. Rather than spend time on lengthy trials to find optimal auxin rates it may be better to seek clones that naturally have a high rooting potential.

Acknowledgements. The statistical analysis was provided by Mr. Ross Cunningham, Australian National University. This work was supported by the Australian Research Council and the National Afforestation Program, Australian Commonwealth Dept. of Primary Industry and Energy, Canberra.

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The Production of Evergreen Azaleas in a Sub-Tropical Climate

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It is often thought that Brisbane is too hot to grow Indica azaleas (*Rhododendron*). Our climate is subtropical with summer day temperatures averaging near 30C and winter day temperatures 15C. We are situated on a latitude of 27°S and have an average annual rainfall of 1150 mm (45 in.) which predominantly falls in the summer months.

This paper will outline how we have adapted this particular plant to our environment.

CULTIVAR SELECTION

Careful matching of cultivar to environment is perhaps the key to success in any crop. In azaleas we look for the following traits for a successful cultivar:

- Flower colour
- Amount of flower
- Flower longevity and holding capacity
- Number of flower flushes in a year
- Foliage colour
- Growing habit of plant
- Overall appearance
- Resistance to diseases
- Ability to propagate.

Our trials to access the above characteristics can quite often take 2 to 3 years. One year is not enough time to evaluate fully the potential of a new cultivar, as quite often the plant can perform above or below average in the first year and needs more time to settle into its new environment. It is also very important that we trial our own plants that we have propagated and not plants that we have brought in from outside our system, as they may behave differently.

PROPAGATION

Medium and Nutrition. The propagation medium is a 1 peat and 1 sand (v/v) mixture. Dolomite is incorporated at a rate of 1 kg/m^3. There are no fertilisers added at this stage of production.

Facilities Required. If propagation is timed correctly no heating or cooling is required. Therefore, we need only to control light intensity and relative humidity. Light is controlled by no less than 50% shade cloth and a mist system is used to reduce water loss through transpiration from the cuttings.

Availability of Cuttings. Being an evergreen, material is available all year-round, however, cuttings are taken from January to April. In our system cuttings taken any later than April do not root because root initiation will be without temperature control and the cold causes dormancy.

If timed correctly, the collection of cuttings may act as a light pruning for the growing crop from which the cuttings are collected.

Method of Propagation. Semihardwood cuttings are used and they are collected in the morning before the heat of the day. The cuttings are kept moist until they are prepared and planted. Preparation of the cutting involves grading to length, removing unwanted leaves, and removing the apical bud. The average cutting length is 10 cm and the bottom two-thirds of the leaves are removed, leaving intact a minimum of three leaves on the cutting. The apical flower bud is removed to promote vegetative and root growth.

Once prepared, the cuttings are planted one per cell in cell trays. Rooting hormone powder containing 8 g/kg IBA is applied to the base of the cutting immediatly before planting. Planting depth is approximately two-thirds the depth of the cell. Root initiation is inhibited with deeper planting and shallower planting may not give the cutting ample support.

It is very important to use protective fungicides to minimise diseases in the wet, humid conditions under mist. We have found that an application of Thiram (active - 800 g/kg Thiram) no later than three days after planting, will significantly reduce disease incidence.

Hygiene. Hygiene plays a critical part in successful Azalea propagation. It is crucial that anything touching the open wounds of the cutting be disinfected or sterilised.

Hardening Off. Misting frequency is gradually reduced as the cuttings develop their own root systems. It takes approximately 10 to 12 weeks from taking the cutting to developing the plant to the stage whereby it no longer requires any mist.

GROWING ON

Media and Nutrition. The medium used consists of 2 composted hardwood sawdust, 1 composted pine bark, and 1 peat (by volume), to which is added a basal level of nutrients. Ongoing nutrition is supplied via a slow-release fertiliser added at 5 to 6 kg/m^3 as a direct dibble at planting. This is supplemented as needed with liquid feeding.

Potting. Potting from propagation tubes into 140-mm (6-inch) pots takes place during October, November, and December. The planted pots are placed out on their growing beds. These need to have good drainage away from the bottom of the pot. The single-flowering cultivars grow on beds in the full sun and the double and kurume culitvars grow under 30% to 50% shade provided by shade cloth.

The majority of these plants will be sold in the following spring (August to September). Some early-flowering cultivars are sold from April onwards.

Pruning and Training. All plants are pruned and trained. The first light pruning occurs in January when cuttings are taken for the next crop. This pruning encourages the plant to fill out. Soon after all propagation material is collected, each plant is individually trained by pruning back unnecessary wood and creating a framework, so that at the time of sale the plants will be well structured. Plants have to be pruned no later then early April, otherwise they have insufficient time to set buds for spring.

Water Quality. Diseases caused by *Phytophthora* species are common in azaleas. Contaminated water must be treated.

Plant Protection. Weeds in pots are controlled with pre-emergent herbicides or pulling by hand.

Insect pests are monitored and sprayed on a need basis only, whereas fungicides are sprayed on a regular preventative program.

CONCLUSION

By careful selection of cultivars we find that evergreen azaleas are a very successful crop for us here, even though our climate is often thought to be too tropical for this crop.

Government Regulations and Nursery Accreditation

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There have been many changes to government regulations and operational strategies and policies which may have significant impact on nurserymen throughout Australia. I will discuss accreditation and water management regulations and their implications for nurserymen through examples.

The Eltham Shire in Victoria is introducing a Pest Plants Local Law to ban or restrict sales of environmental weeds from nurseries. Similarly, there have been government initiatives on a national weed strategy and more rigorous policing on noxious weed regulations. There has been more emphasis on health and safety issues and the environment. Examples include changes to pesticide regulations and safe work practices.

Government organisations and, in particular, the Australian Quarantine Inspection Service, have changed significantly. This will influence the importation of PVR plants and the development of plant exports.

There is obviously an emphasis on the environment and regulations that will minimise pollution. Probably the most significant development is the NSW Clean Waters Act and similar legislation proposed in other states.

HISTORY OF NURSERY ACCREDITATION

I will first discuss nursery accreditation and the implications and benefits for nurserymen.

There have been various plant improvement programs and accreditation schemes. Of the current state accreditation schemes the Victorian and Northern Territory schemes are the longest running. The Minister for Agriculture launched the Victorian scheme on the 11 July 1989. Now there are 18 accredited nurseries, including two specialist propagation nurseries.

Western Australia and Queensland have more recently developed accreditation schemes and Tasmania, South Australia, and New South Wales are working towards accreditation. In August 1992, representatives of all state nursery associations met to discuss the introduction of a national accreditation scheme. The administrative requirements and the first draft of the technical criteria have been prepared.

ADVANTAGES AND BENEFITS OF NURSERY ACCREDITATION

The ultimate advantage of any scheme should be increased profits. This will come from improved nursery practices and increased consumer confidence in products sold by accredited nurseries and allied trades.

In Victoria, the aim was to improve the quality of nursery stock and to minimise diseases including those caused by *Phytophthora* species. This scheme has applied only to production nurseries. The Victorian scheme was based on quality management throughout the production process. Similar schemes in the past have failed because of the emphasis on a regulatory approach. In Western Australia, the state government applied pressure to stop the spread of *Phytophthora* root rot to native forests. The Queensland scheme was based on the Victorian and Western Australian schemes. It has a greater emphasis on *Phytophthora* species control, though this is not due to government pressure as in Western Australia.

The state nursery industry associations administer accreditation, however, they all have government involvement in the establishment and maintenance of standards. Participation is voluntary in most state schemes.

The national Nursery Industry Accreditation Scheme of Australia will operate through the Nursery Industry Association of Australia and state industry associations. It will be open to all nurseries and will be voluntary.

ACCREDITATION ASSESSMENT

The assessment criteria include:

General criteria

- General appearance of the nursery
- Growing structures
- Storage areas—pesticides, containers, media
- Propagation plant material
- General hygiene
- Plant protection practices, plant nutrition, and safe handling of pesticides—spray program, equipment, safe handling
- General vigour and appearance of plants
- Irrigation and water supply
- Disposal of waste

The emphasis and importance of these criteria may vary with the type of nursery. For example, propagation facilities, practices, and hygiene are emphasised in specialist propagation nurseries.

Nursery accreditation is not another name for government regulation. It is self regulation by the industry, and should be based on quality management throughout the production process. Elimination of *Phytophthora* species from the nursery industry is a commendable objective, but probably not achievable in practice. The improvement in productivity and quality achieved through participation in accreditation is a real and achievable objective.

WATER TREATMENT AND RECYCLING

The recycling of nursery runoff and treatment to control pathogens is a significant issue locally and overseas.

LOCAL WATER MANAGEMENT LEGISLATION

You should all be aware of the NSW Clean Waters Act and the implications for all nurserymen. In NSW, it is an offence to pollute any waters. The Act establishes limits for various substances—including insecticides, fungicides, herbicides, and fertilizers— contaminating surface and groundwater.

Other Australian states have environment protection legislation that can apply to nursery runoff. In Victoria, government inspectors have investigated complaints of tree damage downstream from nurseries, with particular emphasis on herbicides used in the nursery. This is a significant issue for most states and the relevant government departments are developing policies and eventually regulations to control the discharge from nurseries.

In the United States, private individuals have taken court action against organizations involved in polluting local rivers. Many of these cases have resulted in multimillion-dollar settlements against the offenders. This is possible under local legislation.

In the United States and Europe there are very strict controls on drainage from nurseries and water recycling is becoming more common.

IMPLICATIONS OF REGULATIONS FOR NURSERYMEN

For the reasons outlined above, it is becoming more important for nurserymen to consider water conservation and recycling.

Recycled water should be treated to control plant pathogens. The incidence and extent of*Phytophthora* and other water-borne pathogens in nurseries are such that water recycling without treatment will lead to increased losses due to root rot.

Potting media may be suppressive to *Phytophthora* and other pathogens. However, the presence of these pathogens will cause losses during periods of water stress or after planting in the garden. Effective treatment of recycled water and other hygiene practices can eliminate this problem. To comply with regulations, production areas could be covered to collect and direct water to tanks for recycling. Concrete, bitumen, or heavy grade black plastic covered by screenings could be used to prevent water entering the soil. It may be necessary to store the first 35 mm of rain falling on the nursery site.

CHALLENGES IN WATER MANAGEMENT IN NURSERIES

Fertilizer and pesticide residues in nursery runoff may not contribute significantly to contamination of ground and surface water compared with discharge from industrial and domestic sources. However, the regulations will still apply. Research has commenced to evaluate fertiliser runoff from various agricultural and horticultural situations to help clarify the situation.

There are other water management problems facing nurserymen. There is increasing pressure to improve the efficiency of water use due to the increasing cost of water and the associated labour and equipment costs. In response to government pressure, some industries have made significant savings through recycling and improved production practices.

PRACTICAL SOLUTIONS TO WATER MANAGEMENT PROBLEMS

Some problems facing nurserymen include:

- Reduce waste water from container standing areas
- Reduce water cost and labour associated with hand watering
- Increasing water supply by collecting runoff
- Maximise irrigation efficiency but maintaining growth
- Concerns over nitrate and phosphate content in runoff
- Regulations or impending Regulations controlling runoff
- Reduce fertilizer use by monitoring plant needs

Possible solutions include:

- Grade pot standing areas to direct runoff to a tank
- Use of drip irrigation systems
- Increased size of dams to collect all runoff
- Optimise potting media and water use
- Use of "water-saving" polymers and wetting agents
- Computer control of irrigation management and fertilizer addition based on environmental monitoring
- Use of more efficient irrigation equipment and practices and relating use to need
- Pulse watering allows water to soak in before more is applied
- Growing drought tolerant plants
- Grass strips between rows to filter runoff
- Use of antidesicants and wetting agents
- Monitoring nutrient levels in recycled water and adjustments to supply the plants needs
- Adopt capillary or ebb and flow watering systems
- Use and management of appropriate controlled-release fertilizers which only supply the plant requirements

WATER TREATMENT IN ACCREDITED NURSERIES

Treat recycled water before use. As propagators, you should be aware of the potential problems caused by water-borne pathogens and the need to minimise or eliminate disease. There are many water treatment systems available; however, they are not equally effective in treating irrigation water.

Some recent installations have concentrated on the engineering required to mix the treatment chemical or gas with the irrigation water. It is important to first evaluate the efficacy of the technique proposed and then consider the installation. In my experience, each nursery situation is unique and what may be effective and economic in one nursery may be totally inadequate in another.

Consider the source of water, the chance of serious pathogens, the amount of suspended particles, the amount of organic matter, and the use of the treated water.

Chlorine will kill plant pathogens if the concentration (minimum 2 ppm) and contact time (minimum 20 min) are sufficient. However, increasing organic matter or suspended particles will reduce the efficacy of treatments.

AVAILABLE WATER TREATMENT SYSTEMS

The following are readily available water treatment systems that may have application in nurseries. The price may range from $2000 to $30,000 for an average nursery. Efficacy and reliability of these systems may also vary significantly. The following lists some available systems.

Liquid Chlorine

- Usually sodium hypochlorite
- Inexpensive to install if flow is constant (<$1000 depending on available equipment e.g. tanks)
- Injection rates can be controlled automatically, though this adds significantly to the cost

- Best used with storage tanks to provide sufficient contact time
- Higher concentrations required for "dirty" water supplies
- Equipment will rapidly corrode at higher concentrations (>3 ppm)
- Sodium hypochlorite is alkaline and may cause problems with alkaline water supplies
- Chlorine is less effective in alkaline water and the dose must be increased to be effective

Chlorine Gas Injection

- Similar to liquid chlorine, though it will acidify water
- Chlorine gas is dangerous and requires special precautions

Brominators (Erosion Feed System)

- Bromine is more effective than chlorine at higher pH
- Some equipment on the market may be unreliable and inaccurate
- Inexpensive (<$2000)

UV with Ozone

- The amount of ozone produced by UV tubes may be too low to be effective
- Very expensive for higher flow rates ($20,000 to $30,000)

Ozone

- Ozone is generated by corona discharge
- Ozone in sufficient concentration is considered the best method for sterilising water
- Very expensive to install (> $30,000)

Microfiltration

- Filtration to less than 5 microns is effective though generally not practical for most nursery situations
- Expensive for higher flow rates

Chlorine Dioxide

- Widely used overseas for water treatment
- More effective for controlling *Phytophthora cinnamomi* than liquid chlorine at low doses (unsubstantiated nursery trials)
- Moderately expensive though systems are well engineered and likely to be very reliable ($10,000 to $15,000)

As nurseries move towards water conservation and recycling, the need to effectively control water-borne pathogens in irrigation water has become increasingly important. Consider why you are installing the system and ensure that it is likely to be effective. Ensure that the suppliers and installers of equipment are aware of the biological requirements for controlling plant pathogens and then consider whether they can provide and install well engineered and reliable equipment.

Dormancy Release of Tree and Shrub Seeds Using a Compost Activator Pretreatment

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Results from initial trials at Writtle College indicate that the germination of several economically important tree and shrub seeds, including *Acer campestre*, *Crataegus* spp., and *Tilia platyphyllos*, can be improved by a compost activator treatment developed initially for rose rootstocks. Treated seeds gave a higher field emergence and germinated earlier than untreated controls and subsequently produced better quality seedlings. However, the improvement was not as marked or as consistent as had been found with seed of rose rootstocks. Further work is now being supported by a grant from the Horticultural Development Council.

INTRODUCTION

Seed dormancy is common in many temperate tree and shrub species. There are obvious evolutionary advantages in possessing dormant seeds. For example, in many species the dormancy mechanism provides a means of avoiding autumn germination. In order to overcome dormancy the horticulturist must stratify these seeds to mimic winter conditions experienced in nature. Dormancy may also provide a means of spreading germination, so that in nature all the seedlings produced by a plant are not wiped out if a disaster should occur. This natural process gives the horticulturist the problem that as seeds do not germinate together the final grade-out of the seedlings will be very varied, as seedlings which emerge early will tend to suppress the growth of those which emerge later.

For those tree and shrub species which have been studied in detail, a range of different seed dormancy mechanisms exist which in turn has given rise to a varied set of pretreatment conditions being applied to overcome that dormancy. Gordon and Rowe (1982) have reviewed both dormancy mechanisms and pretreatments for a wide range of species.

Cullum et al. (1990) adopted a novel approach to the problem of seed dormancy in the rose rootstock *Rosa corymbifera* 'Laxa'. They demonstrated that a proprietary compost activator, Garotta (produced by Sinclair Horticulture and Leisure Ltd., Firth Road, Lincoln, LN6 7AH), can be used successfully to germinate the rose achenes in the following spring. The pretreatment used is 10 g moist achenes, 25 g moist vermiculite, 0.5 g Garotta compost activator, followed by storage at 20C for 12 weeks and then at 4C for 12 weeks. Results over four years showed that the addition of Garotta significantly increased the germination rates compared with achenes which had received the warm and cold treatments only.

In 1990 'Forestart' and Writtle College agreed to start joint trials to investigate whether the pretreatment developed for *R. corymbifera* 'Laxa' could be effective for other dormant seeds.

In these trials some 10 species were treated with and without Garotta each year. Criteria for species selection was that their normal pretreatments were similar to *R. corymbifera* 'Laxa'. Any species which showed a response was then subjected to a more thorough replicated field trial in the second year.

MATERIALS AND METHODS

All seeds were supplied from commercial seed lots at 'Forestart', and soaked in water overnight before use. Moist vermiculite was prepared by adding 400 ml deionised water to 250 g vermiculite (medium grade) and stirring thoroughly. Twenty-five grams moist vermiculite were used for each 10 g seed being tested and the compost activator was added as required. The mixture was stored in a polythene bag, tied loosely to admit air and then weighed. The bags were kept at 20C for 12 weeks followed by storage at 4C for a further 12 weeks. Each week during the treatments the bags were shaken to aerate the contents and returned to their original weights by adding deionised water.

After the time of cold treatment was complete, seeds were sown into a seedbed treated the previous autumn with the soil sterilant dazomet, then covered with a layer of 4- to 6-mm gravel to prevent capping. Percentage field emergence was recorded.

Experiment 1: Initial Screening of 12 Tree and Shrub Seeds (1990). For each species, four batches of seeds were prepared, each batch containing at least 100 seeds. Each batch was weighed and added to moist vermiculite in the same proportions as described above. The first treatment was left without further addition to act as a control. The remaining three were then treated with Garotta at the rate of 0.25 g Garotta/10 g of seed (low Garotta), 0.5 g Garotta/10 g seed (medium Garotta), and 1.0 g Garotta/10 g seed (high Garotta). The following species were tested: *Acer campestre, Berberis darwinii, Carpinus betulus, Cornus mas, C. sanguinea, Cotoneaster divaricatus, Crataegus crus-galli, C. monogyna, Euonymus europaeus*, *Rosa canina*, *R. rubrifolia*, and *Tilia platyphyllos*.

All treatments commenced on 9 October 1990 and the field trials were sown on 27 March 1991.

Experiment 2: Initial Screening of Eight Tree and Shrub Seeds (1991). The following species were treated as in the 1990 screening: *Acer japonicum, A. palmatum*, *Carpinus betulus, Cornus mas, C. sanguinea, Crataegus laevigata* [syn. *C. oxyacantha*], *C.* × *prunifolia*, and *Elaeagnus angustifolia.*

All treatments commenced on 16 October 1991 and the field trials were sown on 1 April 92.

Experiment 3: Replicated Field Trial in 1991 of Two Species Which Appeared to Show a Response to Garotta in 1990.

A) *Acer campestre*. The treatments were:
- Control (treated as described in 1990 initial trials)
- High Garotta (1 g Garotta for every 10 g seed)
- Very high Garotta (1.5 g Garotta for every 10 g seed)

Each of the treatments was set up in duplicate and after the 12 weeks warm followed by 12 weeks cold treatment, four lots of 100 seed were counted from each of the replicates and sown in the seedbed using a replicated design.

All treatments commenced on 9 October 1991 and the field trials were sown on 25 March 1992. Field emergence was counted regularly and seedling quality was recorded 6 and 12 weeks after sowing.

B) *Cotoneaster divaricatus*. The treatments were:
- Control
- Low Garotta (0.25 g Garotta for every 10 g seed)
- Very low Garotta (0.125 g Garotta for every 10 g seed)

The method then followed that of *A. campestre* and field emergence was recorded regularly.

RESULTS

Experiment 1: Initial Screening of 12 Tree and Shrub Seeds in 1990.

Table 1. Percentage field emergence 12 weeks after sowing.

Species	Control	Low Garotta	Medium Garotta	High Garotta
Acer campestre	8	23	36	44
Berberis darwinii	0	0	0	0
Carpinus betulus	4	11	3	8
Cornus mas	0	0	0	6
C. sanguinea	91	61	70	61
Cotoneaster divaricatus	7	51	18	23
Crataegus crus-galli	1	0	0	0
C. monogyna	43	57	63	62
Euonymus europaeus	5	4	4	10
Rosa canina	8	73	79	85
R. rubrifolia	0	0	1	0
Tilia platyphyllos	14	13	18	20

Experiment 2: 1991 Initial Screening of Tree and Shrub Seeds.

Table 2. Percentage field emergence 12 weeks after sowing.

Species	Control	Low Garotta	Medium Garotta	High Garotta
Acer japonicum	0	0	0	0
Acer palmatum	3	4	5	5
Carpinus betulus	3	6	5	5
Cornus sanguinea	82	82	98	97
C. mas	0	1	1	0
Crataegus laevigata	5	14+2*	4+9*	15+1*
C. × *prunifolia*	3	13	19	12
Elaeagnus angustifolia	5	8	6	2

(+* = *C. prunifolia* - unexplained contaminant)

Experiment 3. 1991 Replicated Field Trial of Two Species Which Appeared to Show a Response to Garotta in 1990.

Acer campestre: field emergence.

Table 3. Mean percentage field emergence (weeks after sowing).

	Week 4	Week 6	Week 8	Week 12
Control	17.1 (a)	54.12 (a)	55.2 (a)	54.6 (a)
High Garotta	30.8 (b)	60.5 (a)	60.2 (a)	59.0 (a)
Very high Garotta	35.8 (b)	57.1 (a)	57.3 (a)	57.1 (a)

Different letters in column indicate significant difference between means at 95% confidence. LSD 5% = 5.83. For treatment details see method.

Acer campestre: seedling quality.

Table 4. Mean percentage of seedlings with first true leaves expanded to at least the horizontal stage measured 6 weeks after sowing.

	Mean
Control	9.2 (a)
High Garotta	20.8 (b)
Very high Garotta	25.0 (b)

Different letters indicate significant difference between means at 95% confidence. LSD 5% = 5.41. For treatment details see method.

Acer campestre: seedling quality.

Table 5. Mean percentage of seedlings over 20 cm in height, 12 weeks after sowing

	Mean
Control	13.3 (a)
High Garotta	21.3 (b)
Very high Garotta	19.8 (b)

Different letters indicate significant difference between means at 95% confidence. LSD 5% = 5.87. For treatment details see method.

Cotoneaster divaricatus: field emergence.

Table 6. Average percentage field emergence (weeks after sowing).

	Week 4	Week 6	Week 8	Week 12
Control	0.8	5.25 (a)	12.1	12.6 (a)
Low Garotta	8.7	19.5 (b)	24.2	24.3 (b)
Very low Garotta	8.5	15.1 (b)	20.4	20.6 (b)

Different letters in columns indicates significant difference in means at 1% confidence. Week 6 LSD 1% = 5.40, Week 12 LSD 1% = 4.61.

DISCUSSION

The initial screening in 1990 demonstrated the beneficial effect of Garotta on *R. canina* with a markedly increased field emergence (this confirmed previous unpublished work at Writtle—and it was decided not to investigate *R. canina* further).

Several economically important species, *A. campestre, C. divaricatus, C. monogyna,* and *T. platyphyllos*, also appeared to respond to the Garotta pretreatment. The percentage field emergence figures in Table 1 do not include any indication of seedling quality. For all four of these species the seedlings were much larger after 12 weeks. Only with *C. sanguinea* did Garotta appear to reduce field emergence.

Results for the second year of initial screening indicated a possible improvement in field emergence in *C. laevigata* and *C.* × *prunifolia* (Table 2).

Because of limited research time, only two species, *A. campestre* and *C. divaricatus*, were further tested. As *A. campestre* had shown the best response to the high Garotta, a very high treatment of 1.5 g Garotta for every 10 g of seed was included to check if the optimum rate had been reached. Similarly, as *C. divaricatus* had shown the best field emergence at the low Garotta rate, a very low Garotta treatment of 0.125 g Garotta for every 10 g seed was used too.

In the replicated field trial treating seed of *A. campestre* with Garotta led to significantly earlier germination (Table 3) with the Garotta treated seedlings being more advanced at 6 weeks (Table 4) and significantly taller at 12 weeks (Table 5). However, the marked improvement seen in the unreplicated trial the previous year was not evident.

Seeds of *C. divaricatus* showed a significant improvement in percentage field emergence when treated with Garotta (Table 6).

The Garotta treatment developed for *R. corymbifera* 'Laxa' does appear to have potential for use on other species. But, the response to the pretreatment is not as marked, or as consistent, as was found with *R.* 'Laxa'. Variation between seed batches may account for some of these differences. Even in the first year of this work it became apparent that to investigate thoroughly the number of species which appeared to respond was beyond our resources. In 1992 funding to support the work was received from Horticultural Development Council. This has led to the appointment of a research assistant, David Morpeth, who will be conducting extensive field trials at Writtle College and investigating the physiological effect of the Garotta treatment on seeds. It is hoped that at the end of the project we will understand the effect that 'Garotta' is having on seeds and that this technique will then have a wider commercial application.

Acknowledgements. To the horticulture undergraduates at Writtle College who set up much of this work.

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Cost of Production in Commercial Micropropagation and Research Strategies

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Research strategies in commercial micropropagation essentially require a thorough understanding of the components in the cost of production allied with a dissection of the processes involved in the technique (de Fossard, 1976, 1990, 1993). The major component is overheads and the first task is to distribute these costs to various parts of the laboratory. The laboratory can be conveniently divided into three main areas—the preparation area, the inoculation area and the incubation area.

COSTS OF PRODUCTION

The Preparation Area. This is concerned with the preparation, dispensation, sterilization, and storage of culture media. The preparation area "sells" vessels of sterilized culture media to the inoculation area. How much it "sells" each vessel for depends on the effective utilization of this area—on whether, if it has a capacity to produce 500 vessels per day that it, in fact, produces 500 vessels per day. Under-utilization of this part of the facility can double if not triple the cost of production per vessel.

The Inoculation Area. This area "buys" sterilized media in culture vessels from the preparation area and places plant material in them aseptically. The costs in this area reflect three cultural properties, multiplication rate of the species concerned, inoculation rate, and the number of cultures which can be grown in each vessel. All three properties are worthy objects for the research worker. The multiplication rate of a species is the number of useable pieces a culture can be divided into at the end of its incubation cycle. The inoculation rate is the number of pieces an inoculator can "plant" on fresh medium per hour or per shift. The inoculation rate can be a reflection of the inoculator's performance and attitude; alternatively, it is a reflection of the type of growth achieved by the "mother" culture, for example, whether there is a lot of root development. Number of cultures grown in each vessel is mainly dependent on the type of growth achieved by a species.

The Incubation Area. This area consists of various systems to expose cultures to light and temperature for periods of growth between inoculation (the beginning of one growth cycle) and division and/or planting out (at the end of the growth cycle). The cost of incubating cultures is calculated by distributing overheads on a ft^2 or m^2 per week basis, calculating how many culture vessels fit into these unit areas, how many cultures are in each vessel, and multiplying this cost by the number of weeks in the growth period for the species in question. Cultures needing only four weeks incubation would clearly cost less than those needing longer. These incubation costs must be worked out before the cost of different multiplication rates can be calculated because this gives the cost of the "mother" vessel whose cultures are to be divided into 2, 3, 4, or more pieces.

The Final Cost. The final cost of producing cultures ready for planting-out is mainly a combination of multiplication rate, inoculatin rate, number of cultures per vessel, and incubation costs. But that is not the end of the story—there are two types of losses which need to be accommodated. One type is the technical or biological losses, cultures discarded because of microbial contamination and/or poor growth. The second type is the "saleable-but-not-sold" loss—everything goes to plan, nice cultures are produced but the market disappears! Needless to say, **all** costs associated with the production of cultures have to be borne by the cultures which are finally sold (Tables 1 to 6).

Notes on Tables 1 to 6. In Table 1, more than 60% of the total cost of production of a vessel of sterilized culture medium is attributable to overheads. These data were derived from a laboratory producing an average of 500 vessels of media per week although its capacity is to produce 1000 vessels per day. However, in Table 2, we see that the cost of a vessel of medium amounts to only 16% of the total cost of production.

Table 1. Cost components of culture medium, inoculation, and incubation.

Sterilized culture medium per vessel:		
Chemicals	2.8¢	3.6%
Gelling agent	2.6¢	3.4%
Vessel	10.5¢	13.9%
Fuel	0.5¢	0.7%
Labour	11.9¢	15.7%
Overheads	47.8¢	62.8%
TOTAL	75.8¢	100.0%
Inoculation costs per 8-hour shift:	$100.76	
Incubation costs:		
Total weekly costs	$577.15	
Used capacity (80% Total)	5760	vessels

Tables 3 to 5 illustrate some of the "dynamics" of cost of production and its relationship with multiplicaton rate, inoculation rate, and number of cultures per vessel. We see from Tables 3 and 4 that there are quite large reductions in sale price when we achieve an increase in multiplicaton rate from ×2 to ×3, but the reductions are less, though still desirable, as we achieve ×4 and ×5. The story is similar with inoculation rate improvements and planting more cultures per vessel.

It is worth noting, from Table 2, that the cost of cultures before and after adjustment for losses and profit mark-up are:

- 21.2¢ per culture at the laboratory door (before losses are accommodated);
- 23.5¢ per culture after 10% technical losses are accommodated;
- 31.4¢ per culture after 25% "not sold" losses are accommodated; ·
- 36.1¢ per culture after addition of 15% profit mark-up.

Table 2. Cost of cultures before and after adjustment for losses and profit mark-up.

Cost of production for a species with:

Inoculation rate	150	vessels per 8 hours
No cultures/vessel	15	
Multiplication rate	4	
Incubation period	8	weeks

Cost of culture vessel	5.1¢		23.9%	21.5%	16.1%
Cost of inoculation	4.5¢		21 2%	19.0%	14.3%
R&D levy:1¢ per culture	1.0¢		4.7%	4.3%	3.2%
Cost of incubation	5.3¢		25.2%	22.7%	17.0%
Cost: Parent culture	5.3¢		25.0%	22.5%	16.9%
SUB-TOTAL	21.2¢		100.0%	90.0%	67.5%
10% Technical loss	2.4¢			10.0%	7.5%
SUB-TOTAL		23.5¢		100.0%	75.0%
25% "Not-sold" loss	7.8¢				25.0%
SUB-TOTAL		31.4¢			100.0%
15% Profit mark-up	4.7¢				
SALE PRICE		36.1¢			

Table 3. Sale price of cultures as affected by multiplication rate and number of cultures per vessel.

Muliplication rate	No. cultures per vessel	Sale price per culture (¢)	Difference (¢)
2	10	79.4	
3	10	59.6	19.9
4	10	53.0	6.6
5	10	49.7	3.3
2	15	54.1	
3	15	40.6	13.5
4	15	36.1	4.5
5	15	33.8	2.3

Table 4. Sale price of cultures as affected by inoculation rate and number of cultures per vessel.

Multiplication rate: 4

Inoculation rate	No. cultures per vessel	Sale price per culture (¢)	Difference (¢)
75	10	68.2	
150	10	53.0	15.3
225	10	47.9	5.1
300	10	45.3	2.5
75	15	46.2	
150	15	36.1	10.2
225	15	32.7	3.4
300	15	31.0	1.7

Table 5. Sale price of cultures as affected by number of cultures per vessel.

Inoculation rate: 150 vessels per 8 hours

Multiplication rate: 4

No. cultures per vessel	Sale price per culture (¢)	Difference (¢)
5	103.7	
10	53.0	50.7
15	36.1	16.9
20	27.6	8.4

Although the labour component (Table 6) is less than 60% in the example given here, there is probably a 50% to 70% range depending on how a laboratory is run and what is classified as direct labour.

MICROCUTTINGS

Tables 1 to 6 are based on the situation where all the cultures at the end of an incubation period leave the laboratory and are "sold" to the planting-out facility for 36.1¢ per culture ($5.42 per vessel). In the planting out facility, each culture may either be divided into four "units" at the time of deflasking or be divided into four after acclimatization—or it may be decided not to divide it at all so as to achieve a "bushy" habit—much depends on the species and the type of "conditioning" achieved in the laboratory.

Another option may be available to the laboratory and this is to persuade the cultures to be harvested as microcuttings. Cultural conditions are varied so that from a basal mass of tissue several shoots arise and, when these are more than about 2.5 cm long, they are cut off in the laboratory (and sent to the planting out facility) and the base of the culture is divided and used for new cultures.

Table 6. Direct labour costs as a percent of cost of production.

Cost of production for a species with:		
Inoculation rate	150	vessels per 8 hours
No.cultures/vessel	15	
Multiplication rate	4	
Incubation period	8	weeks
Labour component		
Cost of culture vessel	15.8%	
Cost of inoculation	98.5%	
R&D levy:1¢ per culture		
Cost of incubation	61.3%	
Cost: Parent culture	53.2%	
TOTAL	53.1%	

Table 7 gives some of the cost of production figures for a cultural situation similar to the one used in Table 2 with the exception that from one to three microcuttings per culture have been obtained.

Thus if only one microcutting per culture is obtained from "mother" cultures, in Table 7, its sale price is 27¢ whereas if three microcuttings per culture were derived from each "mother" culture the sale price per microcutting would be 9.0¢.

Table 8 illustrates the situation with higher multiplication rates in which two basal pieces of culture are subbed irrespective of multiplication rate so that with higher multiplication rates an increasing number of microcuttings are derived from each "mother"' culture with corresponding reductions in sale price per microcutting.

COSTS IN THE PLANTING OUT FACILITY

This gets us to the stage where either microcuttings or vessels with cultures leave the laboratory. The success of the whole exercise depends on getting these cultures and microcuttings to become self-sustaining, photosynthesizing plants and, as far as cost of production is concerned, technical or biological losses in the planting out or acclimatization facility may become a major factor.

Another important factor is the deflasking rate, the number of cultures that are removed from a vessel and placed in a propagating mix per hour or per shift. The deflasking rate is, like the inoculation rate, partly a reflection of the aptitude of the person concerned and partly a reflection of the type of growth of the cultures, cultures with a lot of root development taking longer to deflask and "sow" than**Table 7.** Cost of production of microcuttings (MC) as affected by number of MCs per culture and number of pieces for subculturing (SUB).

Cost of production for a species with:

Inoculation rate	150	vessels per 8 hours
No.cultures/vessel	15	
Multiplication rate	4	
Incubation period	8	weeks
Cost of culture vessel	$0.76	
Cost of inoculation	$0.67	
R&D levy:1¢ per culture	$0.15	
Cost of incubation	$0.80	
Cost: Parent culture	$0.79	
SUB-TOTAL	$3.18	

Number of units for

	SUB 1	MC 3	SUB 2	MC 2	SUB 3	MC 1	SUB 4	MC 0
Cost of culture vessel	$0.76		$0.76		$0.76		$0.76	
Cost of inoculation	$0.67		$0.67		$0.67		$0.67	
R&D levy 1¢ per culture	$0.15		$0.15		$0 15		$0.15	
Cost of incubation	$0.80		$0.80		$0.80		$0.80	
Cost: Parent culture	$0.79	$2.38	$1.59	$1.59	$2.38	$0.79	$3.18	$0.00
EQUALIZING COSTS	$0.00	$0.00	-$0.79	$0.79	-$1.59	$1.59	-$2.38	$0.00
SUB-TOTAL	$3.18	$2.38	$3.18	$2.38	$3.18	$2.38	$3.18	$0.00
10% Technical loss	$3 53	$2.65	$3.53	$2.65	$3 53	$2.65	$3.53	$0.00
25% "Not- sold" loss	$4.70	$3.53	$4.70	$3.53	$4.70	$3.53	$4.71	$0.00
15% Profit mark-up	$5.41	$4.06	$5.41	$4.06	$5.41	$4.06	$5.42	$0.00
SALE PRICE	36.1¢	9.0¢	36.1¢	13.5¢	36.1¢	27.0¢	36.1¢	$0.00

rootless cultures. In Table 9, the unit cost of deflasking varies from 4.0¢ (with 2000 units/shift—the whole culture situation) to 1.6¢ (with 5000 units/shift—the microcutting level).

With whole cultures, there is also the question of whether these are to be divided at the time of deflasking or after acclimatization if, indeed, they are to be divided at all. Table 10 illustrates three main options yielding sale prices for: undivided cultures, divided cultures, and microcuttings. A 35¢ culture has a sale price of 75¢ after 4 weeks acclimatization whereas a divided culture would sell for 30¢. In contrast, a 15¢ microcutting would sell for 37¢ but if its cost were about 5¢ (see Table 8) at the laboratory door, it would sell, after 4 weeks of acclimatization, for about 20¢. A further difference in options with "whole" cultures (not applicable to microcuttings) is to place the vessels in the acclimatization area for a period **prior** to deflasking—an additional cost but one that may be "rewarded" with higher survival rates in this facility.

Table 8. Sale price of microcuttings as affected by multiplication rate with two pieces per culture for subculturing.

Sale price for a species with:

Inoculation rate	150	vessels per 8 hours
No. cultures/vessel	15	
Incubation period	8	weeks

Multiplication rate	No. pieces/culture for subbing	No. microcuttings per culture	Sale price per microcutting (¢)
4	2	2	13.5
6	2	4	6.8
8	2	6	4.5
10	2	8	3.4

RESEARCH STRATEGIES IN COMMERCIAL MICROPROPAGATION

In my view, what matters in commercial micropropagation is the achievement of a high success rate in the planting out facility. This will depend not only on practices in this facility but also on the "conditioning" of the cultures in the laboratory.

So now we are at the point where we can develop strategies for commercial micropropagation. We look first at the planting-out end of things and make a few sweeping generalizations:

- Microcuttings have the potential to be the most cost effective type of unit to "sell" to the planting out facility. The rate of "sowing" microcuttings is much higher than most other types of culture **and** the laboratory does not lose its "mother" cultures. These microcuttings are harvested in the laboratory and the bases of the cultures are divided for the next cycle of growth.

- If a species is not suitable for microcuttings, then aim to produce multi-shooted cultures which can be subdivided either at the time of deflasking or after acclimatization.

Table 9. Cost of production of established plants as affected by a variable deflasking rate and establishment period.

Number of "units" per culture	4	
Deflasking labour costs/hour	$10.00	
Number of hours for deflasking	8	
Total cost of deflasking	$80.00	
Number of cultures or "units" deflasked	2000	5000
Cost of deflasking per culture or "unit"	4¢	1.6¢
Cost seed tray + mix	118.3¢	
Number microunits/tray	56	
Thus, cost tray + mix/microunit	2.1¢	
Overheads/m2/year	$191.48	
Number seed trays/m2 area	9	
Thus, overheads/seed tray/week	40.9¢	
Number microunits/tray	56	
Thus, overheads/microunit/week	0.7¢	
Number weeks establishment stage	48	
Thus, overheads/microunit due to establishment	2.9¢	5.8¢
Plant losses (%) during establishment stage	10	
Saleable-but-not-sold loss (%) factor	25	
Profit (%) mark-up	15	

Research leading to increases in multiplication and inoculation rates is cost effective only up to a certain point and **all** experiments should include an evaluation of the performance of cultures on planting out. If we move acclimatization success rates to the top of our experimental objectives, then our strategies would include experimentation in the laboratory and in the planting out facility. In the laboratory, treatments to increase food reserves in the cultures (for example, by giving them higher concentrations of sucrose in the medium) and to "harden" cultures (for example, by exposing them to lower humidity) could be tested. In the planting out facility, cultures could be given various periods of exposure to a greenhouse environment while they are still in the culture vessel, prior to deflasking—this could include removal of the lids of the vessels. Published research mainly comes from universities and research institutes and much of it is difficult to reproduce in other similar laboratories let alone commercial laboratories. So commercial laboratories must expect to do their own research. Part of the problem about published work is that either important details (such as the constitution of culture media) are excluded following editorial constraints or that the authors may not know that one or more aspects of their technique were important factors in their results. However, another reason is that much of this institutional work is done in test tubes rather than in the types of larger vessels used, on economical grounds, by commercial laboratories. It is important to realise that the type of vessel, the type of closure, and the volume of medium per vessel can influence cultural responses—quite apart from the use of expensive controlled-environment cabinets in institutions, compared to incubation areas in commercial laboratories. Another detail often omitted from published work is planting out details of relevance to nurseries.

Table 10. Sale price of undivided cultures, divided cultures and microcuttings after establishment in seed trays for 4 and 8 weeks.

	Undivided cultures micro-units (cents)					
No. weeks	20	25	30	35	40	45
4	49	58	67	75	84	92
8	54	63	71	80	89	97
	Divided cultures: multiplication rate = × 4 micro-units (cents)					
	20	25	30	35	40	45
	Effective cost (cents) per unit after division					
No. weeks	5	6.25	7.5	8.75	10	11.25
4	24	26	28	30	32	35
8	29	31	33	35	37	40
	Microcuttings micro-units (cents)					
No. weeks	5	10	15	20	25	30
4	20	28	37	45	54	62
8	25	33	42	50	59	67

CONCLUSIONS

This paper has dealt with the cost of production of plants by micropropagation and how such studies influence research directions. A similar study with seeds, cuttings, and other propagules would lead to similar approaches and yield similar complex managerial decisions (de Fossard, 1992). Attempting to lower cost of production is a controllable, worthwhile aim, reducing technical losses is another worthwhile aim but minimizing the "saleable-but-not-sold" losses requires rather different skills and decision-making.

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Learning from Changes in the Marketing of Plants

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INTRODUCTION

The purpose of history is to learn from the lessons and experiences of the past for use in the present and future. This paper presents a brief history of ornamental horticulture over the last 40 years and draws some personal conclusions about the present and future of our industry, and in particular about the market.

1950s

- In this decade we heard the first warnings about the dangers of organic phosphate insecticides.
- It was a decade of flower and vegetable shows.
- The rose was **the** plant—Britain's Royal National Rose Society had over 50,000 members in 1957.
- Public parks were popular—they were full of colourful displays of bedding plants, roses, and herbaceous borders, all set off by acres of neatly trimmed grass.
- We had no garden centres, only nurseries, and no plant retailers—nurserymen sold to the public.
- All the plants sold were either bare root or balled in sacks.
- We sold our plants in the autumn and early spring.
- The Dutch supplied many plants to the U.K. market.
- There was no training.
- There were no herbicides just hoes.
- Life was simple, poorly paid, and jolly hard work.

1960s

Horticulture probably advanced in this decade more than it had during all of the previous 100 years. It certainly set the pattern for the production and selling of ornamental plants as we know it today. The 'New Towns' were started, with them came a new concept in landscape design. The conventional park and its bedding displays were replaced in the new developments with shelter belts of trees and informal plantings of a wide range of foliage and flowering shrubs.

The first favourite in plants was still the rose—largely promoted by colourful nurserymen like Harry Wheatcroft and Sam McGreedy—whose great personalities alone must have sold plants.

Then came perhaps the biggest step that ornamental horticulture had ever taken, it has had a profound effect on gardening, nurserymen, and the society—the garden centre. It came from North America. It was dedicated to selling. It demanded plants available for sale 12 months of the year. As a direct result we saw the first pot-grown plants as we know them today. First in old ice cream containers, which were smelly and the plants were almost impossible to remove. The rose now had competitors—flowering shrubs and conifers.

Ice cream cans began to be replaced by polybags, watering became irrigation, pots became containers, and John Innes compost became too heavy.

Peat-based composts were introduced. They were lighter and grew better plants, but also grew even bigger and better weeds.

We saw the start of dedicated hardy ornamental nursery stock research, which helped with composts watering regimes and herbicides.

1970s

The Garden Centre Association was formed and garden centres became bigger, stocked more types of merchandise, and demanded better service.

Plants sold as long as they were green and a new word came into horticulture, containerized, which meant "green tops, little root, and will probably survive."

The Dutch continued to pour stock into the U.K.

The first attempt to bring our fragmented industry together was launched by an industry personality of the time—Mike Edwards. It was called the Development Council and it failed.

Plants continued selling despite record inflation. However, a new fashion emerged—self sufficiency. Shrub beds and lawns were dug up and replanted with fruits and vegetables. Container production continued to increase, by now many different genera were available as container-grown plants.

In 1978 the Ministry of Agriculture, Fisheries and Food recorded production of 28 million container plants.

1980s

This decade will be remembered for the speed of changes which occurred. This was evident in plant fashions. Self sufficiency had gone, roses had waned in popularity. Conifers and heathers were the "in thing" in 1980 but by 1989 interest was beginning to fade. Bedding plants and herbs became the "in fashion" plants.

It was the decade of National Garden Festivals held at Liverpool, Stoke-on-Trent, and Gateshead, great events and tremendous promotion events for gardening and plants.

By the mid 1980s we saw the rise of the garden centre consultant—who turned garden centres from retail nurseries and plant centres into true retailers. Consultants introduced terms and jargon such as "reserve orders", "stock turn", "stock levels", and "ranging". Plants became "green goods" or "core products".

1990s

So here we are in the last decade of the century, and what have we got?

A nursery stock industry worth about £235 million at wholesale value. Current production of container plants running at 160 million plants per year. Nearly 6000 hectares down to field grown nursery stock. Some 3000 nurseries in England and Wales.

Between 1500 and 2000 retail garden centres supporting the gardening pastime valued at £1.3 billion per year.

LESSONS FOR THE FUTURE

What can we learn from the last 40 years that may help us plan and thrive in the next 5 to 10 years?

We still have a fragmented industry, with nearly 3000 nurseries and 90% of them are under 5 ha. We still do not cooperate. Cooperation has been tried and it has failed several times in the last 40 years. We do need greater cooperation within the growing industry because our wholesale customers are getting bigger and more sophisticated by the day.

The last 40 years have proved that fashions in plants change: roses, conifers, heathers, trees, and fruits have all come and gone as major sellers. Herbaceous plants, herbs, bedding, and patio plants are currently in fashion. Such changes in fashion will undoubtedly continue. Colour has now started to affect the sales of certain plants. Changes will be faster.

Quality, service, and presentation have all moved forward. They will continue to do so. We shall have to strive to reach new levels in quality. Continuity will perhaps be the biggest challenge for the ornamental nurserymen in the years ahead.

Concepts in presentation will also change. We shall be led by ideas from other industries, which will have to be adapted to suit our particular needs.

We have seen the pace of change accelerate from 1980. This will not slow down. So all change will have to be accomplished in the minimum of time.

Plug Production for Seedlings

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The term plug describes modules ranging from 1.5 ml by volume up to 4 cm square—or larger. These are clearly extremes and most seedlings are produced in plugs ranging from about 2 to 10 ml in compost volume. In nursery stock terms it is quite appropriate to think of plugs as mini-liners; the description fits them quite well.

The first experiments with plugs, or modules, occurred in the 1950s. It is debatable whether the idea was actually invented—they probably gradually developed from a scaling-down of larger techniques.

It is certain that American growers must be credited with the first commercial use of what we would now recognise as plugs. They were certainly in use by 1960, and after a relatively slow start their use accelerated; by the early 1970s they were in widespread use throughout the U.S.A. and they were beginning to be used in the U.K. Since that time they have become a very important tool in the production of pot and bedding plants.

There are no statistics about numbers of plugs produced, but my own personal estimate of the number sold in the U.K. by commercial plug producers is about 1 billion annually—and many growers produce their own, too. So what proportion of the bedding plant crop is produced from plugs? Again, there are no reliable figures, but my own estimate is at least 70%.

For the more specialised subjects such as begonias the percentage is likely to be 95% or more.

Commercial plug producers must be amongst the most specialised of all growers of protected crops. The technology includes automatic seeders that can handle virtually any size or shape of seed and sow them in individual cells, and bar-coded trays that the computer can keep a track of right through the production cycle on movable tables. Plants are watered automatically, and heating, ventilation, and shading are all computer controlled.

The need for full cells in the plug tray has also caused something of a revolution in the seed trade, with tremendous pressure for high levels of uniform germination. This has been achieved by improving the inherent germination ability of varieties and also by seed treatment techniques including priming—bringing the seed to the brink of germination and then holding it in that condition. However even the very best seed does not reliably give 100% germination, and subjects such as wild flowers are also grown which are notorious for their uncooperative nature in commercial conditions. But the customer still wants a full tray of plugs.

To date, this has meant a degree of gapping-up by hand, but in the last year or two machines have appeared which can do the same thing. These scan the plug tray and record where plants are missing or inadequate, and further along the line these same cells are blown out by compressed air. The machine to actually put replacement plugs in the cells is still on trial, but likely to be in full use by the end of 1994.

Many growers, too, have chosen to grow their own plugs. Larger ones have adopted the sophisticated technology, but a surprising number of smaller growers produce their own using simpler techniques, usually concentrating on the easier subjects.

There are several advantages of plugs. The most important is the ability to achieve a greater throughput in a production unit; although more time is spent in the propagation area, far less time is spent in growing the finished crop. And, if the plugs are bought in, this is optimised even further. Not only do plugs utilise space better, they are also quicker to transplant, and automatic transplanting systems can be used. Another aspect is the better uniformity and quality of the finished crop when grown from plugs.

The rise in plug production has closely paralleled the spectacular rise in the growth of the bedding plant industry. Since the early 1970s the volume of bedding plants grown in boxes has increased four-fold, and pot-grown bedding has increased from nowhere to about 100 million pots annually. These are Ministry of Agriculture (MAFF) figures, and there is good reason to believe that they are a considerable under-estimate. There are clearly several reasons for this spectacular rise, but plug production is one of the factors which has made it possible. It seems quite likely that the spectacular growth of the bedding plant industry may be slowing down; it could be argued that various aspects of modern horticultural technology have made the growing of the crop too easy, and in the eyes of some growers plugs might well take much of the blame.

Pot plant growers, too, have been quick to adopt plug technology, and wild flowers and perennials are well suited to plug growing. Nursery stock producers too have adapted plug techniques for appropriate seed-raised subjects, as well as for cutting production, and of course, micropropagated plants.

The use of plugs will expand into new areas. We have already seen their use for seed-raised nursery stock, and I have referred to wild flowers, where they have increased the use of species that do not establish well from seed. The potential here for the use of large volumes is considerable, for example in areas subject to soil erosion where seed is unlikely to be successful. Forestry, too, has enormous potential; large "plug" type modules are already used, but the economics of using something smaller are obvious, and open the way to revolutionary ideas such as replanting de-forested areas by aeroplane.

Some Recent Advances in Vegetable and Flower Seed Technology

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The reasons for variation in seed viability, and for the variation in the size of plants grown from seed are described, together with a basis for selecting seed lots to give high germination and uniform stands of plants. The use of seed priming by polyethylene glycol, combined with fungicides and plant growth regulator treatment to improve subsequent seed performance, is outlined.

INTRODUCTION

Module and tray systems, introduced in the 1970s, were a major advance in the production of transplanted vegetable crops. Large numbers of plants can be produced relatively cheaply and both plant quality and ease of handling are greatly improved compared with systems used for producing bare-root plants. However, for all crops a critical factor influencing the efficiency of the system is the proportion of cells sown with a single seed leading to a "plantable" plant.

As the environment in module systems can be controlled to provide optimum conditions for germination and emergence the major factor influencing efficiency is seed quality. Despite improvements in the quality of vegetable and flower seeds offered for sale it is still difficult to reliably achieve more than 85% to 90% of cells filled with a "plantable" plant by sowing a single seed per cell. Variability in the size of plants in a batch is also an important quality factor directly related to germination times of seeds in a lot which can vary over several days.

FACTORS AFFECTING QUALITY

Variability in performance from seed lot to seed lot arises as a result of characteristics in common with the species' wild relatives, for example, highly branched inflorescences, a wide range of seed maturity times, dormant seeds, and fruit and seed structures giving efficient dispersal but which make harvesting difficult.

SEED PRODUCTION AND SELECTION TECHNIQUES

In some species, such as carrot, it is possible to improve seed quality by growing plants at high density to reduce side branching of flower shoots, which improves the uniformity of seed maturity times. This, coupled with the use of the statutory germination test, can do much to ensure that high quality seed is made available to the grower (Gray, 1983).

The adoption of improved production techniques alone will not ensure a reliable supply of high quality seed, as the environment influences seed viability and level of dormancy; treatment of the seed after harvest may be necessary to improve quality further.

PHYSIOLOGICAL TREATMENTS OF SEEDS

Physiological treatments can improve the quality of poorer seeds or induce germination in dormant seeds. Some species which do not exhibit true dormancy can be induced into a "dormant" state by high temperature. On return to low temperature they start to germinate again but over a protracted period. This dormancy can be overcome by the use of growth regulators such as gibberellic acid and cytokinins applied to the seeds. Treatments using these or materials with similar activity are being used commercially.

Induced dormancy can also be prevented by priming seeds in polyethylene glycol (PEG). When seeds are placed in PEG solutions of a given concentration (osmotic potential) the rate of water uptake by the seed and the total seed moisture content can be controlled. During this period, the events in the seed that prepare it for actual germination take place but the emergence of the radicle is prevented—it is unable to take up sufficient water to enable it to extend through the seed coat. Priming allows "poor" seeds in the batch to "catch up" in development with the good seeds. Once the seeds are removed from the PEG and given water to germinate they do so more rapidly, and closer together in time, than untreated seeds.

Table 1. Effect of priming on germination responses.

	Mean germination time (days)	Spread of germination (days)	Percentage germination
Impatiens			
Control(C)	7.9	4.3	92
Primed(P)	5.0	4.1	89
Primed & dried (P&D)	5.9	3.6	89
Salvia			
C	8.9	6.5	66
P	4.0	5.4	76
P&D	8.5	7.1	64
Verbena			
C	7.7	5.3	69
P	4.0	4.7	68
P&D	3.8	4.9	67
Petunia			
C	5.6	3.1	94
P	2.0	3.2	94
P&D	2.3	3.5	94

Priming in *Primula* (-1.5MPa, 10 days), *Impatiens* (-0.75 MPa, 14 days), *Salvia* / *Verbena* (-1.5 MPa, 14 days), *Petunia* (-1.0 MPa, 14 days) all at 15C.

Techniques to scale-up this process to a commercial scale have been developed (Gray et al., 1992) and processes using a solid matrix, PEG in bioreactors and drum priming are in widespread use in the seed industry. The potential of the technique is illustrated by recent work at Horticulture Research International, Wellesbourne, on bedding plants. This work has emphasized the potential for combining priming with plant growth regulator treatment.

Reductions in mean germination time and spread of emergence without loss of viability have been obtained in *Impatiens*, *Salvia*, *Verbena,* and *Petunia,* although in *Salvia* difficulties have been encountered in drying the seeds successfully without loss of the benefits of priming (Table 1). In *Primula*, priming depressed viability and increased the mean germination time and clearly in this species, which requires light for germination, other treatments are required.

Table 2. Effect of combined priming and growth regulator treatment.

	Mean germination time (days)	Percentage germination (%)
Primula		
Control untreated seeds,(CD) germinated in the dark	no data	23
Control, untreated seeds (C)	11	56
Primed (as Table 1) (P)	10	39
Primed + $GA_{4/7}$ 10-4M*(P+GA)	3.5	56
Verbena		
C	15	65
P	3	70
P+GA	3	70

* = $GA_{4/7}$ added to the PEG.

Until recently, very little work had been done to combine different physiological seed treatments. It has been shown now that seeds can be pre-treated with fungicide soaks to control seed-borne disease, followed by priming in PEG solutions to which growth regulators are added. When this was done with *Primula*, positive responses to priming were obtained (Table 2) and, also, with *Verbena* and *Impatiens*, suggesting that this type of approach would be applicable to a wider range of seeds including "difficult" seeds of tree and hardy ornamental nursery stock species.

CONCLUSION

The potential benefits of priming seeds and of combining this with other seed treatments such as fungicide and plant growth regulator seed soaks is now established (Finch-Savage, 1991). In addition, as a result of collaboration between HRI and the seed industry it is evident that these treated seeds can be successfully dried, pelleted or coated in "fluidised bed" coaters, and then stored from one season to another without significant loss of viability or loss of benefit of the seed treatment.

A major outlet for these primed seeds is in the plant raising industry, where control of the post-sowing environment can be achieved. Clearly there are many opportunities to expand its use for flower seeds and for HONS material sown into nursery beds, offering the potential to substantially improve production practices.

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Digging into Composts

Workshop session on peat and its alternatives for container composts: the assessment, sourcing, use, and management of materials.

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AIM OF WORKSHOP

In the UK, and much of Europe, the use of peat as an ingredient in container composts has become an important environmental issue. Environmental groups have given publicity to peat as a non-renewable resource, and to the need to preserve peat bogs as a habitat for wild plants and animals. They have highlighted horticulture as a consumer of peat and hence as a threat to the conservation of peat bogs.

Rightly or wrongly, this has resulted in customer pressure on the horticulture industry to develop alternative ingredients for soil amendments and container composts.

This workshop aimed to highlight the characteristics of peat that have made it so valuable as a container compost ingredient, and which would therefore need to be present in any alternatives. It was also intended to demonstrate the improbability of finding a single material that can replace peat for every growing situation in which peat is currently used. Finally it was hoped to illustrate the kinds of questions growers will have to ask their customers, their suppliers and their advisers before selecting new compost ingredients.

After an initial briefing, the workshop delegates were split into six groups. Each was given a specific crop to produce for a customer who had specified a peat-free growing medium. Each group had to assess a range of materials, samples of which were available, and choose those they felt most suitable for their crop. Neil Bragg acted as the supplier of each material. Margaret Scott acted as the customer for each crop. John Adlam (I.P.P.S. committee member and horticultural adviser) was available to give impartial technical advice to each group.

BRIEFING

The Properties of Peat. The following properties of peat were cited as making it particularly suitable as a container compost ingredient, although it was emphasised that peat is not a homogeneous material but differs according to its place of origin and vegetative composition:

- Clean product to use
- Reliable batch to batch and relatively uniform within the various types
- Reasonable structure for plant growth
- Low nutrient status makes regulation of feeding easy
- Low in weeds and pathogens
- Economical
- Brown "earthy" colour highly acceptable to consumers

Properties of peat alternatives currently available.

- These tend to be generally more expensive than peat
- Many have a tendency to lock-up nitrogen making control of nutrition more difficult
- Animal wastes are high in phosphate, straw-based media are high in potash
- Peat alternatives based on waste products also tend to vary in quality, from batch to batch, more than peat
- Crop management and compost handling procedures invariably need to be changed when compost ingredients change

Peat alternatives available at workshop. Each group was allowed to use up to three ingredients from the following, in a container compost for its crop.

Pine Bark. Waste product from forestry. Needs to be matured, or composted with nitrogen. Wide availability, 1.5 to 2 times price of peat. Slightly less dense than peat. 0N-5P-3K-0Mg. Manganese levels can vary depending on source. AFP 35%. Currently used widely in container mixes at between 20% and 50% by volume.

Spruce/Larch Mixes. Generally as above. Widespread availability, 1.5 times price of peat. Similar density to peat. 0N-5P-3K-0Mg. Manganese levels can vary depending on source. AFP 20% to 30%. Used with varying success in propagation and container mixes.

Composted Bracken. Relatively new material, by-product of forestry industry where bracken is a major weed. Can be composted or matured without N, then shredded or chopped. Further work needed to determine consistency of nutrient status etc. but initial trials in container composts at Efford EHS look promising, especially for ericaceous species.

Polystyrene Granules. Waste material from packaging industry. Non-biodegradable therefore questionable environmental-friendliness. Widespread availability, very cheap, various colours. Chemically and nutritionally inert. Useful for amending other materials, for example increasing AFP. Very low density. Major problem is handling—tends to blow around and become electrostatically charged. Possible residues of plasticiser or boron may lead to phytotoxic damage.

Perlite. Heat expanded volcanic rock. Mined as mineral. Chemically and nutritionally inert granules, little buffering capacity, very high porosity, low density. Widespread availability, 2 times price of peat. Already used in some propagation mixes in nursery stock. Dust may present health hazard.

Vermiculite. Naturally occurring mineral, heat treated (1000C) for horticultural use. Asbestos content may be health hazard. Nutritionally inert. pH very variable depending on source. High cation exchange capacity—can "hold back" nutrients such as potassium and ammonium N. Currently used in mixes for bedding, pot plants, young herbs. Possible role as fertiliser and pesticide "carrier".

Hop Waste. Waste product of brewing industry. Limited availability but relatively low price. Must be composted to avoid fungal growth (spores may present health hazard). Fibrous texture. 0N-9P-0K-5Mg but large residues of organic N which break down releasing N to plant. Density on drying similar to peat. May become difficult to wet with time. Has been used as ingredient (nitrogen source) in mix with pine litter for raising azaleas in Belgium and bulking ingredient in growing bags. May prove useful in mix with straw waste.

Grain Waste. Industrial waste product currently used as animal feed. Limited availability. Price depends on transport costs. Granular texture. 0N-6P-3K-3Mg but contains some organic N released when composted or used in growing media. Low density when dry. Some sources may be high in copper (phytotoxic). Possible health risk from fungal spores. Possible development as ingredient with straw to produce container growing medium.

Municipal Solid Waste/Refuse Derived Humus. Domestic waste consisting largely of paper/card and degradable organic matter. Inconsistent availability, price similar to peat. Soil-like to granular texture. Typical 3N-6P-4K-4Mg but very variable. Problems include possible presence of pathogens (plant and human), heavy metals, phytotoxins, glass. Has been used with varying success as container medium and soil amender.

Despite problems it is a renewable resource and further research may be worthwhile.

Coir. Residue from coconut fibre production. Erratic availability, 2 to 3 times price of peat, fine granular texture with some fibre, some coarser grades. 0N-0P-4K-0Mg (at pH 5.9). Salt contamination may be present. AFP around 10%, similar density to peat. Pathogen and fungal spores may be present. So far shows promising results as container medium. Not necessarily environmentally friendly to use coir in developed countries in long term as big problem in developing countries is loss of organic matter through soil erosion.

Animal Wastes. Pig, cow, poultry, and sheep manure. Widely available, slightly dearer than peat, variable texture and nutrient analysis. Problems of high levels of available nutrients releasing unpredictable amounts of N. Best regarded as potential ingredients in mixes with peat, coco fibre, or straw—fertilisers rather than peat substitutes.

Expanded Aggregates and Slate Waste. Clay waste or slate waste from quarrying etc. Treated at high temperature to expand material. Limited availability. 2 to 3 times price of grit. Hard, granular texture, low density if heat expanded. Typical 2N-1P-1K-0Mg but varies with source. High buffering capacity. Currently included in some potting mixes to improve buffering capacity. Could be developed for use with alpines and salt sensitive plants and for use in semihydroponic systems.

Loam. Traditional material used for John Innes composts. Now very limited in availability. Check for possible contamination with heavy metals or residual herbicides.

Rockwool. Produced by heating rock to 1500C and spinning off "flocks", Fibres can be woven into matting or pads. Widely available, 1.5 to 2 times price of peat. Fibrous texture, very high AFP, very low density, nutritionally inert, pH 8. Used widely in horticulture, sometimes added to peat in container mixes. Well established as partial or complete peat alternative.

Pumice and Zeolite. Produced by fast cooling, in water, of volcanic lava flow. Low availability, expensive, relatively inert. High AFP, low density. Zeolite has high cation exchange capacity. Has been used as an additive to peat and a stand-alone growing medium. Zeolite could be mixed with spent mushroom compost to adsorb high levels of available nutrients.

Sewage Sludge. Waste product. Wide availability, variable price. Crumby texture when dried. Would be co-composted with straw, wood chips or bark for use in horticulture giving a typical 3N-5P-8K-7Mg. Batches vary and may also contain heavy metals, organic residues, phenols, or herbicides. Trials have given inconsistent results as container mix ingredient. Further work needed, especially on human pathogen survival.

Spent Mushroom Compost. Waste product of mushroom growing industry. Mushrooms grown in compost containing chopped straw, manure, calcium sulphate, and sugar source. Consistent availability, fibrous texture when dry. Typical 5N-2P-8K-7Mg, pH 7.3. Density similar to peat. May contain organic contaminants, e.g., herbicides, pesticides. Could be used co-composted with wood chips. Currently used in tree planting composts.

Worm-Worked Composts. Useful method of treating materials that are otherwise difficult/unpleasant to handle. Limited and localised availability, similar price to retail brands of peat-based potting mixes. Friable crumb structure. Typical 0N-8P-8K-2Mg, pH 9.3. Possible heavy metal contamination and possible survival of human or plant pathogens. Has been used as peat amendment but with variable results.

Wood Wastes. Wood shavings, sawdust, chips, and fibre. Variable price, competition from purchasers in chipboard industry. Nutrient analysis depends on how material obtained and processed, can be short of N, can be composted. Similar density to peat when in fibrous state. Widely used in U.S.A. and Australia as basic ingredient for potting mix. Could be useful co-composted with refuse and manures.

Straw. Farm waste, widely available, variable price, needs composting with N after which the C : N ratio stabilises at between 30 and 40 : 1. Herbicide residue may be present. Best considered as co-composting material with other waste products, e.g., sewage.

RESULTS

The crops produced by each group and the media used are the following:

Group 1

Crop. Two thousand *Ficus benjamina* in 5-litre plastic terracotta pots to be used in the landscaping of a shopping mall.

Customer's Criteria. The plants could only be watered in the evening; the compost had to be of a natural looking colour and present no fire hazard—shoppers often drop cigarette ends into plant pots. It had to be pest and disease free, be safe for humans, and contain no pesticide residues. The pants had to have a six month pot life and the pots had to be heavy enough to be stable, light enough for ease of handling. Maximum price set by customer was £3.05/plant.

Compost Choice. Prime considerations identified by the growers were customer requirements plus pH, water retention, and ease of availability of materials. Coir was eliminated because the team felt the risk of human health problems, however remote, would be unacceptable for the given use of the plants. They decided to mix a range of grades of composted bark to give the required water retention, bulk density, and potting machine flowability. Cost of compost was estimated to be 20p/plant, on a total production cost of £1.13/plant.

Group 2

Crop. 60,000 *Erica carnea* in 9-cm pots to be ready for a municipal roundabout planting in March.

Compost Choice. Decided to grow from single stem cuttings taken in September and struck in medium grade (18-mm screen) coir. They would be potted into 9-cm pots the following May—into an 8 Norbark : 1 grit : 1 rockwool (by volume) mixture, with nutrition supplied by controlled release fertiliser and ammonium nitrate—and grown on in a vented tunnel on sandbeds. Total costs were reckoned at £13,900 for the batch.

Group 3

Crop. Spot crop of 50,000 poinsettias for a wholesaler, to be ready on December 10 for Christmas market.

Customer Criteria. Early flowering *Euphorbia pulcherrima* 'Lilo'. Crop to consist of 80% red, 10% pink, and 10% white bracted plants. Twenty-five percent of crop was to be in 8-cm pots, 15 to 20 cm at 75p each, and remainder in 13-cm pots, 25 to 30 cm, at £1.30 each.

Compost Choice. The group decided to grow plants from rooted cuttings, starting on two dates to obtain finished batch of large and small plants together. Rooted cuttings to be grown in Grodan rockwool with liquid feed for ease of control. These would then be potted into a mix of 7 bark : 1 grit : 2 vermiculite (by volume) to give an acceptable light brown colour and a good, open free-draining structure.

Cost Projection. Production cost £38,500, income £58,000.

Group 4

Crop. 50,000 dwarf rhododendrons in 3-litre pots for French market.

Growers Compost Criteria. The following criteria were established:

- pH of 4.5; ease of handling in potting machinery
- Air-filled porosity was critical, had to be 20% at the start of the crop cycle, and not less than 15% after 2.5 years.

A large number of media were eliminated on pH grounds and buffering capacity. The group was left with composted bracken which had a good open structure, low pH, and was resistant to shrinkage; and Corsican pine litter (Corsican pines are widely grown in UK forestry). Corsican pine litter may contain spores of mycorrhizal fungi which was considered a plus point, but the pH was not as favourable as composted bracken for rhododendrons.

Compost Choice. The compost of choice was a mix of 1 composted bracken : 1 Corsican pine litter : 1 composted pine bark (by volume), with a long-term controlled release fertiliser and nitric acid injection in the irrigation water to help keep pH down. Liquid feed was applied as necessary.

Cost. Compost cost reckoned at 3p or 4p/plant, plus the cost of extra management.

Group 5

Crop. 3000 specimen blue conifers for a garden centre chain, available over a 2-year period—100 each March, April, May, June, and July.

Customer Criteria. Peat-free compost tolerant of sporadic irrigation. Maximum price per plant of £3 for 5 litre plants; £4.25 for 7.5-litre plants and £5.60 for 10-litre plants.

Compost Choice. Price was critical and many technically acceptable ingredients were discarded on price. A 13 composted bracken : 7 composted pine bark : 2 clay aggregate (to give weight and stability to the pots) (by volume) mix was selected. Grower had to accept that plants would have to be potted in winter due to bracken availability.

Cost Projection. Estimated cost of compost was £16.40/m^3. This group did not believe they could produce the plants profitably at the customer's specified price.

Group 6

Crop. A crop of 100,000 groundcover roses in 9-cm pots for the amenity market, ready for delivery in late May, was required.

Customer Requirements. A peat-free, non-irritant compost at maximum price of 50p for royalty cultivars and 30p for non-royalty cultivars.

Compost Choice. Plants were to be grown from purchased micropropropagated plantlets. Price of compost was key consideration, with coir, matured bark, and perlite rejected because of cost. Rockwool was rejected because it was an irritant, and bracken was rejected because there was too little information available about performance. Compost selected was a composted bark with 15% to 20% polystyrene granules to reduce the cost and controlled-release fertiliser.

Cost Projection. Compost cost £28.50/m^3.

CONCLUSIONS

Many of the groups came back to choosing a home-supplied product because of worries about the consistency of supply and of quality. The groups were good at quickly eliminating inappropriate ingredients.

However very few members of the workshop actually took samples out of their bags to handle or to physically mix together the materials they had selected. No one asked for samples and no one asked for a complete, recent, compost analysis of their chosen material. No one tried to see what it looked like wet.

These are all things that must be considered, Bragg told the workshop. Salesmen will always try to show their material in the most attractive way, the grower's job is to ask difficult questions.

He also emphasised the need for growers to carry out small-scale trials whenever a new combination of growing medium/crop is contemplated. There was a need to discuss this with the buyer and perhaps to negotiate if they will accept a percentage of the crop in the peat-free and a percentage in your existing mix until both sides were happy with results.

The need to consider peat-free composts as a positive selling point to environment-conscious customers, and the possibility of increasing prices to cover the increased costs involved was also discussed.

Understanding Vegetative Propagation

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INTRODUCTION

There are compelling reasons why propagators in the U.K. should seek increased understanding of relevant underlying principles. The nursery industry here is extremely diverse, producing many thousands of individual taxa on nearly 3000, mainly small, nurseries which are spread throughout the country. Different attitudes towards propagation, different technical backgrounds and working practices, and different commercial objectives compound this diversity. Against such a variable background there is little purpose in developing narrow blueprints for a few specific plants. Nurserymen need new insights, information, and knowledge with which to adapt and improve **their** operations in ways that suit **themselves**. If they don't have the **correct** understanding nurserymen can easily develop the **wrong** understanding, which at best may prevent progress, and at worst be counter-productive as they move to meet the challenge of market-led propagation systems (Vallis, 1992).

INFORMATION WHICH IS HELPFUL BUT NOT ESSENTIAL

Some information comes into the category of "it's helpful to know," because an explanation of how something works gives growers confidence and the ability to apply the information flexibly.

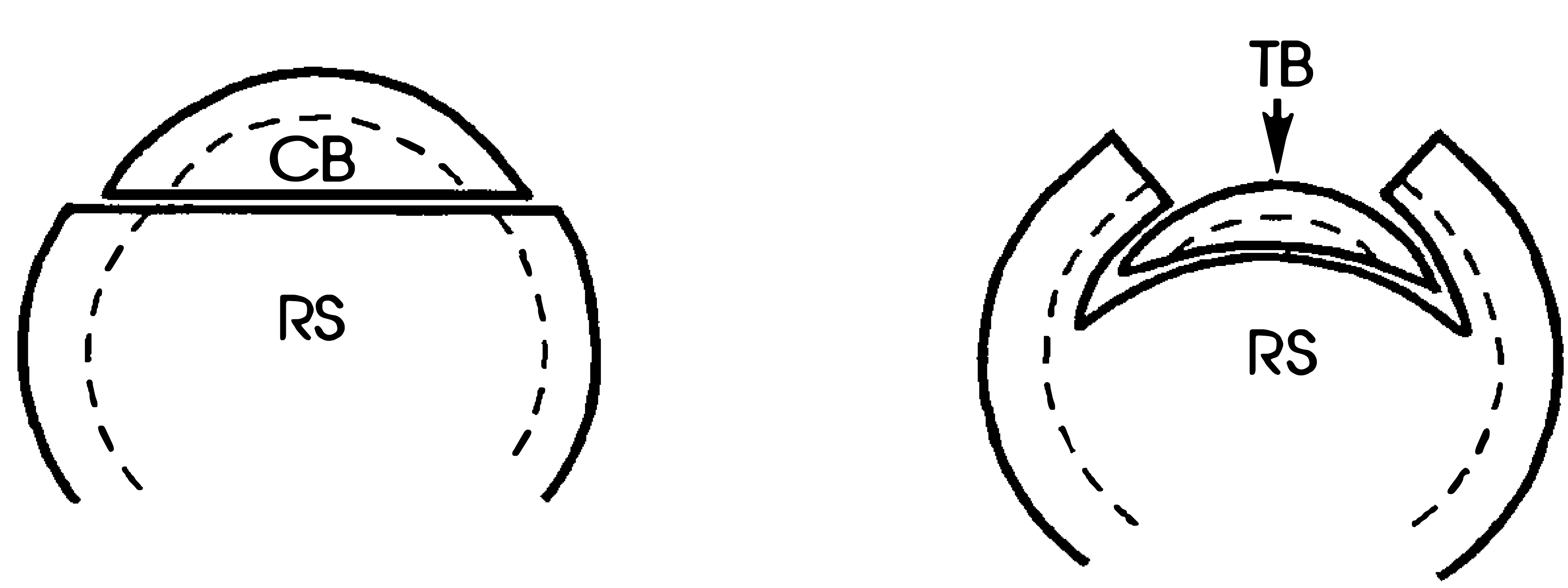

Figure 1. Representation (left) of a cross-section of a chip-bud (CB) and rootstock (RS). Because the chip-bud substitutes exactly for the part of the rootstock which is removed the cambium (— — —) of stock and scion are placed close together resulting in a rapid and strong union. When a T-bud (right) is slipped under the 'bark' the cambium of stock and scion are not adjacent, and union formation can be slow and weak.

Budding. An understanding of the improved anatomical relationships between the scion and rootstock in chip-budding compared to T-budding (Howard et al., 1974; Skene et al., 1983, Fig. 1) has implications for the range of plants that can be budded successfully, the time of budding, tying materials, avoidance of diseases, and the quality of the final product.

Wounding. New insights about the effects of wounding the bases of cuttings come into the same category. The practical benefits of wounding have long been known and exploited by nurserymen, but awareness of the advantages of splitting the ends of non-basal and other difficult hardwood cuttings, to simulate the anatomical advantages at basal nodes of easy-to-root subjects, (Howard et al., 1984, MacKenzie et al., 1986, Fig. 2) convinces nurserymen that this treatment is worth trying in appropriate cases.

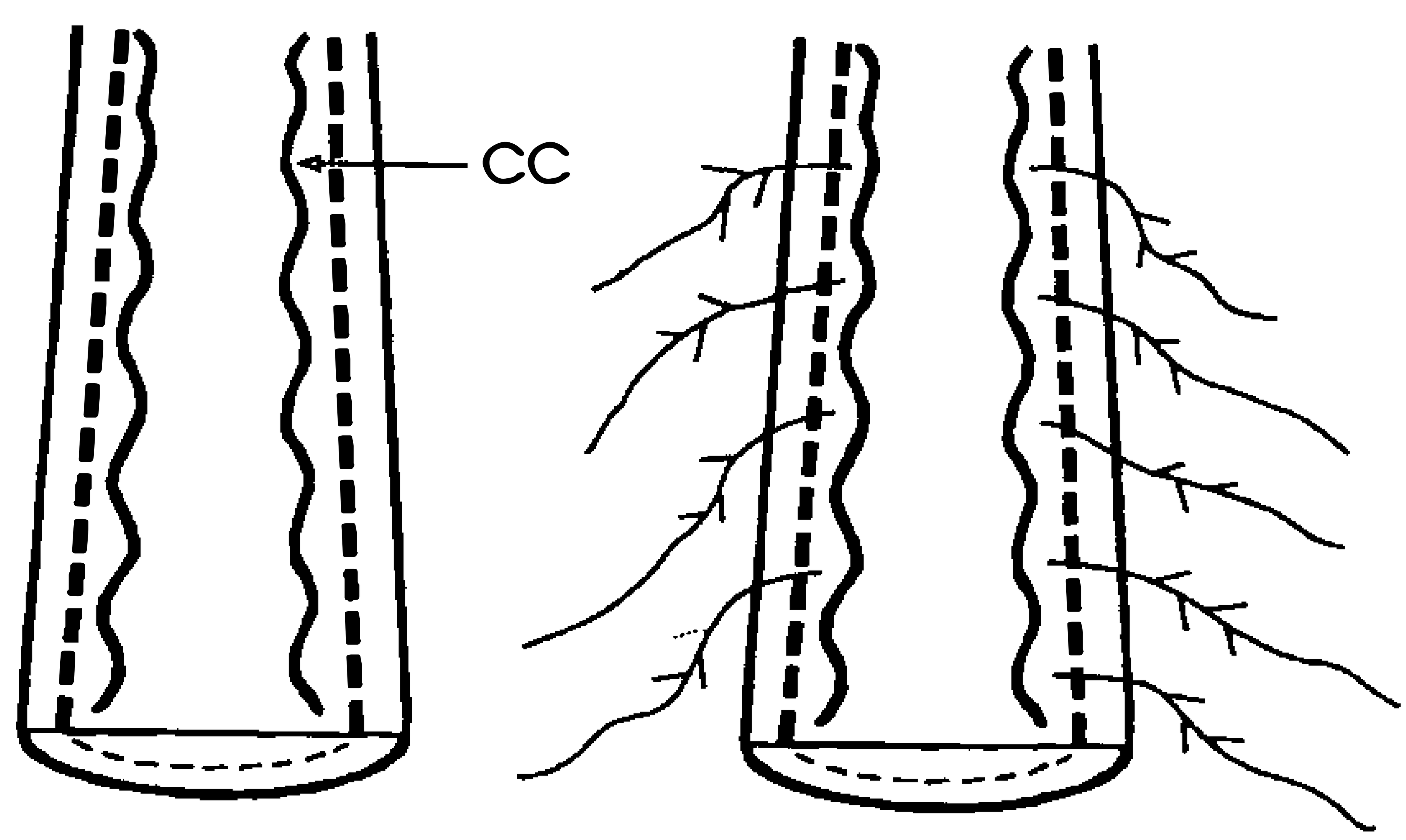

Figure 2. The inner surface (left) of a hardwood cutting wounded by splitting. When split longitudinally, as opposed to cutting across the stem, cambial cells (— — —) are able to regenerate in response to auxin treatment and produce cambial callus (CC) from which roots emerge (right). Other types of wounds expose much less cambium.

ESSENTIAL INFORMATION

In most situations improved understanding focuses on the need to obtain **essential** information, which is made more necessary by the multi-disciplined and highly interactive nature of propagation, where success in one objective based on one scientific or technical discipline is influenced or controlled by conditions elsewhere that are not obvious, and are often unsuspected. The relevant areas of science may range from hormone or nutrient physiology to the physical characteristics of composts. Unless these various interacting factors are all adjusted to optimum levels the results are often poor; when the optimum levels all coincide, results are often impressive.

Hormone treatment. It is widely held that the most critical factor affecting the response of cuttings to hormone treatment is the concentration of auxin in the liquid or powder preparation. In fact, it is the total dose of auxin received by those tissues capable of responding that determines rooting. For quick-dip preparations factors such as duration and depth of dipping, and the position in which the cutting is dried, affect the amount of solution taken in through the cut end of the stem. Both are relatively more important than auxin concentration when treating hardwood cuttings (Howard, 1985a, Fig.3). When using powder preparations important factors are those which affect the transfer of auxin from the powder carrier through the epidermis as well as via the cut end of the stem. These include whether or not the cutting is pre-dipped in an organic solvent, the amount of powder which adheres to the cutting, and whether it is retained or lost at planting (Howard, 1985b, Fig. 3). Awareness that a standardised technique is of greater importance than the concentration of auxin applied provides the incentive for nurserymen to set up simple procedures that will improve overall survival and rooting of cuttings, and increase the uniformity of response within a particular batch.

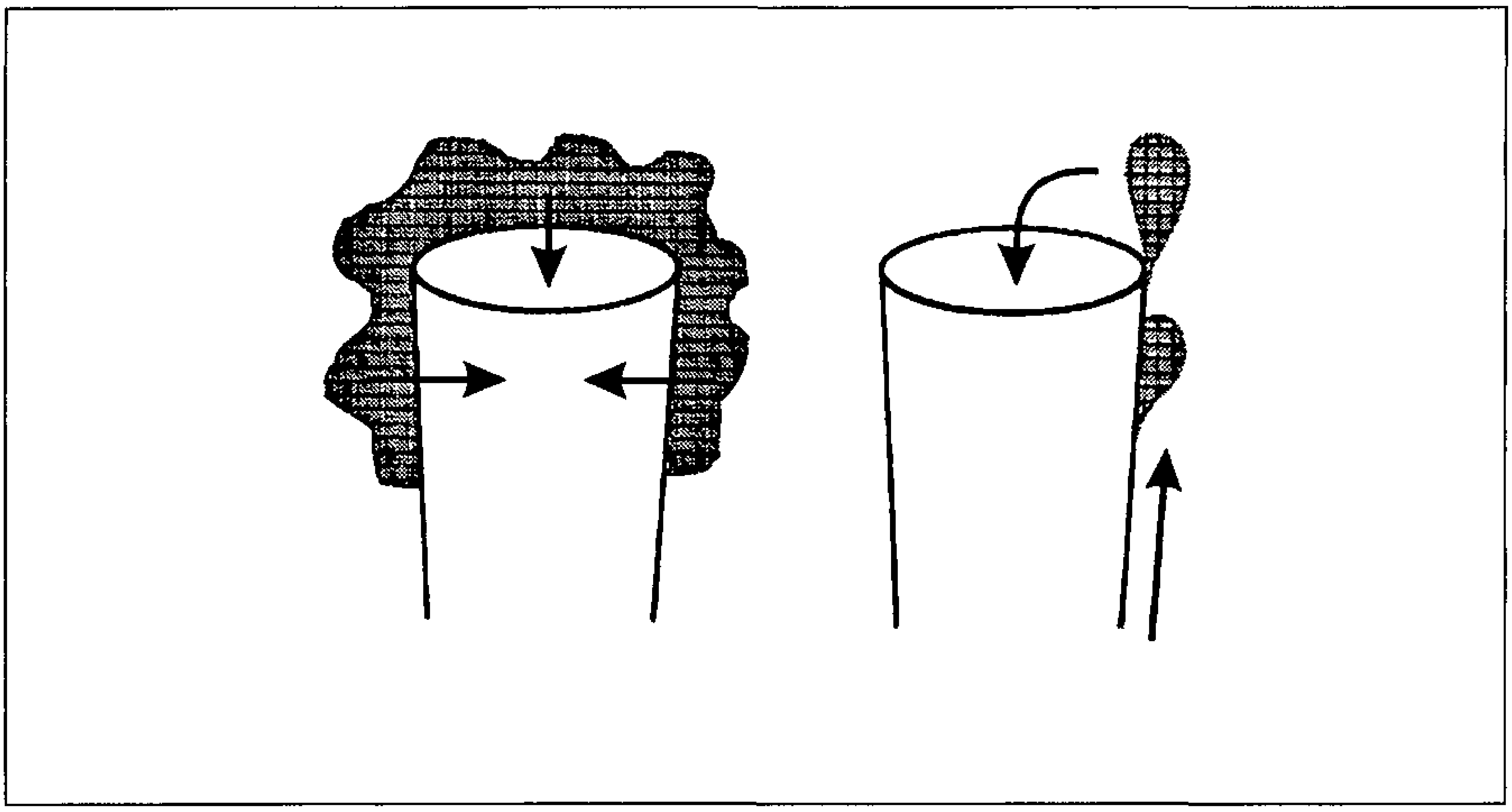

Figure 3. Liquid hormone preparations tend to run-off the waxy epidermis (left) and factors which determine how much solution is absorbed through the cut base are those which mainly determine rooting. In contrast, the rooting response to a powder preparation (right) is determined more by factors which affect its retention on both the cut end and the epidermis, and assist the transfer of auxin into the tissues.

Stockplants. Although cuttings can be taken from plants in the production cycle, this must often be done in association with the need to prune at a certain time, and it can also conflict with marketing objectives. This commercially pragmatic approach may be successful for subjects that have the genetic basis for ready rooting, but it is totally unsuitable for subjects that are difficult to root, and where stockplant management and precise timing of cutting collection contribute to success.

Research aimed at understanding why rooting in cuttings of *Syringa vulgaris* 'Madame Lemoine' is enhanced when stockplants are grown in the dark for a short period from bud-burst (Howard, 1992), hinted at interdependence between the type of cutting and its rooting environment. Cuttings grown initially in the dark were found to have relatively thin stems, resulting in a higher leaf-to-stem ratio than normal light-grown ones, and this was associated with a net accumulation of dry matter at the cutting base before the first roots emerged (Howard and Ridout, 1992). Further work has confirmed this for lilac, and shown that the same principle operates for other species subjected to a period of darkness, as well as to different size cuttings grown normally in the light. As such, these results provide new insights concerning how best to grow cuttings of difficult-to-root species.

Environments. Much is known about the role of leaves in the rooting of softwood cuttings, but nurserymen pay insufficient attention to maximising their beneficial effects and minimising their drawbacks in propagation terms.

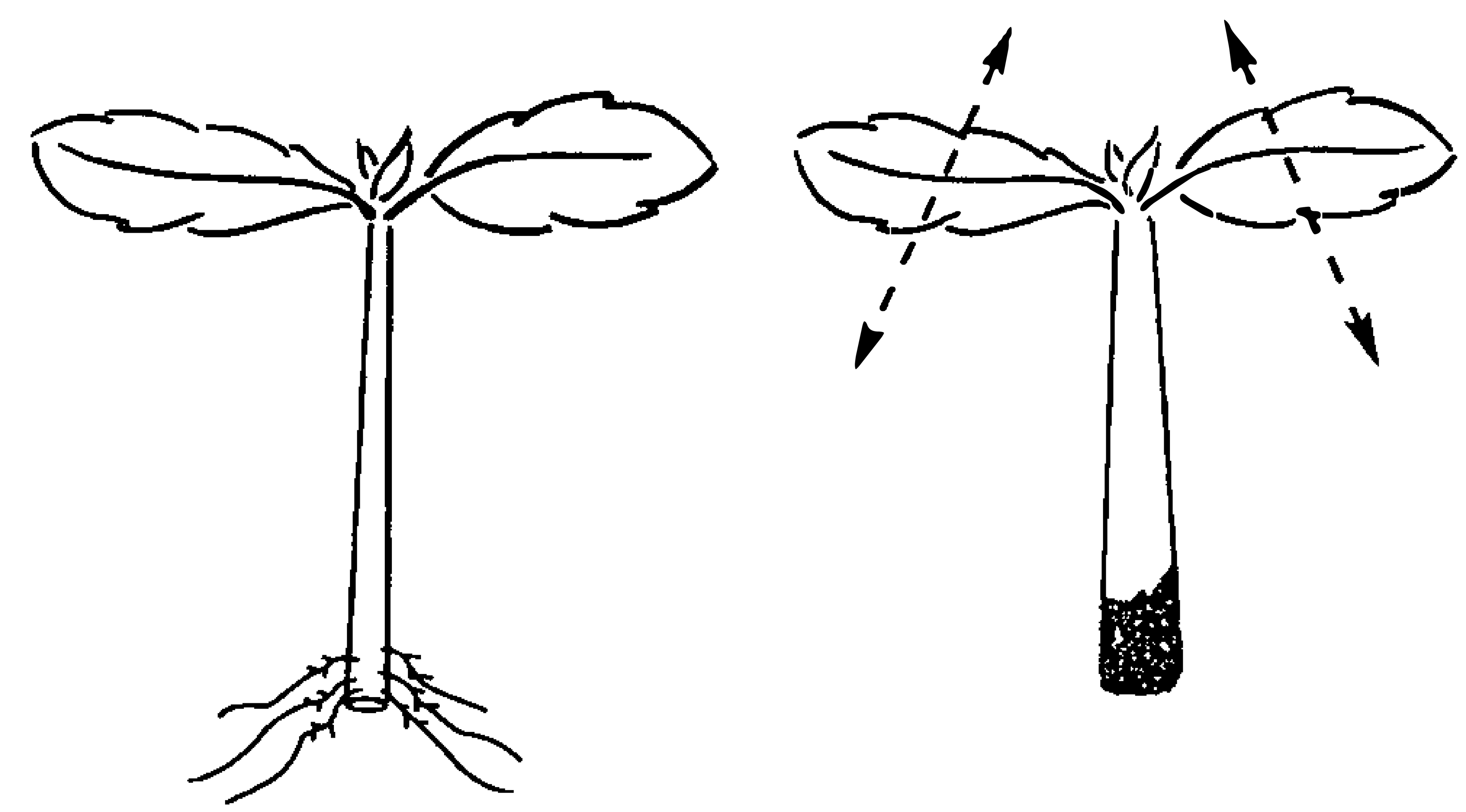

Figure 4. For difficult-to-root subjects factors which favour a high leaf : stem ratio, such as not trimming leaves, and selecting cuttings with relatively thin stems (left) favour rooting, whereas leaf-trimming and selecting thick fleshy-stemmed cuttings may result in stem rotting (right).

This conflict is because the stomata, typically on the underside of the leaf, allow intake of the carbon dioxide essential for photosynthesis, while also allowing water vapour to be lost. Photosynthesis provides the carbohydrates required for energy and growth, whereas loss of water initially causes stomata to close, thereby reducing photosynthesis, and eventually causes wilting and perhaps death of the cutting. This conflict is made worse by the fact that the light energy which drives photosynthesis is accompanied by heat energy which drives water loss through transpiration. It is essential to weight the balance in favour of photosynthesis. A cutting must produce carbohydrate in excess of its maintenance requirements for rooting to proceed, which has implications for the ways cuttings are produced and treated and the environments in which they are placed. Hedges should be grown to produce the maximum number of relatively thin-stemmed cuttings with a high leaf : stem ratio if the variety is difficult to root. Large fleshy-stemmed cuttings are acceptable for *Forsythia* × *intermedia*, but not for difficult subjects such as *Syringa vulgaris* (Fig. 4). By the same token such cuttings should not have leaves removed or reduced in size in order to increase sticking density, nor should they be crowded to the point of mutual shading, all of which have been found to depress rooting. "Wet fog" is seen increasingly as providing conditions suitable for stress-sensitive cuttings

(Harrison-Murray and Thompson, 1988, Harrison-Murray et al., 1988, Fig. 5).

Hardwood cuttings. Here, too, there is interdependence between the rooting potential—governed by the stockplant—and the ability to realise that potential—governed by the propagation environment. The advantage of hard-pruned hedges is not to increase the vigour of shoots to mimic juvenile material, as has long been assumed. Thick cuttings from vigorous shoots may survive better than thinner ones, but the latter root faster as long as propagation conditions are

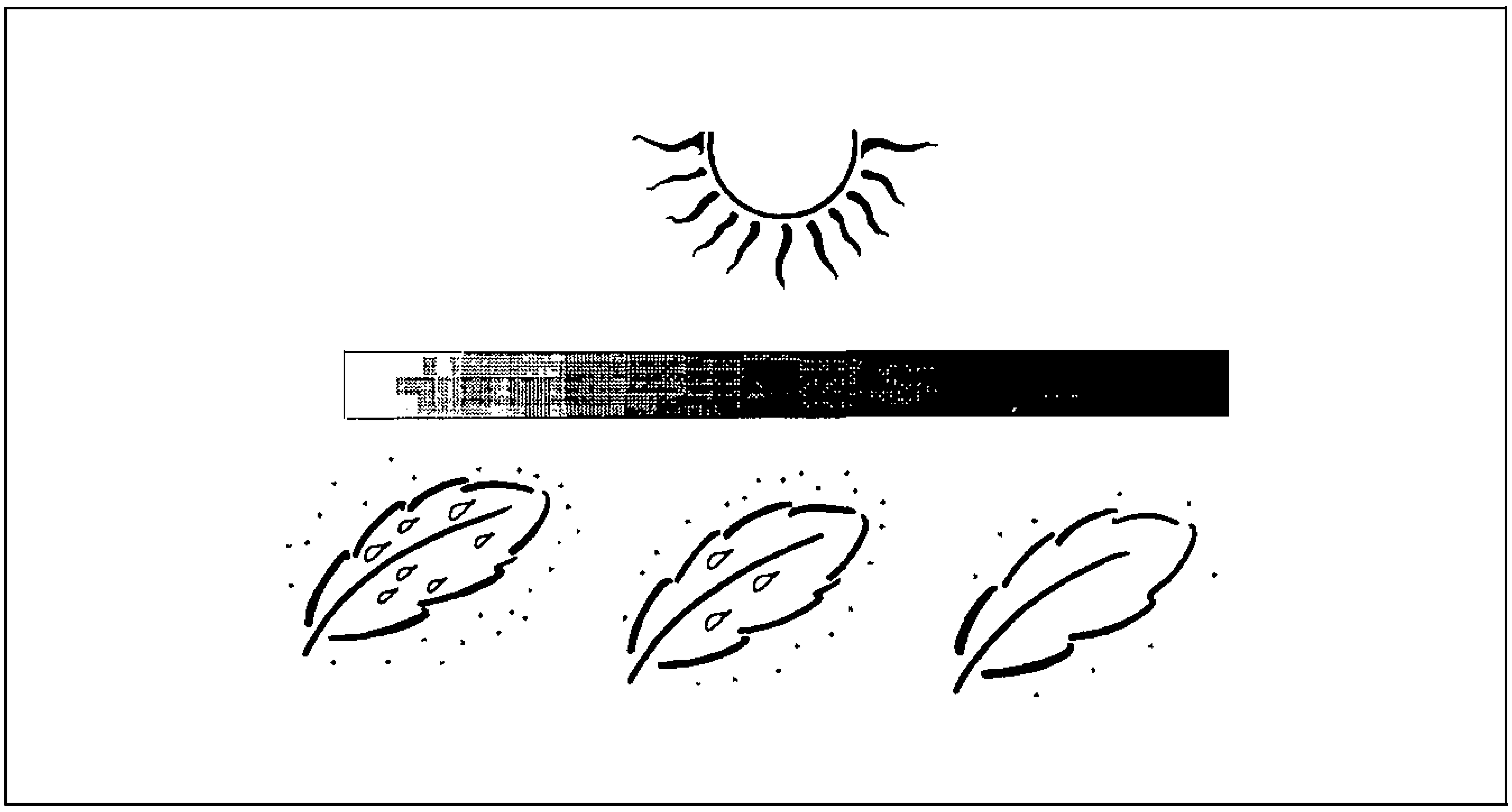

Figure 5. As water deposition on the leaf and water vapour around the leaf decreases (from left to right) shade must be increased to avoid stress, at the expense of beneficial photosynthesis. 'Wet fog', or mist with 'dry fog', provides a suitable mixture of large and small water droplets to enable cuttings to receive adequate light.

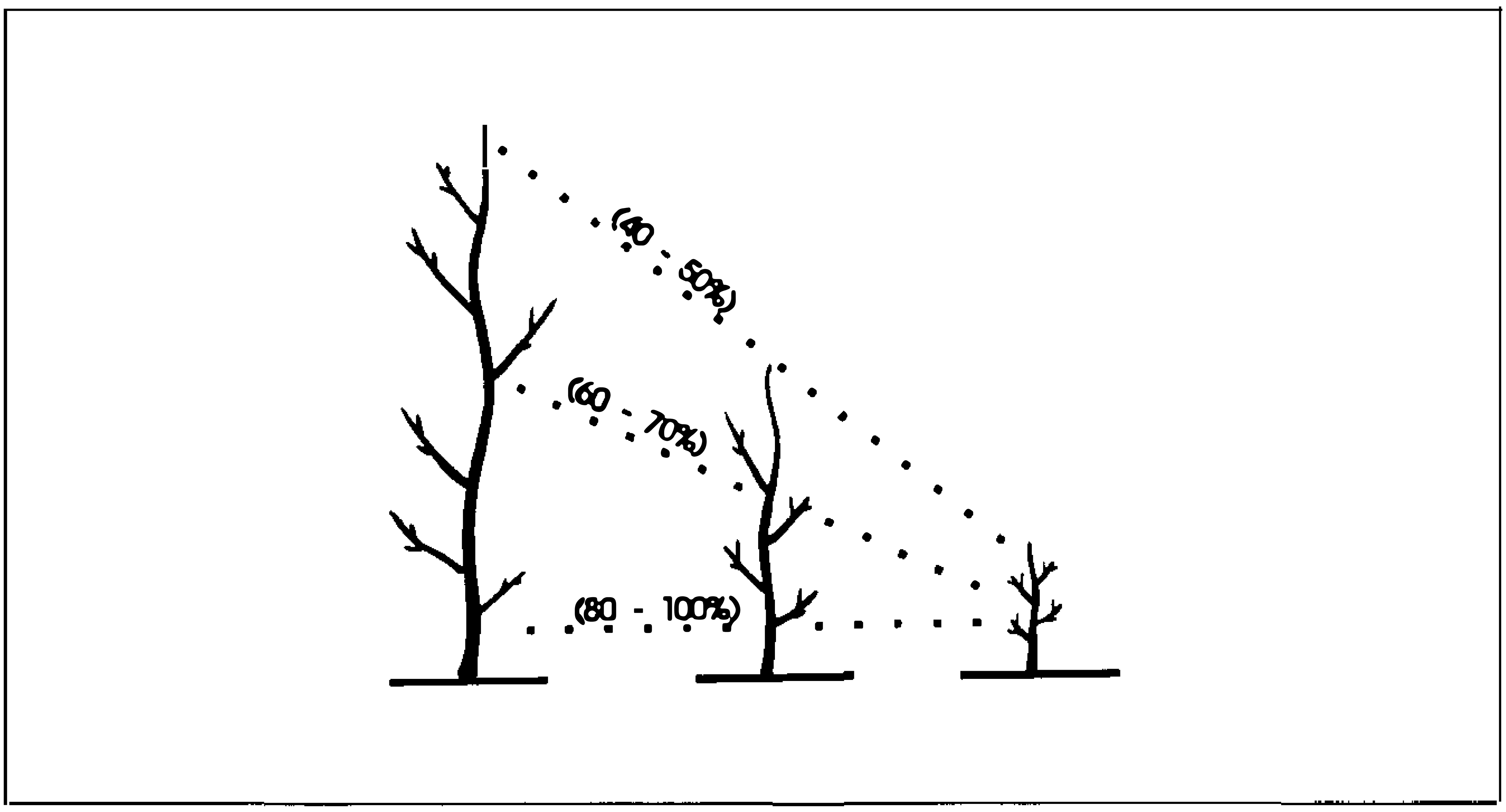

Figure 6. Rooting potential (typical values in brackets) of hardwood cuttings in a hard-pruned hedge is more influenced by the relative position of shoots than by their absolute position in terms of the distance between themselves or from the root system.

designed to rapidly drain away the excess water that causes hardwood cuttings to rot (Howard and Ridout, 1991). Thinner cuttings are particularly prone to rotting.

Ongoing research has confirmed the faster rooting of thinner hardwood cuttings and results of new experiments suggest that rooting potential among shoots in a hedge is more dependent on their relative position than whether or not they are close to the ground, as was previously thought important (Figure 6).

CONCLUSION

Success in understanding general physiological processes in the special context of vegetative propagation provides opportunities for nurserymen to adapt their techniques and procedures and improve their facilities in ways convenient to themselves, and which are compatible with their business objectives. Knowing how and why cuttings can be rooted better, or budding success increased, gives the necessary confidence to implement change.

Acknowledgements. This paper summarises work funded by the Ministry of Agriculture, Fisheries and Food, and by the Horticultural Development Council.

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Magnolia Propagation

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INTRODUCTION

There are many methods which can be employed to propagate magnolias, for example seed, softwood cuttings, semi-ripe cuttings, micropropagation, layering, budding, and grafting. Two methods employed at Hadlow College will be discussed. Firstly softwood leaf-bud cuttings of a range of deciduous magnolias, including the results of a small wounding trial on *Magnolia stellata* 'Royal Star'. Secondly chip budding a range of difficult to root deciduous magnolias onto pot grown rootstocks. The two propagation methods will be discussed separately. Only a brief outline of the method of preparing softwood leaf-bud cuttings and the process of chip budding will be given as these are well known to propagators. More emphasis will be placed on other factors such as source of material, the wounding trial, rootstocks for budding, tying materials, etc.

SOFTWOOD LEAF-BUD CUTTINGS

Stockplants. These have been planted in an old "Dutch light" glasshouse to force early cutting material. This is important because magnolias are fairly late breaking into growth in the spring. Therefore cuttings can be taken earlier (late May/early June) than from plants outside, it is then possible to obtain some growth on the cuttings the same summer, giving far better results with overwintering.

The stock plants are hard pruned in the winter, then fed and well watered at budburst in the spring. This provides good extension growth suitable to use for leaf bud cuttings. During hot weather in the summer the glasshouse is well ventilated and shaded so that the plants are not stressed too much.

Cutting Preparation. The cuttings are prepared with one bud, a leaf, and 6 to 10 cm of stem. A very thin slice wound 2 to 3 cm long is made on the opposite side to the bud. The leaf lamina is reduced by 50% to 60%.

Hormone Treatment. The base of the cutting and the wound is dipped in 0.8% IBA in talc.

Propagation Medium. The medium used is equal parts of moss peat, fine grade bark, and perlite. The cuttings are inserted at 40 per tray, not in too deeply, the bud needing to be above compost level. The cuttings are staggered in the rows to ensure the leaves do not cover the buds on cuttings in the previous row. Overcrowding and inserting too deeply can cause buds to rot off.

Propagation Facility. A conventional mist propagation bench with hoops over the top to support a polypropylene fleece material cover is used. This helps create a higher humidity than open mist, important for magnolias as they scorch easily.

A basal heat of 18C is given and rooting normally occurs in 5 to 6 weeks. After 10 to 12 weeks the cuttings should be fully weaned from the mist. Overwintering should be on the dry side in a frost-free structure.

Wounding Trial. A small trial using *M. stellata* 'Royal Star' was carried out to see if methods other than the conventional slice wound would improve rooting. The following treatments were carried out.

1) No wound
2) Double incision wound with the tip of the knife.
3) Scrape wound
4) Normal slice wound
5) Long slice wound, from just below bud.
6) Split wound for 2 to 3 cm at base of stem.

Forty leaf-bud cuttings were prepared for each treatment. This was carried out on the 13 June. The hormone treatment, propagation media and facilities used were the same as described above.

On the 23 July, nearly 6 weeks after insertion, the cuttings were lifted and rooting assessed. The results are shown in the following table.

Table 1. Effect of various wounding treatments on the rooting of *Magnolia stellata* 'Royal Star'.

Treatment	Well rooted	Light roots but alive	No roots	Dead
No wound	6	6	25	3
Incision	0	7	30	3
Scrape	7	15	15	3
Slice (normal)	14	9	14	3
Slice (long)	9	20	11	0
Split	0	5	34	1

From the above results, bearing in mind the small size of the trial, that no positive conclusions could be drawn from the data. Certainly the normal procedure (normal slice wound) gave the highest number of well-rooted cuttings. Therefore, it would seem prudent to stick with this method.

The long slice wound may well have shown better results if the cuttings were left longer before lifting.

The split wound was disappointing as this works very well with deciduous hardwood cuttings of plum rootstocks. It would be interesting to repeat the trial using a quick dip hormone rather than a talc (normal practice with hardwood cuttings) to see if the split wound would perform better.

CHIP BUDDING

The advantages of chip budding over grafting are, I feel, that it makes better use of scion material, gives a better union, and the resultant plant is more shapely.

Source of Scion Material. This is selected from stock plants which are not too severely pruned or can be taken from the growing crop.

Rootstock Selection. This is important, ideally the rootstock needs to be as genetically close to the scion cultivar as possible. In reality rootstock choice is often limited by availability.

The genus *Magnolia* is divided into two subgenera, *Magnolia* and *Yulania*. The only magnolia we bud in the*Magnolia* section is*M.* ×*wiesneri* [syn. × *watsonii*] and for this we use seedings of *M. hypoleuca*. Seed is available every year in the U.K. and seedlings are of workable size in 2 years. The other subjects we chip bud (*M. cylindrica, M.* 'Albatross', *M.*'Yellow Bird', *M. campbellii*, *M. dawsoniana*, and *M. sprengeri*) are all in the subgenus *Yulania*.

For these we use rooted cuttings of*M.* 'Heaven Scent', this has *M. campbellii*, *M. denudata*, and*M. liliiflora* parentage in it so makes a good all purpose rootstock for this group.

Time of Year. We undertake to do our chip budding at the beginning of August onto well established seedlings or rooted cuttings in 1-litre pots. It is important that the base of the stem is hard wooded (2 years old) and between 5 and 6 mm in diameter.

Procedure. The chip budding operation is carried out in the normal way, ensuring a good match at the cambium layers. The tying in operation is perhaps the most difficult one to carry out and a fair amount of practice is required to master the process. We have used three different tying in materials at Hadlow:

1) 26-mm-wide polythene tape, preferably milky as it stretches round the bud more easily.

2) 13-mm-wide Parafilm (florists stem wrap), this plastic material stretches making it easy to tie round the bud. It is also degradable making untying unnecessary.

3) Rubber grafting strips.

When using the first two tying materials the pots can be left on an open bench. If using rubber grafting strips, a well shaded polythene tent should be used.

One problem we have encountered is that the large base of the leaf petiole can become trapped by the tying in material. When the leaf petiole abscises it is trapped and can start to rot the chip. It is worth removing the leaf petiole once abscission occurs. Unfortunately this is too early for tie removal so that both operations cannot be carried out at the same time.

We now pull the leaf off the bud sticks complete with leaf petiole rather than cutting it off leaving the base of the petiole.

The plants are headed back to the bud in the following February. Once growth commences they are potted on into a 5-litre container and the resultant growth tied in to a cane.

Table 2. Magnolias propagated by softwood cuttings and chip buddings at Hadlow College.

From softwood leaf bud cuttings

'Frank Gladney'
'Galaxy
'Heaven Scent'
'Iolanthe
'Jane'
'Joe McDaniel
'Manchu Fan'
'Sayonara'
'Star Wars'
'Susan'
× *brooklynensis* 'Woodsman'
× *kewensis* 'Wada's Memory'
liliiflora 'Nigra'
× *loebneri* 'Ballerina'
× *loebneri* 'Leonard Messel'
× *proctoriana*
sieboldii
× *soulangiana* 'Burgundy'[1]
× *soulangiana* 'Opal'
× *soulangiana* 'Sundew'
× *soulangiana* 'White Giant'
stellata 'Centennial'
stellata 'King Rose'
stellata 'Norman Gould'
stellata Rosea 32T
stellata 'Royal Star'

From chip budding

'Albatross'
'Caerhays Belle'
'Elizabeth'
'Yellow Bird'
campbellii var. *alba*
campbellii ssp. *mollicomata* 'Lanarth'
cylindrica
dawsoniana 'Clarke'
sprengeri 'Claret Cup'
× wiesneri [syn. × *watsonii*]

[1] Botanical Editor's Note: Most of the plants with this name are *Magnolia* × *soulangiana* 'Purpliana'

Fuchsia Options

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INTRODUCTION

Tamborine Mountain Plants is a specialist nursery reliant on only one major product for the year. Therefore, it is important to establish as many marketing options as possible of that one plant for success of our business. Tamborine Mountain Plants has become Australia's biggest fuchsia nursery. Our fuchsia marketing options are:

- As cuttings
- As tubes
- As 4-in. and 6-in. pots
- Baskets—6-in. and 8-in. plastic, fibre-lined 14 in.
- Retail—using mother stock beds as display gardens
- Mail Orders

Each stage of a product has an advantage to different customers.

PROPAGATION AND PRODUCTION

All our options start with a cutting. Usually seasonal variations play an important role in the availability of good cutting material. However, being a specialist nursery we have year-round availability of material.

Cuttings. Cuttings are light, free of roots, are easily packed in volume for export and airfreight, and do not require the excessive treatments that some countries' quarantine regulations require for rooted plant material.

Cuttings for our own production are taken over the months of December through to the end of January, and again in April to May. However, being a specialist nursery, good cutting material is available all year round.

A good quality cutting depends on:

- How it is taken
- Its origin (from stock or mother plants or production plants)
- The cultivar selection.

The age and quality of the mother stock is vital for the vigour of the offspring. Stock beds are kept as a nucleus of each variety, and, of course, these have a real advantage as mature plants growing in beds lining the driveway and the parking area of the nursery. They give a fabulous display. However, it is from vigorously growing potted material at the optimum of nutritional value, and in a vegetative state, that I aim to obtain all my cutting material for production. These source plants are then regrown to flowering stage and sold. Fresh grown potted plants are then used for further cutting material, constantly selecting the best plants of the given number grown.

Tubes. As the nursery was established 15 years ago, 2-in. tubes in wire trays are the major units used. I have since found cells have limited holding time, whereas tubes give me about a month leeway without them losing quality.

We propagate our fuchsias in a 3 perlite : 1 peat (v/v) mix. These components have a definite and constant standard and are considered free of pathogens, and are all that is used at the nursery as propagation medium.

This medium is lightweight, free draining (vital for our climate), and has none of the variations that our sand supplies can have. Although more costly, it does not take long for costs to balance if the cuttings strike more readily and more rapidly. Weight is also an important factor in the shipping of our mail orders which are despatched in these tubes. These completed trays are set out on wire benches under intermittent mist.

Pots. After each bench-full of tubes has initiated roots, the misting controls are turned off. The tubes are then fertilized with 14-6.1-11.6 Osmocote by hand. Gradually over the months of December and January we have sufficient tubes of Fuchsias for our main planting time. At the end of February the 50% shade cloth covering is then rolled off to sun-harden the plants. We then tip prune these plants, endeavouring to prune down to the last pair of leaves on each small plant, to encourage lateral growth. Once potted these are placed in the main field sections of the nursery. The full winter sunlight enables the plant to produce short internodal growth and the varieties chosen will flower, covering the plant canopy with blooms and following buds. Potted colour will always sell!

Standards. It is, however, prior to this time that we select the rooted cuttings suitable for standard fuchsias. Individual plant and cultivars are chosen on the following criteria:

1) Long straight stem
2) Not brittle
3) Ability to form a soft pliable canopy from as many lateral points as possible on the top three leaf nodes remaining on the plant at its final stopping height.

These are potted into small pots to begin the process of growing straight and tall in a protected position under shade.

We pot our major crop in the last week of March each year. When the tubes are brought to the potting area, they are once again tip pruned. A well organised team is selected from the staff, each of whom must be able to pot at least 1000 plants per day into 6-in. pots and lay them out in the field in rows.

These fields have the ground covered in black plastic and have been without any plants for at least 3 months.

Baskets. This really is making the most of a product. These are the eye-catching display plants from which the smaller pots are sold. As the propagation area empties of stock to be potted, we then pot the basket lines.

I use quite a few of what I term the "dual purpose" fuchsias—the rounded ball-shaped cultivars to pot into baskets, such as 'Cecile', as well as some of the more traditional plants, such as 'Pink Marshmallow'. I find these ball-shaped varieties are better to ship and display well in retail outlets when hung at eye-level. Full cascading varieties are quite impossible to ship economically without damage, and generally many of these varieties are quite straggly plants unless constantly pruned.

We pot three plants to every 8- and 14-in. basket and then hang them on hooks. The benches are used for further baskets, in early stages of growth, for future hanging. Benches are also used for other lines, such as standard fuchsias.

The Retail Section. This was established two years after the wholesale section. Tamborine Mountain is a beautiful area near a subtropical rainforest national park. Its volcanic soil is famous for the production of 'Big Red' rhubarb, avocados, and cut flowers—including bulbs, and, of course, fuchsias.

Our nursery is within a perfect day-trip from the large populations centres of Brisbane and the Gold Coast and surrounding areas.

We stock our own propagation mix; hand-made, hand-painted T-shirts with fuchsias; earrings with fuchsias; coffee mugs with fuchsias; hankies and even hand-painted soap; plus, of course, all stages of fuchsias from starter plants to large baskets.

Mail Order. This is a part of the retail section. We advertise in two major garden magazines with a half-page advertisement and order form. Orders are despatched over the cooler half of the year. The advertisement also brings people from all over Australia to visit the Nursery.

We are gradually building on a reputation of knowledge and sharing that experience with our customers in the true I.P.P.S. ideal "To Seek and Share".

Developing Crop Protection Strategies for the Nursery

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INTRODUCTION

The production of quality, healthy plants is more important than ever before. Consumers have become increasingly demanding in recent years and if nurseries are to survive in today's highly competitive environment, they must produce a consistent, quality product. There has been a gradual increase in records of disease on ornamentals. This may be partly because of a greater awareness of crop health. It is also because there has been an expansion in ornamental production in the U.K. and because there is increasing specialisation within nurseries. The use of re-circulating systems for nutrients and water also causes an increase in disease.

It is increasingly difficult to achieve effective crop health management on ornamentals. The technology surrounding crop protection is constantly changing. New products, techniques, and services are being developed and existing ones are being changed, adapted or removed from the market. There is very little data on ornamental crops in comparison to that on major agricultural and horticultural crops and there are very limited funds available for research into new or unrecorded pest and disease problems on ornamentals.

Growers are under increasing pressure to minimise pesticide use, a situation complicated further by constant changes to approvals and by extensive legislation, which must be understood and complied with. The cost of legislation simply means that the production and sale of horticultural crop protection chemicals is not profitable so there is a decreasing number of them available for use on ornamentals and there is little data on their use. Many pesticides have to be used at the growers own risk. There are relatively few conferences or workshops on crop protection for growers and there is limited coverage on crop protection in books or in the trade press. People are simply not prepared to put the money into what they consider a minor industry.

THE WAY FORWARD

It is clear that a coordinated approach to the development of crop protection strategies is required. If progress is to be made, we need contact between different sectors of the industry, we need a comprehensive research programme to underpin our advisory services, we need a consultancy or advisory service tailored to growers needs, and we need a flexible, informed training facility.

CONTACT BETWEEN DIFFERENT SECTORS OF THE INDUSTRY

The Crop Health Centre operates as part of The Scottish Agricultural College and our main aim is to develop crop protection strategies for the nursery industry. The recommendations which we make are increasingly based on cultural and environmental control methods. It is essential for specialists to understand how crops are produced and what practical difficulties are involved when trying to protect crops. We have found that time spent in conversation with growers is rarely wasted. Every nursery is different. Successful disease and pest control measures must be developed with the nursery and grower in mind. Specialists cannot afford to sit in their labs, they must understand the nursery and they must understand the grower.

Nursery visits, trade-shows, conferences, and growers meetings should be recognised as important opportunities for the exchange of ideas between those involved in different aspects of crop protection.

RESEARCH MUST UNDERPIN ADVISORY AND CONSULTANCY WORK

Research is of the utmost importance if U.K. growers are to remain profitable and competitive within Europe. Advisory and consultancy work frequently gives rise to unanswered questions and a comprehensive research programme is required to support the successful operation of these services. Most growers realise the short-term benefits to be gained from small, near-market trials, and studies. Useful results can be gained quickly with minimum cash outlay from such studies. It is the duty of growers, advisors and research workers to select topics for investigation, to ensure that the trials are properly carried out and to ensure that the results are made available quickly to the industry in a readily understood form.

In many cases, the results obtained from primary trials indicate that there are no simple solutions to a particular problem. The responsibility then falls to larger grower groups and private companies to raise funding for in-depth studies. We must not fail to realise the importance of strategic research in our developing industry. Financial outlay and time spent on research in key production areas will pay great dividends in later years.

A CONSULTANCY AND ADVISORY SERVICE FOR HORTICULTURE

An effective, useful crop health advisory service can best be provided if growers can use it as a one-stop shop. Crop health is dependent on many factors. It is important that specialists in all the main subject areas are located in the one place and that these specialists are in constant contact with each other.

Diagnostic services must be rapid and reliable. At The Crop Health Centre, we have spent much of the past year streamlining our diagnostics lab. A quality assurance manual has been written for all our advisory work along the lines of that required for BS5750. It contains guidelines on procedures and the timescale used for all tests, in an effort to ensure that the grower receives a quality service at all times. Consultants and advisors should be prepared to draw information from a wide range of resources. Recommendations and control measures must be made with the individual grower in mind, which is why specialists must have a knowledge of growing methods and nursery practice. We prefer to build up a relationship with our clients because every nursery is different. The fact that we can draw information from our own research programme and general horticultural backgrounds makes this easier. Advice should be available by fax, phone, and letter. Specialists should be flexible and ready to travel to nurseries at short notice. They should be willing to negotiate and must be able to provide the type of service which is desired.

A COMPREHENSIVE TRAINING SERVICE FOR GROWERS

Training is important for those involved in crop protection at all levels. Those who want to progress in their work are always learning. Growers frequently admit confusion concerning disease and pest identification, current approvals legislation or pesticide safety, cultural and biological control measures, and several other subject areas. In most cases crop protection measures can be better applied if the grower fully understands the nature of the problem.

We need flexible training facilities, with experienced, qualified tutors. Courses must be designed for growers, they must be run where and when required and they must be affordable. Having coordinated several training courses both at our Auchincruive base and on nurseries, our experience is that they are not difficult to run. It is up to growers to say what their training needs are and how they wish them to be fulfilled.

CONCLUSIONS

If progress in development of crop protection strategies is to be made in the U.K., then it is of vital importance that all those involved maintain contact with one another. Growers must speak about their experiences with diseases, pests, and their control. Sales reps, advisors, and research workers must listen and act accordingly. Those involved in teaching and training must keep abreast of new developments. We need to keep in contact, we need quality research, and we need competent advisory and training facilities.

All of these must be addressed if the nursery industry is to move forward, and move forward we **must** if we are to remain competitive into the 21st century.

The Botanical Gardens of Russia and Her Neighbours

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HISTORY

In 1706 a decree from Peter the Great established the first botanical garden in Moscow as a medicinal herb garden. At present, this first garden is a branch of the Botanical Garden of Moscow State University. The second oldest botanical garden, laid down in St. Petersburg in 1714, was called "the pharmaceutical garden". The Botanical Institute of the Russian Academy of Sciences was originally based on this pharmaceutical garden in St. Petersburg. From the time of the first garden until the beginning of this century, 20 botanical gardens have been established (Lapin 1984).

In the 1930s and 1940s large botanical gardens were created in many cities of the former Soviet Union including Omsk, Rostov on the Don, Almati, Baku, Dushanbe, Kiev, Minsk, Ekaterenburg, and Ufa. They played an important role in the conservation of native flora and the enrichment of cultivated plants. Before World War II, unique institutions were founded, such as the Polar-Alpine Botanical Garden (within the Arctic Circle) and the Pamirs Botanical Garden. After World War II, new botanical gardens were established in Tashkent, Moscow, Novosibirsk, Stavropol, Riga, and other cities. Close cooperation between the gardens resulted as they set up their seed and plant exchange programs. It quickly became apparent that it was necessary to form a committee to coordinate all the activities of these various botanical gardens. Initiated by the Main Botanical Garden in Moscow, the Council of the Botanical Gardens was established and registered in 1952.

From the beginning, the Council has given research direction to methods of plant introduction. All botanical gardens were encouraged to work on the problem of "introduction and acclimatization of plants". The variability and survival of plants introduced to new regions has been studied and great attention has been given to the problems of protecting plant species. To this end, explorations and collections have been made of rare and endangered plant species from all regions of the country and methods of propagation and cultivation.

To improve the effectiveness of the Council of the Botanical Gardens, Regional Councils for botanical gardens were formed in 1963. The Regional Councils coordinated the work of the botanical gardens in various geographical zones such as Siberia and the Far East, the Urals, the Baltic Sea area, and Kazakhstan (Lapin, 1984).

After the collapse of the Soviet Union in January 1992, representatives of the botanical gardens of Russia met at a conference and formed The Council of the Botanical Gardens of Russia. This Council embraces 50 botanical gardens and functions as the Council for Plant Introduction in the ranks of the Russian Academy of Sciences. The regional structure of the new Russian Council remains the same as before the breakup of the Soviet Union (Andreev, 1993).

During an organizational conference in 1992, the Russian Council of Botanical Gardens initiated the Euro-Asian Association of Botanical Gardens to retain and further develop scientific relations among gardens of the former Soviet Union. The vast majority of these various botanical gardens have welcomed this step and in April 1992, representatives of the different botanical communities agreed to set up a new Botanical Association. Today, this large Association includes the Council of Botanical Gardens of Russia and its regional branches (Andreev, 1993).

INTERNAL STRUCTURE OF THE BOTANICAL GARDENS

Most gardens within the Botanical Association are generally similar in structure. They only differ in overall size and territory, in the number of staff members, in the emphasis on local and world flora collection, and in the particular direction of study. Each garden studies the adaptability of plants to new growing conditions; maintains collections of herbaceous plants, woody trees and shrubs; provides for seed exchange; and does research on rare and endangered species. The Main Botanical Garden, for example, seriously studies the introduction and acclimatization of plant species. There, selections of resistant species and varieties are based on a deep and thorough understanding of biology and ecology. Good collections from many regions of the country are maintained in St. Petersburg. With an excellent herbarium, St. Petersburg is a research center for plant taxonomy. In Siberia, the focus is on an interesting collection of medicinal and technical plants, whereas in Belarus, great attention is paid to ecological research. In Ukraine at Kiev, the breeding of ornamental plants is emphasized.

THE MAIN BOTANICAL GARDEN OF THE RUSSIAN ACADEMY OF SCIENCES (RAS)

The Main Botanical Garden was founded in Moscow in April 1945 to lead all other botanical gardens of the country in solving problems related to the use, enrichment, and protection of the plant kingdom.

The Main Botanical Garden covers 360 hectares and employs 850 staff, including 175 scientists. There are 10 departments: dendrology, native flora, tropical and subtropical plants, plant protection, crop and fruit trees, propagation, physiology, biochemistry, tissue culture, seed exchange, and exploration.

The following discussion will consider only those departments concerned with plant propagation in open ground. Within the garden, the collections consist of 11,750 taxa which are planted in five principal exhibition complexes: native flora (3000 taxa); oak grove and dendrarium (2000+ taxa); cultivated plants (2900 taxa); ornamental plants (8000+ taxa); Japanese garden (about 130 taxa); and greenhouse (5500 taxa)(Andreev, 1993).

THE DEPARTMENT OF DENDROLOGY

The Department of Dendrology keeps the woody tree and shrub arboretum, which was created in a natural oak grove. The Oak Grove is an important feature of the garden and is unique because it is located near the northern limits of distribution of oak groves, with some trees over 150 years old. The principal tree in the grove is *Quercus robur*. This extremely valuable natural broadleaf forest is carefully protected in the central zone of the European part of Russia. This forest is preserved within the boundaries of a big city (population 9 million), unusual in the world practice of nature protection.

Almost all plants in this collection are planted in accordance with systematic principles. However, some groups of plants are exceptions and are placed together because of their specific ecology or cultural requirements. For example, all lianas are located in the same area (Lianarium) because of unique agrotechnique and vertical landscape methods. *Actinidia arguta*, *A. kolomikta*, *Aristolochia durior* [syn. *A. macrophylla*], *A. manshuriensis*, *Schisandra chinensis*, and other species can be found in the Lianarium.

During its 50 year history, more than 6000 taxa were tested and nearly 2200 were selected as tolerant to the Moscow climate.

The conifer collection is composed of trees from different ecological zones and from different countries. Examples of conifer species in the collection at Moscow include: *Abies balsamea*, *A. concolor*, *A. sibirica*, *Picea glauca*, *P. alba* [syn. *P. canadensis*], *P. pungens*, *Pinus strobus*, *P. mugo*, *Taxus baccata*, *T. canadensis*, and *T. cuspidata*.

Adapted to the warmer climate of Ukraine, the collection of *Catalpa* spp. is an interesting holding of southern plants able to survive in Moscow. During 1978, in the coldest winter recorded, *Catalpa* spp. withstood freezing temperatures which killed many other plants, because they had already reached a deep state of dormancy.

The very attractive collection of *Sorbus* has about 60 taxa, including species, varieties and cultivars. Within the collection, ×*Sorbocotoneaster pozdnjakovii* is a rare species from north of Siberia, included in the *Red Data Book*.

The Japanese Garden is a relatively new area, constructed jointly by the Main Botanical Garden Academy of Sciences and two Japanese companies. The Japanese Garden was designed by the famous Japanese landscape architect, Mr. Ken Nakajima. He was well aware of differences in climate between Moscow and Japan. Nakajima included many Russian plants to produce an overall image of a Japanese landscape. The Japanese garden opened in 1987 and rapidly became very popular among visitors.

THE DEPARTMENT OF NATIVE FLORA

Over 3000 plant species, native to various regions of the former Soviet Union, have been collected by the Department of Native Flora. These collections are maintained in an area of about 80 ha. Many of these plants do very well in the Moscow climate.

At the Main Botanical Garden, several hundred of the 6000 species native to the Caucasus flora are represented on the "Caucasus Hills". The flora of Central Asia, which includes plants native to steppe and semi-desert steppe, is represented by many shrubs such as *Berberis turcomanica*, *Prunus* [*Cerasus*] spp., *Juniperus* spp., and a good collection of *Eremurus* spp. Also from Central Asia are many endemic *Allium* spp. and a large group of attractively blooming *Tamarix* spp. The European flora collection can be viewed in a large glade and adjacent forest, in which there are displays of plants native to the steppes. The Far East flora collection is now in a condition suitable for serious taxonomic and ecological research.

Besides maintaining the species collection, the Department of Native Flora studies the effects of moving certain plants north of their normal limits of distribution; for example, species of such genera as *Prunus armeniaca* [syn. *Armeniaca*], *Prunus* [*Cerasus*], and *Juglans*. It is also interested in selecting cultivars that are horticulturally successful in northern latitudes. Populations of plants originally from different climatic conditions are grown together in a common area of the Botanical Garden and allowed to cross pollinate. From the progeny of these crosses, plants with good flavour, fruit shape, and other desirable qualities have been selected, including an excellent example of *Lonicera caerulea* [syn. *L. edulis*] with very sweet berries and an *Prunus armeniaca* [syn. *Armeniaca vulgaris*] which is tolerant to Moscow's cold climate.

THE DEPARTMENT OF CULTIVATED PLANTS

Cultivated plants are exhibited in almost all the botanical gardens of the former Soviet Union. In the Main Botanical Garden, the origin and evolution of certain cultivated plants are displayed. Collections of fruit trees, berries shrubs, vegetables, medicinal, and industrial plants are also kept by the Department of Cultivated Plants. A very good collection of plants with ethereal oils is represented by *Artemisia*, *Mentha*, *Melissa*, *Nepeta*, *Origanum*, and other genera. Although most of these plants are traditionally cultivated in southern areas, scientists in this department have selected cold resistant forms which are doing well in the Moscow climate. New shrubs that have value to industry are sought such as *Actinidia*, *Hippophaë*, *Lonicera*, *Schisandra*, *Vaccinium*, and *Viburnum*. Several genera are particularly well represented: *Fragaria*, 400 cultivars; *Malus*, 100 cultivars; *Pyrus*, 30 cultivars; *Prunus*, 25 cultivars; and *Vitis*, 50 cultivars. The collection of medicinal plants contains about 100 species, with the greatest focus on *Calendula* spp., *Rhodiola* spp., *Sanguisorba officinalis*, and *Valeriana* spp.

THE DEPARTMENT OF PLANT PROPAGATION

The main target of activity for the Department of Plant Propagation is to develop propagation techniques for various woody and herbaceous plants for use in floriculture and ornamental horticulture. Special attention is paid to the propagation and development of slow-growing plants, which are represented by nine families, 16 genera, and 46 species. The number of newly introduced plants is continually expanding; *Abelia coraena*, *Acer pseudoplatanus*, *Berberis julianae*, *Euonymus nanus*, *Hydrangea arborescens* ssp. *discolor* [syn. *H. cinerea*], *Tsuga canadensis* and others have recently been propagated. Scientists within this department have worked together on propagating 82 genera, 324 species or taxa. The assortment of propagated fruit and berries is enriched with non-traditional species such as *Actinidia kolomikta*, *A. arguta*, *Berberis* spp. *Prunus tomentosa* [syn. *Cerasus tomentosa*], *Chaenomeles japonica*, *Lonicera edulis*, and several taxa of *Sorbus*.

Propagation techniques are also being developed for winter hardy plants such as *Vaccinium uliginosum*, *Schisandra chinensis*, *Clematis*, *Spiraea* spp., conifers, and others. All together, propagation techniques for 41 genera, 93 species, 145 cultivars and forms are being explored.

THE LABORATORY OF BIOTECHNOLOGY

In the Laboratory of Biotechnology, methods of in vitro propagation of rare, endangered, and economically important species are developed. Thirty-three genera are targeted from families such as Bromeliaceae, Ericaceae, Liliaceae, Orchidaceae, and Rosaceae.

THE DEPARTMENT OF ORNAMENTAL PLANTS AND FLORICULTURE

Many different varieties and selections of plants are tested for use in parks and gardens by the Department of Ornamental Plants and Floriculture. The results of many years of selection work and the latest achievements of World Floriculture are displayed in their collections. The *Rosa* collection is the largest in this department with up to 2250 species, cultivars, and forms: hybrids tea, floribunda, climbers, perpetuals, and miniatures. From this collection, about 250 rose cultivars have been selected and studied. The most beautiful and hardy specimens are recommended for practical use in ornamental gardening. Besides roses, the collections of other flowering plants include: *Paeonia*, about 500 varieties; *Iris*, about 28 native species and 520 garden cultivars; *Gladiolus*, 549 cultivars; *Phlox*, *Dahlia*, and others. Members of the Department of Ornamental Plants and Floriculture have used native plants collected on field trips for further ornamental study and future selection for landscape gardening.

LABORATORY OF SEED EXCHANGE AND EXPLORATION

The Laboratory of Seed Exchange and Exploration exchanges seed with over 50 foreign countries. Seed lists include material collected from plants grown in the Main Botanical Garden, as well as, supplementary seed collected on field trips. Seed lists are sent to over 550 different botanical institutions throughout the world.

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Editor's Note: The following three papers by Christopher George, James Newell, and Jeanette Freyer were Mary Helliar Travel Scholarship Awards for 1993 and are present as a group.

Rhododendron Propagation—Methods and Techniques Carried out in the Pacific Northwest of the U.S.A.

Christopher George
Osberton Grange Nurseries, Worksop, Nottinghamshire

For me, the missing link in the *Rhododendron* production cycle is propagation. At Osberton Grange, we are growing-on 300,000 rhododendron plants at any one time, but I have never had the opportunity to study the propagation stage.

Therefore, in spring 1993 I used my Mary Helliar Travel Scholarship Award to visit the U.S.A. to fill in this gap in my experience. My first visit soon achieved this goal, as it took me to the source of all the rhododendron plants grown at Osberton Grange.

BRIGGS NURSERY, OLYMPIA, WASHINGTON

Ninety nine percent of Briggs' rhododendrons are produced by tissue culture in their laboratory on the nursery. The present laboratory was completed in 1988 after operating on a small scale for the previous 10 years and researching the subject for 10 more years prior to that.

Bruce Briggs feels that its heavy investment in such facilities has been rewarded by the large number and high quality of plants that leave the nursery each year. To give an idea of the success of the operation, Briggs Nursery produced 6.5 million tissue-cultured plants last year. These were either sold as micropropagules, grown on and sold as liners or grown on at the nursery for its own container production use.

Not without its critics, Briggs Nursery and other tissue culture labs have had to answer to growers who have complained of problems with their micropropagated plants. However, the general feeling I found in the trade is that although problems have occurred, these have certainly been outweighed by the advantages seen with micropropagated material. Tissue culture propagation is still a relatively young technology and can be refined each year if communications between the lab and its customers are good. Such communications help the lab to recognise problems and correct them for the future.

I have no doubt, after seeing the Briggs Nursery micropropagation unit that this is the future in plant propagation. As one nurseryman told me, "Growers must be selective and choose from the most reputable suppliers, and if troubles do occur they are easily approachable. Remember that not all problems are caused at the source—examine your own growing techniques and cultural practices for optimum success."

Briggs Nursery uses eight different media, all variants on the standard Murashige and Skoog medium, with the pH adjusted to suit individual types of plants. One of the most impressive aspects of Briggs' tissue culture operation was the cleanliness of the laboratory. This is very important and helps explain why Briggs can boast such a high percentage of plantlets growing on in tissue culture successfully. This success is apparant after only 4 weeks. Four weeks later (a total of 8 weeks following initiation), after cytokinins are added, the test tubes are three quarters full and the nutrients in the agar medium exhausted. The cultures are ready for multiplication at this stage. For multiplication the shoots are cut into 25-cm sections every 8 weeks. Then they are moved to the production room and grown on in baby food jars, which in turn are housed in trays and double-stacked as space is at a premium. The trays are regularly swapped around for an equal share of the light. May is the best time of year for initiation as material is more likely to be pathogen free after the plants have put on a new flush of growth.

Plantlets are transferred to another medium for root initiation. After root initiation, the propagules are transferred again.

The propagules leave the sterile lab conditions once roots have been initiated, are potted into 4-in. pots with 25 plantlets per pot, and then transferred to a weaning house.

Apart from the obviously impressive facilities, Briggs also has a research room within the lab for trailing small amounts of new plants. This ensures a constant supply of new cultivars entering the market.

Of the 6.5 million plants which passed through the lab last year, 150,000 plants per week were supplied to the liner unit for potting and subsequent weaning.

VAN VEEN NURSERY, PORTLAND, OREGON

This nursery was a complete contrast to Briggs' Nursery. Van Veen has been growing rhododendrons for over 60 years with a fine tradition attached to the nursery, since one of the pioneers in the field, Theodore Van Veen, established it in 1926.

Little has changed to the propagation system since he was growing here. Modifications have been made over the years but the general principles laid down then still apply today with great success.

The nursery is on two sites—Portland and Woodburn. Portland has 4 acres of glass and growing on areas; Woodburn has 85 acres of field-grown stock.

Over 400 different cultivars are grown with 291,000 rooted cuttings being propagated last year. Of these, 60% went to the field unit at Woodburn, with the remainder staying at the Portland site to be grown on and eventually planted into the field as liners.

Cutting material is obtained mostly from the field-grown plants at Woodburn, with stock plants surrounding the Portland nursery supplying the rest. Cuttings are taken early on in the day when they are turgid and flexible. They are wrapped in burlap, watered, and stored in the shade until transported to Portland where they are stored at 45F until stuck.

To maintain hygiene, all clippers, gloves, bench tops, knives, etc. are sterilised with Physan at 1 : 10 (v/v). Cutting material is washed using Shield at 1 oz/4 gal, with Syphonex at 1 : 16 added—the plant material is well-drained prior to use.

Cuttings are wounded deep enough to expose the cambium layer. Hormones used are Hormodin #3 for most subjects but for dwarfs and lepidotes 1 : 10 IBA in alcohol is used. For harder to root types, Hormodin #3 plus boron and 1.6% IBA is used.

Cuttings are inserted at 5 cm square spacing using a medium of 1 peat and 1 pumice (v/v). Pumice is preferred over perlite as it is heavier, available locally (being a volcanic substance), and cheap.

Cuttings are watered-in and treated with Vapourguard to help control water loss. As they are only 5 cm long they would tend to dry out quickly without this treatment.

For the first 6 weeks to 2 months, cuttings are watered each morning and mist is applied from 11 a.m. to 7 p.m. depending on weather conditions. Mist application is regulated by an automatic leaf. Heating between 72 to 78F is by means of electric bench cable. Ventilation in the roof is manually operated with a higher humidity preferred for best results. Callusing is expected to occur in 1 to 2 weeks and rooting by 2 to 4 months.

MONROVIA NURSERY, DAYTON, OREGON

Propagation at Monrovia takes up an area of 20 acres with 140 people employed, including the liner team, so it was particularly interesting to see how rhododendrons fitted into the propagation schedule.

Of the 15 million plants grown at Monrovia last year, 500,000 were rhododendrons. Thirty rhododendron cultivars are propagated from October to November. Traditionally rhododendrons were produced in flats but currently they are direct-stuck into a liner pot. This is because the cutting would be too woody by the time it had been potted on into a liner pot. Now, with the direct sticking method, the liners go into a 1-gal (5-litre) pot as a younger plant and this ensures better lower branching.

The material is prepared in the propagation shed and then goes to the mist unit where the pots are stacked up and filled with media consisting of 3 peat moss : 2 perlite (v/v). Prior to insertion the cuttings are disinfected with Consan at 200 ppm and then washed in chlorinated water (15 ppm chlorine).

Depending on the culitvar, the hormone used is Hormodin #2 or #3. The cuttings—7.5 cm to 10 cm long and pencil thickness—are inserted into the pots and placed onto the bed in the mist unit.

The propagation house is filled with concrete beds which slope down both sides from the centre to collect water in a gulley for recycling. Bottom heat is kept at 64 to 65F and supplied by 25-mm copper tubing below the surface. Four boilers maintain the temperature with the water needing to be kept at 100F to achieve the desired basal heat in the bed. Intermittent mist is used, coming on one hour after sunrise and off one hour before sunset. The cuttings are misted for 2 sec every 10 min.

Monrovia boasts an average 90% take on its rhododendrons, depending on the quality of the wood used. For example, *R.* 'P.J.M.' was giving 85% in 1992 but was down to 70% in 1993 because the cutting material was too woody.

Cutting material is removed from 5-litre and 10-litre container plants in the nursery. In the propagation room, there is enough space for 50 cutters to operate. They cut and prepare their own material and are encouraged to take 3000 cuttings per day. If an individual does not achieve this number, their technique is analysed so that any problems can be ironed out. A table is pinned to the wall showing each cutter's performance. Top of the list was a lady who made 4700 cuttings on the previous day. This was achieved by a superior technique with both hands being active all the time, and good concentration on the job.

A SANDY RHODODENDRON, SAND, OREGON

A very young nursery, started only four years ago, but one which produces many excellent, quality, rooted cuttings and liners. Around 60,000 have been grown over the past year for sale to the trade, with over 450 species and hybrids on the list.

Propagation is by conventional cuttings which Chris Hoffman, the proprietor, believes to be the most natural way for the plant to thrive. "As long as the best possible conditions are employed, there is no reason why 100% rooting should not occur," he says. The nursery currently achieves an average of 95%.

The cuttings are propagated from May onwards, depending on the subject. The majority are propagated in July and will root from September onwards, again depending on the subject in question. Cuttings are given two wounds, one longer than the other, not too heavy and not too deep. As much leaf area as possible is retained, with only the longer leaved subjects being reduced for space conservation.

Cuttings are inserted into a medium consisting of 2 perlite : 2 moss peat : 1 fine grade hemlock bark (by volume). The bottom of the propagation bed is also lined with bark to encourage the roots to spread out and take advantage of the microbial activity there. After sticking, cuttings are sprayed with Wiltproof to reduce transpiration and protect against fungal spores.

The mist unit consists of beds running the length of the propagation house, with Mypex on the ground and the beds built on top. The atmosphere is kept as humid as possible, preferably 100% RH, with the vents closed and a summer temperature of 120F. Reducing the air flow means a reduced chance of disease spores getting into the house.

The aim here with misting is not to have the medium too wet around the base of the cutting to avoid rotting, especially around the critical months of June, July, and August.

Once rooting has occurred, in the autumn, the cuttings are transferred to another house to grow on in an unheated bed. The medium here consists of bark, mixed with a strange cocktail of nutrients given at intervals: kelp and fish, vinegar, household ammonia, rock sulphate, glacial dust, and molasses.

In May the young plants are moved outside into a bed containing the same medium described above. They will grow on here until two flushes of growth have been achieved by the autumn.

I was very impressed with the quality of the plants, which Chris Hoffman puts down, at least partly, to his use of natural fertilisers. The kelp (African seaweed) contains 56 trace elements and 13 vitamins. The fish emulsion results in better break-down of the rest of the mixture for the plants to obtain nutrients more readily. The kelp is sprayed once per week, the fish emulsion once every 3 weeks.

Apart from foliar feeding, the kelp together with the vinegar is used as a natural rooting hormone for harder to root subjects. Coupled with Hormodin #3 this results in the cuttings producing large, pure white callus after 3 days. The vinegar, incidentally, helps the uptake of the kelp ingredients by the plant.

These feeds help Chris Hoffman produce good, compact plants with better branching, less leggy growth, shiny, healthy looking foliage, and a super indumentum.

Pests and diseases are very infrequent as the natural defence of such strong, vigorous plants are high. Sap sucking insects have seldom been seen on the nursery over the last couple of years. Chris believes that when chemicals such as Subdue are used, then natural microbial populations are reduced and the plant becomes more prone to attack without this benign microbial activity which keeps it strong.

OREGON STATE UNIVERSITY, AURORA, OREGON

Of the many experiments taking place here, I picked up on one of the 'pet' subjects of Bob Ticknor, Professor of Horticulture. This was the capillary sandbed system, which is highly recommended to American nurserymen by Professor Ticknor and his team. They are trying to prove its undoubted benefits.

At Osberton Grange, we grow all our rhododendrons on such a bed—based on the beds designed and developed at Efford Experimental Horticulture Station. We are very happy with the benefits of the beds, which include: water conservation, reduction of nutrient leaching, automatic watering thus reducing labour requirements, reduced weed problems, and better drainage leading to better aeration of the container compost.

Experiments at Oregon State University have also proven these advantages. However, one argument against such a system is echoed frequently, the inability of growers to achieve the absolutely level piece of ground the bed requires for success. In this area of Oregon, the rolling landscape does not lend itself to level beds, so an experiment is under way to counter the problem. A capillary bed of 70-ft long is being operated with a 1-ft gradient down its length, with capillary piping running down the surface of the bed. A series of dams is positioned at intervals in the bed so the water does not run straight to the bottom but is evenly distributed.

Another experiment concerns the breeding of *Phytophthora* resistant rhododendron cultivars. This is done with some reluctance, as finding such a plant gives the public the idea that rhododendrons are generally susceptible which may 'back-fire' on the trade. A popular plant being used in breeding is *R. calendulaceum* [syn. *R.bakeri*] but others subjected to the disease have shown no ill effects so far during the trials.

Other work concerns 'late bloomers' which Professor Ticknor is trying to hybridise. This is because many visitors to the area come too late in the rhododendron flowering season and miss the main show of colour. As the last weekend of May (Memorial Weekend) signals the start of the holiday season, such plants could extend the flowering season into June and give visitors that extra viewing time.

Acknowledgement. I would like to thank all of my hosts during the study tour who were only too willing to share with me invaluable information on all aspects of the production cycle of rhododendrons. I learned a lot and made some good friends.

Editor's Note: Space does not permit inclusion of details of the following nurseries which Chris George visited but the author, and GB&I Region, would like to extend thanks to them, as well as to the nurseries described in this paper, for their help with this study tour. A full account can be found in the Mary Helliar Travel Scholarship Report, which is available to any I.P.P.S. Member who sponsors the Scholarship.

Other Nurseries Studied: Woodburn Ornamentals, Woodburn, Oregon; J&L Nursery, Silverton, Oregon; Kraemer Nursery Inc, Mt Angel, Oregon; Sorums Nursery, Sherwood, Oregon; Clarke Nursery, Long Beach, Washington; Berryhill Nursery, Sherwood, Oregon; Klupenger Nursery, Aurora, Oregon; Honsuchachac Rhododendron Garden, Salem, Oregon; Wrights Nursery, Canby, Oregon.

Plant Improvement and Nursery Production Techniques in New Zealand

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New Zealand has given the British Isles many popular garden plants such as *Cordyline*, *Hebe*, *Leptospermum*, *Olearia*, and *Pittosporum*. With assistance from a Mary Helliar Travel Scholarship Award I spent one month in New Zealand looking at plant improvement schemes and production techniques.

The plant improvement schemes I studied concentrated on New Zealand's native flora. At Auckland Regional Botanic Gardens, a *Hebe* breeding programme started in 1982 by Jack Hobbs, has produced 12 named cultivars. Most names carry the "Wiri" prefix, for example, *H.* 'Wiri Joy' and *H.* 'Wiri Image'. These have a superior appearance and garden performance to other cultivars especially in the hot and humid Auckland climate where septoria leaf spot (*Septoria exotica*) and downy mildew (*Peronospora grisea*) are a problem (Hobbs, 1991). I am uncertain about their hardiness in the British Isles. Another notable plant introduction in recent years is *Weinmannia* 'Kiwi Red'.

Manaaki Whenua Landcare Research Ltd., near Christchurch, which primarily functions as a herbarium, has several breeding programmes. Currently it is trying to select for greater cold hardiness in *L. scoparium,* to expand the potential for export of New Zealand plants to Western Europe. Field trials of seedlings are being run by INRA, Station d'Amelioration des Especes Fruitieres et Ornamentals, Angers, France. They hope the selections will provide a basis for future breeding of this plant (Harris and Decourtye, 1991) Other work involves breeding whip-cord type hebes. They have named one of the seedlings, *H.* 'Karo Golden Esk' which is a *H. armstrongii* × *H. odora* hybrid. Interesting work is being carried out on producing half standard hebes. For example the prostrate growing *H. strictissima* has been top grafted onto a 1.2 m stem of *H. macrocarpa* var. *latisepala*. The result is an evergreen, weeping, half standard which has potential as a novel patio plant.

The success of these programmes may be a result of the comprehensive collections of botanically named species and cultivars held by the institutes. The new cultivars from both Auckland Regional Botanic Gardens and Landcare Research are now widely produced by the nursery trade, a result, perhaps, of the close links between the institutions and the industry. Revenue raised from Plant Variety Rights helps to fund further work, although the programmes are still largely dependent on Government money.

Individual nurseries are also selecting new forms. Mark Dean, of Omahanui Native Plants, in Tarangia, has named a compact *Clianthus maximus* with deep red flowers 'Kaka King' and a *Sophora microphylla* with rich yellow flowers 'Dragon's Gold'.

One horticulturist I visited had an alternative vision for the future of New Zealand native flora. Graeme Platt, of Auckland, believes that selecting hybrids for traits such as dwarfing habit and variegation is regressive evolution. Such hybrids, he believes, are weak and disease susceptible and therefore make poor garden plants compared to the species. He preaches "excellence of the species and not mongrelisation." After 20 years of selection work on plant species, many of the superior forms are in general production and are marketed in New Zealand as Graeme Platt Selections. Currently he is involved in improving cold hardiness of shrubs by selecting plants from wild populations at high altitudes and more southerly latitudes. Several U.K. nurseries have this new material. Extensive selection and tree establishment work is being carried out on the native Kauri pines (*Agathis australis*). Platt hopes improved plant material and knowledge will enable this native species to displace the exotic *Pinus radiata* for timber production in its natural range in North Island.

Production techniques vary from those in the U.K. partly because of the difference in climate and the cost of natural raw materials. The warm maritime climate gives virtually all-year-round growing conditions in North Island. This results in a production cycle approximately three times faster than the U.K. for evergreen plants. Nurseries tend to use only polythene and glass structures for propagation. However, they do have to erect net covered structures for shading and the protection of liners from wind and heavy rain. Most nurseries grow in containers, although field growing and containerisation are used by some rhododendron nurseries. A pine-bark-based (*Pinus radiata*) container medium is extensively used as it is cheap and readily available—unlike peat. To improve the water holding capacity of the medium, pulverised bark fibre or saw dust is added. Silica gel has been trialled by some nurseries to help prevent the medium drying out. The addition of coarse river sand or pumice seems to be common practice, to maintain the air filled porosity of the medium as the bark breaks down. The nitrogen lock up associated with bark break-down is minimised by the addition of chelated iron and extra nitrogen to the medium.

I left New Zealand with a positive view of its horticulture. I especially enjoyed the diversity of outlooks on plant growing. There still seems a huge potential to produce competitively-priced, high-quality plant material for the world market. I also feel that there is still huge potential for new plant species and varieties to be developed as ornamental plants because of the plant diversity that exists there.

I would like to express my gratitude to all the New Zealand horticulturists I met and members of the Great Britain and Ireland I.P.P.S. Region for their help with this trip.

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Determination of the Cotoneaster Collections in three European Botanical Gardens

Jeanette Fryer
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At the National Botanic Garden, Salaspils, Latvia, I worked with the Curator and Head of Dendrology, Dr. Raimonds Cinovskis, on the determination of the extensive collection of cotoneasters grown in this interesting garden.

Consisting of around 120 taxa, including some species from native sites in the Baltic States and Russia, this collection holds many fine specimens worthy of cultivation. Particularly attractive were the white flowered *Cotoneaster megalocarpus* and *C. submultiflorus*, and the pink flowered *C. roseus*. These three species all have red fruits in the autumn.

After gathering propagation and herbarium material from the gardens I travelled to Bjuv, in southern Sweden, to work with Dr. Bertil Hylmo, who has studied the genus *Cotoneaster* for the past 30 years and has a magnificent collection of around 300 taxa growing in his "Cotoneasteretum."

Many beautiful cotoneasters which could be—and should be—utilized by the nursery trade are grown in this Swedish garden.

We were joined by another expert on the genus *Cotoneaster*, Dr. Antonin Nohel, from Brno Botanic Gardens in the Czech Republic. Dr. Nohel was, until quite recently, the International Registrar for cultivars of *Cotoneaster* and has raised an selected many excellent cultivars which can be seen in Czech gardens.

Outstanding species in Bjuv included the following:

- *C. duthieanus*, a low growing shrub with large bright red fruits;
- *C. lucidus*, an extremely hardy species much used in Sweden as hedging, black fruited with brilliant red leaf colouring the autumn;
- *C. insculptus*, more attractive than the well known *C. sternianus* (below)
- *C. sternianus*, this species has shiny deep-veined leaves and orange fruits;
- *C. shansiensis*, a beautiful elegant shrub with pink flowers and pendulous apricot-coloured fruits, this species would be very useful grafted as a half standard for small gardens;
- *C. multiflorus*, laden with large wide-open white flowers, abundant red fruits in the autumn;
- *C. przewalskii*, flowers large and open, petals white and mauve, this species has purple young growth and dark red fruits;
- *C. ludlowii* with masses of white flowers and pinky-orange fruits;
- *C. albokermesinus*, a very unusual species, again with a profusion of white flowers, has fruits that begin white and ripen to a one-sided pinkish blush, extremely hardy, and as with many other deciduous cotoneasters, reasonably resistant to fire blight;
- *C. meiophyllus*, a species brought by the plantsman Roy Lancaster from Shanghai Botanic Garden, cream flowers early summer, orange fruits throughout the winter into spring;

- *C. microphyllus*, low growing, with white flowers and cherry-red fruits, in the British Isles shrubs grown as *C. microphyllus* are usually the closely related species *C. integrifolius*.

Fungus and Relative Humidity

Bent Løchenkohl
Planteværnscentret, 2800 Lyngby

The environment in propagation units is ideal for fungi to grow—nice warm temperature and high relative humidity (RH). At the same time it is difficult to use fungicides in a propagation unit. Therefore, cuttings have to be free of fungal diseases by good care of the stockplants. Under normal conditions in a greenhouse, should there exist a high RH, climate computers are able to control it—this is not the case in a propagation unit.

Fungi grow small hyphae, 4-6 µm in diameter, that develop into mycelium. In order to grow, fungi have to absorb water so that nutrients can move into the hyphae. If transpiration is too high, the hyphae dry out and die. Therefore, from the fungi's point of view it is not the RH but transpiration and subsequent condensation which controls its growth.

It takes some time to get used to considering evaporation instead of RH as controlling the growth of fungi. Even in a greenhouse with 100% RH, evaporation\transpiration occurs because some areas are warmer and others are cooler. Therefore, water will move from the warm to cooler areas. At lower RH values, evaporation increases when air moves. Evaporation requires energy, and water will evaporate from the warmest areas and condense in the colder areas. This is why greenhouses are cooled during ventilation.

If a greenhouse is to be controlled by evaporation one must measure RH and air movement. This may prove difficult to do, but will ensure new and better use of the climate computers.

Photosynthesis in Cuttings During Rooting

Bjarke Veierskov
Royal Veterinary and Agricultural University, Institute of Plant Biology, Thorvaldsensvej 40, 1871 Frederiksberg C. Copenhagen

It is well known that a large variation exists among plant species in their ability to utilize light for growth. Most of these variations are caused by genetic differences where some plants (shade plants) are light saturated at very low levels of irradiance, while others are not light saturated at naturally existing light conditions. Because plants generally grow close together with many overlapping leaves, light saturation is seldom observed under normal growing conditions.

Cuttings are different. They often only have a few leaves, and not having a root system, are unable to absorb water. To compensate for the lack of roots, mist propagation and enclosed plastic are used to ensure a high relative humidity in the environment surrounding a cutting during rooting.

A high level of irradiance causes a high carbohydrate production.

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A high level of irradiance causes a high carbohydrate production.

This carbohydrate is normally used for growth in an intact growing plant. In a cutting growth has ceased, and this leads to carbohydrate and starch accumulation in the leaves. Such an accumulation may lead to the destruction of the chloroplasts which we observed as photobleaching.

We have shown with *Hibiscus* cuttings, that the best light conditions for rooting occurs at an irradiance level just above the light compensation point. At this light intensity, respiration almost equals photosynthesis and the build up of carbohydrates is very slow. This is the light condition that a shade plant normally likes best. As soon as the cutting starts to make roots and bud break is observed, the cutting again becomes a normal intact plant, and it will require those optimal environmental conditions for normal growth.

Production of Seedlings

Bent Petersen
Frisa Plants

A/S Frisa Plants is a producer of annual (summer) plants for gardens and pot plant nurseries. All production is based on seed propagation—this places seed quality, germination, and vitality at the center of production.

All seeds are germinated in flats with one seed placed in each cell. Therefore, it is of utmost importance that seed quality is the best. Fungal diseases occurring during germination may be caused by pathogens on the seed. To ensure the proper fungicide treatment after sowing, all seed lots are tested for the fungus/fungi they may be carrying. Immediately after sowing, the flats are treated with the fungicide required to control any fungal problems identified on the seeds. The flats are placed in a mist room for one day and then into the propagation room with or without light as needed. For most seeds the best germination is observed in the light (10 to 20 W m^2). The young seedlings are shaded the first few days after germination.

Kalanchoe blossfeldiana

Knud Jepsen
A/S Knud Jepsen Nursery

A/S Knud Jepsen Nursery was founded in 1963 and today consists of two production units with an overall yearly production of more than 10 million *Kalanchoe blossfeldiana*. Most production is for export with Germany being the major market. The latest addition to the nursery, 19,000 m^2 in size, is run by the most advanced greenhouse control equipment available today. Because of this, plants are only handled when they are propagated and at the time of sale.

A cornerstone of production is quality and research. Two full-time staff members are assigned to research. This ensures that production is utilizing the latest techniques and new cultivars are introduced regularly. We have our own plant

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breeding program to ensure new cultivars for the market.

All propagation begins with stock plants (elite plants) which are kept in a section of the nursery where only the propagator is allowed. These plants are tested regularly for diseases and uniformity. Cuttings taken from these elite plants are used to propagate mother stock plants from which cuttings are taken to produce plants for sale. Cuttings are stuck into the final selling pots and placed on transportable tables that are automatically moved into the propagating area. Depending on the time of year, mist propagation or enclosed plastic is used. We try to keep a relative humidity of 60% to 70%.

We have tested DIF (difference in day and night temperature) only on a few plants. In *Exacum* and *Gerbera* the use of a high night temperature caused plants to become more compact.

Biological treatments are used to keep the soil free of insects. We use 0.75 liters of Vectobac to 4 m^3 of soil, and all water in supplemented with nematodes (500 million per 700 m^2).

Temperature—DIF

H.E. Kresten Jensen
Department of Floriculture, Research Centre for Horticulture, DK-5792 Årslev

INTRODUCTION

Until a few years ago, standard practice in the greenhouse industry was to keep the night temperature for potted plants set lower than the day temperature. The reasoning was, that photosynthesis at day should be promoted by a high temperature and respiration at night should be limited by a lower temperature. In addition, the free heat from the sun during daylight should he utilized and the energy consumption at night should be limited to reduce production cost. Plant height and elongation growth was not considered—compact growth was obtained by the use of chemical growth retardants.

The use of chemicals, i.e., growth retardants, is now questioned and in society there is a general wish that chemicals should be used to a lesser extent. In Germany and Sweden, Alar is prohibited and this may also happen in Denmark for this and other chemicals. For these reasons growers and researchers are looking for other means to control plant height.

Therefore, much interest was generated by experiments in the United States of America which showed that a higher night than day temperature reduced internode length and plant height when compared to the normal temperature programme (higher day than night temperature) (Erwin et al., 1988; Erwin et al., 1989). It was shown that the diurnal average temperature was not the decisive factor controlling elongation, but the difference between day and night temperature was important. This difference in day and night temperature was abbreviated to DIF, and the concept of DIF was defined as day temperature (DT) minus night temperature (NT) (DIF = DT minus NT). From this three terms arose:

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- Positive DIF—where the night temperature is lower than the day temperature.
- Negative DIF—where the night temperature is higher than the day temperature.
- Neutral DIF—where the night temperature is the same as the day temperature.

Negative DIP is the interesting combination of day and night temperatures, since this may produce plants with short internodes and hence compact growth.

EXPERIMENTS

The first experiments in the U.S.A. were carried out with *Lilium longiflorum* Thunb., which is not grown in Denmark. A later review of the literature shows that the effect of negative DIF varies among plant species, and some plant species do not respond to DIF (Jensen, 1991).

In our own experiments we have investigated the effect of raising the temperature for a part of the night as opposed to all night. Rooted cuttings of *Pelargonium* × *hortorum* 'Pink Cloud' [syn. *P.* × *zonale* 'Pink Cloud'] and *Dendranthema* × *grandiflora* Tzvelev 'Choral Charm' were subjected to 0, 2, 6, or 10 h of 6C higher night temperature than day temperature after sunset, around midnight, or before sunrise. The diurnal average temperature was 18.5C for all treatments.

The results with *Pelargonium* showed that -6 DIF reduced internode length by 11% and plant height by 8%. Interestingly, the effect of negative DIF treatment was equally good whether given for 2, 6, or 10 h and whether the high temperature period was placed after sunset, around midnight, or before sunrise. There was no influence on the number of nodes (Jensen, 1993a).

The results for *Dendranthema* were different. Two hours of high temperature after sunset gave 11% shorter internodes and 13% lower plant height than neutral DIF, and there was no influence on the number of nodes. On the other hand, 6- and 10-h of high night temperature after sunset showed no effect on plant height because 8% to 15% more nodes counteracted the 17% shorter internode development. When the high night temperature was placed around midnight, plants became 22% higher at a 2-h duration because there was no effect on internode length and a greater number of nodes indicating delayed flower formation. A 6 or 10 h duration around midnight produced shorter internodes, but the number of nodes was greater and the final result was unchanged plant height compared to neutral DIF. When the high night temperature was given for 2 h before sunrise, the internodes became shorter than at neutral DIF, but the effect was too small to compensate for more nodes. At 6 and 10 h of high night temperature before sunrise, plant height was reduced by 12% to 17%, the internodes were 17% shorter, and there was no effect on the number of nodes compared to neutral DIF. Thus, for *Dendranthema* the best retardation of plant height was obtained by placing the high night temperature period 2 h after sunset or 6 or 10 h before sunrise. The number of days to visible flower bud increased with the duration of the high night temperature period, and the delay of flower formation was greatest when the high night temperature period was placed around midnight (Jensen, 1993b).

In another experiment the aim was to see how poinsettia, *Euphorbia pulcherrima* Willd. 'Lilo', responded to negative DIF before sunrise. The treatments were +4, 0,

-4, and -8C DIF placed before sunrise for 2, 6, or 10 h. Day and night temperatures were set to give a diurnal average temperature of 20C for all treatments. During the first 43 days no differences were observed. From then on the plants grew taller at negative DIF than at neutral and positive DIF. The explanation for this unexpected result was delayed time to visible flower bud appearance and the formation of more leaves at negative DIF compared to neutral and positive DIF. The best plants were produced at a constant temperature of 20C (Jensen, 1994).

CONCLUSION

At present, the main conclusion from the work on DIF is that the plant height retarding effect of negative DIF is in the order of 10% to 15% compared to neutral DIF. For some plant species, e.g., poinsettia, the best result may be achieved by choosing neutral DIF, i.e., the same temperature day and night. The best temperature will then be the one which favours flower formation.

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Shading of Plants

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INTRODUCTION

The use of shading screens in the greenhouse not only influences the irradiance but also the greenhouse climate, e.g., relative humidity and air temperature (Andersson, 1991; Andersson and Skov, 1991). The aim of shading plants is first and foremost to reduce the energy load and to create the right level of light for the plant species which are grown in the greenhouse. A shading screen also influences the natural ventilation of the greenhouse (Andersson, 1991a; Andersson, 1992) and thus the air temperature and humidity. It is possible to take advantage of the reduced ventilation rates when rooted cuttings become acclimatized after propagation.

ENERGY LOAD

One of the aims of shading plants is to reduce the energy load. For rooted cuttings, shading results in a greater ability to maintain the water balance because of a smaller energy load. A rooted cutting has a greater leaf area than the root system can adequately supply with water. Even though the cutting has only a few leaves, all the leaves are fully exposed to radiation because the leaves do not shade each other. If rooted cuttings are exposed to high radiation, the water balance will be upset, cooling by transpiration will stop, and the risk of leaf damage will increase. The best way of reducing the energy load is by reflecting the irradiance. It can be achieved by using a highly reflective shading material. White shading screen materials or materials containing aluminum stripes have a high reflection. By mounting the shading screen parallel to the greenhouse covering material the highest possible reflection and the lowest energy load will be obtained.

AIR-CHANGE RATE

The rise of air temperature on a sunny day is mitigated by natural ventilation of the greenhouse. If a rise in air temperature is to be avoided, natural ventilation should be high. One of the problems in shading is to have a high level of shade and at the same time be able to keep the air-change rate up. A shade screen material with a high shade factor very often has a low air change rate which restricts the natural ventilation of the greenhouse. This results in increased air temperature.

The problem with ventilation of the greenhouse can be solved by the way the shading screen system is mounted. In many Danish greenhouses which are orientated east-west, the shading screen system is divided into two separate parts, one facing the southern side and one facing the northern side of the greenhouse (Gammelgaard et al., 1993). The two parts of the shading screen system are individually controlled. This increases natural ventilation because the northern part of the shading-screen system is closed only a few hours a day—even on bright days. This kind of shading screen system is probably not the most suitable for a propagation greenhouse. Instead, a shading screen system consisting of two shading screen materials with different shade factors is used. On the southern side a shading screen material with high shade factor and reflection is used and on the northern side a shading screen with low shade factor and an open weave for increasing the change of air is used.

AIR HUMIDITY AND TRANSPIRATION

Transpiration can be divided into two types—transpiration dependent upon aerodynamic conditions and transpiration dependent upon radiation. The term radiation depended transpiration is used even if it is the increase in tissue temperature of the leaves which influences the rate of transpiration. The term is used because the irradiance is measured, whereas the canopy temperature only occasionally is measured.

Transpiration rate depends on the water vapor pressure gradient between the intercellular spaces of the leaf and the surrounding air (Andersson, 1991b). At low irradiance the transpiration rate depends on the aerodynamic conditions because the energy load is small and the water vapor gradient is the limiting factor.

During acclimation of rooted cuttings, climatic control is difficult, because both low air temperature and irradiance are wanted. Low air temperature is established by a high shade factor and a high rate of ventilation. High air humidity is established by a low air-change rate, but an increase in air temperature is unavoidable due to reduced ventilation. A high air humidity during acclimation decreases the transpiration rate and the cutting does not develop a negative water balance. At a high irradiance level, the energy load is high and temperature increases. The actual water pressure of the air has little influence on the transpiration because the water vapor pressure in the intercellular spaces is high. By using a very high level of shade, transpiration depends only on the water vapor pressure, but very often the shade-screen material with a high shade factor reduces natural ventilation. The necessity of ventilation is reduced when the shading material has high reflectivity. Under such conditions the air humidity increases and the transpiration rate is lowered. The growth of the cuttings is promoted because the water balance is stable, damage to the leaves is avoided, and a maximum growth rate of the root system is obtained.

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Biological Process Control in Greenhouses: A Physiological Approach

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INTRODUCTION

Photosynthesis takes place practically everywhere on the earth from the Arctic to the tropics where plants, unlike animals living in the same conditions, need to be able to adapt to changes in environmental conditions to survive. The latter phrase may sound dramatic, however, most ornamental pot plants are exposed to major changes in environmental conditions even in a greenhouse, and especially during the last journey from the greenhouse to the consumers.

The ability of plants to adapt to changes in environmental conditions partly depends on their original ecological niche. A prerequisite for optimal production of these ornamental pot plants is knowledge about their natural demands, and especially their physiological adaptability.

Photosynthesis as an expression of a plant's reaction to climatic conditions is the basis of part of the research project "Biological Process Control in Greenhouses" that is carried out in collaboration between the Department of Floriculture (Danish Institute of Plant and Soil Science) and departments at the Royal Veterinary and Agricultural University. The long-term objective is to develop computer-based management tools for climate control in greenhouses based on knowledge about the physiological responses of the plants. At the Department of Floriculture, two projects are exclusively dealing with photosynthesis while the projects at the Royal Veterinary and Agricultural University focus on microclimate and modelling, and development of the computer programme and user interface.

Today, research in photosynthesis is intensive and is carried out at several levels. A significant effort is concentrated on the description of the photosynthetic processes at the cellular level, whereas the interest with respect to the leaf and the whole plant is limited. It is, however, necessary to study at several levels in order to explain the mechanisms lying beneath the physiological responses observed.

LIGHT STRESSES DURING GROWTH?

Fluorescence measurements are used in the project to study light stress of plants—if necessary in connection with other stress factors such as shortage of water or nutrients. At this stage, it seems that the plants obtain a "knowledge" about the amount of light—the light sum—to which they have been exposed during the course of the day. If a certain threshold is being exceeded, the plants become photoinhibited—photosynthesis is inhibited thus biomass production drops. In a glasshouse, knowledge about light stress can be used to develop strategies for the use and density of shade curtains. While the curtains reduce temperature they also diminish the amount of valuable light.

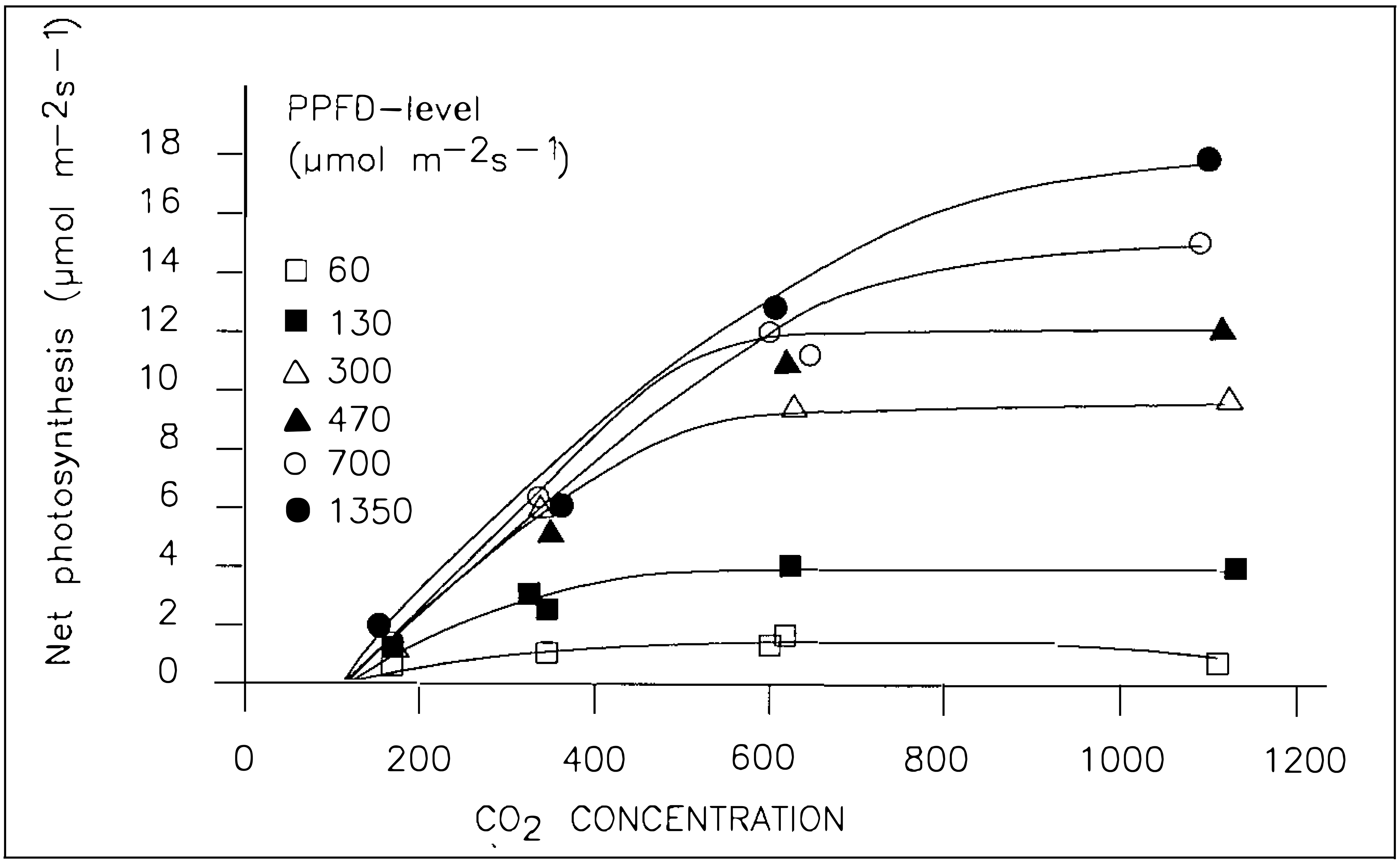

Figure 1. Net photosynthesis as a function of CO_2 concentration and irradiance level.

EFFECTS OF CO_2 UNDER SUBOPTIMAL CONDITIONS

For the last 40 years it has been routine to supply CO_2 to greenhouses to stimulate growth of plants. The increasing CO_2 concentration in the atmosphere and the subsequent problems related to the greenhouse effect have given rise to many recent investigations. The effects of CO_2 on growth under low irradiance conditions do not seem to be as evident as previously believed. Plants may adapt to elevated CO_2 when grown for a prolonged period under elevated CO_2 conditions. When photosynthesis is measured under a combination of different CO_2 concentrations and irradiance conditions results from experiments with several foliage species, such as *Ficus benjamina* and *Schefflera arboricola*, indicate quite clearly that during low light conditions in the winter period, the effect of elevated CO_2 conditions is limited. Gas exchange studies showed a maximum rate at a CO_2 concentration of 5 to 600 ppm at low irradiance conditions (<343 µmol $m^{-2}s^{-1}$) (Fig. 1).

HOW DO WE IMPROVE THE QUALITY OF POT PLANTS

Pot plants are in principle grown under optimal conditions, therefore, they tend to become more sensitive to both biotic and abiotic stresses. In this context, stress conditions refer to the capabilities of plants to sustain the environmental influences that they are subjected to during packaging and transport and so, before they end up in the window sill. Our knowledge about the genetic background for stress tolerance and the effect of growth conditions on this is limited. One reason could be the differences in the sensitivity to ethylene. However, when otherwise similar plants from different nurseries react very differently to a keeping quality test, the causes may be physiological. A physiologically based keeping quality test is, therefore, one of the important steps to include in order to adjust a biologically controlled greenhouse system.

Effect of Nitrogen on Blueberry and Juniper Grown in a Fish Waste Compost:Fir Bark Medium

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***Juniperus horizontalis* 'Bar Harbor' and *Vaccinium corymbosum* 'Bluecrop' rooted liners were transplanted from 2-1/4-in.to 1-gallon containers in a 1 ground bottomfish waste hemlock/fir sawdust compost : 3 Douglas-fir bark (v/v) growing medium. Nitrogen was applied as a liquid once every 2 weeks at the following concentrations: 0, 150, 300, 450, and 600 ppm, N as NH_4NO_3. Results indicated that the addition of 450 ppm N once every 2 weeks was sufficient to produce the best overall growth and quality of blueberry and juniper plants.**

INTRODUCTION

In a single Washington coastal county, Pacific County, more than 30 million pounds of seafood waste was generated during a 3-year period (Bonacker et al., 1989). Environmental regulations have restricted the options for disposal of these wastes and necessitated a search for alternatives to traditional disposal methods. Recycling the seafood waste by composting is a viable means of disposal and produces a value-added, marketable product for the seafood processing industry.

Studies have shown that high-quality composts can be produced using seafood wastes (Frederick et al., 1992; Jellum and Kuo, 1992; Johnson et al., 1992; Mathur et al., 1988;). Jellum and Kuo (1992) composted ground bottomfish waste and shrimpshell sludge with red alder or a mixture of western hemlock and Douglas-fir sawdusts to produce four composts. They compared their composts to commercially available sewage sludge and cow manure composts for the production of greenhouse-grown corn and an orchardgrass/perennial ryegrass mixture. With the exception of the red alder-shrimpshell sludge compost, they found the fishwaste composts to be equal or superior in promoting dry matter production.

The ground bottomfish waste with hemlock/fir sawdust compost had a C to N ratio of 27, and a total N content of 1.3% of which 30% was inorganic (Jellum and Kuo, 1992). This compost was selected for additional tests of its potential as a growing medium and N source for the production of container-grown nursery stock. The objective of the present research was to determine the growth and quality response of blueberry and juniper plants to a Douglas-fir bark container medium amended with the ground bottomfish waste hemlock/fir sawdust compost and fertilized at five different nitrogen rates.

MATERIALS AND METHODS

In early June 1992 2-1/4-in. (5.7 cm) rooted liners of *Juniperus horizontalis* 'Bar Harbor' and *Vaccinium corymbosum* 'Bluecrop' were obtained from Briggs Nursery (Olympia, WA) and transplanted into 1-gal (3.8 liter) containers filled with a 1 ground bottomfish waste hemlock/fir sawdust compost : 3 Douglas-fir bark (v/v) growing medium. The pH values of the fir bark (B) and bottomfish waste hemlock/fir sawdust compost (FWC) were initially 4.3 and 7.8, respectively. Before the components of the growing medium were mixed, the pH of the FWC was adjusted to reflect the pH of B by adding 30 ml of one normal H_2SO_4 per pound of FWC. The medium for both species was amended with Micromax micronutrient mix at the rate of 1.75 lb/yd^3 (1038 g/m^3). The juniper medium had an additional amendment of 8 lb/yd^3 dolomite.

Nitrogen fertilizer solutions were applied to the containers every 14 days at concentrations of 0, 150, 300, 450, and 600 ppm N as NH_4NO_3, which corresponded to 0, 80, 160, 240, and 320 mg N/container, respectively. A single phosphorus and potassium solution was applied to all containers concomitant with the N application.

There were eight replications of each nitrogen treatment. Plants were arranged in a randomized complete block design on an outdoor gravel nursery bed. Overhead sprinkler irrigation was applied as needed (usually daily) at a rate of about 1/2 in. (1.3 cm).

At the end of the growing season, in late October 1992 the performance of the plants was evaluated by measuring shoot height, width, and fresh and dry weights. From the height and width data, a shoot growth index (SGI) was calculated [SGI=(height +width)/2]. Plants were grouped by species according to their quality, a rating of their potential marketability to consumers. The groups were then assigned numbers from 1 (indicating dead) to 5 (indicating well-branched, deep-green, and of superior quality). On this scale, a plant had to have a rating of 3 to be considered marketable. A separate analysis of variance was performed for each species and the orthogonal polynomial trend comparisons procedure (Gómez and Gómez, 1984) was used to evaluate the effect of nitrogen rate on plant growth and quality.

RESULTS AND DISCUSSION

Results of this experiment indicated N rate had significant linear and quadratic effects on shoot dry weight, SGI, and quality of blueberry and juniper grown in a 1 FWC : 3 B (v/v) medium (Tables 1 and 2). Shoot fresh weight data is not presented because of similarity to dry weight measurements. Shoot dry weight and SGI of both species increased with increasing nitrogen up to 450 ppm N. When 600 ppm N was applied dry weight and SGI of blueberry and juniper decreased slightly. Blueberry quality increased with increasing N fertility while juniper quality was not influenced by increased N fertility above the 300 ppm N rate (Tables 1 and 2).

Blueberry and juniper plants in the 0 ppm N treatment grew very little and were not of marketable quality (Tables 1 and 2). Although the FWC had a total N content of about 1.3% of which 30% was inorganic (Jellum and Kuo, 1992), analysis of leachate collected from plantless containers by the pour-through method (Wright, 1987; Yeager et al., 1983) indicated that this nitrogen fraction was rapidly leached from the medium by the frequent application of overhead sprinkler irrigation water (data unpublished). In this experiment, when no additional N was added, the 1 FWC : 3 B medium did not produce blueberry or juniper plants of acceptable quality to the consumer.

Table 1. Effect of nitrogen rate on shoot dry weight, shoot growth index (SGI) and quality of *Vaccinium corymbosum* 'Blue Crop' grown in 1 fish-waste compost : 3 fir bark (v/v) medium.

Nitrogen rate	Dry weight (g)	SGI[1]	Quality[2]
0 ppm	4.21	28.1	2.0
150 ppm	26.53	46.6	3.4
300 ppm	36.61	57.2	3.9
450 ppm	43.52	59.2	4.4
600 ppm	41.20	58.1	4.6
Significance[3]			
Linear	***	***	**
Quadratic	***	***	***

[1] SGI = (height + width)/2.
[2] Quality was rated on a 1 (dead plant) to 5 (superior plant) scale.
[3] NS, *, **, *** = nonsignificant and significant at $P \leq 0.05$, 0.01, or 0.001 level, respectively.

Table 2. Effect of nitrogen rate on shoot dry weight, shoot growth index (SGI) and quality of *Juniperus horizontalis* 'Bar Harbor' grown in 1 fish-waste compost : 3 fir bark (v/v) medium.

Nitrogen rate	Dry weight (g)	SGI[1]	Quality[2]
0 ppm	5.51	18.7	2.0
150 ppm	13.26	33.2	3.1
300 ppm	17.76	32.1	3.5
450 ppm	18.77	33.9	3.5
600 ppm	17.22	30.0	3.5
Significance[3]			
Linear	***	***	***
Quadratic	***	***	***

[1] SGI = (height + width)/2.
[2] Quality was rated on a 1 (dead plant) to 5 (superior plant) scale.
[3] NS, *, **, *** = nonsignificant and significant at $P \leq 0.05$, 0.01, or 0.001 level, respectively.

The 1 FWC : 3 B (v/v) medium used in this experiment was a satisfactory growing medium for the production of container-grown blueberry and juniper plants. Although the nitrogen present in the fishwaste compost alone did not produce marketable plants, adding a 450 ppm N solution to the medium once every 2 weeks was, in general, sufficient to produce the best growth and quality of blueberry and juniper plants.

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Disease Control in the Propagating House

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To understand strategies for disease control in propagating houses, it is necessary to understand some basic concepts of how diseases develop. Three components must be present before a disease will occur: (1) a pathogen (micro-organism that is capable of causing disease), (2) a susceptible host plant, and (3) favorable environmental conditions for the disease to develop. In addition, all three must be present for a sufficient length of time to allow infection to take place. If any of these components is lacking, no disease will develop. If these components are present at a less than an optimum level, disease will develop at a slower rate.

Because of the environmental conditions in a propagating house, the potential for disease is very high. Free moisture, high humidity, and mild temperatures favor the development of many fungal and bacterial diseases. Propagation houses could almost be considered by a pathologist to be an ideal inoculation chamber to study diseases. The vast majority of fungal spores require free moisture to germinate, a prerequisite to infection. Bacteria also require free moisture to be present before they can actively move into plant tissues. High humidity favors spore production and disease development.

Wounds (cuttings, leaf removal, bruises, epidermal abrasions, etc.) break the natural plant barriers potentially allowing easier access to the pathogens. Because of the humid environment, stomates tend to be open predisposing these tissues to infection. In general, stressed plants are often more susceptible to disease. Thus, it is likely that cuttings will be more susceptible than under normal growing conditions. Pathogens attacking seedlings may not be serious problems when the plants have matured. Thus, the favorable environment for disease and the vulnerability of the plant material make disease control in a propagating house an extremely challenging situation.

Disease control strategies are based on three general methods: cultural, chemical, and genetic resistance. Successful control programs will often utilize or integrate all three of these methods.

Good sanitation practices are the first line of defense. Preventing the introduction of the pathogen is very important. It has to be remembered that no disease will develop if no pathogens are present.

There are numerous avenues by which the pathogens can gain entry into a propagating house. The propagation medium may be contaminated, for instance from a previous crop. Various steam, chemical, and heat treatments are commonly used prior to planting the crop in an effort to eliminate pathogens from the propagation medium. The planting material itself (seeds or cuttings) may be contaminated. Acceptable planting material can often be obtained from disease-free areas, isolated stock plants, or certified commercial sources. These plantings should be isolated from production fields to minimize their exposure to pathogen contamination. Chemical treatments are also available which will remove surface contaminates from both seeds and cuttings. Knives and containers used in processing cuttings should periodically be sterilized to prevent inoculation of the wounded tissues.

Irrigation water derived from ponds or outdoor irrigation ditches can become contaminated with plant pathogens. Only uncontaminated water should be used in a propagation situation. Chlorination, bromitization, ozonation, and possibly filtration can be used to de-contaminate water. Weeds and sometimes "decorative plants" can also act as host plants for various diseases and when left in or nearby greenhouses can function as inoculum sources.

Infected crops growing adjacent to greenhouses can also produce inoculum which can be transferred by air currents, equipment, or personnel to the propagating area. Propagation houses or areas should be separated from production areas and ideally serviced by their own equipment and personnel. These houses should have a minimum of foot traffic in and out and only key personnel should be allowed access to the area. Dirt from outdoors and greenhouse floors can be readily tracked in by foot traffic. Cull piles, contaminated pots and containers, and "ignored plants" can all be sources of disease inoculum. Eliminating or minimizing these sources of inoculum is a must in any disease control program.

Regarding chemical control, a question consistently arises, should fungicides be used on a routine preventative basis in propagating houses? There seems to be no easy straightforward answer to this question. Since fungicides basically function in a preventive or protective way, routine use prior to disease development is a logical practice. On the other hand, spraying when it is not necessary does not make economical or environmental sense. In addition, fungicides have been known to inhibit growth, in particular, germination and root growth of some plants. Finally, routine spraying can encourage poor cultural and management practices. There is a natural tendency to let some cultural practices slide thinking a spray program will protect the crop. If previous crops have been healthy and the crop can be closely observed, routine use of preventative sprays would in most cases not be necessary. But if diseases have been a problem in the past and there is evidence that no phytotoxicity would be expected, preventative use would be encouraged.

Some of the newer and more active fungicides are prone to the development of resistant strains of fungi which are no longer sensitive to the fungicide. Once resistance has developed, that fungicide is no longer effective as a disease control agent. These shifts in fungal populations from sensitive to resistant are aggravated by continual and overuse of these at-risk fungicides. Since they give superior control, the temptation is to overuse them. To minimize the potential for the development of resistance, the total number of applications should be limited. They should be applied only as protective sprays to avoid treating large populations of the pathogen, less susceptible cultivars should be used when possible and cultural controls should be fully utilized to minimize disease pressure. It is also suggested that these at-risk fungicides be alternated or used with tank mixtures of other registered fungicides having different modes of activity. There are other advantages to tank mixing fungicides including broadening the potential number of diseases controlled and possibly taking advantage of synergistic activity. Recent work from Pennsylvania State University has demonstrated the synergistic effects of tank mixtures of Ornalin, Fore, and Daconil 2787. These fungicide mixtures not only provided longer-term control but did so at below normal rates.

Because of the extremely favorable environment for disease development in a propagating house, taking special preventative measures to avoid the introduction of pathogens is the key to a successful control program. Continual close surveillance and immediate response to disease detection is also important in minimizing losses.

The Potential for Chemical Root Pruning in Container Nurseries

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INTRODUCTION

Deformed root systems of container-grown plants are a longstanding concern of nursery managers, landscapers, and foresters (Armstrong, 1951; Burdett, 1979). Kinked or circling roots can strangle the plant, impair long-term growth, lead to instability or toppling, and cause death. Halter et al.(1993) found a reduction in growth and an increase in root deformities in 11-year-old lodgepole pine, *Pinus contorta* ssp. *murrayana*, planted as container stock. Plants with deformed roots are more sensitive to environmental stress, such as drought, and to attack from insects and disease. Certain plants develop deformed roots rapidly, especially when they are grown in small containers.

Root systems become deformed when the growing root tips deflect off the smooth container wall, grow sideways, and accumulate on the periphery of the root ball. Harris (1967) suggested that if roots where encouraged to grow in the center of the medium, plants could remain in containers longer, before serious root circling occurred. Containers modified with vertically oriented ridges, ribs, or grooves intercept circling roots and direct them downwards. Containers designed to air prune roots, such as porous-walled containers, often promote fibrous roots on the periphery of the root ball (Privett, 1992). Another option is to coat the walls of the container with a chemical root-pruning agent (Landis et al., 1990). Every root tip that comes in contact with this chemical barrier is pruned and usually results in a fibrous root system with a greater number of roots in the upper portion of the container. A quality tree seedling is one with a large, fibrous root system with a large surface area for absorption of water and nutrients (Thompson, 1985).

HISTORY

Evaluation of chemical root-pruning agents to control root morphology began in the late 1960s. But almost 30 years before that, Leatherman (1939) used copper resinate to treat paper pots to prevent decomposition and found no indication of toxicity to tomato plants. In another early trial, cyclamen grown in clay pots dipped in copper naphthenate, for control of algal growth, had more extensive root growth within the medium than untreated clay pots (Stinson, 1956). After the Ontario

Department of Lands and Forests initiated a program to plant containerized seedlings, Saul (1968) demonstrated that roots could be confined to tubes if copper metal sheeting, copper-coated paper, or copper paints were used to line the flats holding the tubes. Later trials with woody landscape plants showed that root growth could be prevented near container walls treated with copper naphthenate or with copper sulfate (Furuta et al., 1972).

So began the search for chemical compounds to coat the inside walls of containers to prune root tips. Pellet et al. (1980) evaluated metal compounds containing cobalt, copper, manganese, nickel, silver, zinc, and others, and found that several of them effectively pruned roots. Several non-metal chemical compounds were also investigated for their root pruning potential: oryzalin (Surflan™, DowElanco) and indolebutyric acid (IBA) were also found to be effective in controlling root growth (McDonald et al., 1984; Ticknor, 1989). But the copper compounds, especially cupric carbonate, consistently gave excellent results for chemically pruning plant roots with no visual plant toxicity. Recently, cupric hydroxide has emerged as an alternative to cupric carbonate (Arnold, 1992).

EFFECTS ON ROOT GROWTH

Chemical root pruning modifies the root system of container-grown plants by reducing the elongation of roots and by promoting a more fibrous root system. Since root growth is influenced by the amount of auxin in the root tip, a dead or arrested root tip causes the root to branch. Early studies by Duncan and Ohlrogge (1958), reported the effects of fertilizer bands on root pruning in a production system. The first-order root tip was apparently killed when it contacted the fertilizer band and second-order roots developed. Second-order roots produced a large number of higher order roots, increasing the total number of root tips. Similar observations were made when cork oak, *Quercus suber*, acorns where sown in flats with a bottom layer of osmocote, treflan, or copper naphthenate-soaked perlite (Nussbaum, 1969). All three chemical layers prevented taproots from elongating through the treated layer and the seedlings had more secondary and tertiary roots.

Chemical root pruning is actually a mild form of copper toxicity. Although the physiology of copper toxicity is not thoroughly understood, copper is only negligibly translocated in the stem (Bennett, 1971). Symptoms of copper toxicity are stunted roots with blackened, thickened root tips, and reduced shoot growth and foliar chlorosis. Arnold and Struve (1989) found copper toxicity symptoms of green ash, *Fraxinus pennsylvanica,* only on root tips in contact with cupric carbonate-treated surfaces. In addition, they found that high copper concentrations were confined to the terminal 1.5 to 2.0 in. of the root. Whether or not a root tip will renew growth once removed from the copper treated zone depends on plant species and copper formulation and concentration (Arnold and Wilkerson, 1993).

APPLICATION TO CONTAINERS

Several nurseries have used homemade solutions to bind a chemical root- pruning agent to the container. Copper is applied to the inside of the containers using latex paint as the carrier and adhesive. Either cupric carbonate or cupric hydroxide is used at the rate of 100 g/liter of paint. While brush application is very time consuming, an airless sprayer can treat several thousand 2¼-in. liner containers in 1 h. Uniform coverage is more difficult with narrow, deep containers. How long the copper treatment remains effective depends on the thickness of the coating, type of adhesive, and the amount of wear or chipping.

Commercial products have recently become available for nursery use. Spin Out™ (Griffin Corporation) is a liquid flowable product that has received registration for use on plastic nursery containers. In South Africa, Plazdip (Starke Ayres) is used extensively for producing containerized forest seedlings. Another product operationally used in forest nurseries, is the Trimroot Styroplug™ (Beaver Plastics), that is a styrofoam container whose cavities are coated with cupric carbonate. Larger pre-treated containers for producing landscape plants may become available in the near future. Chemical root pruning agents are considered a plant growth regulator and must have EPA registration.

ENVIRONMENTAL AND SAFETY CONCERNS

Environmental issues regarding the use of chemical root-pruning products are very important concerns. Although copper is rapidly and strongly fixed in organic matter, the leaching potential has not been thoroughly studied in container nursery stock production. The current, federal, maximum, permissible contaminant level for copper is 1.0 mg/liter for water delivered to any user of a public water system (U.S. EPA, 1991). Cupric hydroxide is toxic to fish. When using copper-treated containers, irrigation tail-water that is stored and recycled should be monitored for levels of copper throughout the growing season. In addition, disposal and recycling of treated containers may be a concern.

Nurseries who use chemical root-pruning products must comply with local, state, and federal worker safety regulations. Health and safety issues focus on exposure during application of the product to containers and during handling of the treated containers. Nursery managers must consider: (1) maintaining material safety data sheets, (2) record keeping regulations,(3) appropriate protective clothing for applicators, (4) restricted-entry intervals, and (5) worker training.

NURSERY POTENTIAL

There is high interest and increased use of chemical root pruning in container nurseries. Nursery managers are finding that more plants pass the grading requirements and that markets are starting to demand fewer root deformities. For example, foresters in British Columbia, Canada, are requiring that lodgepole pine be grown in copper-treated blocks. Chemical root pruning of seedlings has become an established practice in South Africa.

More information is needed on phytotoxicity and on long-term outplanting performance of plants with chemically pruned roots. Potential benefits of a root system confined to the interior of the medium is improved tolerance to extreme medium temperatures. Roots should be more insulated from high temperature during the summer, and from low temperatures during the winter. Interior root tips are less subject to desiccation and to mechanical injury when transplanted. Crop water requirements and shelf life may also change due to the fibrous nature of chemically pruned root systems.

CONCLUSION AND RECOMMENDATIONS

Although the potential benefits of chemical root pruning are great, we advise nursery managers to proceed with caution. First, always do small trials when introducing a new plant species to copper-treated containers and watch for any phytotoxicity. Be aware that environmental and safety regulations regarding the use of chemical root-pruning agents could change, as it often does for pesticides and plant growth regulators. And finally, follow the latest research as it relates to nursery practices and outplanting performance.

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Using "Limiting Factors" to Design and Manage Propagation Environments

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THE PRINCIPLE OF LIMITING FACTORS

One of the basic concepts of ecology is called the principle of limiting factors which states that, when a process is governed by several factors, its rate is limited by the factor that is closest to the minimum requirement (Odum, 1971). Conceptually, the idea of limiting factors can be visualized with the wooden barrel analogy which Whitcomb (1988) used to explain mineral nutrient deficiencies. Plant growth is represented by the water in the barrel which is constructed of wooden staves, each representing a different limiting factor (Fig. 1). The water level (plant growth rate) at any one time or location is limited by the height of the shortest stave (limiting factor) in the barrel.

If we expand this concept to nursery design and management, we can identify those environmental factors that are potentially limiting to plant growth. The main factors of the atmospheric environment are light, temperature, humidity, and carbon dioxide and the two principal factors of the edaphic environment are water and mineral nutrients (Fig. 2). The atmospheric factors are primarily determined by geographic location and type of nursery facility and so must be carefully considered during nursery site selection and construction of propagation

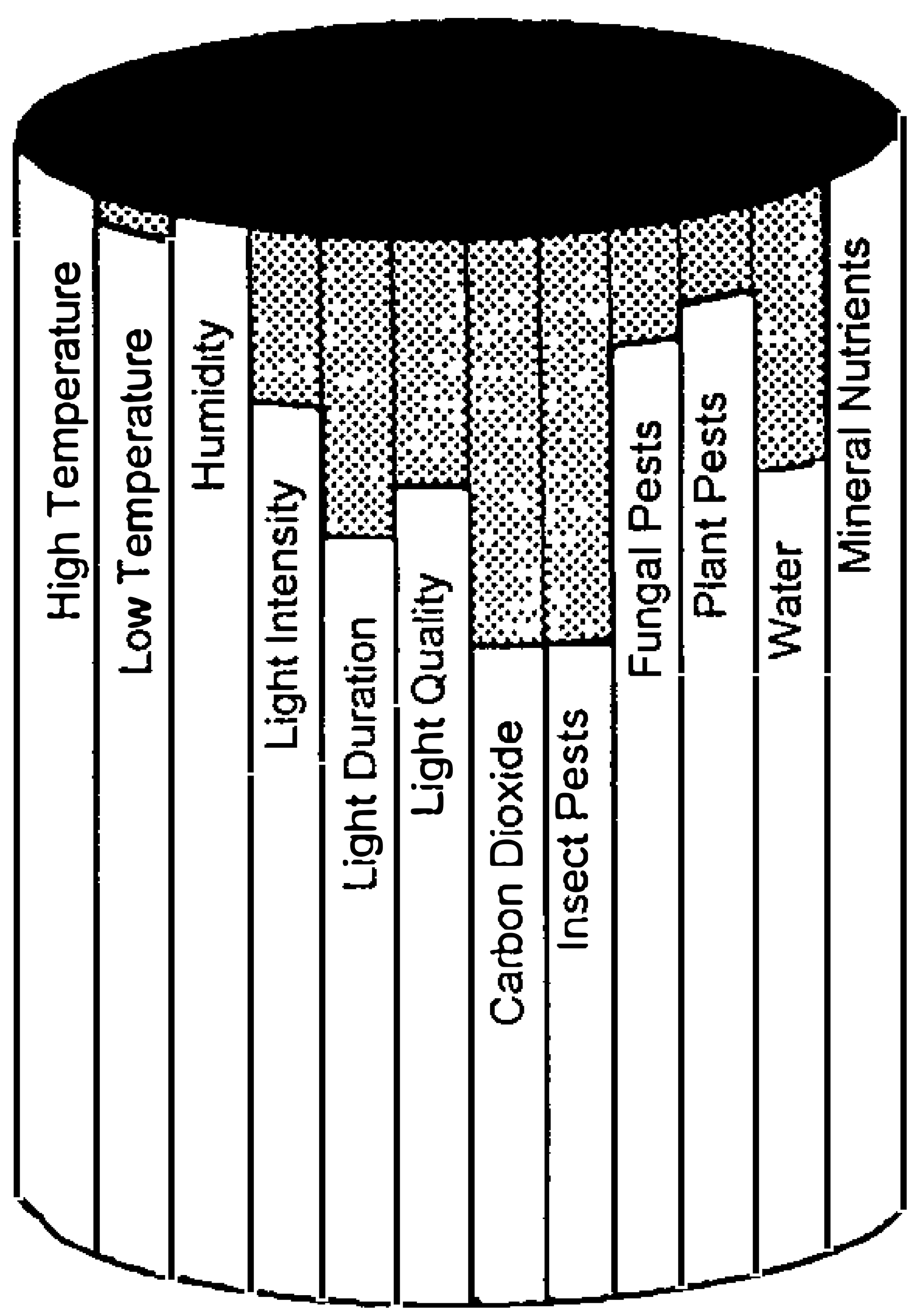

Figure 1. The concept of limiting factors can be visualized as a wooden barrel in which the height of each stave controls the amount of water (plant growth rate) in the barrel (modified from Whitcomb, 1988).

structures. In container nurseries, the two edaphic factors are independent of nursery location and can be completely controlled by the type of growing medium and cultural practices.

In addition to the physical and chemical factors listed above, the propagation environment also contains a biological component—other organisms that often limit plant growth (Fig. 2). Pathogenic fungi and insect pests can injure or even kill succulent nursery plants and, because of the lack of natural biological controls in nurseries, pests can build up to damaging levels very quickly. One of the primary attractions of container nursery culture is that growers have more control over these biological factors and can design a propagation environment that excludes pests.

DESIGNING A PROPAGATION ENVIRONMENT—ATMOSPHERIC FACTORS

A good container nursery design will reflect both the environmental conditions on the site and the biological requirements of the specific crop. So, the first step is to determine crop requirements—a propagation environment that is ideal for one group of plants may be biologically or economically unsuitable for another. Nursery crops can have radically different environmental requirements which nursery developers must factor into the nursery design process. Most forest and conservation nurseries produce a number of different species; therefore, different propagation environments must often be designed to meet the needs of the various crops. On a practical basis, however, most nursery developers must compromise for some sort of average environment in which they can grow the entire range of crop species.

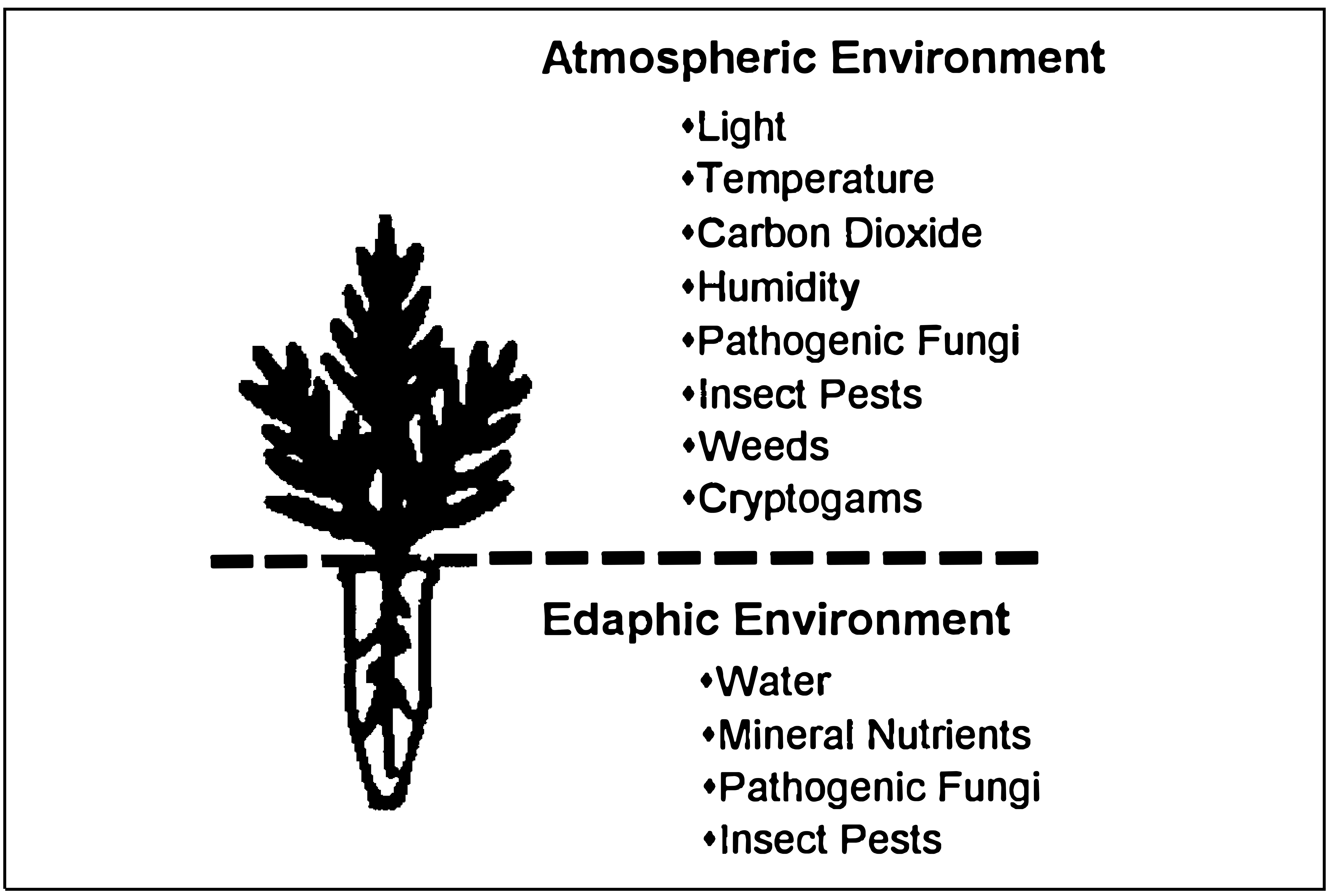

Figure 2. Environmental factors that can potentially limit growth in the container nursery environment.

Next, the nursery developer must determine the amount of environmental modification that will be necessary on the selected site. Of course, the costs of nursery development and operation increase with the amount of environmental modification that will be required. The nursery that matches the biological requirements of the crop to environmental conditions of the site will also be the most economical, and so nursery developers should devote ample time to site analysis before the type of propagation environment is selected.

Container nursery facilities can be categorized by their relative amount of environmental modification: fully-controlled environments, semi-controlled environments, and minimally-controlled environments.

FULLY-CONTROLLED ENVIRONMENTS

A fully-controlled growing environment requires a propagation structure that contains all the environmental control equipment necessary to keep all the potentially limiting factors at optimum levels (Table 1). Greenhouses are suitable for almost any type of climate due to the high degree of environmental control, reducing the risk of losing a crop to severe weather. The favorable growth conditions permit forest and conservation nursery crops to be grown year round with a rotation of 3 to 9 months, making multiple crops a distinct possibility. However, fully-controlled environments are the most expensive to build and operate, primarily due to high energy requirements.

Table 1. Potential to control limiting factors in different propagation environments.

Limiting factors	Type of propagation environment Minimally controlled	 Semi-controlled	 Fully controlled
Atmospheric			
Temperature- high	No	Partially	Yes
Temperature-low	No	Yes	Yes
Humidity	No	Partially	Yes
Light-photoperiod	Yes	Yes	Yes
Light-photosynthesis	No	Yes	Yes
Light-quality	No	Yes	Yes
Carbon dioxide	No	Partially	Yes
Pests	No	Partially	Yes
Edaphic			
Water	Yes	Yes	Yes
Mineral nutrients	Yes	Yes	Yes
Pests	Yes	Yes	Yes

The traditional way of growing forest and conservation nursery crops was to start the seedlings in a greenhouse and then move them to a shadehouse for hardening. In fact, growers soon learned that the hardening phase was the most challenging and began to look at ways of modifying the crop schedule. Many began removing the greenhouse covering so they could harden their crops in place without the additional labor expense of moving the seedlings. Others began looking at structural modifications to the traditional fully-controlled greenhouse.

SEMI-CONTROLLED ENVIRONMENTS

This category includes a wide variety of growing structures which, as their name infers, are designed to control only certain aspects of the ambient environment (Table 1). Crops can be propagated in semi-controlled structures in all but the most severe climates. Depending on the type of structure, crops can be grown from spring to fall with generally one crop produced per year; winter crops are not economical in harsh climates. From an economic standpoint, semi-controlled environments are cheaper to build and operate, although there is considerable variation between the different types of structures.

To better suit the conditions in the western Oregon environment, a modified greenhouse was developed with a permanent transparent roof and flexible walls that can be rolled up (Hahn, 1982). This "shelterhouse" design permits considerable flexibility in environmental control. In the spring, or in unusually cold weather at any time during the growing season, the sidewalls can be lowered and heat turned on to maintain ideal temperatures. When ambient temperatures become favorable, the sides can be raised to permit natural ventilation, eliminating the need for forced air cooling. Other than these structural modifications, shelterhouses can be outfitted with any or all of the standard greenhouse environmental control equipment to modify most growth-limiting factors (Table 1).

Recently, computer technology and a variety of new shading materials have made many different types of semi-controlled propagation environments possible. Cravo Equipment Ltd. of Brantford, Ontario has developed an innovative new design which features a retractable roof which can modify sunlight and crop temperature as weather conditions change. The roof material can be constructed of transparent fabric or a variety of different shadeclothes. These retractable systems can open or close automatically in only 3 to 6 minutes allowing the crops to receive more light early in the morning and late in the day or throughout the day under partly cloudy conditions. Retractable-roof propagation structures are particularly suitable for crops that need to be fully hardened before shipping because they can be gradually exposed to outside conditions while being protected from climatic extremes.

MINIMALLY-CONTROLLED ENVIRONMENTS

Although open growing compounds are the least expensive way to produce forest and conservation crops, seedling growth rates are slow and, depending on the climate, it may take 1 to 2 years to produce a shippable seedling. Weather damage, such as a killing frost or torrential rain, is also a constant concern and so the risk of crop loss is the highest of all types of propagation environments. Cold injury to overwintered seedlings has also been a serious problem at some nurseries, and so open growing compounds are only used in relatively mild environments.

MANAGING THE PROPAGATION ENVIRONMENT—EDAPHIC FACTORS

Many growers focus on the atmospheric environment and forget they can also control the edaphic environment. Actually, due to the use of artificial growing media and the fact that irrigation and fertilization are easier in container nurseries, growers have relatively more control over edaphic factors. Container characteristics, especially container volume and spacing, control the availability of water and mineral nutrients. And, new developments in container technology, such as chemical root pruning with copper compounds, will change the way in which growers manage the edaphic environment.

The composition of the growing medium offers many opportunities to culturally control this potentially limiting component in the edaphic environment. A wide variety of commercial growing media offer different physical, chemical, and lately, biological properties. Exciting new options for managing the biological characteristics of growing media will alter the management of the edaphic environment. Specially prepared composts can be used to make growing media suppressive to root pathogens (Hoitink et al., 1991), and forest and conservation nursery managers are inoculating their media with beneficial microorganisms such as mycorrhizal fungi and rhizobacteria (Linderman and Hoefnagels, 1992).

THE IDEAL PROPAGATION ENVIRONMENT

Nursery managers have numerous opportunities to control the propagation environment both in the design of their nursery facilities and through their cultural practices. However, there is not one propagation environment that is ideal for every crop - what works well for one crop may be entirely inappropriate for another. By consulting the scientific literature and talking with other nurseries, growers can determine crop response to each of the potentially growth-limiting factors.

Nursery developers must carefully analyze the climate at their site to determine which potentially limiting factors need to be modified to produce optimum plant growth. Several new innovations in the design of propagation structures are now available and existing structures may be easily modified. Growers should also periodically analyze their propagation environments to determine if some aspect of their cultural regime may be limiting to the growth of their crops. Container growers should pay particular attention to the edaphic environment and consider the influence of their containers and growing medium. Fertilization and irrigation practices should be re-examined, and new growing medium components and amendments should also be tested.

Although the propagation environment is complicated and dynamic, the concept of limiting factors can help growers to design better nurseries and identify and correct problems in their cultural programs.

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Question Period I

Jeff Bohn: Are there any detrimental effects of copper on mycorrhizal fungi?

Tom Landis: There actually have been studies to show them to be beneficial by making a more fibrous root system which has more loci for the mycorrhizal fungi to invade. There was some research done several years ago with Ponderosa pine that actually improved mycorrhizal infection.

Jeff Bohn: That's with the ectomycorrhizal fungi. Has there been any work done with endomycorrhizal fungi?

Tom Landis: I'm not sure.

Jeff Bohn: That exists in the root tip itself whereas the ectomycorrhizal fungi can attach itself further up the root can't it?

Tom Landis: I would think the principle would be the same by promoting more fibrous root tips for the infection to occur. I would think you can get better invasion and better inoculation with chemically pruned roots.

Kathy Echols: Have there been any studies done on the benefits of mycorrhizal fungi on ornamental plants as opposed to forestry species?

Rich Regan: There really isn't anything in the literature as far as the copper treatment, but there is literature on the effects of mycorrhizal fungi on ornamental plants.

Larry Landauer: Have there been any studies on the possibility of developing resistance to multiple fungicides if they are all used at the same time?

Ralph Byther: Good question. Probably not any good studies using a mixture of three. It's well documented that you can have a fungus that has developed a resistance to two of them, but this has probably occurred through misuse where one material was used for a long period of time and the fungus developed resistance to it and then by using another material the fungus developed resistance to that, so you then had resistance to both of those compounds.

Larry Landauer: We try to fight resistance by alternating one after the other and if you use all three at once, what do you do if resistance develops? Do you have any alternative at that point?

Ralph Byther: That's correct. If one of those in the mixture are not-at-risk materials like Daconil we don't have resistance develop. In mixtures, it's best to combine not-at-risk materials with the at-risk materials. But, I don't know of studies to show what you are talking about.

Voice: What was the timing for the application of nitrogen?

Rita Hummel: The nitrogen was applied once every 2 weeks as a liquid for those different rates of nitrogen and there was phosphorus and potassium in the liquid fertilizer, but the rate of that was held constant across all nitrogen rates.

Question Period II

Richard Walhood: With regard to your international acquisitions, how are you affected by plant quarantine laws or is that another function of the university?

J.C. Raulston: You'll lose a whale of a lot of plants going through quarantine people. Basically, my procedure is that when I go somewhere and collect I assume it's all expendable, as painful as that is. There will be times when you come through everything else comes through; there are times you come through and for some reason it's the wrong day. It's an unpredictable thing. It is very difficult. We have lost a lot of materials as have all nurseries and public gardens, but we do work with the quarantine people. We take things through. The trip to Mexico a few weeks ago, they collected for so long they knew people by name and everything as they come through. We spent probably 3 h and it was very slow since they went through everything. It's a process you go through.

Don Kleim: *Campsis grandiflora*. How large a flower?

J.C. Raulston: The flowers are 2-1/2 in. in diameter. They're huge. The picture on the cover really doesn't do them justice. They are spectacular.

Don Kleim: In 1926, W.P. Clark brought in a collection and what was *Campsis grandiflora* [syn. *Bignonia grandiflora*], he brought in a cultivar called 'Splendor'. A 4-in. blossom, shrubby as such we still have a few plants, but it is a big one.

J.C. Raulston: I appreciate that list, but it brings up a very important point. Much of what we're doing is not new necessarily, but plants cycle through and they are handled by individuals and then up with collectors. It is glamorous to take an expedition to China, but my theory is that you can throw a dart at a map and in a 5-mile radius anywhere you can find amazing plants, either seedling variations on plants that are native there, mutations on the landscape plants, old plants that somebody brought in, literally, there are wonderful plants everywhere and they go out of the trade and we need to constantly bring them back.

Kristin Yanker-Hansen: Can anybody be a member of your organization?

J.C. Raulston: We would love to have you as a member.

Kristin Yanker-Hansen: What are the membership benefits?

J.C. Raulston: I get so happy when people send me checks. We produce what I call our periodic newsletter because I write it and it's very periodic at this point and one's due right now. We do have a variety of mailings that go out to people. On the local scene there are lectures and plant distributions and things like that. Long distance it's a matter of keeping up with what we're doing as much as anything. If you get up to higher membership levels, we have a connoisseur level. Each year we do by mail a distribution to those people of our choicest and most exceptional plants that we have. As professional nurserymen, literally any of you have access to our collections. We do the best we can. Write to us and let us know what you are interested in and we'll process it as we can. I have a few membership brochures here and in the handout there is an address.

Barbara Selemon: You give away so much. How do you recoup your expenses?

J.C. Raulston: We get support from the industry and people give us donations and we work very hard. At this point the university provides 0.5% of our operating budget. The rest we get from the public and memberships. We are not allowed to sell plants. So we depend on donations. The nursery industry has been very supportive. We apply for grants, we tap dance, we do everything we can. At this point our operational budget runs $200,000.00 a year which we have to raise every year. It's a struggle. But, we have fun at it.

Intensive Cultivation of *Taxus* Species for the Production of Taxol®

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Taxol®, a novel anti-cancer drug registered in the U.S. in 1992 for the treatment of ovarian cancer, is derived from plant tissues of the genus *Taxus*. While the bark of Pacific yew (*T. brevifolia* Nutt.) is the only current approved source of Taxol, several alternative sources are under development. One promising alternative is the intensive cultivation of yew plants in tree nurseries, as is being developed by Weyerhaeuser Company. Since 1987 the company has been active in *Taxus* research and has embarked on a large scale production program to supply yew biomass for the production of Taxol. We believe this approach can best provide a dependable, long-term and economical supply of paclitaxel, the active compound on which Taxol is based. The program is supported by Bristol-Myers Squibb, the pharmaceutical company developing the drug in the U.S., and by the National Cancer Institute.

INTRODUCTION

Taxol® (paclitaxel) is considered by the U.S. National Cancer Institute (NCI) as one of the most important anti-cancer drugs to be developed in the past decade. The molecule paclitaxel is a diterpene, belonging to a group of closely related chemicals called taxanes, extracted from the bark and other plant tissues of yew trees (*Taxus* species). Taxol, the drug formulation of paclitaxel, has been approved by the U.S. Food and Drug Administration (FDA) for treatment of patients with ovarian cancer whose first-line or subsequent chemotherapy has failed. Taxol is being evaluated for the treatment of many other cancer types and appears promising for several, including breast, lung, head, and neck cancers.

The story of Taxol and its development began over 30 years ago. In 1958 the NCI initiated a long-term program, ultimately screening about 35,000 plant species for anti-cancer activity. As part of this program, samples of Pacific yew (*T. brevifolia*) bark, needles, and roots were collected in 1962 and sent to the NCI for evaluation. In 1964, extracts from these samples showed anti-cancer activity in *in vitro* cancer cell line screening trials.

The active ingredient of the yew bark extract (paclitaxel) was first identified and reported by Drs. M.C.Wani, Monroe Wall, and others of the Research Triangle Institute, North Carolina, in 1971 (Wani et al.). Due in part to the difficulty of obtaining the raw resource, and extracting and purifying the compound, further development of paclitaxel was delayed for several years. In 1979, the unique mechanism of action of paclitaxel was discovered by Dr. Susan Horwitz's laboratory at the Albert Einstein College of Medicine in New York (Schiff et al., 1979).

They found that paclitaxel inhibited the depolymerization of microtubules during mitosis, thus inhibiting the rapid growth of cancer by interrupting cell division. Virtually all other cell division inhibitors affect microtubule assembly. This uniqueness suggested that paclitaxel could be used in conjunction with other therapies with mechanisms of action that were different and in fact, the drug is currently being used in combination therapies in several clinical trials.

Human clinical trials were begun by the NCI in 1983. Initial results with ovarian cancers were very promising; those with melanomas less so. Early problems were experienced with formulations and delivery. Limited Phase II and III trials began in 1985 and 1990, respectively. Again, the limited availability of Taxol affected the speed at which clinical trials could proceed. Paclitaxel derived from Pacific yew bark was the only approved source for clinical trials, and the harvest from that resource lagged behind expectations and needs during the early years of clinical evaluations.

In 1991, following a competitive bidding process, Bristol-Myers Squibb (B-MS) was awarded a Cooperative Research and Development Agreement (CRADA) from the NCI to further develop and bring Taxol to market. In July of 1992, B-MS filed for a New Drug Application for the use of Taxol for ovarian cancer and in late December 1992, Taxol was approved by the FDA for treatment of patients with ovarian cancer whose first-line or subsequent chemotherapy had failed. In 1992, B-MS and their contractor, Hauser Chemical, harvested over 1.6 million pounds of bark and increased Taxol production from 5000 to 50,000 vials per month (Stull, 1992; DeFuria, 1992). This increase in available drug has permitted a dramatic increase in the number of clinical protocols, from a total of 30 between 1983 and 1990, to over 60 in 1992 alone (Arbuck, 1992). These trials included over 1700 patients. Today the numbers are even greater and virtually anyone in need of the drug can obtain it.

To date, the bark of the Pacific yew, a forest tree species native to the U.S. Pacific Northwest and British Columbia, remains the only approved source of Taxol for clinical trials or cancer therapy. Because of its limited occurrence and relatively slow growth rate, much concern was expressed over the environmental impact associated with the harvest of Pacific yew. The long-term supply of this resource seemed dubious. Consequently, one of the requirements of B-MS as stipulated in the CRADA was to identify and develop alternative sources of paclitaxel.

Several possible alternative sources have been identified and are receiving considerable research (and media) attention. They include foliage from wild populations of several species of *Taxus*, cell culture, total synthesis, semi-synthesis, and biomass from cultivated sources. Of these, semi-synthesis and biomass from cultivated sources appear most imminent as probable cost-effective alternative sources. Semi-synthesis requires taxane precursors derived from *Taxus* plants, whether from cultivated or wild sources. A combination of the above sources is probable in the future.

WEYERHAEUSER'S TAXOL PROGRAM—GOAL AND EARLY DEVELOPMENT

Of the above supply alternatives, Weyerhaeuser has focused its efforts on nursery cultivation, one of the Company's core businesses and an area of considerable expertise. The goal of Weyerhaeuser's Taxol Program is to provide, through intensive cultivation of *Taxus* biomass, a renewable, reliable and economic supply of paclitaxel and other desired taxane precursors for semi-synthetic production of Taxol.

Weyerhaeuser's Taxol Program began in 1987 when we were contacted by NCI's Natural Products Branch as a prospective contractor to supply Pacific yew bark. Weyerhaeuser is a major owner of timberland in the Pacific Northwest, managing nearly 3 million acres of private forest lands in the states of Washington and Oregon. However, only a relatively small portion of this land base contains native Pacific yew. We recognized and proposed the potential for intensive cultivation as a supply alternative. This was based not only on our knowledge of the relative scarcity of yew in the region, but also on the belief that cultivation would provide for a more reliable, long-term and environmentally friendly solution to the supply issue.

The initial steps toward establishing a cultivation program were directed at developing an information base, since virtually nothing was known about the genetics, physiology, or chemistry of the Pacific yew and related species. Our first research efforts included establishment of a large population/genetics study (Wheeler et al., 1992) and a survey of the taxane levels in literally hundreds of yew accessions. This was followed by establishment of a comprehensive research and production program, based on early research results of the genetics study and on extensive experience within the company in tree improvement, plant physiology and propagation research, as well as large-scale forest tree nursery operations. This program received support in 1991 with the signing of research and production agreements with Bristol-Myers Squibb and the awarding of a competitive research grant from the National Cancer Institute (NCI). NCI also supported earlier work through the provision of analytical support.

KEY ELEMENTS FOR A SUCCESSFUL CULTIVATION PROGRAM FOR TAXOL PRODUCTION

For a cultivation program to be successful—both technically and economically—several criteria must be met. Those key elements particularly necessary for a Taxol (paclitaxel) program are:

- An understanding of genetic and environmental factors contributing to taxane yields and plant growth. This understanding leads to the ability to select and use genetic material with the desired traits, and the ability to focus control on environmental variables affecting these traits. This includes identification of cultivation protocols that insure acceptable chemical profiles.
- Production systems capable of reliably and cost-effectively producing large amounts of high taxane-yielding biomass. This applies to all phases including propagation, growing, harvesting and processing.
- Crops dedicated to the specific purpose of Taxol/taxane production. This allows for the optimization of taxane content and biomass production, without the need to compromise for other product values, i.e. ornamental, form, etc.
- Strong research, technical, and analytical support. These are critical components for program start-up, optimization, and continuous improvement.

The cultivation approach is characterized by three discreet steps or processes : selection, propagation and grow-out.

With *Taxus*, three sources are available for genetic selection; (1) native or wild populations of several species, (2) unique genotypes found in arboreta and gardens, and (3) varieties or cultivars produced for the ornamental trade. The first contains the greatest amount of genetic variation and holds the most promise for continuous genetic improvement. The last has a more limited genetic base and thus a limited potential for improvement, but is available in numbers large enough to develop a large scale production program quickly.

Material from the commercial sources are routinely propagated through the use of rooted cuttings. Tissue culture would be highly attractive for bulking-up desirable, but rare or unique genotypes; the status of this technology is currently under review. Seed orchards could provide seedling stock, but the loss of genetic integrity, due to gene segregation, would likely reduce genetic gain opportunities.

The current emphasis in Weyerhaeuser's program is on intensive nursery production. This approach provides the most rapid production scale-up of acceptable biomass in the shortest possible time, as well as the opportunity to incorporate improved material into the production program as quickly as it becomes available. Hedging could be a viable option once the desired trait is well understood (i.e., which taxane(s) are desirable), acceptable levels of it are found in the shearable portions of the plant, and ample time is available to reach the biomass production stage.

CHALLENGES FACED IN CULTIVATION OF *TAXUS* FOR TAXOL PRODUCTION

The cultivation of yew specifically for Taxol production has presented numerous technical and production challenges. Although yew is grown on a grand scale for ornamental use in the Upper Midwest and Northeast, when we began growing yew virtually nothing was known about optimizing plant growth for taxane yields.

Technical challenges of note include: (1) defining the sources and magnitude of variation in taxane content as a function of genetic, epigenetic, and environmental factors, (2) defining heritabilities and genetic correlations for traits of interest, (3) understanding postharvest stability issues, (4) evaluating growth regulator effects on biomass and chemistry of plants, (5) developing reliable and accurate assay protocols, (6) optimizing propagation and cultivation protocols, etc. to name but a few.

Production challenges are perhaps of greater interest to this group. Our production hurdles were defined primarily by the urgency and scale of start-up. We needed to develop reliable processes to integrate rapidly accumulating technical data into propagation and cultivation regimes that could accommodate literally millions of units within a period of 2 to 3 years. We did this by using the combined wisdom of experienced ornamental growers, like Zelenka Nurseries, and our own greenhouse and nursery staffs, who produce over 250 million conifer seedlings a year. In addition, we were able to benefit from a tremendous pool of expertise in our forestry research organization.

Our most notable progress came in the area of propagation. We jumped from a few hundred cuttings a year, in 1990, to over 12 million in 1993 (Fig. 1). Our initial efforts focused on sand and perlite rooting beds, standards of the ornamental industry. However, problems with control of pathogens and efficient handling lead us to develop a containerized system with rolling benches. Cuttings are stuck in assembly-line fashion on a moving belt (in a head-house), placed on aluminum-frame tables, and taken by trailer to the greenhouse where they are rolled into bays. At harvest the reverse process is used. Water and fertilizer are provided by an overhead gantry boom. We have taken a pro-active approach to disease control, using a two-tiered fungicidal attack: a sanitation dip prior to sticking , followed by preventative drenches. We are still experimenting to determine which fungicidal products are optimal in our system. Except for the use of containers, our rooting conditions are rather traditional, with bottom heat, provided by hot water fins, and high humidity provided by overhead foggers. Although environmental conditions are critical to health and rooting success, the single most important factor in rooting appears to be the cutting wood itself. Rooted cutting harvest is performed with both manual and mechanical extractors, the cuttings boxed and transported to one of our 4 western nurseries, and machine-transplanted, preferably within 24 to 48 h of harvest.

A great deal of research is underway to determine optimal protocols for the cultivation of yew for taxane production. We are becoming increasingly aware of a number of environmental factors that influence taxane yields, including fertility levels, soil types, etc. Coupled with genetic and epigenetic (time of harvest, tissue effects) sources of variation in taxane yields, these environmental factors result in a rather complex management protocol that we are still working to optimize. With

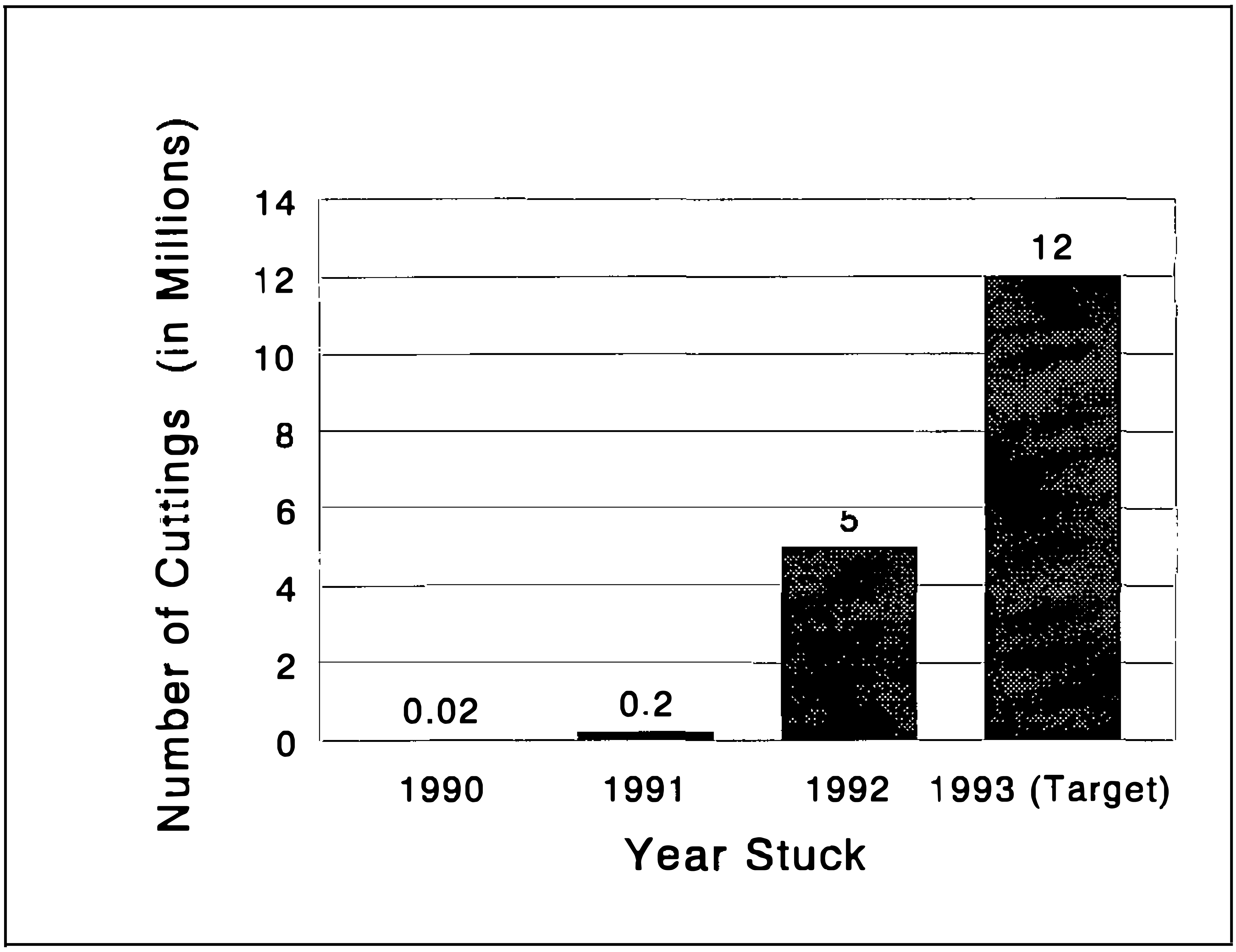

Figure 1. Number of yew cuttings stuck during the start-up of Weyerhaeuser's Taxol production program.

over 100,000 plants in some 70 research trials, and about 15,000,000 plants in production plantings, Weyerhaeuser is aggressively seeking to provide a renewable and cost-effective source of Taxol for years to come. Weyerhaeuser's yew cultivation approach will not only provide for a reliable and uniform source of material for Taxol, but will allow for an early exit from natural forests, thus insuring the maintenance of this small component of diversity in our forest ecosystems. The Taxol program is a welcome addition to an ever-expanding conifer nursery business that also insures we will never run out of trees.

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New and Outstanding Plants

Vancouveria hexandra

northern inside-out-flower
Berberidaceae

Wilbur L. Bluhm

Northern inside-out flower, *Vancouveria hexandra* (Hook.) Morren & Decne., a Pacific Northwest native, is an attractive, reluctantly deciduous, herbaceous, groundcover for shade and semi-shade sites along the Pacific coast. It grows naturally in coniferous woods west of the Cascade Mountains.

Its common name, inside-out-flower, comes from exposure of the ½-inch long stamens and pistil by the sharply reflexed sepals and petals. The sepals and petals are both white, but the petaloid sepals are the larger and showier of the two. The nodding flowers, in open panicles above the foliage, are each about a half-inch wide.

The foliage, however, is the quality making this plant a useful landscape subject. Some people say it's airy, or fern-like. Compound leaves stand up to a foot high on wiry stems which emanate from ground level. Individual leaflets are up to 2 ½ in. long and nearly as wide, often ovate in shape overall. The leaflets are quite unique, having three rather indistinct lobes with shallow sinuses.

The light green color of the foliage gives the plant a fresh appearance from spring until the leaves drop in late fall or winter. Leaflets sometimes show a bronzing, adding further interest to the plant. Leaflets turn dull yellow a few weeks before falling, commonly in December in Oregon's Willamette Valley. It may be nearly evergreen in warmer climates of its range.

Vancouveria hexandra spreads by slender woody rhizomes. Planted at 1 ft to 18 in. on center, it may provide solid cover after little more than a year or two of growth in an organic soil. In a soil without considerable organic matter, it may take several years to fill.

Vancouveria hexandra is useful west of the Cascade Mountains in the Pacific Northwest and along the coast to Southern California if irrigated. Everywhere it may benefit from occasional irrigation during dry summer periods. It is tolerant of temperatures to 0F (-18C) or lower, especially with snow cover.

This plant is useful as a groundcover under deciduous as well as conifer trees. It has potential to emerge afresh in spring through fallen leaves, and not be laden with leaves as would evergreen groundcovers. Tree roots seem to be no problem. It can also be grown among rhododendrons and other shrubs. The only observed problem is root weevils. Adults feed on the foliage and larvae, presumably, on the root system.

Interest in *V. hexandra* is spreading. There is reported interest in its use in Midwestern U.S.A. and it is soon to be featured in a *Wall Street Journal* article.

Nursery propagation is by seed or division. Fresh ripe seed is sown in the fall and overwintered in flats or pots. Divisions in early spring, planted in pots with an organic soil mix or directly planted into beds, has been successful. Rhizome cuttings might be tried. Smith (1992) reports "unrooted portions of the slender rhizomes can be planted as cuttings in pots or flats, with no rooting hormone."

Two closely related species, *V. chrysantha* E. Greene, golden inside-out-flower, and *V. planipetala* Calloni, redwood inside-out-flower, are native to southwest Oregon and the northern coast of California. Both are evergreen and considered by some to be more desirable as ornamentals. The golden-inside-out-flower, showiest of the three in flower, has the reputation for being difficult in cultivation, but the shiny and leathery-leaved redwood inside-out-flower is very attractive and nearly as easy as *V. hexandra*. The useful range of redwood inside-out-flower appears not to be as far south in California as that of *V. hexandra*.

Vancouveria is closely related to *Epimedium* and has similar foliage, but different flowers. Overall they are similar in appearance. Both are in the barberry family.

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Itea virginica

Virginia sweetspire
Saxifragaceae

Tamara Buchanan

A semi-evergreen shrub standing 1 to 2 m tall with a 1 to 2 m spread. It has a dense, compact form and a moderate growth rate. The leaves are simple, elliptic, serrulate, bright green, and glabrous in an alternate leaf arrangement. The inflorescence is a fragrant, white, raceme appearing in June to July. *Itea virginica* is a low maintenance plant and can be used as a background plant, foliage accent, specimen, barrier, hedge, or around a pool. It has a multi-trunk habit, is valued for its fall color and is pest-free. It will grow in acidic, organic, heavy, wet or fertile soils. It's adapted to full to half sun exposures and heat and humidity. It is propagated by cuttings. It is especially valued for its incredible winter interest.

Heuchera cylindrica
no common name
Saxifragaceae

Tamara Buchanan
A herbaceous perennial standing 10 to 15 cm tall with a 15 cm spread. It forms a clump and grows slowly. The leaves are simple, reniform, lobed/incised, light green, and smooth. The inflorescence is a white raceme appearing in June to October. *Heuchera cylindrica* is a low maintenance, drought tolerant, and pest-free plant and can be used in the landscape as a foliage accent, groundcover, shade, border, container, hillside or rock garden plant. It will grow in sandy, organic, rocky, light, dry, well-drained, sterile, or fertile soils and will withstand full to half sun, dust, and heat. It is propagated by seed, cuttings, and division.

Polygonum vacciniifolium
Himalayan fleece flower
Polygonaceae

Tamara Buchanan
A semi-evergreen herb standing 14 cm tall with a 1 m spread. It grows as a mat with a moderate growth rate. The leaves are simple, obolanceolate, entire, and smooth in an alternate leaf arrangement. The inflorescence is a light to dark pink raceme appearing in June to November. *Polygonum vacciniifolium* [syn. *Persicaria vacciniifolia*] is a low maintenance plant and can be used as a foliage accent, shade, cascade, or poolside groundcover. It has outstanding fall color and is pest-free. It will grow in acidic, organic, light, heavy, wet, well-drained, or fertile soils and will withstand shade to full sun, dust, heat, and humidity. It is propagated by seed, cuttings, and division.

Abutilon palmeri
no common name
Malvaceae

J. Michael Evans
A herbaceous perennial native to San Diego County (California), Baja, California; Sonora, Mexico; and Arizona standing 1 m tall with a 1 m spread. It grows fast as a dense sub-shrub. The leaves are simple, cordate, blue-grey green, pubescent with incised margins and net venation. The inflorescences are yellow axillary or terminal panicles appearing in April to October. It is monoecious with light brown, non-edible, capsule fruits appearing in the summer. *Abutilon palmeri* is a low maintenance plant tolerating alkali and drought. It can be used as a foliage accent, border, hedge, hillside, poolside, container, or rock garden plant and is pest-free. It will grow in sandy, light, rocky, dry, or well-drained soils and will withstand full sun and heat. Hardiness is to 28F with some damage to growing tips. Plant will not tolerate severe freeze. It is propagated by seed and cuttings.

Magnolia denudata
Yulan magnolia
Magnoliaceae

Roger Gossler
A deciduous tree standing 10 to 15 m tall with a 10 m spread. It grows fast when young. The leaves are simple, obovate, entire, green, and smooth in an alternate leaf arrangement. The cream-colored infloresence is terminal, fragrant, and appears in March to April. It is monoecious having pink, non-edible, spindle-shaped fruits, 10 cm long appearing in August to October that contain 1.5-cm black seeds surrounded by orange pulp. *Magnolia denudata* is pest-free and can be used as a multi-trunked or specimen tree. It will grow in acidic, sandy, clay, organic, moist, or well-drained soils and will withstand half to full sun. It is propagated by seed, layering, budding, grafting, and cuttings.

***Magnolia stellata* 'Jane Platt'**
pink star magnolia
Magnoliaceae

Roger Gossler
A deciduous tree or shrub standing 5 m tall with a 3 to 4 m spread. It has a bushy form and a slow growth rate. The leaves are simple, narrow, oblong, green, and smooth in an alternate leaf arrangement. The pink inflorescence is terminal, lightly fragrant, and appears in March to Arpil. It is monoecious having pink, non-edible, spindle-shaped fruits appearing in August to September containing 2-mm, black seeds surrounded by orange pulp. *Magnolia stellata* 'Jane Platt' is valued for its fall color and as a multi-trunk specimen tree. It can be grown in containers. It will grow in acidic, sandy, clay, organic, moist, well-drained, or fertile soils and will withstand half to full sun. It is propagated by layering, budding, grafting, and cuttings.

***Athyrium filix-femina* 'Fancy Fronds'**
dwarf fimbriate lady fern
Dryopteridaceae (Aspleniaceae)

Judith Jones
Deciduous; 6 to 8 in. The parent to these sporlings has delicately dissected pinnules set closely together and embellished with fimbriate edges and tips. The uncrested parent has yielded two distinct dwarf forms as well as some larger setigerate forms with flabellate tips. The dominant form that occurs from spore is an exquisite lightly fimbriate congested form with a demure apical crest.

This named form is offered as a strain since spore production is not 100% true to the parent. *Athyrium filix-femina* cultivars are not known for their reliability from spore although there are exceptions. The variations that occur from the 'Fancy Fronds' parent have all been of a superior caliber and I am pursuing further selections. One other selection already made is a form with highly developed pinnae and apical tips which I call the Frilly fronds strain. (Zones 3-8)

***Osmunda regalis* 'Purpurascens'**
purple-stemmed royal fern
Osmundaceae

Judith Jones
Deciduous; 4 to 6 ft. This is a fern of unparalleled mimicry with its sterile fronds copying the locust tree leaves and its fertile panicles echoing faded astilbe seedheads. In the spring there are curious wooly caps on the fiddleheads which detach as the unfurling progresses. This English form has purply-red new growth which is maintained on the stipe throughout the year. The thick woody rhizomes overlap and interlace, forming a dense spongy mass. Given ample root moisture the fronds will stand exposure to sun and wind with impunity.

This fern comes true from spore with few complications. Young plants respond readily to rapid potting on for maximum size in minimum time. Young sporlings may be kept from going dormant to gain growing time but once they are beyond 4-in. pot size it is best to let them have a winter dormancy. (Zones 3-9)

***Dryopteris dilatata* 'Jimmy Dyce'**
Jimmy's upright broad buckler fern
Dryopteridaceae (Aspleniaceae)

Judith Jones
Evergreen; 2 ft. This fern was just known at the nursery as an upright broad buckler fern until The British Pteridological Society (BPS) Centennial meeting in London in 1991. On that occasion the BPS*Pteridologist* editor, Martin Rickard, and I determined that it should bear Jimmy Dyce's name in honor of being its discoverer.

Here in the Pacific northwest 'Jimmy Dyce' is gaining a reputation as a top notch landscape plant. Because of its stiffly erect habit and its attractively domed caudex complimentary plantings may be meshed right up to the crown and still be clearly visible. The frond has a 3-D carved character due to the dichotomous nature of having the surface concave, curled forwards and convex, curled back at the same time. (Zones 5-9)

Dryopteris lepidopoda
sunset fern
Dryopteridaceae (Aspleniaceae)

Judith Jones
Evergreen; 1-2 ft. This is one of the most exciting ferns I brought back from England in 1991. Superficially one might say this fern bears a similarity to *D. wallichiana* while sharing the sunset tints of *D. erythrosora.* Actually *D. lepidopoda* has new fronds which begin flushing in orange-gold tones and the frond surface it lightly polished. The ovate frond is bipinnate with blunt, oblong, minutely serrate-edged pinnules and the pinnae apices echo the long acuminate fused frond apex with tips curled up like the waxed mustache of melodrama villain. The basal pinnae droop earthwards while the pair above seem undecided whether to cast their lot up or down. I truly believe this fern will become a garden classic. (Educated guess: Zones 6-9)

Fallugia paradoxa
Apache plume
Rosaceae

James F. McConnell

A small, densely branched shrub with small scale-like, gray-green leaves. It can grow to 7 ft in height and takes on a informal mound shape. The flowers are white and similar to potentilla. They appear from May through August with the heaviest bloom being in May. The flowers give way to pinkish-purple feathery plume-like seed heads. It is as attractive in seed as it is in flower.

It will tolerate dry sandy or gravelly soil, but requires good drainage. Propagation can be accomplished by seed or softwood cuttings. Seed requires no pre-treatment. Rooting of softwood cuttings can be enhanced by a quick dip in an IBA solution of 1,000 ppm. (Zone 5)

Forestiera pubescens [syn. *Forestiera neomexicana*]
New Mexico privet or desert olive
Oleaceae

James F. McConnell

This plant is native to the Southwestern U.S. from central California to Colorado and Texas and northern Mexico. It grows in lowlands and along river banks, but in relatively dry locations. The foliage is gray-green and privet-like. Tiny yellow flowers cover the branches in April and May before the leaves emerge. The main ornamental value would be as a privet substitute in droughty areas. It could be trained as a small multi-stemmed tree. Plants can be either male, female or bisexual. Those plants that produce seed have blue-black fruits which ripen in early fall.

Seed germination can be enhanced by cool moist stratification. Softwood cuttings root easily and rooting is hastened by a quick dip in IBA at 1000 ppm. (Zone 5)

Genista tinctoria 'Royal Gold'
royal gold common woadwaxen or royal gold dyer's greenweed
Fabaceae

James F. McConnell

Native to Europe and Western Asia. Its golden yellow flowers are borne in terminal and axillary racemes. It flowers from June to September but primarily in June. This is an erect plant of about 2 ft in height with fine-textured foliage. It would be considered a sub-shrub in Minnesota because it dies back to the crown each winter. It would be winter hardy in western Washington and Oregon. It does well in poor soils and dry areas.

Softwood cuttings root easily in June and July and rooting can be enhanced by treating the 4- to 5-in. cuttings with a quick dip in a 1000 ppm IBA solution. (Zone 4)

All three of these plants are xeriphytic. Many regions of our country experience droughty and poor soil conditions. These three plants should be quite usable in many of these sites.

PSEUDERANTHEMUM LAXIFLORUM

drividrivi
Acanthaceae

Fred D. Rauch

The genus *Pseuderanthemum*, a member of the acanthus family (Acanthaceae), includes about 60 tropical, cultivated, ornamental, greenhouse shrubs. *Pseuderanthemum laxiflorum* (drividrivi) is a round-headed shrub to about 6 ft or more high and as wide from Fiji with purple flowers produced much of the year. The opposite, dark green, entire, pointed leaves are 2 to 5 in. long. The plant can be grown in full sun or light shade in most well-drained soils in frost-free climates. It is useful as a specimen shrub or for color mass in the landscape. This plant was distributed to commercial growers in Hawaii by the Horticulture Department in 1986 and has become a popular plant in the landscape.

A series of studies including propagation, nutrition, light, and the use of growth regulators have been conducted on this plant. It roots readily from terminal cuttings in 3 to 4 weeks without root-promoting chemicals. It responds to relatively heavy feeding in container production and flowers best in high light. It responds well to growth regulators, but the rate must be reduced below the normal recommended rates.

A number of trials have been conducted to determine the potential for *Pseuderanthemum laxiflorum* as a flowering potted plant. These have resulted in the following recommendations:

Propagation: Direct stick 6- to 8-in. terminal cuttings, with a hard pinch, 3 per 6-in. azalea container. Remove from the mist after rooting (usually 3 to 4 weeks).

Medium: A well-drained mix, such as a 1 peat : 1 perlite (v/v) mix amended with Osmocote, Micromax, dolomitic lime, and superphosphate.

Growth regulator: Drench with chlormequat (Cycocel) at 100 mg/pot in 300 ml of water when the new shoots are 0.5 to 0.75 in. long. Top dress with 1 tsp Osmocote 14-14-14 per pot.

Environmental conditions: Maintain under relatively high light conditions. Can be finished in 3 to 4 months.

Treatment with the growth regulator results in a more compact plant, purple color to the new leaves, and a more showy inflorescence. The plant will continue to bloom under low light interior conditions for several months or until all the initiated flower buds have opened.

Trials are continuing to determine the potential of this plant as a low color mass in the landscape through the use of growth regulators to maintain a low, compact growth habit.

Arbutus andrachne

Greek madrone, Turkish arbutus, andrákla, eastern strawberry tree
Ericaeae

Warren G. Roberts

An evergreen tree standing 8 to 15 m tall with a 10 to 20 m spread. It grows slowly eventually forming a rounded crown. The leaves are simple, ovate, 12 cm long, dark green above, pale beneath, smooth, and usually entire with net venation. The white-pale green flowers are borne on a terminal panicle appearing in the spring and have a honey-like fragrance. It is monoecious with red, edible berries appearing in the fall to early spring. *Arbutus andrachne* is a low-maintenance plant tolerating some alkali and drought. Once established it requires no irrigation and can be used as a background plant, screen, specimen, or hillside plant and for shade. Red berries provide fall and winter color. Pest-free and tolerant, it will grow in acidic, alkaline, sandy, silty, clay, rocky, light, dry, well-drained, sterile, or fertile soils with an optimum pH of 7.0. Withstands half to full sun, dust, and heat and is hardy to about 0F. It is propagated by the 2 mm, ivory seeds (moist stratification for 2 months) and semi-hardwood cuttings. The most beautiful feature of this tree is its very smooth bark. Each fall the red-brown bark peels and drops away in small scrolls to reveal the pale green bark beneath, which becomes white then tan to brown and finally red. It's like a smaller and easier-to-grow, pest-free version of *A. menziesii*. The natural range of this species is the eastern Mediterranean including southeast Europe, Asia Minor and the Crimea. This tree is not new to horticulture, but is difficult to find in commerce.

Cneorum tricoccon

spurge-olive, olivilla
Cneoraceae

Warren G. Roberts

An evergreen shrub standing 1 m tall with a spread of 1.5 m. The growth rate is moderate, producing a rounded crown and natural hedge form. The leaves are simple, entire, dark green, smooth, 2 to 3 cm oblong, and arranged with an alternate leaf arrangement. The yellow flowers are solitary, axillary appearing in spring to mid-summer with no noticeable fragrance. It is monoecious having a red, non-edible schizocarp fruit appearing in fall to winter. Seeds are 4 mm long and brown. *Cneorum tricoccon* is a low maintenance plant and is alkaline, drought and somewhat saline tolerant. Once established it requires no irrigation. It can be used as a pest-free background plant, low screen, border, hedge, hillside, and possibly as a poolside rock garden, or container plant. Grows in alkaline, sandy, silty, clay, rocky, light, dry, well-drained, sterile or fertile soils with an optimum pH of 7.0. Tolerates half to full sun, dust and heat and is hardy to about 10F. It is propagated by seed and semi-hardwood cuttings. The best use of this shrub is as a low hedge for dry gardens, especially in part shade or full sun. If placed correctly, it should need little or no pruning. Its bright yellow flowers and red fruit add subtle but attractive color for most of the year. Medicinally, it is one of the best rubefacients, all parts are rich in tannin, and all parts are "revulsive" and "violently purgative". In the wild this is a shrub of the western Mediterranean from the Italian and French Riviera west into Spain.

Urginea maritima
sea squill, cebolla-albarrana
Liliaceae

Warren G. Roberts

A herbaceous, perennial standing 2 m tall (in bloom) with a 1 m spread growing from a very large tunicate bulb. The leaves are narrowly ovate, 10 cm wide and 40 cm with parallel venation, long, entire, dark, glaucous green, and smooth arranged in a basal whorl. The white, pink, or pale yellow flowers are borne on a narrow raceme in late summer. They are monoecious and produce dry, tan, non-edible capsules (three-valved, loculicidal) in the fall containing 1 mm, black seeds. *Urginea maritima* is a low maintenance plant and is alkali, saline, and drought tolerant. Dramatic for background, specimen, container, or hillside plant use, it is also pest-free. It grows in alkaline, sandy, silty, clay, rocky, light, heavy, dry, well-drained, sterile or fertile soils with an optimum pH of 7.0. Tolerates half to full sun, salt spray, smog, dust, and heat and is hardy to 20F. Propagation is by seed, division, and bulb scales. This is an excellent substitute for *Eremurus* in Mediterranean climates and makes a perfect tall accent for the perennial border. Leaves are produced in the fall through spring, deciduous and dormant in summer, flowers in late summer when leafless. The top of the bulb should not be buried. The plant contains medicinal glucosides that have been used as a cardiac stimulant, diuretic as well as a rat poison. Its natural range extends from the Portuguese shore and along the Mediterranean to Syria, also the Canary Islands and South Africa.

Conradina verticillata
Cumberland Mountain rosemary
Lamiaceae (Labiatae)

Chris Santana

An evergreen shrub with a moderate growth rate to 30 to 45 cm tall and 30 to 45 cm wide. The leaves are simple, linear, entire, arranged in whorls. The pink-lavender inflorescence is arranged as a whorl and appears in June. Its fragrance is similar to rosemary. *Conradina verticillata* is a low maintenance plant useful in rock gardens. It grows in well-drained soils and tolerates half to full sun and heat in Zone 5. It is propagated by cuttings. This plant is a threatened species and a federal permit is required to propagate and sell it interstate or overseas. It may only be produced asexually.

***Hydrangea macrophylla 'Pia'* PINK ELF™**
pink elf™ miniature French hydranga
Hydrangeaceae

Chris Santana

A deciduous shrub standing 40 cm tall with a 40 cm spread. It grows fast into a rounded form. Leaves are simple, broadly ovate, green, serrate with pinnate venation, and arranged in an opposite leaf arrangement. The inflorescence is a rich pink cymose corymb appearing in July to August. The fruit is a capsule containing 3 to 5 mm seeds. *Hydrangea macrophylla* 'Pia' Pink Elf™ is a low maintenance plant useful as a foliage accent or in borders. It grows in acidic, organic, moist or well-drained soils, and tolerates half to full sun in Zone 7. It is propagated by cuttings. It maintains its rich pink flowers in acidic soils. It is a branch sport of *H. macrophylla*.

Phlox subulata 'Candy Stripe'

candy stripe creeping phlox
Polemoniaceae

Chris Santana

An evergreen shrub standing 15 cm tall with a 1 m spread. It grows moderately fast into a low-lying mat. The leaves are simple, linear to subulate and green arranged in an opposite leaf arrangement. The inflorescence is 2 to 3 cm wide, non-fragrant, white with pink brush strokes and appears in April. *Phlox subulata* 'Candy Stripe' is a low maintenance groundcover. It tolerates full sun in Zone 3 and is propagated by cuttings. This plant came from Woodbank Nursery in Tasmania, Australia where it is known as *P. subulata* Tamandnagalei.

Bupleurum fruticosum

shrubby hare's ear
Apiaceae (Umbelliferae)

Barbara Selemon

The first plant I would like to introduce is *Bupleurum fruticosum*, commonly named shrubby hare's ear. It is a broad-leaved evergreen plant native to Southern Europe and the Mediterranean region. First introduced to England over 300 years ago, it is still rare in European and in U.S. gardens. Hardy to Zone 7, it grows into a rounded globe that reaches an ultimate diameter of 6 to 8 ft. It is fast growing, achieving up to 3 ft of new growth per year. It has handsome, shiny blue-green foilage. New leaves are duller and lighter in color becoming dark, shiny green with age. The leaves are long, entire, strap-like, and 1 to 2 in. wide with a prominent midrib, held on glaucous stems. In summers, nearly all terminals carry umbels of yellow flowers up to 4 in. across, a soothing contrast to the blue-green foilage. *Bupleurum fruticosum* is drought and salt tolerant. It prefers a well-drained soil, as well as some shade. Winter shade is a real benefit in protecting it from sunscald on bright sunny days when the temperature dips below freezing. It responds very well to pruning which is required when grown in containers to keep the gangly, sprawling new stems in bounds. It has no known pest nor disease problems. In the landscape it can be useful in a variety of settings, such as, sunny banks, dry shade, rockeries, underneath larger shade trees, as well as in the mixed perennial border. Its color contrasts well with darker greens and purples, as well as with white-foliaged plants. In the shadier areas, it provides a bolt of color when in bloom. It is easily propagated by seed, which the self-fertile plants produce in abundant quantities. A 1- month cold-moist stratification period hastens and evens germination. Vegetative propagation using softwood to semi-hardwood cuttings is also successful. Using a liquid hormone, Dip 'n Grow 10 : 1 ratio, in a pumice/peat medium under mist produced good results last September. The fast growth rate of *B. fruticosum* makes it both a quick-selling container plant as well as a rapidly maturing plant in the new landscape. I highly recommend *B. fruticosum* as a new plant for the nursery trade, especially one in which unusual shrubs and/or drought-resistant plants are favored.

Nothofagus antarctica 'Puget Pillar'

Puget pillar Ñirre
Fagaceae

Barbara Selemon

The species,*Nothofagus antarctica* is a southern beech, native to the volcanic peaks of Chile as well as to the arid landscapes of Patagonia and Argentina. It is a deciduous tree of medium size, with alternating 1 in. long broadly ovate leaves. The leaves are set in a singular plane, which produces a layered, distinctive look that is particularly handsome on younger trees. More mature specimens develop an open habit which makes them look sparse overall. The Washington Park Arboretum has selected a clone that is broadly fastigiate, with dense, upward-growing foilage. This new clone retains many of the characteristics of the species, but it has a denser, fuller crown and upright form, making it a more desirable tree for the urban landscape. Mature trees can reach a height of 40 to 50 ft with an 18 to 20 ft spread. This clone came to the Washington Park Arboretum in 1951, received as three trees from Hilliers' Nursery in Winchester, England. One of these original clones, as well as cuttings made from the original, are part of the arboretum's collection. These mature trees have never suffered serious crotch or crown damage, even during the heavy, wet snowfall experienced during various winters in Seattle. In the U.S., 'Puget Pillar' is best adapted to the Western sections of Zone 7 or above. Open sunny areas are recommended; however, 'Puget Pillar' will tolerate shade. Supplemental irrigation is not necessary, except for extreme drought conditions. British specimens of *N. antarctica* are known to do poorly in calcareous soils; therefore, we can assume that it would respond adversely to similar situations in the U.S. No serious pest problems have occured on 'Puget Pillar' in the arboretum; however, the grounds staff have reported finding small populations of leaf hoppers in late summer. *Nothofagus antarctica* 'Puget Pillar' is propagated by semi-hardwood cuttings, taken in late summer, using a liquid hormone, Dip 'n Grow 10 : 1 ratio, in a peat/pumice medium under mist. It is fairly fast-growing, averaging 2 to 3 ft of growth per year in the container nursery. It would make a suitable tree along roadways or in small spaces requiring narrow foilage. I highly recommend it for the urban landscape.

Magnolia virginiana (evergreen selection)

evergreen sweet bay
Magnoliaceae

Arthur Lee Jacobson

An evergreen shrub or tree standing 10 to 15 m tall with a 5 m spread. It grows moderately into a large shrub or slender, arching small tree. The leaves are simple, alternate, elliptic with entire margins, glossy green above and matte whitish-blue beneath. The flowers are borne singly, rosy-lemony fragrance, creamy-white appearing in June, July, and September. *Magnolia virginiana* is a useful as a foliage accent, background, multi-trunk, pest-free specimen plant. It grows in acidic, loam, clay, wet, organic, moist, fertile soil and tolerates full sun. It is propagated by seed and grafting. It is commonly grown as nondescript, usually deciduous, seedlings. Evergreen selections are much superior ornamentals. 'Henry Hicks' is the most familiar evergreen clone. Much selection and research on propagation is still needed.

Sorbus sargentiana

Sargent mountain ash
Rosaceae

Arthur Lee Jacobson

A deciduous tree standing 5 to 13 m tall with a 5 m spread. It has a broad, upright form and a slow growth rate. The leaves are compound with 9 to 11 leaflets, sharp-toothed, dark-green above and pale beneath in an alternate leaf arrangement. The berries are tiny and produced in enormous clusters of sometimes more than 200. The inflorescence is a fragrant, creamy-white corymb appearing in May. *Sorbus sargentiana* is a low maintenance plant and can be used as a foliage accent, specimen, pest-free plant with red late fall color. It will grow in acidic, organic, heavy, clay, fertile, or well-drained soils. It's adapted to full sun exposures. It is propagated by seed budding and grafting. Sargent Mt. Ash was introduced from west China to the U.S. in 1908 by E.H. Wilson. Overall, it is very rare and little known. It is unlike familiar *Sorbus* species, as it bears large, red, sticky buds as in *Aesculus hippocastanum*, and its foliage is so bold as to remind one of members of the Juglandaceae.

Intermittent Sprinkler Irrigation Reduces Water Loss from Container-Grown Plants

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Water application efficiency can be improved by approximately 4% to 10% via intermittent irrigation. However, efficiency, regardless of application method, is primarily a function of pre-irrigation moisture content and the volume of water applied; efficiency decreases as volume and substrate moisture content increases. For pine bark, relatively high efficiencies can be achieved if irrigation occurs when the pre-irrigation substrate moisture content is below 88% and the volume of water applied does not exceed 300 ml (0.32 qt).

INTRODUCTION

Overhead sprinkler irrigation is the predominant system to irrigate plants grown in small containers (12 liter, 3 gal). Due to the relatively porous nature of soilless substrates, a significant fraction of the applied water leaches from containers. Intermittent irrigation, application of a plant's daily water allotment in more than one application with prescribed intervals between applications, is an irrigation strategy to reduce the amount of water and fertilizer lost from containers following irrigation. Intermittent irrigation was first proposed by Karmeli and Peri (1974) working with mineral soil and was termed "pulse irrigation." Since the commercial irrigation industry uses the term pulse irrigation for a specific water delivery mechanism, this paper will use the term intermittent irrigation. Intermittent irrigation has been shown to increase water application efficiency of spray-stake-irrigated plants compared to applying the daily water allotment in a single continuous application (Lamack and Niemiera, 1993), but no work has occurred with sprinkler irrigation. Thus, the objective of this overhead sprinkler irrigation project was to determine how water application efficiency was influenced by the duration of the interval between intermittent applications and by pre-irrigation substrate moisture content.

MATERIALS AND METHODS

A simulated overhead sprinkler irrigation system delivered water at 1.4 cm/h (0.55 in./h) to containers. Pine bark (PB) was amended with sand (S), 9 PB : 1 S (v/v), and dolomitic lime at 0.19 lb/ft^3 (3 kg/m^3). Approximately 3.5 liters (3.7 qt) of substrate were added to each 3.8 liter (1 gal) container. Marigold (*Tagetes* 'Apollo') seedlings were transplanted into substrate-filled containers and greenhouse-grown. Plants were fertilized with Osmocote 14-14-14 (0.7 oz/container) and hose irrigated as needed until the commencement of the experiments. Plants facilitated removal of water from the container via evapotranspiration (ET) to prescribed container moisture levels prior to irrigation treatments. After irrigation treatments (to be discussed), leachate was collected and water application efficiency computed using the formula: [(vol applied - vol leached) $\div$ vol applied] $\times$ 100. Treatments were replicated at least six times.

Time Interval Between Intermittent Applications. Water was applied continuously (single application) or intermittently in which three applications (each one-third of ET) were applied with 20-, 40-, or 60-min intervals between applications. Containers were weighed when fully wet (weight before ET) and before irrigation (weight after ET). The volume of water applied was the difference between wet weight and weight before ET. Pre-irrigation moisture content ranged from 73% to 94% of container capacity (CC) and the volume of water applied (= ET) ranged from 66 to 663 ml (0.07 - 0.7 qt).

Substrate Moisture Distribution After Irrigation. Two hundred and seventy-five ml (0.3 qt) were applied continuously or intermittently in which 33%, 66%, or 100% of the 275 ml was applied in one, two, or three applications, respectively. Each intermittent application was one-third (92 ml) of the total volume and interval duration between applications was 60 min. Leachate volume was measured at the end of each interval just prior to the start of the next application to determine efficiency of each application. After the last application in both continuous and intermittent treatments, containers were covered, drained for 45 min, weighed and leachate volume measured. Substrate in each container was transversely tri-sectioned into approximate equal sections (5 cm, 2 in). After removing roots,

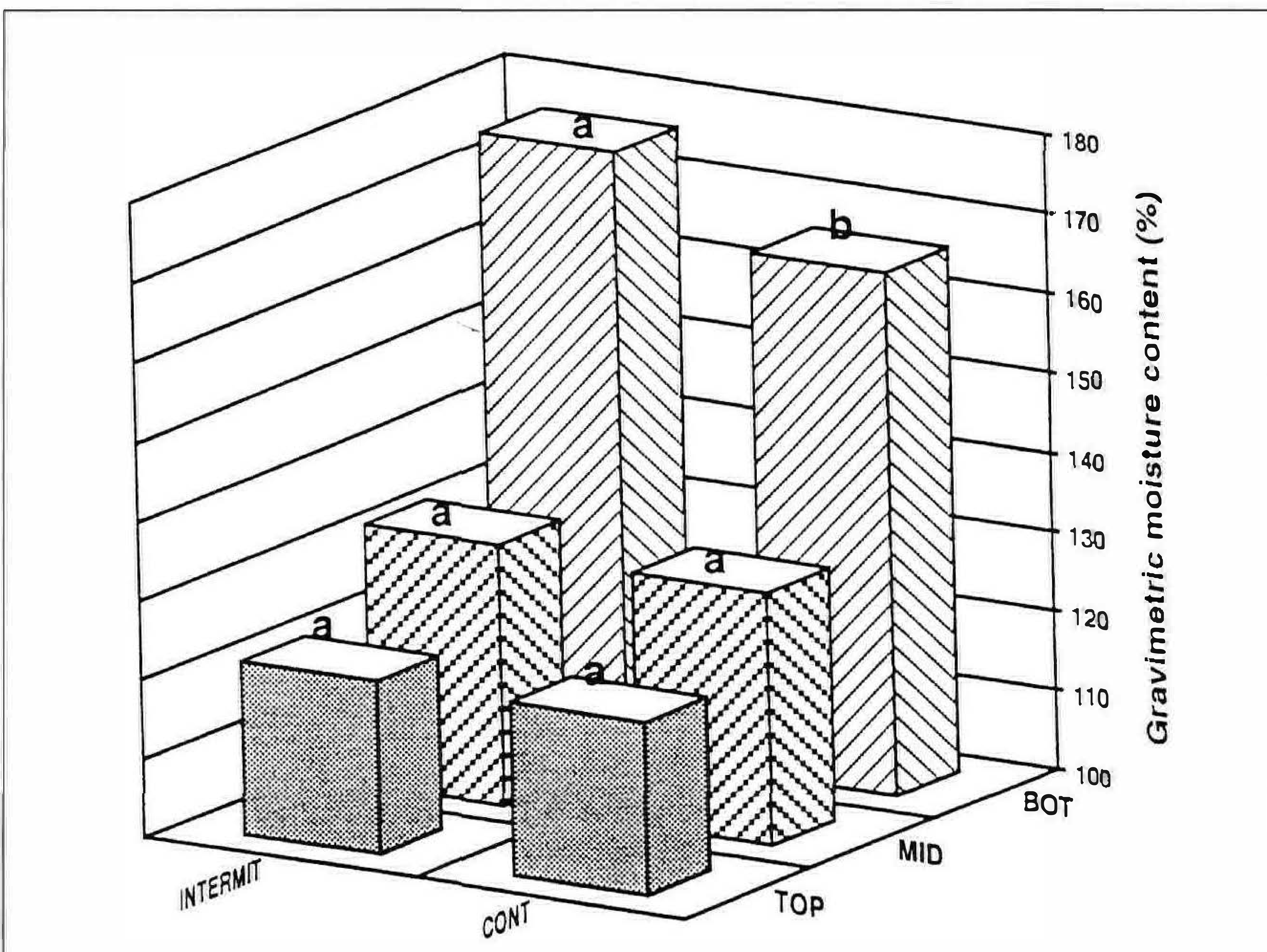

Figure 1. Gravimetric moisture content (%) of top, middle (MID), and bottom (BOT) sections of a 9 pine bark : 1 sand (v/v) substrate after receiving the same volume of water continuously (CONT) or in three intermittent (INTERMIT) applications. Letters above columns indicate section differences between continuous and intermittent irrigation at P = 0.01 (Substrate moisture distribution after irrigation, Expt. 1).

substrate in each section was mixed thoroughly and a sub-sample of each section was weighed then oven-dried to determine gravimetric moisture content.

RESULTS AND DISCUSSION

Time Interval Between Intermittent Applications. There was a positive linear relationship between irrigation efficiency and interval duration between intermittent applications (Table 1). Results are in general agreement with a trickle irrigation study (pine-bark-filled 11-liter container) in which irrigation efficiency increased by 10% (absolute basis) when interval duration increased from 20 to 40 min (Lamack and Niemiera, 1993). Increasing the interval duration between irrigations decreased the time averaged application rate (TAAR). As interval duration between intermittent applications increased, the time for water to move through the substrate and enter micropores was increased and thus allowed for more absorption of water by the medium As substrate moisture content and volume applied increased, leachate volume decreased (Table 2).

Substrate Moisture Distribution After Irrigation. Following irrigation, regardless of irrigation treatment, gravimetric water content increased with increasing substrate depth (Fig. 1) which was expected due to the greater gravitational force acting on the top third than on the bottom third of the container (Bilderback and Fonteno, 1987, Spomer, 1990). Only the bottom third collected more water with intermittent irrigation compared to continuous. The likely reason that the bottom third collected more water (9%) is that the intermittent time intervals between irrigations allowed water to be adsorbed to less accessible micropore sites and absorbed into intra-particle sites

Table 1. Influence of continuous (single application) versus intermittent (three applications with 20-, 40-, or 60-min intervals between applications) irrigation on application efficiency

Irrigation treatment	Application efficiency (%)	Time averaged application rate (cm/h)
Continuous	85	1.40
20 min	87	0.73
40 min	89	0.50
60 min	91	0.38
Significance[z]		
Linear	***	-
Quadratic	NS	-
Cubic	NS	-

[z] NS,*** Nonsignificant or significant at P = 0 001, respectively, n = 42.

Table 2. Volume of water leached for intermittent and continuous irrigation as influenced by irrigation volume and substrate pre-irrigation moisture content (% of container capacity)

Volume applied (ml)	Volume leached (ml) Pre-irrigation moisture content (% CC)			
	73	80	87	94
		Intermittent		
125	0	0	0	75
250	0	0	57	149
375	0	34	125	223
		Continuous		
125	0	0	0	79
250	0	0	70	167
375	0	55	152	255

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Reduction of Nitrates in Nursery Surface and Ground Water

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INTRODUCTION

Nitrogen is an essential element in the production of plants. Management of nitrogen to prevent surface and ground water contamination will be affecting all nursery operations in the future. Some nurseries have already had to address this problem. Nurseries provide a product that is a benefit to the environment, but past and current fertility practices have created environmental problems. Federal and state governments are examining nitrate sources in agriculture and commercial agriculture will most likely be looked at more closely than family farms. Potential problems and some solutions in greenhouses, fields, and container areas will be discussed. Examples of what Evergreen Nursery is doing to combat these problems will illustrate what has been done in one operation.

GREENHOUSES

Nitrate contamination of surface or ground water has not been considered to be a serious problem in greenhouses. Large numbers of plants are grown in a relatively small area. High plant density and lack of rain leaching nutrients caused little nitrate to leave the greenhouse. However, recent studies have shown nitrate concentrations in the top 3 ft of soils under some benches to exceed 2000 pounds of nitrogen per acre in decades-old greenhouses (Mcavoy et al., 1992).

Nitrate loss from greenhouses can be reduced by altering the method and types of nitrogen applied Monitoring fertility levels in the growing medium and applying nitrogen only when the electrical conductivity (EC) or soil test falls below the level required for the crop is necessary to avoid excessive loss. Research to determine the necessary level of nitrogen may be necessary. Sub-irrigation where benches or floors are flooded during irrigation captures and reuses water and nutrients thus eliminating loss. Designing greenhouse floors to capture and reuse runoff will reduce nitrate loss Drip irrigation is another efficient way to irrigate plants. Water and nutrients are applied only to the pots and not the surrounding surfaces. Slow-release fertilizers release nitrogen directly to the medium, eliminating loss caused by irrigation runoff from the foliage and surrounding surfaces. The simple practice of repairing leaky hoses and pipes will reduce nitrate loss from greenhouses.

At Evergreen Nursery, we have worked at reducing nitrate loss by monitoring the EC in our greenhouse crop media. This has reduced the frequency of injection feed during irrigation. It is very important to closely monitor crop growth. We have seen a reduction of growth when EC levels dropped below what the crop requires.

FIELD

Field fertility recommendations in the past were designed to provide a high level of nutrients to the crops at all times It was more cost effective to apply additional nitrogen beyond the crops needs to prevent the financial loss of underfed and undersized plants. With the knowledge that the potential for surface and ground water nitrate contamination exists, new recommendations are necessary to determine the most efficient level of nitrogen needed to grow the crop.

Development of a fertility program requires an understanding of the needs of the specific crop. consulting universities and other growers is helpful. The form of nitrogen, method of application, timing of application(s), and irrigation program should all be considered. Regular soil sampling may be necessary to determine the correct nitrogen loading. Sampling in and below the root zone will provide information on nitrate loss from the field. Identifying the actual nitrogen removal by a crop will help determine nitrogen needs. A conifer seedbed study showed that 152 to 265 lb of nitrogen per acre was removed from the soil (Iyer et al., 1989). Crop density, type of crop and weather will affect nitrogen removal.

Nitrogen loss can be reduced using drip irrigation, arranging planting beds and fields to prevent excessive runoff and filling sink holes that provide an open conduit to the ground water. Knowing the current nitrate levels in the ground water and the direction of flow is information that can affect the amount of nitrogen that is applied annually to a crop.

Evergreen Nursery has done extensive work to reduce soil and ground water nitrates. In 1989 a fertility management study plan was developed by Evergreen Nursery to provide the State of Wisconsin with data for nitrate management on our site. The birch crop was used to determine the most efficient form and level of nitrogen to apply to the crop. Test plots were set and monitoring wells installed upgradient, two in fields of different nitrogen loadings and one down gradient. Nitrogen was applied in organic and inorganic forms to the test plots. Soil was sampled at 0 to 10 in. and 10 to 18 in. Ground water was sampled every two weeks.

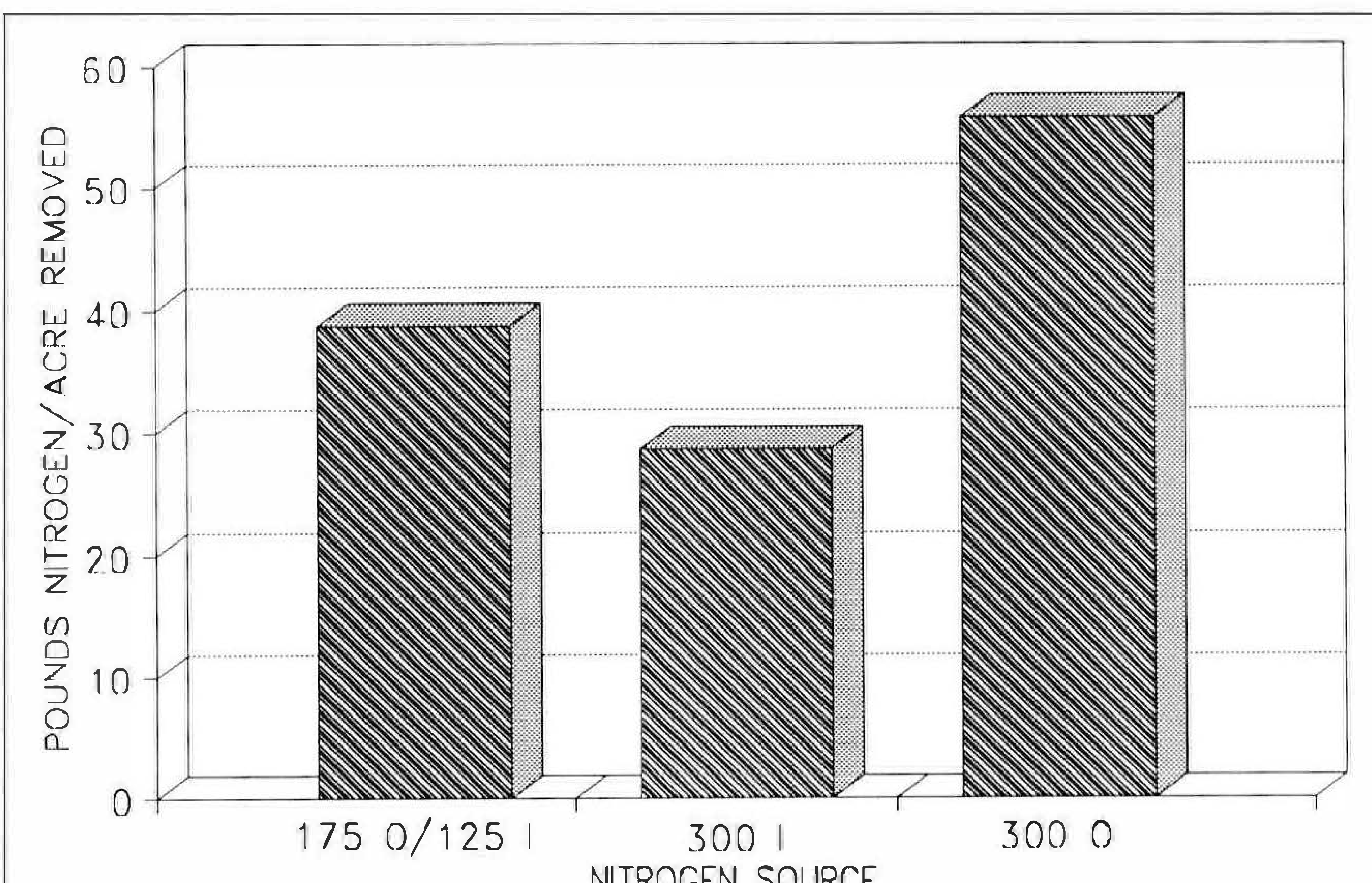

Figure 1: Nitrogen removal by crop. Organic vs inorganic nitrogen.

Plants were harvested at different times during the growing season and at the end of the season and analyses performed to determine nitrogen uptake and removal. The crop was measured annually to determine the effect of nitrogen on growth. Irrigation was modified to put less water on more often to prevent leaching of nitrates.

Soil and ground water sampling is ongoing. Monitoring wells have shown a steady decline in nitrates Soil nitrates have decreased with a decrease in nitrogen loading. The form of nitrogen applied has affected both the soil nitrate levels and dry weight accumulation (Fig. 1). The initial loading rate of 300 lb/A of nitrogen in 1989 was reduced to 150 lb/A in 1990, this caused a decline in growth (Fig. 2) and nitrogen loading was raised to 200 pounds per acre in 1991. In 1992, all plots were fertilized with organic nitrogen applied as Milorganite.

Conifer field plantings have had nitrogen reductions and applications are timed to provide nutrients at the estimated time of optimal uptake. The county soils and water conservation department is working with us on a plan to further reduce our runoff and prevent surface and ground water contamination.

CONTAINERS

Container growing areas are a major concern for nitrate runoff Container media differ from soils in their ability to hold water and nutrients, usually requiring greater inputs of both. Spaced containers occupy only a part of the total surface area. Injection feed systems may waste up to 75% of the nitrogen applied between the pots. Slow-release fertilizers applied directly to the pots eliminate nitrogen between pots, but the irrigation frequency and need to flush water through the pots causes irrigation runoff. Medium rate applications of slow-release fertilizers

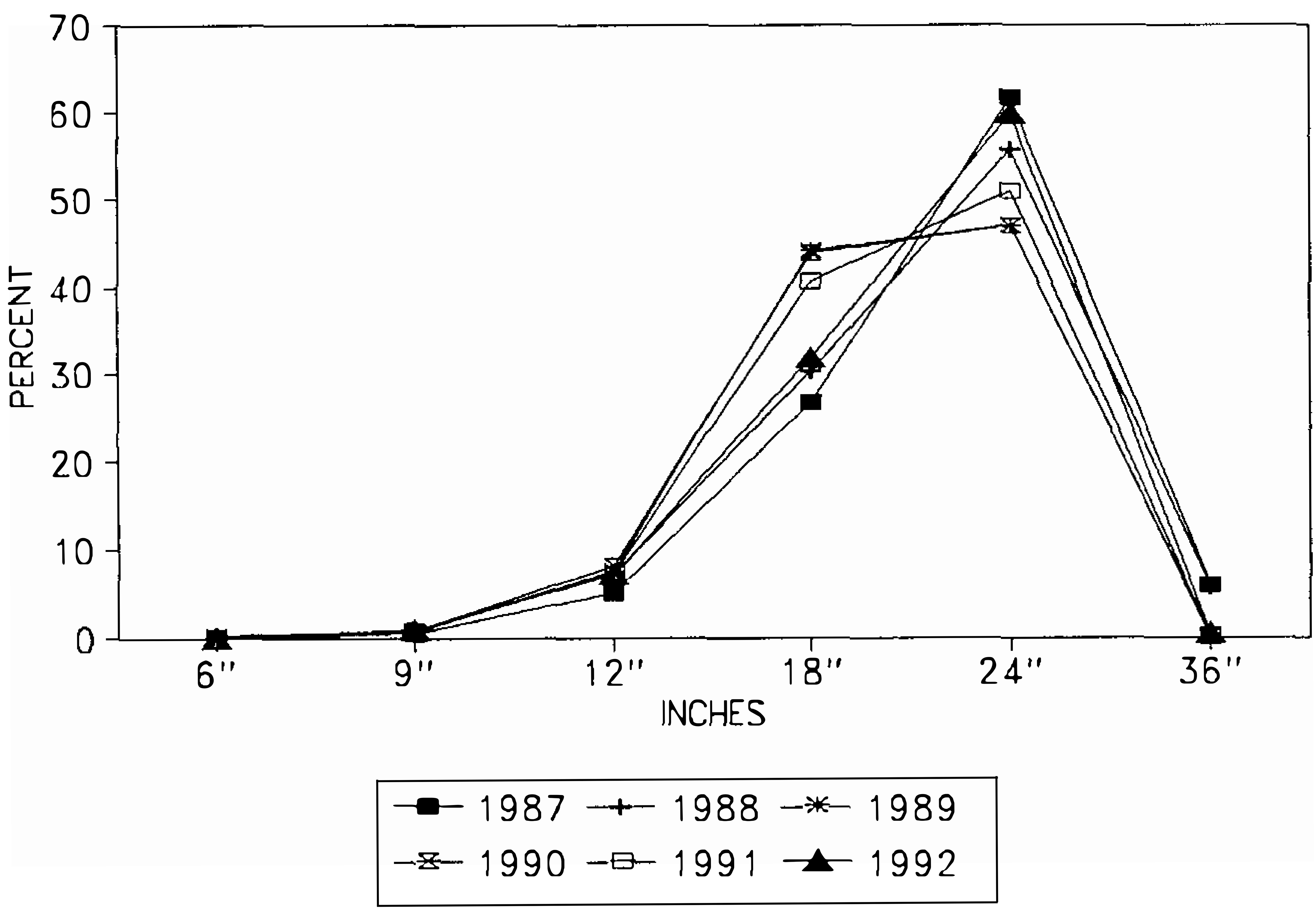

Figure 2: Birch size by year.

applied to un-spaced pots can represent nitrogen loading rates of over 800 lb of nitrogen per acre.

Reducing nitrate loss in containers is in some ways more complex. Efficient irrigation systems are as important as nitrogen application. Application of water through drip irrigation reduces total water use and runoff Sub-irrigation contains and reuses irrigation water. Watering based on plant need instead of a schedule can also reduce irrigation loss Altering media for greater water holding capacity will reduce the irrigation frequency. Wetting agents can increase the rate of water absorption to reduce the length of irrigation.

The method of reuse or disposal of irrigation water will determine the nitrates leaving the container area. Reuse of irrigation water can be done by designing areas so water is collected, treated, and reapplied This is basically a closed system that can be expensive and may not be possible for many growers. Disposal of irrigation water can be done by draining container areas to evaporation ponds. Collected water could be land applied to other crops. Wetlands have been looked at as way of reducing nitrates from runoff. Wetlands have been constructed to reduce nitrates and filter water. Municipal treatment systems could treat irrigation water, though this would not be practical in may areas.

At Evergreen Nursery the container operation has switched from injection feed to slow-release fertilizer with injection feed backup. Water-holding capacity of the growing medium was increased. To determine how much nitrate nitrogen was leaving the container area, pot stands were set up in different locations of the container area to collect irrigation run-off from the pot and area surrounding the pot. Samples were collected from slow-release pots and from injection-feed pots. Nitrate run-off in slow-release fertilizer plots averaged 8.6 mg/liter nitrate nitrogen and in injection-feed plots 69.3 mg/liter nitrate nitrogen This proved the benefit of slow-release fertilizers but also provided data on the loss of nitrates from the container area.

Slow-release fertilizers are effective products in providing plant nutrients. In 1992 we had a cooler than normal year The slow-release products did not release fast enough to provide adequate fertility to the crop. Injection feed was necessary to supplement the nutrition. This reinforces the need to collect and control the runoff from container areas. In 1993, containers were placed on a growing area that has a monitoring well. Ground water nitrate data and soil nitrate data is being collected to determine the effect slow-release, fertilizer-fed containers has on the site. Evergreen Nursery in currently working with engineering consultants, soil conservation departments, and state agencies to develop the best possible management plan for our nursery.

CONCLUSION

Reduction of nitrates in surface and ground water in nurseries is a complex problem. The best approach is to collect as much information as possible about the nursery and surrounding area. Determine groundwater nitrate levels by testing irrigation wells. Ask the local geological survey for direction of ground water flow to see what other sources are influencing the ground water. If government becomes involved, work with them to accumulate information on needs of your crops It may be up to the nursery to educate the government agency on nitrogen usage.

Nurseries provide an environmentally positive product, and with education and research the production of the products can be environmentally positive as well.

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Effects of Biocontrol Agents on Plant Growth

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Soilborne root diseases frequently limit the growth and survival of plants propagated in nurseries as well as field-grown crops The first level of defense against such diseases has been the application of chemical pesticides marketed for the control of root diseases. The number and availability of such chemicals, however, has dwindled in recent years because of human health risk and the high cost of registration and re-registration. This has forced the search for viable alternatives, including improved cultural practices and biological controls. A few biocontrol agents are available to nurserymen, but most have been developed for use in food crop production, and little is known about their efficacy in nurseries My research program is dedicated to developing improved strategies for finding and characterizing effective biocontrol agents for application in nurseries. This report is to describe some of the effects of the biocontrol agents on plant growth discovered during this research

BIOLOGICAL CONTROL OF PLANT PATHOGENS

Biological control of plant pathogens, in this case root pathogens, is the use of one or more biological processes to lower inoculum density of the pathogen or reduce its disease-producing activities (Baker and Cook, 1974). Biological control of root diseases is usually the result of the activities of bacteria, actinomycetes, or fungi living and functioning on or near roots in the rhizosphere soil. These microorganisms may be resident in the soil or medium before planting or be introduced at or after planting. They may inhibit root pathogens by antibiosis (production of antibiotic chemicals), by parasitism (direct attack and killing of pathogen hyphae or spores), or by competing with the pathogen for space or nutrients, sometimes by producing chemicals such as siderophores which bind nutrients (such as iron) needed by the pathogen for its disease-causing activities. Microorganisms that suppress fungal root pathogens are everywhere in soil and organic substances, but their numbers may be insufficient to completely suppress pathogens at the time and place where initial infections occur. The strategy of biocontrol research is to find effective antagonists and apply them in high numbers at the potential infection site before pathogen ingress.

FINDING CANDIDATE ANTAGONISTS

Antagonistic bacteria and fungi are present everywhere. We have developed strategies for finding and characterizing these organisms using principles that are fundamentally logical and that have support from some successful examples of biocontrol (Linderman et al., 1983). We have isolated bacteria and actinomycetes from soils or potting media components (peats, composts, etc.) by dilution plating soil solutions (treated first at 50C for 15 min to eliminate all but hardy spore-forming bacteria or actinomycetes) on weak nutrient media and overspraying with spores of test pathogens, such as *Thielaviopsis basicola* or *Cylindrocladium* *scoparium*. Bacterial colonies that show a zone of inhibition of the pathogen are isolated and further tested on several media, at different temperatures, and against several other pathogens including species of *Phytophthora*, *Pythium*, *Rhizoctonia*, *Verticillium*, and *Fusarium*. Bacteria that show promise throughout these tests are studied further to characterize their mode of activity and their efficacy in greenhouse and field tests, applied singly or in combinations with other bacteria or with mycorrhizal fungi. Our studies indicate that the number and inhibitory capacity of antagonists increases in rhizosphere soil, especially in the presence of mycorrhizae (Linderman and Marlow, unpublished results; Meyer and Linderman, 1986).

CHARACTERIZING CANDIDATE ANTAGONISTS

In the course of evaluating candidate antagonists against root pathogens, we have discovered that many bacteria have more than one mechanism of inhibiting fungal pathogens. Sometimes the same bacterium can produce specific antibiotics, Fe-chelating siderophores, and volatile inhibitors, one or all of which can contribute to the suppression of root pathogens. The discovery that many rhizobacteria produce volatile inhibitors, given an appropriate substrate, is a new finding. We have identified the volatile as ammonia gas (NH_3) (Linderman and Marlow, 1992a), and have shown its effectiveness in inhibiting many root pathogens, especially *Phytophthora* and *Pythium* We have developed seedling assays to test candidate antagonists against the black root rot pathogen, *T. basicola*, and the widespread root pathogen, *Phytophthora cinnamomi*. A relatively low proportion of candidate antagonists identified from *in vitro* tests show activity in preventing seedling disease and the degree of protection varies from complete to low. Nearly all the candidate bacteria we have tested, however, show remarkable capacity to enhance plant growth in the absence of the known pathogens. It is this unexpected benefit that is the point of this report.

PLANT GROWTH ENHANCEMENT BY BACTERIAL ANTAGONISTS

We have observed plant growth enhancement in the absence of known pathogens since 1981 (Linderman and Malajczuk, unpublished results), but were unsure of the significance until more reports appeared in the literature (Broadbent et al., 1977, Burr and Caesar, 1984; Chanway and Holl, 1992) and we continued to make such observations in recent studies (Linderman and Marlow, 1992b). In all these studies, we have inoculated plants, usually seedlings, with a suspension of cells of candidate bacteria. In some cases, we have incubated the bacteria on the plant roots for some time before challenging the plants with the root pathogen. In other cases, we inoculated a group of plants with bacteria alone to compare growth with that on plants also challenged with the pathogen In either case, several weeks after inoculating with the bacteria, we observed improved growth compared to the non-inoculated controls (Table 1). There seems no doubt these bacteria grow on the roots of the test plants and produce some metabolite therein that stimulates growth beyond that of non-inoculated control plants. There is often considerable variation in the degree of response by replicate plants given the same treatment, and also some apparent specificity between bacteria and plant species. Undoubtedly, the growth conditions also influence the magnitude of response (Schroth and Becker, 1990). The challenge is to identify the mechanism of activity and to develop the technology to exploit this phenomenon in the propagation of plants.

Table 1. Effects of inoculation with bacterial antagonists on total weight and number of flowers of petunia plants grown for 8 weeks under greenhouse conditions (unpublished data of Linderman and Marlow).

Antagonist treatment	Total plant weight (g)	Number of flowers
9921	3.60 a	5.70 abc
B8	3 53 a	5 60 abc
9620	3 52 a	5.20 abc
9684	3.44 ab	5.50 abc
9645	3 34 abcd	4 40 bcde
6109	3 31 abcd	5 10 abcd
J51	3.30 abcd	6.40 ab
9691	3.29 abcd	5 70 abc
9952	3.28 abcd	7 00 a
9623	3 18 bcd	4 60 bcd
9938	3. 14 bcd	4.50 bcde
MS	3 13 bcde	3 80 cde
K18	3 03 cde	2 90 de
Control	2 82 e	2 30 e

* Values followed by the same letter are not significantly different

MECHANISMS OF PLANT GROWTH ENHANCEMENT BY BACTERIAL ANTAGONISTS

Several mechanisms for plant growth enhancement by bacterial antagonists have been proposed in the literature:

- Suppression of deleterious microbes that produce toxins that limit plant growth—their suppression by the inoculated bacterium allows plants to grow closer to their genetic potential,
- Production by the bacteria of growth regulating (phytohormonal) substances that directly stimulate plant growth,
- Increased availability of nutrients that may be limiting plant growth, and
- Induced changes in the microbial composition of the rhizosphere that favor growth-stimulating microbes. The mechanism involved remains in question and is the subject of on-going studies.

CONCLUSIONS

Our results clearly support the contention that antagonistic rhizobacteria, by some means, do influence plant growth. If one were to try to manage this rhizosphere phenomenon, early inoculation of plant propagules (seedlings or rooted cuttings) appears to be necessary. Until the mechanisms of activity are known, it will be difficult to predict potential benefits from inoculation. Perhaps inoculation with combinations of bacteria or combinations with mycorrhizal fungi will come closest to simulating natural conditions of the mycorrhizosphere.

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A Protected Diffusion Zone (PDZ) to Conserve Soluble Production Chemicals

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Inefficient, repeated applications and waste discharge of agricultural production chemicals can be curtailed if means, such as the protected diffusion zone (PDZ), are provided to retain the chemicals within the plant root zone and to deliver them at appropriate times in adequate concentrations to meet requirements for plant growth and pest control. Application of fertilizers and pesticides in the PDZ of the closed, insulated pallet system (CIPS) or in the "Conserver" within the open plant root zone will decrease waste discharge of the applied, soluble chemical, e.g., potassium nitrate or Subdue.

INTRODUCTION

Inefficient application and waste discharge of fertilizer and pesticides from agricultural production areas is a worldwide concern. Methods to target delivery and retain effective plant-available concentration of applied agricultural chemicals in the plant root zone decrease quantities applied and discharged

In open root zone systems (ORS) with evaporative top surface and a draining bottom surface, flowing water moves through, dissolves, and convects fertilizer salts. A major portion of the fertilizer may be rapidly convected away as leachate before it can be intercepted and taken up by plant roots. Conversely, upward movement of water in the root zone in response to surface evaporation carries dissolved salts to the surface where they accumulate as salt deposits.

In surface irrigated fields and containers (open root zone systems), fertilizer is rapidly convected or flushed in the irrigation water. The movement of fertilizer by chemical diffusion in these "flushing" systems is insignificant. However, diffusion is the primary mode for movement of soluble fertilizer within a zone shielded or protected from gravitational and evaporative water flow. The rate of movement of fertilizer ions by chemical diffusion is very slow compared to the rate of convective movement. This slow rate of diffusion of ions within a protected diffusion zone (PDZ) allows time for root growth into the PDZ and efficient interception/uptake of the ions prior to their diffusion beyond the PDZ. The process embodied in the Fertilizer Apparatus, U.S. patent number 5,212,904, is the "protected diffusion zone." The PDZ of the closed, insulated pallet system (CIPS) and the PDZ of the

Conserver are designed to protect fertilizer ions and other water soluble chemicals of environmental pollution concern (e.g., nitrates) from convection in leaching and evaporative water flow.

RESULTS AND DISCUSSION

The Protected Diffusion Zone. The "protected diffusion zone" is a 3-dimensional zone or volume within the plant root zone (soil or container media) with a moisture-impermeable material enclosing the top and sides to prevent downward convection of gravitational water or upward movement of evaporative-capillary water through the soluble chemical. The soluble chemical is placed on the top surface within the protected zone The purpose for placing the soluble chemical (e.g., fertilizer, soluble fungicide, etc) within the PDZ is to prevent rapid convection of the chemical downward with gravitational flow of surface-applied water or movement of the chemical upward to the soil or media surface in the evaporative water flow pathway. Within the protected zone, the soluble chemical moves primarily by chemical diffusion. Plant roots grow in the protected diffusion zone and intercept the chemical ions prior to their diffusing from the protected zone.

Results from research to evaluate the feasibility of conserving fertilizer within a PDZ in both the CIPS and in the open root zone systems at Briggs Nursery and Oregon State indicated that movement of K^+ and NO_3^- fertilizer ions within the PDZ is between rates reported for diffusion in water and in soil (Olsen and Kemper, 1968). Rates of ion movement downward in the PDZ in the media are compatible with ion diffusion being the dominant component of fertilizer movement.

Fick's laws (Crank, 1975) were applied to determine relationships among the variables in the PDZ research. Diffusion zone cross section area (diameter of the diffusion tube), diffusion zone length (length of the diffusion tube), and effective diffusion coefficient of the applied fertilizer. The length of the protected diffusion zone (diffusion tube length) can be varied to protect the diffusing ions for different lengths of time. The longer the diffusion tube (diffusion distance) the greater the amount of time before the chemical exits the diffusion tube. The diameter of the diffusion tube can be varied to provide delivery of different quantities of diffusing chemical. The greater the diameter of the diffusion tube (cross-section area through which diffusion can occur), the greater quantity of a given chemical delivered at any time. The solubility of the applied chemical as well as the volume of moisture, the cation exchange capacity, and other characteristics of the media within the diffusion tube can be altered to tailor the effective diffusion rate of the diffusing chemical The effective diffusion rate (D_e) will determine the rate of fertilizer movement in the PDZ For a given fertilizer salt, effective diffusion coefficient, and diffusion tube length and diameter, the movement of fertilizer within the PDZ over time can be predicted to allow tailoring the PDZ to specific crops and conditions.

Embodiments of the Protected Diffusion Zone. A PDZ can be created in the root zones of various plant production systems. Major embodiments are illustrated in Fig. 1 (left to right, top to bottom).

CREATING A PDZ WITHIN THE CLOSED INSULATED PALLET SYSTEM, FIGURE 1, EMBODIMENT 1, CIPS

The entire pallet lid and sides can be considered to be a PDZ with multiple number of plants extending through the top surface of the PDZ The major features of CIPS are an array of plant units with roots enclosed within a closed, insulated pallet. Plant shoots extend upward through a seal in the pallet top. The pallet lid is essentially continuous, water-impermeable, light reflective, solar and thermal radiation opaque, and insulating Fertilizer placed on the top surface of the media is shielded from leaching and evaporative water-flow pathways within the created PDZ and diffuses to the plant roots. The fertilizer ions will diffuse in the absence of plant roots and uptake, but ion uptake by the roots will create a steeper diffusion gradient and cause the ions to diffuse more rapidly. In this sense, fertilizer ion diffusion within the PDZ is plant-driven. Water movement upward from the water reservoir in the base of the pallet is by adsorption onto the surfaces of the wick and media particles and by capillarity. After adsorption and capillary equilibria are achieved, further movement of water by capillary flow is in response to plant uptake to support plant growth and transpiration. Water uptake is plant-driven

As an alternative to placing the fertilizer or other chemical to be protected beneath the pallet lid, the chemical can be placed within a Conserver inserted through the pallet lid into each plant unit (Fig. 1, Embodiment 2, CIPS with Conserver). The Conserver can be envisioned as a tube or cylinder with a cap on the top to provide a moisture-impermeable, insulated, thermal-solar radiation opaque-reflective top and sidewalls. The soluble chemical within the Conserver is protected from convection downward in the gravitational water flow pathway and from movement upward in the evaporative water flow pathway. The duration of protection and the rate of delivery are dependent upon the length of the diffusion tube and the diameter of the diffusion tube respectively. The individual Conserver is open on the bottom side to allow root growth into the diffusion tube to facilitate interception and uptake of the diffusing chemical before it exits the protected zone. Fertilizer ions diffuse downward through the media inside the cylinder until they are intercepted and taken up by the plant roots. The Conserver allows periodic replenishment of fertilizer through the cap.

CREATING A PDZ WITHIN AN OPEN ROOT ZONE (ORZ)

The individual Conserver can be effectively used independent of the CIPS The individual Conserver can be used in an open container or used in field or landscape plantings to provide a PDZ for soluble chemicals, Fig. 1, Embodiment 3, ORS/ container and Embodiment 4, field-landscape.

CREATING A PDZ WITHIN A SEMI-CLOSED FIELD OR LANDSCAPE SYSTEM (FIGURE 1, EMBODIMENT 5, SEMI-CLOSED FIELD SYSTEM)

When digging the hole into which the plant is to be transplanted, a water-impermeable basin to act as a water reservoir is placed beneath the root zone of the transplant. The basin is filled with porous, load-bearing, capillary media (e.g., rockwool slabs) covered with a copper hydroxide coated fabric. Growth and terminal dominance of root tips will cease when they contact the copper-coated fabric. Higher order branching of the roots will occur. The root system will spread laterally beyond the subtending basin. Roots will eventually extend downward beyond the basin to deeper soil moisture regions. The basin is intended as a temporary, efficient, readily available water supply during establishment of the transplant in the landscape. Water is periodically added to the reservoir through the fill pipe on the left; the fill pipe can be placed close to the plant to also serve as a plant stake. The plant stem is surrounded at the soil surface by an impermeable, circular moisture barrier that extends from the plant stem outward to the edge of the root ball; the barrier prevents evaporative and leaching movement of water through the subtended root zone and aids in establishing stable moisture and fertilizer gradients. A long-term, extended supply of fertilizer, with the exception of calcium and phosphate, is applied in the Conserver. Calcium phosphate is uniformly incorporated in the root zone to promote root growth.

ECONOMICS OF THE PDZ

CIPS PDZ. A differential cost analysis comparison of the CIPS with five traditional container production systems including models with ebb and flood and models with leachate recycling technology showed that cost of production with CIPS was less or equal to that of the other systems (Welch et al., 1991).

Conserver PDZ. The Conserver will eliminate or reduce fertilizer discharge from the open root zones of container- and field-grown plants. The savings in annual

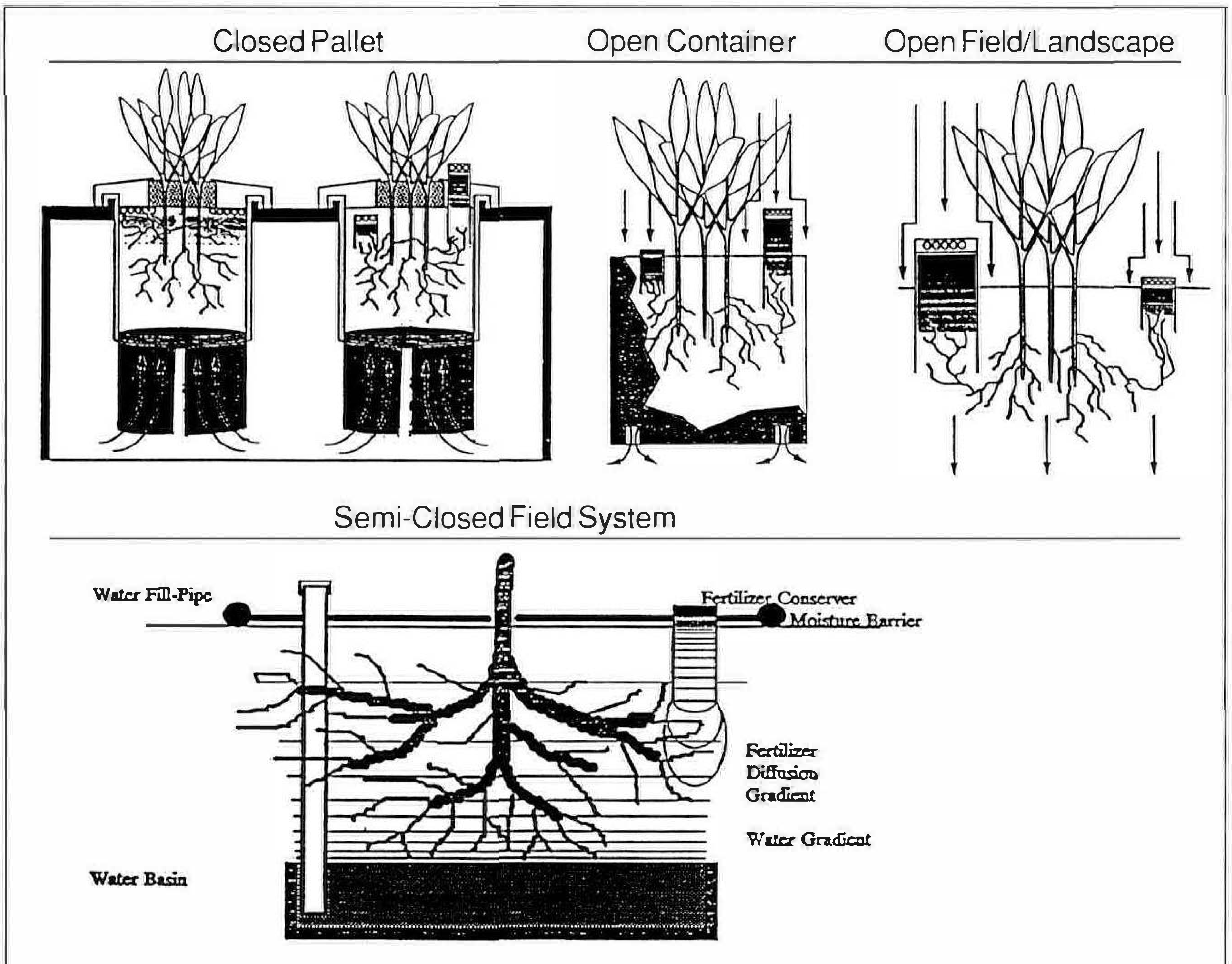

Figure 1. Embodiments 1 to 5 (left to right, top to bottom): Protected diffusion zone (PDZ) in the closed, insulated pallet system (CIPS) with and without a Conserver; PDZ in a container with an open root zone system (ORS); PDZ in a field or landscape ORS; PDZ in a field or landscape semi-closed root zone system.

differential costs/bed-acre of using the Conserver compared to the costs involved in converting an area to leachate collection, treatment and recirculation are considerable (Welch et al., 1991)· $746/bed-acre annual savings in land improvements (installation of collection, treatment, and recirculation system not required with Conserver); $3297 savings in cost of fertilizer when Conserver-applied; $434 savings in cost of chemicals for water treatment plant Assuming 43,560 plants (Conservers) per acre and that a given plant (Conserver) is in place for a 2-yr period, $4477 ($746+$3297+$434 savings) divided by 21,780 conservers/ year would provide $0.20 per conserver. OR, the break even purchase-installation cost per Conserver is $0.20 or less. If there were only 10,000 1-gal plants per acre, then savings would provide $0.895 to offset cost of each conserver.

CONCLUSIONS

Decreased water availability necessitates innovative methods and technology to adjust plant-available fertilizer to the varying frequencies and quantities of plant-available irrigation water and plant growth rates Availability of fertilizer applied in the protected diffusion zone to the plant is directly related to the quantity of water in the plant root zone since the fertilizer must be dissolved in water before it can diffuse and must be in solution prior to plant uptake Therefore, availability of fertilizer in the PDZ is self-adjusting to the quantity of plant-available water. Because fertilizer is primarily retained within the PDZ and intercepted by plant roots prior to its exiting the diffusion zone, soluble fertilizer is not moved to and accumulated at the soil surface by water evaporation

Water soluble, systemic pesticides such as the fungicide Subdue can also be applied and shielded within the Conserver from leaching and dispersion The necessity of drench applying Subdue on a 3- to 4- week frequency to maintain effective concentrations against leaching of the pesticide within the root zone might possibly be replaced by less frequent application of smaller quantities of Subdue through the Conserver.

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Using Manmade Snow to Protect Outdoor Perennials

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Skagit Gardens is a wholesale grower of bedding plants and container-grown herbaceous perennials. We are located at sea level lat. 48.5°N in northwestern Washington state. We overwinter about 2 million plants per year outside

Hardiness varies greatly among varieties but, in general, a plant is much less hardy in a pot on top of the ground than it would be if planted in the ground. Our particular climate can be cold in the winter (below 10F) for several weeks at a time. Due to our strong marine influence, it can also be in the 50s and 60s in the winter. Our experience has been that greenhouse grown plants tend to be soft and leggy if the weather gets unseasonably mild and we cannot reliably produce a plant that will be hardy in the interior regions of the continent. We do carry a crop of perennial liners in the greenhouse through the winter and some of the 4-in. crop inside to help with early availability for the local and warmer climate customers. These houses are kept as cool as possible. Since the plant produced outdoors is the hardier and more desirable plant to our customers, we must seek ways to protect the crop and reduce shrinkage through the cold spells that we can get Since the weather can get very mild causing the plants to begin growing, we are not able to simply cover the crop for the entire winter. Our best crops have been in years when we had a good snowfall preceding an extended cold period. These crops were actually better than the crops in mild winters since they didn't overgrow. With this in mind, we decided to make artificial snow to cover the crop during severe cold weather. The snow naturally melts, exposing the plants to the normal environment when the weather gets mild.

We purchased a snow gun, a fire hose and an after-cooler (a radiator to cool the compressed air) for the snow making operation. Two hoses transport water and air to the gun. The most expensive piece of equipment needed to make snow is the compressor. We rented it so we were able to keep costs quite low. Compressed cooled air is mixed with water at the gun and when the temperature is below freezing, snow will result. At least 100 psi at the gun is required for good results and it requires a considerable amount of time to get a good protective layer on. We were able to blow snow about 75 ft but the operation is strongly affected by even the slightest breeze and it is a very slow process. We place our crops in the field by hardiness and at the early signs of an extended arctic front we cover the plants with a fabric called Typar. When temperatures are cool enough we begin making snow to cover about 2 to 3 acres of plants with 2 to 3 in. of snow. This took us about 2½ days. The operation is carried out around the clock until the crop is covered sufficiently This is necessary because the hose carrying the water would freeze if you stopped. Using this technique we have been able to maintain soil temperatures of near 32F when the ambient air temperature was reaching 9F at night and not above 20F in the day for about 10 days.

Since we used a combination of fabric and snow to protect the plants, we cannot know the extent to which the snow alone helped protect our crop. But the results were very good with excellent survival in the kind of winter weather that has produced substantial losses in the past. We are presently planning to use two guns next winter if the weather gets cold enough.

The Commercial Propagation and Production of Fuchsias at Tamborine Mountain

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I spent most of my young days at boarding school on the coast or on my father's sheep property in far South West Queensland, approximately 600 miles away, and then 20 odd years on another sheep property even further west. I came to Tamborine Mountain in 1976. Tamborine Mountain is about one hour's drive from Brisbane and about 20 min. from the major coastal highway which runs along the east coast of Australia. It is about 1800 ft above sea level, giving it a temperate climate in contrast to the subtropical climate of the coast and the arid conditions of my earlier life I was offered a job in a production nursery on Tamborine Mountain and it wasn't long before I established my own small nursery on a third of an acre at the rear of my home. Three years later, when a well-drained and well-positioned 4.5 acre piece of land became available, the present nursery was established By then, I had a clear picture of the ideas I wished to build into the new nursery and of the opportunities arising from the special climate of Tamborine Mountain and its geographical position in Australia. Together, these led me to specialize in fuchsias.

The components were·

- To endeavor to keep any development simple and flexible
- To grow out in the open in full winter sun using natural light levels to produce a short internodal plant with a cosmetic bloom.
- To keep capital costs to a minimum.
- Not to let any other crop interfere with *Fuchsia* production -use the same growing medium for other crops or don't grow them.
- Take advantage of the autumn, winter and early spring markets which are traditionally short of colour.
- Produce a plant that was also potted colour rather than just a shrub in flower.

I do not breed fuchsias; instead, I conduct a 3-year cycle of testing fuchsia cultivars (there are more than 10,000 registered cultivars and many more unregistered ones worldwide). Apart from beautiful flower colours and forms, I look for the cultivars that will flower in our mild winter conditions, are naturally self-branching, are easy to pack in cartons for shipping, and are not brittle to handle. Some cultivars are incredibly reactive to ethylene and will defoliate completely after three days in a carton on a truck. Other cultivars may lose all their flowers and buds. Right from the start of the nursery, the product name, "The Tamborine Selection", was registered for my fuchsias and the number of cultivars is kept in this "selection" to between 20 and 30. It includes a good cross-section of colour and form, both single and double, bold and soft colour combinations. Successful cultivars in the selection trials have to be better than the ones in "The Tamborine Selection". In effect, a newly selected cultivar displaces one in the "selection". Importantly, apart from many other attributes, all cultivars in "The Tamborine Selection" must still be in good condition after 3 days in a carton in a truck

The propagation area was designed for flexibility and multiple use and is also a growing area Most of the striking of cuttings is done in a 50% shade-covered section and then the shade cloth is rolled off to harden the tubed plants Most of the 100,000 cuttings are put down in January and February each year for the main wholesale markets. In late March these plants are transplanted to pots and placed in the open field sections, and by May-June (that is, mid-winter) these plants are ready for sale The field area is divided into ten blocks, protected from strong winds by 6-ft-high shade-cloth fences These blocks are watered by overhead sprinklers and these sprinklers are also activated by frost and heat sensors I accompanied the development of the production side of my nursery with a great deal of attention to promotion of fuchsias. This I did by writing regularly about my product for monthly magazines and in newspapers, and by educating my customers—the retailers and garden centres—with good information on how to keep fuchsias looking good in their holding and display sections with a "Care Sheet" and another "Care Sheet" to hand to their customers. My original plan of defining my market, of keeping things simple and of having low capital expenditure worked very well, however, it also meant that I employed people for only half a year. The problem with this strategy was that I was not able to keep good staff. I was at the mercy of the elements—a hail storm or a cyclone had the potential to wipe out my income for the year. So I have now diversified by growing other flowering perennials so as to be less dependent on one crop, and I now have a successful garden centre called "The Fuchsia Farm" Mailorders are also despatched weekly from April to September throughout Australia. The advertising for these brings many customers, both wholesale and retail, to the nursery itself.

Strategies in Commercial Micropropagation

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I can trace my learning curve in micropropagation from 1961 and now I can pose questions such as "What is important to the achievement of a successful micropropagation operation? Where should I direct my research?" In a few words, the answer is "to the achievement of high success rates in the acclimatization stage".

In this paper I will be concentrating on my experiences with culture media and my current approach to the selection of media And to start at the end product I will present my latest basal medium and ideas for using it (Table 1) The medium consists of a micronutrient section, a growth factor section, and a gelling agent. Macronutrient, auxin, cytokinin, and carbohydrate sections are treated as experimental variables. Full strength macronutrients are listed in Table 2—and these are diluted (either in groups or as individual components) to prepare different concentrations to suit different purposes. Types of auxins, cytokinins, and carbohydrates and their concentrations are determined by experiments. All media and experimental treatments are dispensed cold into the culture vessels used in my commercial operations—and these vessels receive the same volume of medium and are closed the same way—the point to stress is that whatever methods are used in a commercial operation must also be used in experiments—the emphasis is on reproducibility of results.

THE BASAL MEDIUM

The rationale for my new medium and experimental approach is that macronutrients, auxins, cytokinins and carbohydrates are "important" and worthy of experimentation whereas micronutrients and growth factors are not so likely to yield important results.

MICRONUTRIENTS AND GROWTH FACTORS

It is probably wise to have some growth factors and micronutrients in the medium because their absence may be detrimental with prolonged subculture but, in terms of research effort, we can better concentrate on other ingredients and conditions.

GELLING AGENT

In 1991, the author began testing carrageenan and specifically one called Gelcarin GP812 (FMC Corporation, Marine Colloid Division, Rockland, Maine). This is now used at 6 g/litre and has the clarity of Gelrite and otherwise the properties of agars—it is also inexpensive. Gelcarin GP812 is currently the only gelling agent used in the author's laboratory, and is under test in 15 laboratories in Australia—in particular, the author is waiting to hear whether laboratories which experienced vitrification problems with Gelrite also have this problem with Gelcarin GP812.

Preliminary results, from the laboratory of Dr. Acram Taji (Department of Botany, University of New England, Armidale, NSW), with *Boronia ruppii, Lechenaultia formosa, Ptilotus exaltatus, Rosa* spp , and *Zieria fraseri*, all species which suffer from vitrification on Gelrite media, indicated that Gelcarin media was similar to agar media with respect to this problem.

Table 1. Basal medium consisting of micronutrients, growth factors, and gelling agent

Chemical	Amount per litre
Micronutrients	
H_3BO_3	100.00 µmol
$CoCl_2$	0 10 µmol
$CuSO_4$	0 10 µmol
$MnSO_4$	100.00 µmol
KI	5 00 µmol
Na_2MoO_4	1.00 µmol
$ZnSO_4$	30 00 µmol
Growth factors	
Inositol	600 00 µmol
Nicotinic Acid	4.00 µmol
Pyridoxine	2 00 µmol
Thiamine	1.00 µmol
Glycine	50 00 µmol
Gelling agent	
GELCARIN GP812	6 g
Ions	**Amount per litre**
Cl	0.2 µmol
SO_4	130 1 µmol
Na	2.0 µmol
B	100.0 µmol
Mn	100 0 µmol
Zn	30 0 µmol
I	5 0 µmol
Mo	1 0 µmol
Cu	0.1 µmol
Co	0.1 µmol

MACRONUTRIENTS AND IRON

Of course, the Basal Medium would not be used without the addition of at least macronutrients and a carbohydrate supply. In general, experimentation with macronutrients is regarded as being very important and also very difficult to do and to interpret. In general, the (high) concentration of macronutrients in Table 2 appears to be suited to many ferns and herbaceous plants whereas half concentration in Table 2 favours woody species. Experience has shown that research with hormones is not rewarding unless cultures are placed on media without "limiting" factors—an incorrect concentration of macronutrients can be "limiting". In the latest model for experimentation described here, it is suggested that only two concentrations of macronutrients need to be tested in the initial or "ranging" experiment.

Table 2. Full strength (×1) macronutrients and iron compound The concentrations of these nutrients are used as experimental variables either individually or as a group(s)

Chemical	Amount per litre
Macronutrients and iron	
$NH_4H_2PO_4$	2.00 mmol
NH_4NO_3	18 00 mmol
$CaCl_2$	2 00 mmol
$Ca(NO_3)_2$	1 00 mmol
$MgSO_4$	1 50 mmol
KNO_3	20.00 mmol
FeNaEDTA	100 00 µmol
Ions	Amount per litre
NO_3	40 0 mmol
NH_4	20 0 mmol
N	60 0 mmol
P	2.0 mmol
K	20.0 mmol
Ca	3 0 mmol
Mg	1 5 mmol
Cl	4.0 mmol
Fe	100 0 µmol
SO_4	1500 0 µmol
Na	100 0 µmol

CARBOHYDRATES

In initial experiments, I would not anticipate that a species would prefer a carbohydrate other than sucrose but I would expect that, in some species and with some objectives, experiments with different concentrations of sucrose may be rewarding. My experience with *Chenopodium rubrum* made me aware that a species could have a requirement for a very low concentration of sucrose. Most of my culture media have either 60 mM or 90 mM (approximately 2% and 3%,w/v, respectively) sucrose but, for the preparation of cultures for planting out, it is worth testing 120 mM, 150 mM or higher concentrations of sucrose—these higher concentrations are used with *Lilium* and *Begonia* Rex Cultorum Hybrid [*Begonia rex*] leading to stronger cultures and high acclimatization success rates.

AUXINS AND CYTOKININS

In the mid 1970s, I decided to test, as a group, six substances in the auxin category and two substances in the cytokinin category with the idea that a species may regard this as a smorgasbord and select whichever auxin and cytokinin it preferred and ignore the rest. By and large, this approach was quite successful, it really did appear as if plants were able to select just the hormones they needed, for example, *Eriostemon australasius* used BAP and ignored kinetin in a mixture of the two cytokinins. But, as part of the investigation of riboflavin action, it became clear that the auxins, NOA, pCPA and 2,4-D, tended to induce callus formation in our cultures whereas IAA, IBA and NAA, tended to keep cultures in an organized state We also learned that with at least three woody species (*Simmondsia chinensis* [jojoba], *Eucalyptus*, and *Eriostemon*) that either BAP or PBA stimulated multiplication whereas kinetin, 2iP, and zeatin did not.

The strategy today is to test three auxins (IAA + IBA + NAA) as a group and two cytokinins (kinetin + BAP) as a group with initial research with untried species. If research has been published on a species and other auxins and cytokinins had been used, then these other hormones would also be included in initial experiments. For micropropagation, zero hormone control treatments would always be included in experiments.

SUGGESTED INITIAL EXPERIMENTS

The following initial experiment would probably yield interesting information with many species:

1) Initiate cultures on a medium consisting of:
   - Basal Medium
   - Half-strength macronutrients
   - 60 mM sucrose
2) Subculture apparently aseptic cultures to the following treatments:
   - Basal Medium
   - Macronutrients: ×½ and ×1 strength
   - Sucrose: 60 mM and 90 mM
   - Auxins (IAA + IBA + NAA): 0, 0.1 µM, and 1.0 µM
   - Cytokinins (kinetin + BAP): 0, 1 µM, and 10 µM

This is an experiment with 2 × 2 × 3 × 3 treatments, that is 36 treatment combinations. If insufficient material for 36 treatments were available, consideration could be given to using only one concentration of macronutrients (for example, ×1 for herbaceous species, ×½ for woody species) and one of sucrose (for example, 60 mM for woody species, 90 mM for herbaceous species)—this would give an experiment with 9 treatments.

3) Follow up experiments would concentrate on simplifying media for different objectives. For example, for multishoot formation, for yielding microcuttings, and so on. The aim of this research is to develop a satisfactory multiplication system, to minimize technical losses and to yield plants which have a high planting out success rate. While initial experiments need not involve planting out the cultures, later experiments should **ALWAYS** involve evaluation of treatments in terms of planting out success rates—all costs in the laboratory ride on the cultures sent to the planting-out facility and all losses in acclimatization have to be accommodated by plants which are to be sold.

EXPERIMENTAL METHODS

Refining a culture medium is best done by using equal increment dose-response type experiments (Fig. 1) Equal-increment dose-response experiments are recommended where single substances such as hormones, carbohydrates and micronutrients are tested. They can also be used with macronutrients but interpretation of results is more difficult—if the growth of cultures increases with increase in concentration of KNO_3, is this response due to K^+ ions or to NO_3^- ions?

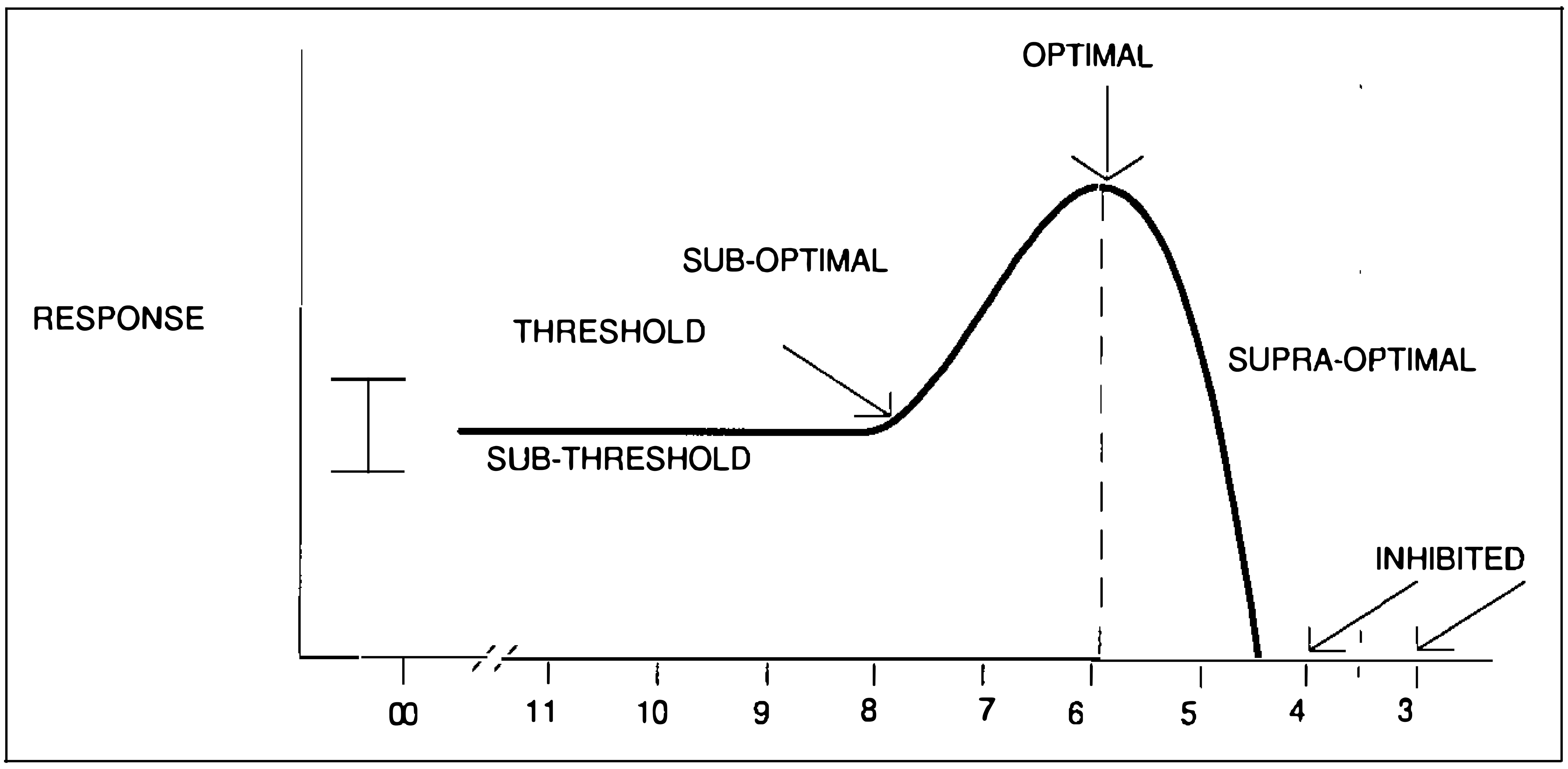

Figure 1. Graph showing sub-threshold, threshold, sub-optimal, optimal, supra-optimal, and inhibited responses of cultures to increasing concentrations of a substance

IMPLICATIONS OF THE PARABOLIC RESPONSE OF CULTURES TO COST CUTTING

One outcome of receiving formal training in science is to be precise and accurate with measurements, one disadvantage of this is that one balks at not being precise and accurate. Yet if less accurate methods were to reduce the cost of production in a commercial operation, can one rationalize one's use of them? Is there any way to feel "comfortable" with less than precise methods? I think it is important to be accurate when making concentrated chemical stock solutions for culture media and when doing experiments but, when a "good" medium has been evolved through experimentation, I think that cultures will not "notice" small variations in chemicals, and this thought leaves the way open to use cheaper methods of production. And the reason for this conclusion can be found by looking at any "parabola" of response. Say a culture medium's recipe calls for 10 ml of 10,000 µM FeNaEDTA per litre of medium and that a cheaper method for the preparation of media results in sometimes 9 5 ml and other times 10.5 ml being added per litre. If the accurate method were followed, then the medium would have a final concentration of 100 µM FeNaEDTA—with the less accurate method, the final concentration of FeNaEDTA would be in the range 95 µM to 105 µM FeNaEDTA. The question comes down to this : "Would cultures respond in a significant way to such differences in concentration?" By answering "not likely" to this question, has allowed me to develop rapid methods for the preparation of culture media and for its dispensation to culture vessels and, thus, minimizing my cost of production in this area

USING A PUBLISHED MEDIUM IN A COMMERCIAL OPERATION

The type of "fuzzy logic" described above has other uses in my laboratory Most published research in micropropagation comes from universities and research institutes, and cultures are tested under various conditions and with various media using, mostly, test tubes or other small vessels. Larger vessels are used in commercial operations and, for published research to be relevant to commercial operations, ideally the same type of container, the same type of closure, and the same volume of medium should be used, as well as the same types of preparation procedures. These factors do influence cultural responses—at least, it is better to assume that they do. This is where cost of production analyses again enters the equation. In the author's laboratory, all media are dispensed cold and, for both experimentation and production, 250 ml polycarbonate vessels fitted with polypropylene screw on lids (Techno-Plas Pty Ltd., P.O.Box 239, Melrose Park, South Australia 5039) are used—volume of medium per vessel is 50 ml.

The problem is that different commercial laboratories use different procedures and containers. The lesson is that if researchers do not at least approximate commercial conditions, then their work is largely irrelevant—and the next part of the message is that commercial laboratories must therefore do their own research, research appropriate to their own commercial conditions.

CONCLUSIONS

Using the types of approximations described in this paper for the technical aspects of micropropagation, I have been able to "translate" most published media into forms which I can prepare from the stock solutions used to prepare the medium in Tables 1 and 2, with a minimal amount of other stock solutions. The impetus for this is partly (largely?) to do with minimizing my cost of production in a commercial micropropagation laboratory but, amongst other things, the studies involved have led to a clear ranking of objectives in commercial as distinct from academic micropropagation.

Top ranking goes to achieving a high success rate on planting out cultures and next ranking goes to getting the greatest number of suitable plants per culture and to maximizing the rate of deflasking. These objectives are affected by having a suitable planting-out facility/methods and by getting the right sort of cultures in the laboratory. In turn, that involves finding the best culture medium and testing other pre-deflasking treatments, such as exposing cultures in vessels to ambient conditions in the planting-out facility prior to deflasking.

Exciting New Peony, Hosta and Hemerocallis Introductions

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Working with plants and servicing customers is an ever-changing, learning process We all fail our customers when we don't bring forward the newer and better cultivars. Presented here are some of the many new and exciting creations available in these three perennial plant genera that can excite customers and staff to create better business. They also offer a solution for the old, unexciting,and often times far surpassed clones.

New and improved clones presented were:

Peony: 'Coral Charm' PP #4247, 'Pink Hawaiian Coral', 'Golly', 'West Elkton', 'Cora Stubbs', 'Martha Reed', 'Nice Gal' [*Paeonia lactiflora* 'Nice Gal'], 'Etched Salmon', 'Ann Berry Cousins' [see also *P* 'Anne Cousins'], 'America' PP #4246, 'Scarlet O'Hara', 'Pink Parasol Surprise', 'Gold Rush', 'Paree Fru Fru', 'Fringed Ivory'.

***Hosta*:** 'Sun Power', 'Solar Flare' PP #7046, 'Fragrant Blue', 'Fall Bouquet', 'Great Expectations', 'Fragrant Bouquet', 'On Stage', 'Summer Music'.

***Hemerocallis*:**, 'Mini Pearl', 'Siloam Doodlebug', 'Carefree Yellow', 'Sun Capers', 'Heron', 'Red Regatta', 'Golden Tycoon', 'Prize Picotee Deluxe', 'Resurrection Yellow', 'Pretty Miss', 'Fragrant Bouquet', 'Apricot Surprise', 'Emerald Treasure'.

Perennial Production at Valleybrook Gardens Ltd.

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INTRODUCTION

Valleybrook Gardens is a large, wholesale production nursery located near Abbotsford, British Columbia Abbotsford is in the Fraser Valley region of BC, east of Vancouver, and is in USDA Zone 7.

Our sales are primarily made to independent garden centers throughout western Canada and the Northwest U.S. Production consists primarily of herbaceous perennials in containers, but also includes herbs, ferns, ground covers and grasses. Some annuals are grown in 15-cm (gal) containers for summer sales as well Several million containerized plants are grown annually, comprising over 1000 taxa

The production of herbaceous plants puts a grower into a separate class, distinct from both greenhouse growers and nursery managers, but sharing characteristics of each. Propagation, as well as a considerable amount of production, takes place in protected environments, yet many plants perform best outside in a nursery environment. The boundaries between these different classes of growers is diminishing, as bedding growers are dabbling in seed production of perennials, and nursery growers are diversifying from junipers into daylilies

At Valleybrook Gardens Ltd , one of the most important steps in production occurs before any plants are propagated. This step, often overlooked in our industry, is marketing. Marketing drives almost everything we do at Valleybrook, from selecting varieties, setting prices, even the colour of our pots. Although marketing is such a vital part of what we do, it is a major issue best addressed at another time.

PROPAGATION

At Valleybrook Gardens, most plants sold are propagated on site Exceptions would be where crop failures have occurred, where new varieties of plants are required, or where plants are propagated by tissue culture. The three main techniques used here include seeding, cuttings, and divisions.

Seeding. About half of the 9-cm plants grown at the nursery are propagated by seed. Seeding is carried out using several styles of seeding machines. The majority is done on a Blackmore seeder, into 288 or 512 trays Perennials seeds come in all shapes and sizes, however, and many cannot be sown with this style of machine. We also use two models of the Vandana vacuum plate-type seeders, which are more labour intensive but more adaptable to these seed types.

Germination of perennials can be quite inconsistent compared to annuals. Various treatments including pre-soaking and stratifying are necessary for some species. Information on requirements for individual species can be hard to find, requiring considerable experimentation.

Once seeds are sown, they are moved into our fog house for germination. The foghouse consists of a gutter-connected range, utilizing bench-top micro-climate heating, several styles of fogging systems, and high intensity lights to allow photoperiodic control. A few perennials are pre-germinated in our cooler before entering this house.

After growing past the cotyledon stage, they are liquid fed until moved out for hardening off We use 20-20-20 at 50 to 200 ppm The length of time between sowing and potting can range from 4 weeks to many months, depending on crop and time of year

Seeding is generally the least expensive propagation method, but it only works for a limited range of plants. For this reason, we utilize some of the following asexual propagation methods.

Cuttings Cuttings are taken almost the entire year although peak time is from May to September Stem cuttings are used as a primary propagation method for many of the most important crops at Valleybrook. Root cuttings are used on a limited number of perennials.

Most herbaceous plants root easily, and don't require hormone. We do use hormones, however, to increase the speed of rooting. The less time cuttings spend in the propagation house, the less space we require. Cuttings are rooted in media consisting of various ratios of peat and pumice. The media is placed in plug trays, ranging in size from 98s to 200s. Once rooted in the foghouse, plants are moved out and hardened off before potting

Since we are now producing so many plants, the issue of stock plant management has become very important. We have moved from the concept of stock plants in pots to in-ground stock beds. This is done for many reasons including increased winter survivability, reduced maintenance costs, and also because the sales department finds it more difficult to sell stock plants required by the propagation department. Finally, stock beds can be used to beautify and landscape the nursery property

It is very easy to spend large sums of money and time on stock beds, even in the ground. Stock plants require replacement ranging from every 2 to 5 years, depending on species. Weeding is an expensive task, so we use weed barrier cloth as one labour-reducing method. Plants require fertilizing and occasionally pruning to encourage good cuttings at the appropriate time

Since reducing the number of stock plants required for a given production number reduces these costs, we have been experimenting with growth regulators such as gibberellic acid to increase the number of cuttings per plant. Results have been interesting, with a real benefit for some plants *Ajuga*, a plant that is certainly easy to root but that does not often produce a lot of stem cuttings, responds marvelously to GA_3.

The use of GA_3 and other compounds has only been experimental until now. After a few years of work, we should have extensive data on what works on which plant. At this time, however, it appears that GA_3 increases internodal length, and growth rate, without affecting the rooting percentage of cuttings This effect depends on the time of year, with most varieties responding most strongly early in the growing season.

Division At Valleybrook we have been using division with our own open ground stock for about 3 years. This technique is used for those varieties which cannot be propagated effectively any other way. We grow only certain varieties ourselves, primarily those that are very expensive, or difficult to obtain from other growers.

For the run-of-the-mill items, such as *Astilbe* or *Iris* , we cannot compete with products purchased from large, specialized, and mechanized growers. Our own divisions have been very useful in allowing us to bulk up new varieties imported from Europe.

Divisions are made primarily in the spring or fall. For some varieties timing is important, for others less so. After being dug, they are split by cutting or breaking apart, and then potted, usually in 15-cm pots. Bare-root perennials often have bulky roots of all sizes, making mechanized potting of these items difficult.

GROWING ON

There are two peak potting times at Valleybrook. Summer potting begins in August and ends around the middle of September. These plants require overwintering and are sold early in spring. A second flurry of potting takes place from March until May. These plants are sold later in the spring and into the summer and fall.

Plants are grown in either 9-cm, 11-cm, or 15-cm square, plastic pots. The growing media consists of peat, fir bark, and pumice amended with Dolomite lime, gypsum, and time-release fertilizer We mix all our own soil in a rotating drum mixer, and since we grow so many different crops, we use more than a dozen soil mixes. Each of these involves a different ratio of ingredients.

Weed control is an ongoing battle, since many of the weeds so closely resemble the crops we are growing, and so few herbicides are registered. We rely extensively on hand weeding, which is very expensive, and not generally considered a plum posting by the unfortunate staff assigned this responsibility The main weeds we battle are liverwort and snapweed (*Cardamine oligosperma*). Lesser weeds include *Poa annua* and *Sagina*.

Keeping our plants alive through the winter is one of our enduring challenges. Five years ago, we failed miserably in this effort and lost 70% of the plants on our nursery. Three years ago, we lost 40%. These winters were some of the lowest points in our history and we have learned much from them We looked at every aspect of our production to reduce the risk of this happening again.

The main winter problem we have is with inconsistent winters. One year may be exceptionally mild, with perhaps -5C the coldest temperature. The next may be equally mild until the end of January, when the temperature can drop from 12C to -18C in 12 h, to accompanied by 100-km winds. If we could rely on consistent winters, or on snow cover, protection would not be a great issue.

We have responded by dividing our plants into differing overwintering regimes, based on our hard won experience. These are:

- Outside unprotected
- Outside covered when required
- Cold frames
- Cold frames with supplemental heat

Outside covered means that plants are left uncovered until weather predictions call for an Arctic outbreak. Our system allows us to cover the entire nursery, using 4 to 6 people in half a day. We used a spun-bonded polyester for a cover in the past, but now use a heavier material commonly used for heat retention curtains in greenhouses. Heated greenhouses are normally only heated to around the freezing point and only when outside temperatures plummet or new growth has begun.

We have also been experimenting with growth regulators in our growing stage. Here, we have found success both with speeding up growth and in maintaining a more compact plant for ease of shipping. Results here again are experimental, but show good promise for the future.

COMPUTERIZATION

Timing is everything in producing good perennial crops. Plants potted too early can overgrow and become unsalable in 2 weeks Plants potted 2 weeks too late in the fall can be too small to withstand winter. With the complexity inherent in producing millions of units of over 2000 products, many of which grow at different rates and require different growing conditions to satisfy the needs of customers in diverse climates, it is imperative to be highly computerized.

In fact, virtually every aspect of life at Valleybrook Gardens is governed, regulated, analyzed, recorded or directed by the computer Several years ago, a custom scheduling program was written for our nursery which specifies every production step required each week. This includes seeding requirements, cutting requirements, and potting requirements, including numbers, soil mix type, overwintering requirements, and much more. It even generates orders for seeds from suppliers, taking into account seeds per gram, germination rates, and quantities of plants required

Bar code capability is included in this software and has been used for two years now. These bar codes are currently used for internal use only. We use these codes to provide our customers with updates on plant availability, to update plant locations in our computer and improve our shipping efficiency, and also to provide sales information for our marketing decisions. In the future, we envisage extensive increases in the use of bar-codes throughout our operations

CONCLUSION

At Valleybrook Gardens our focus is on providing plants when the customer wants them, in the condition the customer expects. This should be the goal of everyone in the nursery business, and I expect it is the goal of most of the growers here. Our customers, however, remain the final judges of how successful we are

Question Period IV

Lawrence McMurtrey: Regarding the artificial snow, could you give us an estimate of cost including labor and everything? How much would it cost per acre for just one snow application?

Michael Poynter: I haven't analyzed it that closely. The large compressor can be rented for $600 to $1200 per month. It will probably cost $2000 to $3000 per acre.

Voice: Could you sketch all the problems you had. It looked good, but I'm sure there must have been many difficulties as you went through it.

Michael Poynter: We found out that we needed considerably less water and considerably more air than we first thought. I suspect that will vary with the climate and conditions. We were worried about not having enough water and we just kept turning the water down and increasing the quality of the snow so we know we have plenty of water for a couple of guns, but we need more air. In that respect we figured we needed 100 psi at the end of the gun. The problems that we had were actually not too bad. We figured out most of the problems. You cannot stop unless you can drain that water hose or it will freeze and you won't be able to start again At night you can't see so you can't tell what you are doing. If you ask somebody to stand by a gun or sit in a tractor when it's 10F degrees outside with this noisy equipment out in the middle of a field that's pitch black, it's kind of weird I think what they did is set up the best they could Flashlights did not work very well. They would set it up, go inside for 30 to 45 min and then run out and move the gun It takes a long time. We spent 3-1/2 days to cover 2-1/2 acres with 2-1/2 in. of snow. If the wind had been blowing we would have been in trouble. As often happens in the Skagit Valley, if the wind is blowing in Bellingham and further north it won't be blowing right in the valley. We predicted that and that part did work.

Voice: Was the output about 100 gal per minute.

Michael Poynter: We started at about 100 gal/ min and were down to about 10 when we were really making good snow. We just couldn't get enough air through that. The other method of making snow is where you use lots of water and very little air, but the gun costs $40,000 to $50,000 and it runs on electricity so you have tremendous electrical needs. We weren't ready to make that investment since we had no idea whether this would work or not anyway so this was the cheaper way to go You can find snow guns at ski resorts they will likely give you because they are not using them anymore. They are all using the new technique.

Bruce Briggs: When you put the snow on did you go out and look at areas where you had it very deep and very shallow? Did you determine what depth you needed to give you adequate protection?

Michael Poynter: No, not in any scientific way Our feeling is that if we can get 2-1/2 to 3 in. of snow on the perennials we can withstand just about anything. We make several assumptions such as the plants are big and mature enough to go through the winter in the first place Also, I think the fabric underneath the snow, while it might not be the perfect scientific experiment, did help get the snow blanket on since the snow will fall down in and around the foliage. The fabric allowed us to create a more even layer of snow, uniformly over the entire bed

Kristin Yanker-Hansen: What is the optimum depth to plant peonies?

Roy Klehm: The general consensus of opinion is that in the southern areas you plant the eyes at ground level, whereas in a colder zones we plant the eyes 2 in. deep. The quality of the soil can affect the ability of the peonies to grow.

Kristin Yanker-Hansen: Is it temperature related?

Roy Klehm: Peonies to overcome dormancy should have 600 h below 32F ideally. Knowledge is needed on the growing of peonies in warmer climates.

Roger Slaby: I have a question regarding daylilies. We used to get brilliant reds and the cultivar brought to this part of Washington tends not to have a deep red and the assumption was that the summer temperatures in Illinois brought those color pigments. Have they overcome that problem with some of the newer hybrids?

Roy Klehm: That's a good question. I think daylilies do better where the summer nights are warm. I analyze daylilies everyday and it's amazing how they respond to different temperature and moisture patterns. Some days you can go out and look at them and they are all ugly and other days you go out and they are all champions. I think the better cultivars would perform well over different geographic areas, but I don't think anyone has addressed that specific question. In England they don't do as well because the evenings are not warm enough for them to really respond.

Kathy Echols: When you are working with the gibberellic acid, have you found that it affects certain plants in different ways? Have you written up the research that you have done?

John Schroeder: Different species have different responses. The same plant requires different rates of gibberellic acid from the beginning of the year to the end of the year to get the same results so it's full of variables right now. We will continue to refine the research and we will make it available.

Kathy Echols: With the use of gibberellic acid, are you finding that after the plant has gone through a period does it return to its original growth habit?

John Schroeder: The *Veronica austriaca* ssp. *teucrium* 'Crater Lake Blue' grew taller than you would normally expect, but for most of the plants it speeds the rate at which they get to their ultimate height and then they stop and everything else catches up later.

Steve McCulloch: Is the agar substitute commercially available in the United States?

Ronald DeFossard: Yes, from an American firm, FMC. They are very active in pharmaceuticals and they have a variety of these colloids.

Bruce Briggs: We have trouble in our country with some of the synthetic types with vitrification especially when trying to grow conifers and some other plants. We haven't had the problem with the plants we grow at the lab. There was some work done over in Europe where they cooled off the bottom and there was moisture formed in the jar. Did you have that problem or did you grow plants that do not have that problem?

Ronald DeFossard: I didn't have the problem. I didn't look for it either. I might say that the new gels are incredibly cheap. We pay less than $30 (Australian) per kilogram. Without the freight costs, I think it would be less than $20 (U.S.) per kilogram.

The History of the Flower Bulb Industry in Washington State

Charles J. Gould[1] and Gary A. Chastagner[2]
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Washington State has been the major producer of iris, narcissus, and tulip bulbs in the United States for many years and ranks only behind the Netherlands and Great Britain in the acreage of these bulbs in the world. Why has this state been so successful?

Several factors have contributed to this success. They include good soil, intelligent and creative farmers, scientific research assistance, and especially a very favorable climate. The cool, moist winters in western Washington encourage root growth which produces larger, better quality bulbs than those grown elsewhere in the United States while the warm, dry summers facilitate digging and proper curing. The cooler spring and summer weather in this area also helps to control certain diseases which cause severe losses in warmer climates.

The question is often asked as to how Washington bulbs can compete with the cheaper and more plentiful bulbs from overseas. The answer is quality. Washington bulbs produce flowers that are larger, have a deeper color, and are more uniform in blooming. They also bloom about 2 weeks earlier than do those produced in Holland and, therefore, command a premium price in the bulb and flower markets. The successful mechanization of many operations by Washington growers has helped to keep the cost of production reasonably competitive.

Bulbs for private gardens in Washington State were brought in by some of the earliest settlers, but the oldest available record of commercial bulb production refers to a planting in 1892 by George Gibbs on Orcas Island. Gibbs later moved to Bellingham in 1899 and his success with bulbs there apparently stimulated others in the vicinity to get into the business so that Whatcom was probably the leading bulb county in the state until about 1920.

In 1906 and 1907, the United States Department of Agriculture (USDA) sent a team of scientists around the country to look for suitable areas for research on bulb

[1] The text of this article consists of the Summary chapter taken from Dr. Charles J. Gould's new book on bulb growing in Washington. Dr. Gould is a Plant Pathologist Emeritus, who spent his entire career (1941-1977) at Washington State University's Research and Extension Center in Puyallup, Washington. His research specialization was the cause and control of diseases of bulbs, turfgrass and other ornamental crops. In 1993, Dr. Gould's book entitled *History of Bulb Growing in Washington* was published. This 309 page book covers bulb growing during the last 100 years, the 900+ growers, the markets, the financial value, the places and dates, the horticultural practices, the equipment, the problems, the associations and companies, the state- and federal-supported research, and the spring flower bulb festivals. This book is available from Washington Watershed Publishing Company, 9792 Edmonds Way, Suite 178, Edmonds, WA 98020.

[2] Talk presented by Dr. Gary Chastagner, Research Plant Pathologist, Washington State University Research and Extension Center, Puyallup, WA.

growing. Gibbs and others had previously sent letters and samples of their bulbs to the Department and had cooperated with them in experiments so it was not surprising that the scientists chose Bellingham as a major test site in 1908, and established a Bulb Station there. The USDA had two major goals: to determine whether bulbs could be produced commercially in the United States and to raise bulbs for members of Congress to give away to their constituents, a political custom at the time.

Experiments began at the Station in 1908 and continued until 1935. Dr. David Griffiths became supervisor of the Bulb Station at Bellingham about 1917 and deserves much of the credit for its success. He was an excellent promoter for the fledgling bulb industry and much of the information in his bulletins is still valid today. If we consider Gibbs to be the "Commercial Father" of the Washington bulb industry, then Dr. Griffiths certainly rates the title of the "Scientific Father."

Washington's bulb industry grew slowly at first. Sales of cut flowers were probably the main source of income, with bulb sales being secondary. Among the earliest growers were Mrs. Mary Stewart on Samish Island (Skagit County) and Edwin Wines on Fox Island (Pierce County), both starting about 1908. George Lawler began raising narcissus at Fife (Pierce County) in 1910, initially for cut flower production, and, by 1920, was probably the largest bulb grower in the state. By that time, there were also several others growing bulbs in smaller plantings in several counties.

The greatest stimulus to American bulb production was the USDA announcement of a quarantine against the importation of narcissus and certain other bulbs, imposed in an effort to protect domestic bulbs from invasion by insect and nematode pests carried on imported bulbs. It was announced in 1922, but did not go into effect until 1926. During the interval, many American farmers in several states imported bulbs for planting and several Dutch firms sent representatives and bulbs in order to establish their own bulb farms in the United States.

The federal quarantine was modified in 1936 and revoked in 1938 but, by that time, the Washington State bulb industry was well-established. Some contraction occurred during the Depression years from 1932 to 1935 when many small growers went out of business. Markets were good during World War II but manpower shortages and higher costs affected production and profits.

The wartime shortage of labor and rising costs accelerated the trend toward mechanization in digging, cleaning, planting, and other operations. Mechanization proved to be very cost-effective. By hand, 40 man-days were required to dig an acre of iris. With machines, it took just one man-day. Mechanical planting of Iris went even faster, requiring only 0.2 of a man-day by machine as compared with 20 man-days per acre when done by hand. Because the demand for such mechanical equipment was small, however, none of the commercial farm equipment manufacturers were interested in producing it. Growers had to invent, build, and maintain their own machines.

After World War II, a heavy influx of Dutch bulbs at lower prices caused many Washington growers to reduce their acreages or to quit raising bulbs entirely. Iris growers, for example, plowed under 25% of their crop in the spring of 1953 because of surpluses and poor prices. Ironically, this was followed by a large increase in demand for them by Dutch bulb dealers in 1954 after an extremely severe freeze during the winter of 1953/54 damaged the iris crop in Holland. Overseas orders for

Washington Iris increased annually after that, reaching a peak of over 30 million bulbs in the late 1960s. Between 1966 and 1972, 199 million Washington iris were exported to England, Europe, and Canada. The demand tapered off, subsequently, for a number of reasons.

In general, the largest bulb acreage in Washington has usually been in narcissus, followed by bulbous iris, tulips, lily, gladiolus, and a few acres in hyacinth, crocus and other minor crops. Most of the gladiolus are now grown in eastern Washington while the other bulb types are raised in a 180-mile strip between Woodland and Mount Vernon in western Washington. Most of the lilies grown now are of the Oriental and Asiatic types but Washington once had a small and thriving Croft Easter lily industry. The center for Easter lily production is now located in the coastal areas of northwestern California and southwestern Oregon.

The total acreage of iris, narcissus, and tulip (INT) bulbs in Washington is estimated to have been about 5 acres in 1900 and perhaps 100 in 1920. It then climbed rapidly to 1796 acres in 1942. Since 1942, it has fluctuated between 1285 and 2355 acres. In 1989, for both bulb and flower production, there were 517 acres of iris, 1097 of narcissus, 608 of tulip, 77 of lily, 50 of gladiolus, and 6 of miscellaneous bulbs. This 2355 acres included the farm of the Washington Bulb Company in Skagit County which grew bulbs on 1310 acres and is the largest producer of iris, tulip and narcissus in the United States. The present bulb acreage in Washington State is one of the largest on record.

More than 900 Washington farmers have grown bulbs since 1892. The list includes 520 INT growers, 357 lily growers, and 134 gladiolus growers. Undoubtedly, there are many more growers of whom no record has been found so far. The total number of growers has declined since the 1920s. Although there are no data on the number of iris and tulip growers in 1929, there were 162 narcissus growers that year but only 15 in 1989. There were 80 INT growers in 1947, but only 17 in 1991. Three others grew bulbs in 1991 but only for cut flowers.

As the number of growers became smaller, average farm size became larger. In 1929, the average planting was 3 acres for narcissus, the bulb type which accounted for 86% of the total bulb acreage that year. In 1947, the average for all three major bulb types was 22 acres per farm. This grew to 69 acres in 1970 and to 117 acres in 1990.

The number of INT bulbs sold rose from 14.1 million in 1930 to 80.5 million in 1988. The latter figure includes 33.4 million iris bulbs, 24.6 million narcissus bulbs, and 22.5 million tulip bulbs. In addition, there were probably another 10 million INT bulbs used solely for flower production. That number, plus an estimated 12 million of the gladiolus, lily, and miscellaneous bulbs and corms produced, would have brought the grand total of all bulbs sold in Washington to 100 million in 1988.

The largest market for Washington narcissus originally was for greenhouse forcing in the eastern United States. Now, most narcissus bulbs are used by local growers for field-cut flower production and for their own forcing, although a few are sold to the dry sale trade. Bulbous iris are still in heavy demand for greenhouse forcing elsewhere in the United States and for sale to California producers for field-cut flower production. Most Washington tulip bulbs are now used for local forcing or field-cut flower production with only a few going into dry sales.

The bulb varieties upon which the industry was founded are not often seen now in the festivals and display gardens. The excellent 'King Alfred' narcissus reigned for over 40 years, but has been replaced by larger new yellow trumpet cultivars, such as 'Dutch Master' and 'Unsurpassable'. 'Wedgwood' was the most popular blue Iris from 1930 to about 1970, but has yielded its throne to one of its sports, 'Ideal'.

The sale of field-cut flowers has become big business. Official data is not available but the total number of flowers sold in 1989 was estimated to have been about 70 million. This included 50 million narcissus, 5-million iris and 15-million tulip bulbs.

Sales of forced and field-cut flowers have become so important that they now represent 70% to 90% of the total gross income of many growers, a situation almost completely the reverse of that in 1940 when income from bulb sales was far more important. Estimated gross income for INT growers was over $5 million for bulbs and over $6 million for field-cut flowers in 1989. This $11 million total does not include the income received from flowers forced in the growers' own greenhouses.

Bulb growers, just like other farmers, have problems, some natural and some man-made. Natural problems include drought, freezing, flooding, insects, and diseases while man-made problems include warehouse fires, bulb surpluses, labor shortages and the urbanization.

Natural problems, such as periodic severe freezes, caused bulb growing to die out in Whatcom County over 40 years ago. The most destructive freeze of all occurred during the winter of 1978/79 and affected all bulb types in all areas of western Washington.

Another natural problem, flooding, by the Columbia and Lewis Rivers, destroyed over 265 acres of bulbs at Woodland in 1948. This figure, however, has been dwarfed by the losses from a combination of flooding, waterlogging and freezing weather in the winter of 1990/91 when many tulip, iris, and some narcissus crops were destroyed in both Pierce and Skagit Counties.

Man-made problems include fires which put two growers out of the bulb business and caused serious losses at three other farms. Bulb surpluses have been an intermittent problem but were especially severe in the late 1940s and early 1950s when large imports from overseas coincided with good crops in Washington State. This surplus situation occurred at a time of changing markets and the combination was largely responsible for the decline of INT acreage from 1800 acres in 1949 to a low of 1285 acres in 1959, before it began to climb again. The latest man-made problem is the increasing shortage of suitable land, resulting from uncontrolled industrial and residential development. It has already crowded out most of the bulb industry in Pierce County and threatens to do the same in Skagit County where 70% of the state's bulb acreage was located in 1989.

Several bulb cooperatives have been organized in Washington and two are still active. Growers in the Puyallup Valley organized the Puget Sound Bulb Exchange in 1926 to sell, pack and ship its members' bulbs. The other organization is the Puyallup Valley Flower Cooperative which was established in 1956 to sell and ship field-cut flowers.

In order to facilitate the exchange of cultural information, bulb growers organized the Northwest Bulb Growers Association in 1924. Later, they developed the Washington State Bulb Commission in 1956 to provide additional funds for research and advertising. Both of these groups have cooperated, since 1948, with scientists from Washington State University at Puyallup and Mount Vernon in sponsoring annual Bulb Grower Conferences which keep growers up to date on new developments.

Bulb production has been aided by the research of many state and federal government scientists. The first research got under way in 1908 at the USDA Bulb Station at Bellingham where the major emphasis was on cultural techniques. Later, other USDA and WSU scientists at various locations worked on the control of diseases, insects, nematodes, and weeds, as well as on improved methods for handling and forcing bulbs.

When beauty came by the acre, it was only natural for bulb festivals to spring up. The first large one was an annual Tulip Festival held at Bellingham from 1920 to 1930, followed by the beginning of the Puyallup Valley Daffodil Festival in 1926. The LaConner Civic Garden Club in Skagit County put on a Tulip Show from 1946 until about 1971. In 1970, Oak Harbor on Whidbey Island started its Holland Happenings which originally included a Tulip Show. Next to develop was the Skagit Valley Tulip Festival which was organized by the Mount Vernon Chamber of Commerce in 1984. The most recent one is a Tulip Festival held in Mossyrock during the month of April every year.

But times change. Bulbs were once the major source of income for growers; now flowers are. The center of bulb production shifted from Whatcom County south to Pierce County and now has moved back north to Skagit County. As mentioned before, the most critical issue facing bulb growers today is not climate but land. There may not be enough bulbs left by the year 2000 to supply flowers for even the local festivals unless some method is found to preserve it. Meanwhile, the 2000 acres of blooms which are still available in western Washington should be fully appreciated and enjoyed now.

Flower Bulb Growing and Forcing

John Roozen and Richard Roozen
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Although commercial bulb growing has been attempted at various times in most parts of the world, major production has become centered in certain temperate countries with comparatively mild climates. Generally, these countries lie in the north temperate zone, between lat. 30° and 55°. In these areas, extremes of winter and summer are tempered by winds from oceans or other large bodies of water. In the United States, Washington State leads in the production of bulbous iris, tulips, and daffodils. Available precipitation records indicate that the Skagit Valley, located in the northwestern part of the state, more closely fulfills the natural curing requirements of the main bulb types than does any other major growing area. Skagit Valley also has an abundance of Puget silt loam and Puget clay loam soils. Drainage is a major factor in bulb production and is a critical factor when selecting fields. Crop rotation with large acreage agronomic crops like green peas and grains to break the disease cycle is very important and possible in Skagit Valley. Research support from WSU stations in Puyallup and Mount Vernon cannot be over emphasized. Through the Washington State Bulb Commission growers assess themselves based on production to support continuing programs with Dr. Andy Anderson, Dr. Gary Chastagner, Dr. Kassim Al-Khatib, to name a few. Sounds almost too good to be true doesn't it? Why are there not more growers? The fact remains that the industry is very specialized; costly mechanization allowing growers to remain competitive has eliminated many smaller farms. An industry supporting 200 growers in the 1930s has dropped to less than 20 today.

As a grower of fall flower bulbs, our primary goals at Washington Bulb Co. are to produce essentially disease- and insect-free bulbs true to type that will flower successfully.

Disease-free planting stock is planted in 8-in. rows on 40-in. centers starting in late August and hopefully finishing before Halloween. Bulbs are planted between 3000 lb and 7 tons per acre, depending on type, variety, and length of time they will remain in the field. Planting stock is separated by size after digging. These daughter bulbs are a result of the naturally occurring asexual reproduction system of flower bulbs. Growing these daughter bulbs to a flowering size is primary to the entire system.

Fertilizer is placed below and a few inches outside the row at planting times. Approximately 500 to 1000 pounds of a 10-20-20 analysis is used depending on soil analysis and grower feeling. Soil pH is maintained between 6 and 6.5.

The bulbs are planted in raised rows to facilitate drainage with approximately 6 in. of soil cover. After planting, prior to emergence, systemic and soil residual herbicides are applied. Surface drainage ditches are installed and basically bulbs are tucked in for the winter. During winter months, bulbs form roots and shoots. Iris emerges first in early December, followed by daffodils in late January or early February, with tulips emerging right behind.

As Spring arrives, growth of the above ground part of the plant increases and the natural flowering cycle is upon us. For daffodils, this is the middle of February, followed by tulips in April and iris in May. Selective harvesting of field flowers is a large part of our flower production. Since photosynthesizing plant parts are harvested, a balance must be maintained between this harvest and bulb production. As Spring continues, a close watch is maintained for foliar diseases and timely fungicide applications are made.

Cultivation for weed control and moisture retention is an ongoing chore. Great care is taken to cultivate only when foliage is dry. This is just one of several considerations to reduce pesticide usage.

Prior to topping and or flower senescence, off types and virus-infected plants are removed. The rouging process is labor intensive and expensive but ensures varieties are clean and true to type. Mechanical "topping," especially in tulips, encourages the plant to concentrate its energies on the below-ground parts and asexual reproduction. It also helps in *Botrytis* control by removing floral parts before they fall among the leaves. The "grand period of growth" for the bulb starts after bloom. Good cultural practices continue and sometimes foliar fertilizers are applied. Increasing temperature, decreasing moisture, and natural genetic traits trigger dormancy as summer arrives for tulips, and a few weeks later for daffodils and iris.

By the end of May, choppers, skimmers, digging machines, trucks, washers, sand machines, and a host of other specialized equipment is readied and mobilized to harvest the bulb crop.

Mechanization in recent years has eliminated hand digging but the work force still reaches 350 people during peak harvest. Bulbs are dug by machine, put in bulk trucks, and brought to the plant for washing, drying, curing, sorting, and grading. Planting stock is stored in well-ventilated areas and treated as necessary to maintain quality. Special disease-control systems are sometimes used. One example is hot-water treatment.

The end result of a bulb is a successful flower somewhere whether in the seed store trade, to a forcing customer, or to our own greenhouses which brings us to the forcing part of our presentation.

At Washington Bulb Co., forcing flowers has become a very important part of our business. We have about 8 acres of greenhouses with more planned in the near future. We force iris and Asiatic lilies year around while also forcing tulips from December until May and daffodils from December until February.

Flower forcing has enabled us to keep more employees busy all year while also bringing about a more even year-round cash flow. We have become more vertically integrated and diversified which helps to spread our risks and ultimately increase profitability.

Vegetable Seed Production in Washington State

Kenneth G. Christianson
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I am pleased for the opportunity to speak to the International Plant Propagators' Society on the subject of vegetable seed production in Washington State. I always enjoy speaking on this subject which appears so little known or understood by the public. So, this morning I hope to inform you on the historical background of our state seed industry, to introduce you to Alf Christianson Seed Co., and to provide a better understanding of the vegetable seed trade in Washington State and the markets we serve.

The first record of cabbage seed production in the United States was in 1866 on Long Island, NY. Prior to this time all production of vegetable seeds for the Western Hemisphere took place in Europe. The first cabbage seed commercially produced in Washington was in 1896 in LaConner by Mr. Tillinghast. Early settlers learned quickly that the moderate summer and winter climate and rich soils of the Skagit Valley region were conducive to the production of high yields of quality seed. By the early 1900s it was well-established that the Puget Sound region was the most ideal area in the country for the seed production of cool season biennials.

Now, it so happens that since vegetable seed was first produced in our country in the Northeast and Midwest States, the major seed houses prevailed in the East. It was not until the mid 1940s that most moved their headquarters to the West Coast to be closer to the major seed production and distribution sites. Today, virtually 100% of the quality vegetable seed produced in the United States is on the West Coast.

Alf Christianson Seed Co. was founded by my grandfather in 1926. Alf grew up on a farm in Angelholm, Sweden. He immigrated to the United States as a teenager. In 1909 he took a job with the Charles H. Lilly Co. located in Seattle, Washington. Lilly was one of the leading seed production companies of the day, specializing in production for the large seed houses in the East. Alf managed Lilly's seed production throughout the Puget Sound Region for seventeen years. In 1926 he opened his own firm in Mount Vernon where we continue to operate today.

Alf Christianson has grown to be a major breeder and marketer of beet, cabbage, carrot, radish, spinach, and other crops. The company also conducts extensive custom contract production of vegetable seed for other companies around the world. In this case the company produces seed from the customer's stock seed returning the entire crop for sole distribution by the customer.

The major vegetable seed crops produced in Washington State today and their approximate acreage include:

Red beet	450 acres
Cabbage	600 acres
Carrot	3000 acres
Radish	3500 acres
Spinach	3500 acres
Turnip, rutabaga, collards, kale	400 acres

The trend for acreage of these crops is steady to slightly down. This is largely due to the fact that most markets are transitioning to hybrid cultivars for the benefits of improved vigor, disease resistance, yield, and general performance. Since the price for hybrid seeds is high, growers are adapting new cultural methods, equipment, and planting systems to conserve on seed consumption and optimize performance. Although commercial growers worldwide are using less seed on a per acre basis, there still are many opportunities for Washington state seed producers. All markets are demanding high quality, consistent supply, innovation, security, and trust. Our climate, grower expertise, and reputation in the trade put us in the forefront to achieve these objectives and maintain market share. The new world order is providing new market opportunities in many countries previously out of reach. These include India, China and the many countries of Eastern Europe. European vegetable production is rapidly shifting to Spain, Portugal, North Africa, and Turkey. We should not overlook the opportunities to do more business with Mexico and the rest of Latin America. No longer is vegetable production limited to local markets. It is becoming a global market for vegetables. Already we see large amounts of fresh as well as processed fruits and vegetables coming from south of our border. In many cases this is produce grown from seed produced in Washington State. Today all developing countries of the world are looking to make technology leaps in agriculture. This can best be done through the purchase of quality seed of the latest cultivars available. By combining this with reliable cultural information, even growers in these emerging countries can realize the benefits of the latest in modern plant breeding. At this point I would like to share with you some slides of Washington state seed production and some of the markets we serve.

Production of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, Rooted Cuttings for Reforestation by Weyerhaeuser Company

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Although most forest planting stock has historically been propagated from field-collected seed, the recent availability of high-quality genetically improved seed has spawned efforts to bulk up quantities of this material using a rooted-cutting approach. Around the world, many important timber producing conifers (*Cunninghamia lanceolata, Cryptomeria japonica, Pinus radiata, Picea mariana, P. sitchensis, P. abies*) and hardwoods (*Populus* spp., *Salix* spp., *Eucalyptus* spp.) are being propagated in this manner.

At Weyerhaeuser Company, in western Washington state and Oregon, an effort has been underway since 1986 to develop a system for commercial production of coastal Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, planting stock through cuttings. The system is being applied to bulk up seed from elite, control-pollinated (CP) families. The three-year propagation regime begins with greenhouse production of stock plants, followed by rooting of cuttings under fog, and finally finishing the rooted cuttings in an outdoor bare-root nursery. Production is currently running at about 1 million per year—enough to plant about 2000 acres. Future scale up is anticipated.

INTRODUCTION

Nearly all forest tree planting stock is propagated from seed. However, with very high quality and expensive seed now flowing from seed orchard programs worldwide, many attempts are being made to increase (bulk up) the supply of this elite genetic material using vegetative propagation through rooted cuttings (Ritchie 1991, 1993). This paper will present a brief overview of this technology as a prelude to describing a commercial scale Douglas-fir rooted cutting system now under development by Weyerhaeuser Company in western Washington state and Oregon.

REVIEW OF ROOTED-CUTTING PRODUCTION FOR REFORESTATION

Rooted cutting technology is normally employed to capture one of two opportunities. The first is to "bulk up" valuable seed supplies, the second is to "clone" valuable genotypes. In the process of bulking, relatively small numbers of copies are made of a relatively large number of genotypes. For example, 1 lb (0.46 kg) of Douglas-fir seed might produce about 20,000 seedlings under normal nursery practices. That same pound of seed can be bulked into over a million plants in one propagation cycle using rooted cuttings. Cloning, on the other hand, makes a large number of copies of a relatively small number of elite genotypes.

Cloning forest trees is difficult because each individual clone must be field tested prior to its use as planting stock. This requires several years, during which time all clones must be maintained in a juvenile state to await identification, multiplication, and propagation of the elite clones. This is expensive and cumbersome with all species but those relative few that produce juvenile material, such as basal sprouts, as mature trees. Certain species of poplar (*Populus* spp.) willow (*Salix* spp.) and eucalypt (*Eucalyptus* spp.) exhibit this property and are the subject of large-scale cloning programs in Europe, Asia, North America, Brazil, Australia, the Congo, Colombia, and other places (Leakey, 1987; Ritchie, 1993; Zobel, 1993). In Japan, sugi, *Cryptomeria japonica* D. Don, has been cloned on a massive scale for at least 500 years (Ohba, 1993) and the Chinese have cloned Chinese-fir (*Cunninghamia lanceolata* (Lamb.) Hook. f., for a millennium (Li et al., 1990; Ritchie, 1993). Other, much more recent, conifer cloning programs are those with Norway spruce, *Picea abies* L., in Germany, and black spruce, *P. mariana* (Mill.) B.S.P., in Ontario.

Nearly all bulking systems have been developed for use with conifers and nearly all of these for amplifying the supply of genetically improved seed (seed produced in seed orchards). The use of this technique for bulking open pollinated (OP) seed is economically justified only where seed is very scarce and valuable, such as in Scandinavia with Norway spruce (Bentzer, 1993). More often, bulking is used to produce stock from control-pollinated (CP) seed, where genetic gains are higher and seed much more expensive to produce. Sitka spruce, *Picea sitchensis* (Bong.) Carr., a North American conifer that is highly prized in England, Scotland, and Ireland, is propagated by rooted cuttings at a rate of about 6 million annually, most from CP seed (Mason, 1991). Another North American tree, Monterey pine, *Pinus radiata* D. Don, is the principal conifer grown in both Australia and New Zealand. Aggressive breeding programs undertaken during the 1960s and 1970s are now producing commercial quantities of CP seed and much of this is being bulked by rooted cuttings. Australian production in 1992 was about 3.3 million (Ritchie, 1993).

WEYERHAEUSER'S DOUGLAS-FIR BULKING PROGRAM

Weyerhaeuser's Douglas-fir rooted-cutting program is aimed only at bulking CP seed. This seed is produced in grafted seed orchards that were established in western Washington and Oregon during the mid 1960s from phenotypic selections. Seed are from parents whose progeny have been extensively tested over the past 15 years in replicated field trials and whose volume growth and stem-form characteristics are in the upper echelon of the production population. These parents are bred in March from pollen collected the previous year. Crosses are made by hand, using lift trucks, and the cones are bagged following pollination to prevent entry of foreign pollen. Cones are harvested in August to September then after-ripened for several weeks. Seeds are extracted, cleaned, and then stratified for 9 or 10 weeks prior to sowing.

Seeds are sown into cells in "Mini-Plug" trays (cell dimensions = 2 cm x 2 cm x 3 cm deep) and germinated in a greenhouse during early spring. In early May, they are transplanted into gallon (4 liter) plastic cans and arrayed on the floor of a production greenhouse. Cans contain a mix of 1 peat : 1 perlite (v/v) plus Sierra slow-release fertilizer. These stock plants are watered and fed by drip irrigation.

By December, they are about 1 m tall and contain about 50 branches, each of which is harvested and placed into freezer storage (-1C) until late April.

These cuttings are set into Multipot-5 trays in the same type of peat:perlite medium and rooted with high pressure fog and bottom heat. Rooting averages over 90% across the production population. In July, they are weaned and, in August, transplanted into a bare-root nursery using a 7-row Lannen transplanter specially modified for this purpose (Fig. 1). After transplanting, cuttings are watered heavily and continue to produce roots during autumn, but few break bud. In winter they may be frost protected using overhead irrigation if needed. In May, the buds break and the cuttings begin a phase of very rapid growth, culminating in a plant averaging about 7 mm in stem diameter, 45 cm in height, and weighing about 15 g (oven dry) by the following December. During the nursery phase they are fertilized and weeded and often wrenched to stimulate root development. (Wrenching involves first undercutting then drawing a thick blade beneath the nursery bed, which heaves the plants up, loosens the soil, breaks new root tips, and improves root fibrosity). The plants are lifted for field planting between December and February when they are dormant. They are successfully held in frozen storage (-1C) until field planting, which occurs December through April.

Extensive and intensive physiological tests (Ritchie et al., 1992) and field trials (Ritchie et al., 1993) have been carried out with Douglas-fir rooted cuttings to confirm their suitability as forest planting stock. Rooted cuttings tend to cold harden earlier in autumn than genetically similar seedlings and transplants and tend to retain their hardiness later into spring. They have comparable root growth potential (RGP) but exhibit a more intense winter dormancy than the other stock

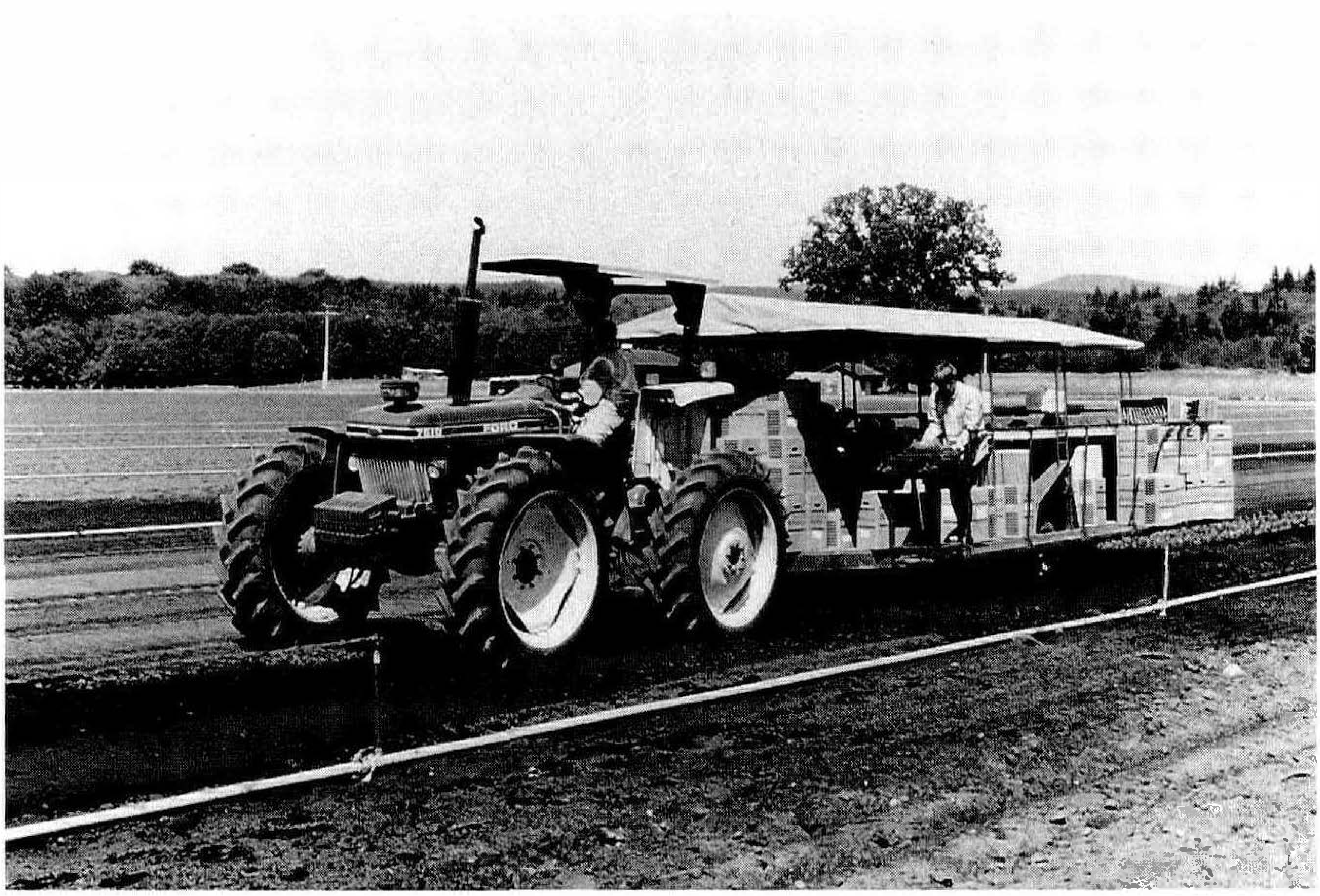

Figure 1. Seven-row Lannen transplanter specifically modified for planting Douglas-fir rooted-cutting plugs. The machine carries about 30,000 cuttings, enough to plant a 1000-ft-long nursery bed.

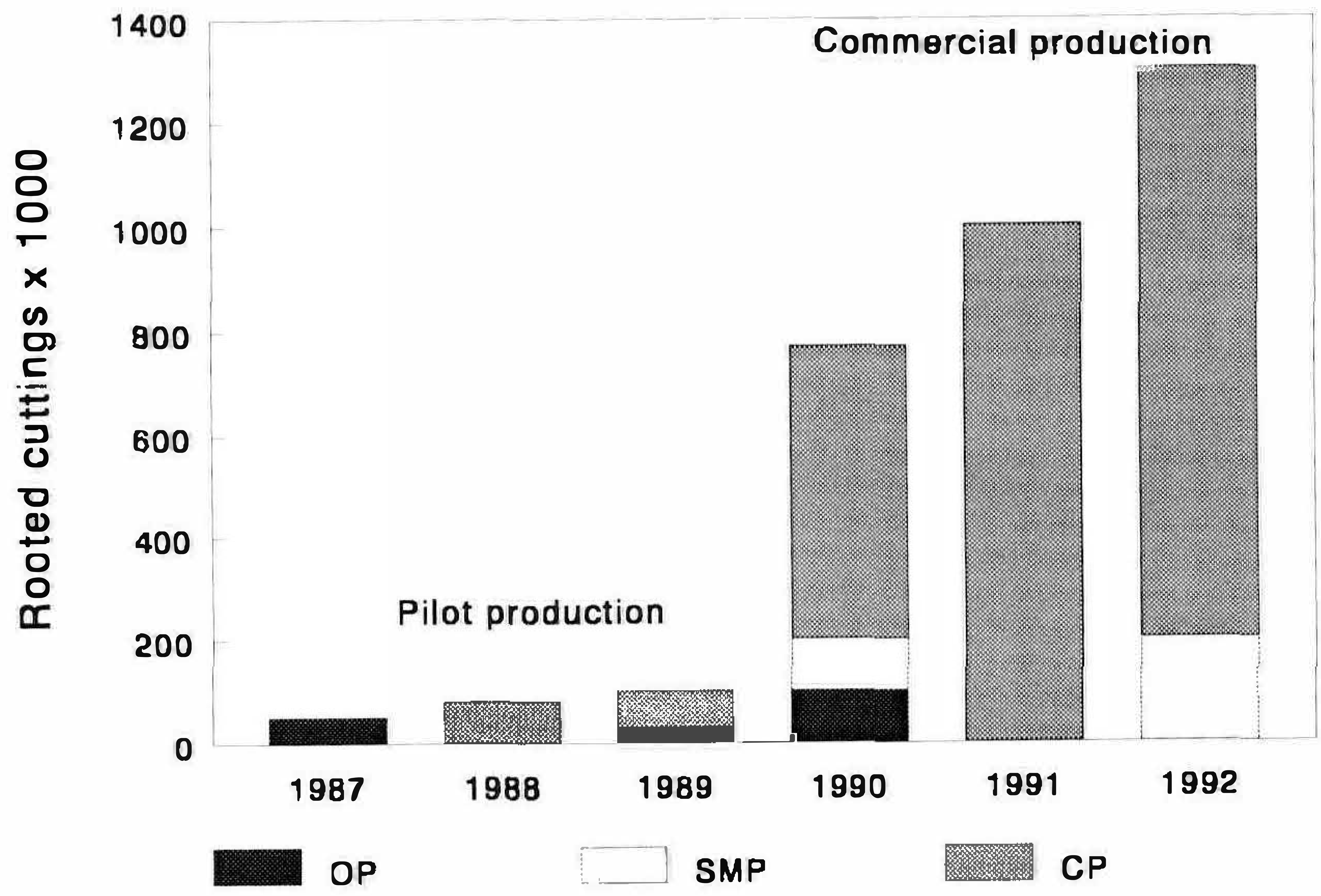

Figure 2. Production history for Douglas-fir rooted cuttings at Weyerhaeuser Company. ●P=open pollinated seed, SMP=supplemental mass pollinated seed, CP=control pollinated seed.

types. Rooted cuttings also tend to have a higher ratio of stem diameter to height than seed-origin Douglas-fir.

Field trials with rooted cuttings over a wide range of sites have led to the following conclusions: (1) after 1 year in the field rooted cuttings are visually undistinguishable from seed-origin material, (2) there is no evidence of maladaptation or unusual growth habit (e.g., topophysis) with rooted cuttings, and (3) rooted cuttings exhibit the same survival and height growth as seedlings and transplants of the same stem diameter, root quality, and genetic background.

Weyerhaeuser's production began in 1987 with a pilot scale crop of about 50,000 (Fig. 2). This was followed with two more pilot scale crops. In 1989, production was scaled up from about 80,000 to about 800,000 and then to about 1 million. Early production was with open pollinated (OP) seed. However, propagation success has led to an orchard breeding strategy specifically aimed at providing CP seed for bulking with rooted cuttings. Current crops are fed entirely with seed from controlled crosses or from supplemental mass pollination (SMP).

Current research is focused on bringing production costs down by improving yields and efficiencies at every step in the process. When this is achieved, and as field trials continue to confirm the excellent performance of this material, production levels may increase.

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Field Propagation of Light Sensitive Species by Seed

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INTRODUCTION

Lawyer Nursery of Plains, Montana has been in the business of producing seed propagated liners and understock since 1959. In 1988, the company purchased a bare root nursery facility in Olympia, Washington in order to take advantage of the coastal climate and add diversity to the product line.

The bare root seedlings and transplants produced in Montana and Washington are marketed throughout the United States and Canada. Our product line is shipped to nurseries, commercial orchardists, conservation districts, highway departments, reclamation projects, and the like.

In order to propagate 275 different species of woody trees and shrubs, we utilize numerous specific seed treatments designed to overcome seed dormancy. Seed treatments vary from simple cold stratification or acid scarification to burying seed below the frost line for 2 to 4 years. We typically sow some seed every month of the year in Washington with the exception of January and February. The largest part of the crop in Washington is sown in the spring. In Montana, the majority of the sowing occurs in early fall.

This discussion will focus on our work with three distinct crops as well as six species of *Betula* to overcome photodormancy or light sensitivity.

The basic mechanism of light sensitivity in seeds involves a photochemically reactive pigment called phytochrome (Hartmann et al., 1990) When the imbibed seed is exposed to red light, the phytochrome pignent is altered and this reaction stimulates germination. In addition to six species of *Betula*, we have successfully treated *Paulownia tomentosa, Populus tremuloides,* and *Buddleja davidii* as light-sensitive crops.

Our birch program includes the following species: *Betula papyrifera, B. pendula, B. nigra, B. platyphylla* var. *japonica*, B. *maximowicziana,* and *B. lenta.* Although birch species are routinely propagated by tissue culture and stem cuttings, there remains a strong demand for two-year seedlings as understock, conservation material, etc. In some species of birch, the requirement for light during germination can be overcome by cold stratification (Young and Young, 1992). We sow dry seed in late spring. We achieved good stands this spring with all of these species except for *Betula lenta.*

Paulownia tomentosa, the Empress tree, is a native of China that has attracted attention in this country for a number of reasons. Its rapid growth, unusually large leaves and high-quality wood have made it popular as an ornamental and a timber species, particularly in the southeastern United States. The wood of paulownia is actively sought by Japanese buyers and has brought prices comparable to that of black walnut. This tree has also been used for strip mine reclamation in Kentucky (Immel et al., 1980). *Paulownia* seeds require long exposures to light for germination (Schopmeyer, 1974). This light requirement can be reduced by stratification, gibberellic acid, and dry cold storage (Carpenter and Smith, 1981). Because of the small seed size (about 6000 seeds per gram), we have found the crop easier to handle by providing light during germination rather than stratification. We sell the stock as two-year root crowns since the tops are usually injured by the first frost and do not tolerate cold storage.

Buddleja davidii, or butterfly bush, is an old-fashioned, multi-stemmed, semi-herbaceous shrub. It is useful in the landscape because of its profuse summer flowers and its tolerance of a wide range of sites. There are several well-known selections of this plant in the trade which are routinely propagated from cuttings. We have offered bare-root seedlings in our catalog for several years and we have had a good response. Although the seeds of *Buddleja* do not require any pre-treatment for germination, we have had our best success treating this crop as if it were light sensitive. The seed is very small and our attempts to cover the seed at all have resulted in poor stands. This crop is also sold as a two-year root crown due to the herbaceous nature of the tops.

Populus tremuloides, quaking aspen, is the most widely distributed tree in North America (Dirr, 1990). Bare root seedlings are used as ornamentals, native plants and as conservation material because of the tremendous adaptability of the species. The seed of*Populus tremuloides,* like that of*Buddleja*, does not require any pretreatment. Because of the small size of *P. tremuloides* seed and the relative weakness of the germinants, we also treat this crop as if it were light sensitive. Two-year-old seedlings in Olympia range in size from 18 in. to about 6 ft. The crop requires a rigid fungicide program the second year to control several foliage diseases including *Mycosphaerella populorum* and Venturia shoot blight.

NURSERY PRACTICE

The largest portion of the sowing at Lawyer Nursery is accomplished with an Oyjord seed drill. This particular drill is quite versatile; it can accommodate a wide range of seed sizes and can drill seed at an impressive range of densities. It will also sow at a 4-row or 8-row configuration which can be changed quite simply. Seed of the species in this discussion, however, are sown by hand since some of these seeds, *Paulownia* in particular, are so light. The seed is distributed by hand on a raised 42-in. bed marked with 8 or 4 rills which are spaced evenly across the bed. It has been our practice in the past to form and rill the seedbeds about 4 to 6 weeks prior to sowing. During this period we would irrigate the beds on a regular basis to promote weed seed germination and pack the seedbed prior to sowing. The rationale was that we could burn off the weed cover with paraquat just prior to sowing the crop and the rills would be sufficiently compacted to prevent the crop seed from getting covered. While we attained excellent weed control with this practice, we noticed that with some species the seed would germinate, but many of the germinants would stall out soon after germination and eventually disappear. We felt that our seedbeds had become compacted just enough to restrict the growth of the very fragile germinants of *Populus* and *Paulownia.* At this time we are sowing seed directly after forming and rilling the bed.

The key to success with these light sensitive crops is frequent irrigation of short duration. We have experimented with several different heads and microjets but what we have ended up with is a customized spacing of our existing lateral lines. Most of the nursery is set up with 2-in. lateral handlines set-up on 52-ft spacing with 14V rainbirds with 7/64-in. nozzles spaced 30 ft apart in the line. In the area that we designate for these light sensitive crops, we moved the lateral lines 26 ft apart instead of 52 ft and replaced the 7/64-in. nozzles with 5/64-in. nozzles. These lines are turned on and off by hand during the first 6 weeks. After 8 weeks we replace the small nozzles and remove the extra line.

Another practice we changed this year was the use of Terrasorb gel. In the past we would broadcast dry Terrasorb, a starch gel, over the seed. As the Terra sorb absorbed moisture, it would form a clear gelatinous slime over the seed and keep the germinating seed hydrated. By changing the configuration of the irrigation lines, we were able to abandon our Terra-sorb program.

We do experience some problems with *Paulownia* and *Buddleja* seed being splashed out of the rills by the irrigation water and wind. We will end up with seedlings scattered throughout the bed, in the rills as well as up on the ridges between the rills and in the aisles between the beds. The birch seed usually stays intact in the rills. The *Populus* seed typically germinates in 48 to 72 hours after sowing and does not experience any movement.

With all these crops we hope to achieve a second year seedbed density of 15 to 20 seedlings per square foot. The first year density is usually significantly greater than this but the seedling population is reduced to an adequate level during the winter. Our cool temperatures this summer resulted in excellent germination and slow growth of the germinants. We sow these crops late partly to control their size. They do not achieve market size in one growing season and two full seasons provides a larger finished product than we want.

To achieve successful stands with field germinated seedlings, constant attention by the grower and the irrigator is required. Treating the seed to overcome dormancy is just the beginning. We like to brag about our sandy loam soil in Olympia, touting it as the best bare root nursery soil in the world. The reality is, however, that our seedbeds really represent a rather harsh environment when compared to the petri-dish in the germination chamber.

By paying special attention to the specific needs of difficult-to-propagate crops such as these, we attempt to close the gap between the germination potential of the seed lot and the actual field performance.

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It's Good Business to Buy Recycled

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The rapid growth of recycling programs threatens the stability of the very markets upon which recycling depends. Strong recycled -material collection systems require equally strong markets for recyclables to remain viable. In support of the development of recycled material markets, King County has developed a recycled product procurement policy requiring County agencies to purchase products manufactured with recycled materials wherever practicable. King County purchases recycled products and materials valued at over 1 million dollars per year. The successes of our "Buy Recycled" program may serve as a useful model for businesses, since environmentally sound practices are important to customers and may represent marketing opportunities:

- Recycled paper is used for all stationery, business cards, photocopying, and printing, and the chasing arrow logo identifies the recycled content of all printed materials.
- Re-refined motor oil is used by all County vehicle fleets and a "Follow-My-Lead" bumper sticker advertises this program. Used oil is returned for re-refining.
- Re-refined antifreeze is used in all vehicles and is recycled to avoid toxic waste disposal.
- Composted municipal yard waste is used as a soil amendment in County road projects.
- Recycled concrete aggregate is used as a temporary road surface or granular fill.
- Recycled plastic lumber is used in place of treated lumber in an increasing number of soil and water contact applications.

Many local, state, and federal government agencies are offering product development grants to businesses for assistance in developing and testing recycled material applications. Although these grant programs are rarely opportunities for direct profits, they can lead to valuable publicity for a business. These agencies also offer award programs that can bring useful publicity to a business. A commitment to support the development of local recycled product industries by trying out new products can also reveal some useful new materials, such as anti-pathogen compost products or recycled plastic lumber.

The complete text of the annual report of the King County recycled product procurement program and a model procurement policy may be obtained from the King County Purchasing Agency.

Direct Stick Rhododendron Production

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At Monrovia Nursery Company, we do most of our *Rhododendron* cutting production directly into liners (rose pots). We are currently growing 44 cultivars from rooted cuttings. We take our cuttings from containers in the field in October and November.

When the cuttings come in from the field, we prepare them by cutting back the leaves (if it's a large leaf) and cutting out the bud that has formed. The cuttings are approximately 3 to 4 in. long, depending on the variety. After the cuttings are prepared, they get a chlorinated wash with 5 ppm chlorine. After they've been washed, we wound the base of the cutting 180 degrees apart. After this process, the cuttings are ready to be stuck in the mist house.

The rose pots are run through a flat filler and filled with a *Rhododendron* cutting mix, which is 3 peat moss : 2 perlite (v/v). The pots are taken to the mist house where the *Rhododendron* cuttings will be stuck. We use Hormodin #2, #3, or Dip 'n'Grow as hormones. The cuttings are stuck into hormone, then into the liners. After each day of sticking *Rhododendron* cuttings, we give them a preventative drench with Subdue.

The cuttings stay on bottom heat (64F), under mist, until March or April. At this time, they are very well rooted and moved to a shade house. The liners will start to push out and will immediately be potted into 1-gal containers. They will be pruned in gallons after they have established themselves and will be of saleable size in 18 months.

Plastic Lumber

Kathy Van Veen
Van Veen Nursery, P.O. Box 86424, Portland, Oregon 97286-0424

In 1991 the Environmental Learning Center at Clackamas Community College approached us regarding the experimental use of plastic lumber in a greenhouse situation. We had a propagating house due to have its crumbling beds replaced that year, so we agreed to try it. We were given, free of charge, enough plastic lumber to replace a section of rooting bed 6 ft wide and 30 ft long, including the side boards.

The plastic lumber consists mainly of recycled milk jugs, yogurt containers, and nursery pots. The plastic is melted and extruded, like toothpaste, into boards. It is said to take 180 milk jugs to make one 2 in. × 6 in., 8-ft board.

The lumber comes in various colors and stabilizers are added to keep the color from fading. The boards we were given were either grayish-green or marbled black.

At the end of March, the cost was $1.25 to $1.35 per ft compared to $0.77 to $0.94 for preserved wood. In addition to being expensive, it is rather difficult to work with. It is heavy, but very strong. When cut, it is dusty. It is hard to hammer nails into, so we had to drill holes before nailing.

On the plus side, there is no maintenance. Regular wood benches need to be completely replaced about every 10 years. They must be painted with wood preservative every year and minor repairs must be made continually. Plastic wood benches will last for a few hundred years, we are told!

Another good point is that plastic lumber could have more of a demand in a time when wood is becoming less available and more expensive. It is a good use for discarded plastics, too.

Right now it is not being manufactured fast enough to meet immediate demand. In Portland, it may be ordered, but it takes a while to be delivered. We are happy to have gotten it when we did, and free at that.

Trying Hard to Stay Small

Ray Swanson
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Many of us entered the industry because of our interest in the beauty and diversity of ornamental plants. I bought Boulevard Nursery, a small retail garden center in Olympia, Washington, and have spent the last 15 years increasing the size of the inventory and creating appeal for the customers. It involves things that are not plant related like making more display areas and designing parking lots.

For more control over what we offer, we needed facilities to grow some of the short term, or non-woody, crops. For that we have greenhouses at another location.

A few years ago we built an insulated room for germinating seeds early in the season primarily to save on heat costs. It has racks for the trays and fluorescent lights on some of them. We are able to control the temperature with simple equipment. A 1500 watt household heater, a 20-in. box fan for circulation, and an exhaust fan for most days. We recently put in a household air conditioner to keep the room cool for summer germination of primroses.

Difficulties in finding and keeping interested and productive personnel made us think about more efficient ways of getting the work done.

We did not want to invest so much and get so large that we had to develop a wholesale marketing effort.

We were pleased with the results of using our insulated room and had extra space so we decided on going to plug trays. We bought a Van Dana seeder and set it up for 288-square plug trays. We have since used it for direct seeding 12 packs and 6 packs with good results. We use a dislodger for the plug trays.

The filling of flats for transplanting has always taken a lot of time. To fix that we bought a small flat filler. It was easy to use but we ended up with pallets full of trays and no way to move them. We bought a pallet jack and it makes for a good operation.

A couple of years ago we installed roller conveyors along one end of the houses. For smaller quantities or limited spaces we use two-wheeled flat carts.

Now with half the employees, less training time and supervision we have more uniform crops to sell at our garden center. We can still enjoy being in the ornamentals business, close to our products and our customers.

The Use of Velcro Strips for Rooting

Barbara Selemon
University of Washington, Center of Urban Horticulture, GF-15, Seattle, Washington 98195

My talk today will be a tale of a trial rather than a propagation tip that can be taken out the door. I will discuss the use of velcro strips with IBA applied to mature trees in the landscape as an aid in the rooting of these difficult species.

As the propagator at an arboretum, I am often faced with the difficult task of propagating rare specimens. Some may have been originally grafted while others fit into the category of being difficult to propagate because of maturity, stress or poor health. Two such plants that I am working on are *Magnolia scheideana*, a native of Mexico and *Quercus robur* 'Concordia', a yellow-green cultivar aptly named the golden oak.

Banding, a method of etiolation using velcro strips to exclude light with added IBA talc, was attempted on mature trees in the Arboretum in the summer of 1992. Weather conditions earlier this year during the so-called non-summer of 1993 were so cool and wet that trials were not repeated. Gathering information from a couple of sources, namely Nina Bassuk at Cornell University, who has done extensive work on banding of oaks, as well as some discussion with folks down at the University of California, Davis Arboretum, who were experimenting with similar trials on oaks there, I decided to attempt this procedure. The primary difference being attempts on mature trees in the landscape, where all sorts of conditions exist. Supplies consisted of latex throw-away gloves, IBA talc, Hormex No. 3 in a sealed plastic bag, velcro pieces cut to approximately 1 in. x 1 in. Strips were applied to branches lower on the trees, both in full sun as well as in full shade. They were to remain for a period of 8 weeks time, managing wind, rain, and other unexpected disturbances. At the end of this time period, semi-hardwood cuttings were made by cutting the stems just below the velcro strips. The results were very apparent wounding, with calloused knobs existing on some stems of the *Magnolia* created by the tight velcro strips placed on the growing plants embedded by the velcro nubs. These cuttings were then stuck in a pure pumice medium under mist. Three of the *Magnolia* cuttings rooted, with only one living past the winter months. None of the oak cuttings rooted. Cuttings of stems not wounded by the velcro were attempted as well, but none rooted. Results are sparse, but further trials are to be attempted next year, with the hope of further success.

High Density *Actinidia* x *deliciosa* Production in a Climatically Controlled Environment

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Aztec Nurseries is presently engaged in a seven-year research project for the development of the commercial production of *Actinidia* x*deliciosa* [syn *A. chinensis*] (kiwifruit) in a climatically controlled environment (CCE) that creates several challenges.

In an attempt to maximize production versus area due to capitalization cost of a controlled climatic environment, changes must be recognized in almost all aspects of production: The physical structure, plant spacing, plant sex, pollination, fertilization, watering, pruning, and training will all have some variation in the Kiwifruit production compared to open field production.

In recognizing that an average field production modified with a structure above would be insufficient in the lb/ft^2 to be economically viable, we attempted to change the physical structure from a horizontal to a vertical lateral production. In this process high-tensile strength wire was placed 12 in. apart horizontally on a vertical structure to a height of 8 ft. This was done to reduce the square feet of plant production. Row spacing could then be spaced 4 ft apart compared to the 15 ft in the field, allowing plant production in an area of approximately 40 ft^2 as opposed to 225 ft^2 in the field.

It is noted (by the B.C. Ministry of Agriculture and Fisheries and Foods) in the commercial field production that the ratio of planting should be five females to one male, (as more than 90% of female flowers are capable of developing and producing marketable fruit). In the CCE there is no cross-pollination due to insect unavailability, therefore there is no need for male plants in the production area. An increase in production is realized since only fruit bearing plants are used. With no cross-pollination available by insects, artificial pollination is the only available solution.

Pollination problems have occurred in open field production when cool, wet weather comes during flowering, limiting insect activity. In the CCE, artificial or hand pollinating by applying pollen with brushes or using the male flowers directly against the female flowers will produce, which can also maximize seed numbers and enhance fruit size. This works well but is very labour intense. An aqueous solution can be used to spray pollen mechanically. This solution is called Carboxymethyl cellulose gum acacia, better known as CBCA, which is mixed with pollen and applied by spray. This is expensive, but commercially viable.

Vegetative growth develops more rapidly in the CCE process. Fertilization is required approximately one month in advance, compared to the field production although both processes require the same macro- and micronutrients:

N	880 - 1130 kg/ha sulphate of ammonia
P	500 - 630 kg/ha super phosphate
K	190 - 250 kg/ha sulphate of potash

Watering must be more frequent in the CCE due to the higher evaporation rate.

Training is a very important step in forming a plant. In the first years a strong main shoot (trunk) must be formed, having the height no more than 7-1/2 ft.

Having reached that height there must be top pruning from then on to avoid apical dominance. They will create cordons, the new shoots on the main shoot, which should be trained along the wire. From these cordons, secondary cordons should be allowed to be produced (the cordons and secondary cordons are where the fruit will set). To maintain a continuous cordon development, frequent pruning and training is required. As cordons will grow as much as 10 in./day, continuous labour is required to maintain proper form inside the CCE.

In conclusion, the production of *Actinidia* × *deliciosa* in a climatically controlled environment has many advantages and disadvantages. The physical structure advantage gives more even crops, high production per square foot, and a friendlier working environment. The disadvantages of the CCE is the capital costs, having to cool the environment enough to make the*Actinidia* × *deliciosa* go into a dormant period during the winter months, costly pollination methods, and labour-intensive pruning and training. Overall, as production seems to be viable, capital cost and labour is high considering the market value for kiwifruit at present. It would appear to be a tight financial situation, unless the capital cost had already been absorbed on previous crops.

Propagation of Pacific Northwest Native Plants from Seed

Linda Date
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The assumption that native plants are easy to grow because they are abundant in nature isn't accurate when you try to grow them in containers in a nursery setting. Since there isn't a lot of information in print on propagating native plants it's up to the individual grower to study the habits and cultural conditions of natives and try to come up with the answers.

At Firetrail Nursery, we propagate Pacific Northwest native plants mostly from seed. The plants I'll be discussing are native groundcovers and woody shrubs.

There are a number of reasons why you'd want to propagate native plants from seed. One that's very controversial right now is genetic diversity. My understanding of introducing genetic diversity is that you use seed of a particular plant species collected from a number of different sites, allow the plants to cross pollinate and let nature take its course. Conversely, landscape restoration projects usually require the seeds to be collected on the restoration site so as not to contaminate that genetically diverse region. For the most part, if it's a nice, healthy plant, nobody asks where it originated.

The reason I prefer to work with seed is the challenge. Unlike the seeds of annuals and most perennials, woody plant seeds have very specialized characteristics. Most of them have dormancy requirements and/or hard seed coats and each plant variety has its own particular seasonal cycle. For example, *Symphoricarpos albus* needs two dormant periods before germination and *Rubus spectabilis* needs scarification and a dormant period before germination. Because of this, they also have specific storage requirements. Some seeds, such as *Cornus canadensis,* will keep indefinitely at 40F. While others, such as *Gaultheria,* need to be used within 12 months because the germination rate steadily declines in storage. Some native plant seeds are best sown directly outside in the fall and left to germinate the next spring. To prevent moss from taking over in the winter, we've found it helps to topdress the sow flats with about 1/4 in. of sand.

Another reason to use seed for propagation of native plants is that some of the plants are difficult to propagate from cuttings. With *Gaultheria shallon,* for example, you can get more uniform flats and larger quantities from seed than from cuttings. Smaller native seeds like *Gaultheria* are sown in cold frames and germinated at cool temperatures of around 55F. Because they take 3 to 4 weeks to germinate and then grow slowly for another 3 to 4 weeks, it is easy for moss and liverwort to take over and suffocate the seedlings. We've found topdressing again a 30 grit sand and then spraying with greenshield provides good control against the liverwort. Because we're on non-chlorinated well water, we've also had to use Agribrom at 10 ppm through the mist system to help control the moss.

For seed, such as *Cornus canadensis*, that needs to be scarified, you can try sulfuric acid, sandpaper, or a rock tumbler. I prefer using a rock tumbler with a 120 grit sand for 5 to 7 days. After a cold treatment of 4 months at 40F, the seed can be sown. After germination, the seedlings are transplanted into plug cells. *Cornus* *canadensis* is very sensitive to being handled at this stage and is very susceptible to *Thielaviopsis* and other root rots, so the mortality rate at transplant can be high.

Although native plants are adapted to harsh conditions, all the conditions must be just right for the seed to germinate. In nature, from all of the seeds that fall to the ground, only one or two seedlings may grow. In the nursery, we expect a higher percentage to germinate and grow into healthy plants. However, proper treatment of the seed and seedlings and a lot of patience are needed to produce a crop.

Propagation of Red Raspberries

Patricia N. Miller
Sakuma Bros. Farms, Inc., Burlington, Washington

Adventitious shoots are produced on the roots of red raspberries (*rubus idaeus*) during the growing season. They are especially abundant on 1- to 2-year-old plants. These shoots elongate, push up through the soil and then root. After the plants are dormant the new bare root plants can be dug and transplanted or can be held in cold storage for several months prior to planting.

Root cuttings can also be used to propagate new red raspberry plants if care is taken to prevent drying of the roots before planting. One can purchase dormant roots from certified berry growers to use as a source of root cuttings. Root cuttings from potted plants are often used by researchers to increase the number of greenhouse grown plants.

When it is desirable to produce plants free of soil and in a vector-proof environment, micropropagation can be used to propagate red raspberries. Plants produced *in vitro* are more expensive and are not available in large numbers unless ordered a year or more in advance. In addition, since these plants are initially more difficult to establish, this method is usually advantageous only when there are problems with other methods. Rapidly growing, tissue-culture-produced red raspberries should not be planted until temperatures are warm. However, tissue culture liners that have matured in the nursery can be handled much like bare root plants when they are available.

Plant Pot Recycling in the Greater Seattle Area

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In 1991, the Association for Women in Landscaping (AWL) initiated the "Recycling Committee" representing 850 members from four professional groups of the Green Industry: AWL, Washington Association of Landscape Professionals (WALP), Flower Growers of Puget Sound (FGPS), and the Washington State Nursery and Landscape Association (WSNLA). We pursued two ideas:

1) We collected and published information about professionals who were interested in getting rid of plant containers and those professionals who were interested in re-using containers. We call this network the "Plant Container Exchange Directory"; it lists phone number, business name, and respective pot sizes and quantities, for free, deliverable etc.

2) We involved the public in pot recycling by setting up the "Plant Pot Drop Spot Event". We knew that some retailers were already offering a drop-off service for pots to their customers, but usually on a limited scale. Problems are limited space, trashy appearance of that corner of the garden center, and the unpredictable quantities and quality of returned pots.

SET-UP

Several local garden centers participate on a set Saturday from 10 a.m. to 3 p.m. Local growers volunteer to sort pots and subsequently take home as many free pots as they can use for their plant production. Also four to eight more volunteers are needed per station to help accept pots, sort, load, and later clean up the site.

The first event happened in September 1992, with about 450 people who returned pots to three garden centers, and about 6 to 8 tons of pots being re-used. In June 1993, a repeat event with 10 garden centers saw 1650 people bring in pots and more than 12 tons of containers being re-used by local growers. The events were funded in part by a grant from the City of Seattle Solid Waste Utility for Waste Reduction and in part by the four organizing professional groups mentioned above.

PROBLEMS

1) Overabundance of different pot sizes, pot colors, materials. We received pots from Denmark, Holland, Alabama, Tennessee, and the East Coast. There were 350 different kinds of pots which slows down the sorting process tremendously!

2) Some returned pots are over 30 years old! The consumer does not throw plastic pots away easily. UV break-down makes those pots too brittle for recycling or re-use.

3) Nursery pots are too dirty for grinding and remelting into plastic granules and the washing and sorting process is costly. Even one grain of sand in plastic resin can destroy a $100,000 injection mold!

4) Local growers only re-use 1-gal and larger pots and plastic flats. Two kinds of 4-in. pots are sometimes re-used but with about 25 different kinds of what every manufacturer calls 4 in., the sorting is hardly worth the end result of two kinds of wanted 4-in. pots.

THE FUTURE:

1) The public needs to be educated as to which pots are easier to re-use than others, such as flimsy sixpacks and sturdy 1 gal. The public will eventually turn to using only locally re-usable pots.

2) The "Third Plant Pot Drop Spot" is scheduled for 9 October 1993, in the Greater Seattle area. It will be funded and organized by the WSNLA and AWL, all on a volunteer basis. Next year, a fourth event is intended for mid to late September, 1994.

3) Maybe a local pot pick-up service for the garden centers can be started. The collector will set up collection bins for specific container sizes at these garden centers, pick up pots monthly or so, and sell used pots to local growers, sorted and maybe washed.

Wisteria Propagation by Root Cuttings

James F. McConnell
Bailey Nurseries, Inc., Yamhill, Oregon

Wisteria is not a difficult plant to reproduce; however, very little is written about the propagation of *Wisteria* by root cuttings. Common propagation methods include softwood cuttings and budding. When rapid propagation is necessary and large quantities of softwood cuttings are not available, it may be expeditious to use root cuttings. *Wisteria sinensis* 'Aunt Dee', a cold-hardy selection of Chinese wisteria from Minneapolis, Minnesota was used in this rooting trial.

In December, 1-year-old field-grown plants were dug bare-root and prepared for retail sales. Root pieces were selectively removed from the plants with polarity being careful maintained. The root pieces were later cut into 2½- to 3-in. sections. At no time were the cuttings allowed to dry. The cuttings were packed in sawdust and stored at 33F in a cooler. No hormones were used to treat the cuttings prior to planting. Ground level beds in an unheated greenhouse were prepared to receive the cuttings. The rooting media was a fine grade of pumice; however, any porous, well-drained medium would work. The cuttings were planted in late March. They were planted vertically with the tops of the cuttings level with the surface of the pumice. Within 3 weeks, new shoots were visible, but emergence was sporadic. Root pieces that were about as thick as a pencil were the most reliable and strongest. Rooting percentages were in the 75% range.

This method will yield big healthy liners if they are held In the greenhouse until the spring of the following year. This is a very simple propagation technique, but it can be a useful tool to supplement a softwood cutting program that is already in use.

Question Box

Moderator: Bruce Briggs

Question: How do you control moss and algae?

Ron Amos: I got a tip about a year ago on using vinegar. We tried some on a crop of plugs under lights in the winter and we had no problems with moss. We started taking about 18% to 20% vinegar on cloudy stays sprayed over the plants. It did a good job on the algae. When it was sunny it didn't burn the needles of the Austrian pine we were growing. We had reasonable control after several applications.

Question: What about other acids instead of vinegar?

Ron Amos: We just tried white vinegar off the shelf. We didn't try acetic acid since our algae problem was not that serious.

Verl Holden: We've used granular ferrous sulfate to good advantage over the top of 4-in. pots. We put in a hand-crank spreader and set it on about #10. That seems to work well.

Bruce Briggs: Did it last very long or did you get pretty good control?

Verl Holden: I think we got pretty good control. This was on moss.

Bill Smith: We still use iron sulfate and find it works about as well as anything available right now.

Question: Are there chemical companies trying to formulate a slow-release form of iron?

Bill Smith: Sierra Chemical Company has a slow-release iron they use in Australia because of alkaline problems there. They brought it here, but we have not gotten good results from its use.

Gary Ritchie: We had problems with moss in both our bare-root and container nursery this year, particularly on the Western hemlock seedlings which are very limp and weak. Our grower fertilized with calcium nitrate that stiffened the stem of the plants which got them up above the moss. It didn't do anything about the moss, but it helped the plants compete with the moss.

Voice: We didn't have problems with liverworts. We had problems with moss and we used the iron treatments that seemed to work at the higher concentrations. When we used diluted solutions we didn't get any control at all.

Question: What is the product that Gary Ritchie mentioned as a "binder"? What is that product and can we buy it?

Gary Ritchie: It's called JP-1 named after Jerry Pulman who was a former tissue-culture scientist at Weyerhaeuser. He invented it and we named it after him. It is an alginate-type material which you apply to the plug and then apply a hardener and it binds. We have a patent on that and we are actually working with people right now in New Zealand who are using it to transplant tissue-culture propagated radiata pine in the nurseries and are having good luck with it. If anyone is interested in pursuing that come see me and I will give your name to the person in our company who is involved with marketing that material. It's called JP-1.

Question: Did you get this idea from Holland?

Gary Ritchie: Our material came out of a brainstorming session that we had. We brought in a consultant from outside the company who put about six of us into a room for 2 days and we brainstormed this thing upside-down, inside-out and came up with that idea and it's been extremely successful.

Question: Is the planting out of large numbers of genetically identical clones a problem in forestry? Are you worried about insects or pests taking over?

Gary Ritchie: This is a common question and an interesting question coming from a group of horticulturists who live by clones themselves. Actually, we're not cloning this material. Any one seed might produce 30 plants that would be members of a clone, but then they are mixed up with a million other plants and all spread out. So, what we're producing are family level genetic variants not clonal level. Clonal forestry is not practiced in North America, but has been practiced in Japan for 500 years with Sugi, *Cryptomeria japonica,* and in China for over 1,000 years with *Cunninghamia lanceolata* very successfully. To get at the question of genetic risk with using family level materials in forestry, we're quite aware of what those risks are and we've given considerable thought to that. We have a very rigid set of rules which we obey with respect to deploying that material in the field. How many families can be used per year, how many must be planted across a certain land base, etc. and we follow those rules. We also plant this material as individual family blocks. By doing that, if problems should show up in some of these families, we recognize them immediately and get them out of the production population. Generally, another thing that is not widely understood, is that you can put together a forest plantation from family material that can be genetically more diverse than wild plantations. If you look at wild conifer populations in detail, are you terribly genetically diverse. So, they are actually in some cases broadening the genetic base of forest plantations by doing this. The bottom line is, yes, we're aware of the risk, we're dealing with it, and we do think it is very manageable and is far outweighed by the benefits of genetic improvement.

Question: Are you working toward genetic clones that root better? How did you prevent those cuttings from showing plagiotropic growth?

Gary Ritchie: For the first question, no, we are not selecting families for rootability. It's conceivable that in the future as we gain more experience there may be families in our population that do not lend themselves well to vegetative propagation and we will probably remove those from the population. Our selections are based on field performance as trees, as volume growth and stem quality. If you know how to do it, they all root quite well. The other question had to do with plagiotropic growth which is very typical in conifers that are propagated from cuttings. There are two ways around that. One is by using juvenile mother plants. Our mother plants do not age beyond 1 year. The second way around the problem is getting the rooting cuttings out of the rooting environment and planted outdoors as quickly as possible. Whether that is a light-mediated effect or whether it is a pot-binding effect or root-development effect I can't really say. What I can say is that within one year in a bare root nursery it's difficult to find one plagiotropic cutting out there whereas if you had grown that crop in containers in greenhouses virtually all would be plagiotropic.

Question: Is there any real data to show that pasteurization kills pathogenic organisms and not beneficial organisms?

Deborah Law: That was my question that I did not put my name to. Generally, many of the larger nurseries do pasteurize, but I have always been a little suspicious of this and that is why I wrote that question. I cannot see how pasteurization kills only the pathogenic organisms while not damaging the beneficial ones. My nursery does not pasteurize. I use clean products and I use ultra-clean methods and my concern has always been that under nursery situations recontamination occurs by dust or when plants go into the general growing areas.

Jeff Bohn: I can't give you any scientific data. It was just recommended. We grow native California plants which are extremely susceptible to *Pythium* and *Phytophthora* and we have had, from time to time, the steam break down and have taken a chance and that has usually resulted in more dead plants. We've stopped taking chances and don't do anything without pasteurizing anymore.

Tom Pinney: We do not pasteurize.

Steve McCulloch: In our propagation area we had a problem that we couldn't quite identify the source. It wasn't clear cut, sometimes we would see a problem, other times we wouldn't and we wondered if it was due to perhaps some bales of peat that may have been contaminated with a fungal problem called *Cylindricladium*. Ever since we started steam pasteurizing peat moss we have been able to control a very serious problem. It's expensive, but the alternatives are much more expensive.

Gary Ritchie: We pasteurize our growing mix to control soil-borne diseases and root diseases. We don't have problems with weeds in those mixes.

Robert Wright: We hope to utilize a bark mix even though we don't pasteurize it that will have sufficient aeration to not cause problems with some of the water molds caused by *Pythium* and *Phytophthora*. I don't know of anyone in the nursery industry anywhere across the southeast that produce 1-gal or larger material that do any pasteurization other than the composting or aging of pine bark which will go through a heat treatment getting to 130F sometimes and they have to turn it sufficiently to prevent that from happening and building up acids and alcohols. We probably get by with it because of the composting the bark goes through.

Todd Herrick: Harry Hoitink has done quite a bit of research on the subject of composting of barks and there's data in the literature that would suggest that there is a beneficial effect of suppression of pathogens by use of pine bark in container media. I would suggest anyone interested in this to contact Harry Hoitink. All that information is available.

Ron deFossard: I don't think we've heard anything today that answers the question. We often hear this speculation that pasteurization kills the pathogens and not the beneficials. To me, that is utterly illogical. The question is why? I did ask Ken Baker directly and he said it was true. I searched his work before I asked the question and I couldn't see one bit of evidence that was the case. I am not saying that pasteurization is not effective against all sorts of things; it's the story that goes with it that I question.

Tom Pinney: After cuttings have rooted in a rooting medium containing no peat moss is there a fertility regime that someone could suggest before the cuttings are potted?

Robert Wright: I don't think there would be any need to change the fertility program. One may have a little different cation exchange capacity than the other or one may hold a little more water than the other, but the fertility regime can probably remain the same. Peat moss can be replaced with finely ground pine or fir bark.

Question: Does anyone have experience working with witch hazel in tissue culture?

Steve McCulloch: I made a statement at an Eastern I.P.P.S. meeting when someone asked me about the difficulties with witch hazel in tissue culture. We have produced witch hazels in our lab. The trick was using more juvenile material. When we started getting scion material, grafted material from the growers we had more difficulty establishing the culture. Other members of the Hamamelidaceae family are fairly easy in tissue culture at least the ones we have worked on like *Corylopsis* and *Liquidambar*. The *Hamamelis* group generally are very slow to respond. The use of rapid re-culture or more juvenile material will help.

Ron deFossard: I have worked with them and the story is true for many of the woody species. If you want to clone a mature tree of *Eucalyptus*, you go to the very base of the tree and wound it deliberately to get adventitious buds coming out from which you can take cuttings and get them into tissue culture.

Question: Does anyone have experience rooting *Clematis 'armandi'*?

Bruce Briggs: We have done some tissue culture and found that 'Armandi' was hard to get in, but we don't have any in culture at the moment. It's amazing in the *Clematis* family that anything that has *jackmanii* in its background is quite easy to go into tissue culture; other families that are not *jackmanii* are hard.

Keith Howe: I've talked to Ernie Schuster who has been very successful at doing it. He indicated that it is a very easy plant to root single node cuttings. The trick to get it to break is to keep the nutrition level very high.

Bruce Briggs: Many years ago there were people who grew it and they did the same thing. There was a problem with them not growing after they were potted. If they kept the rooting hormones real low they would break; high hormones seem to retard the breaking of the bud.

Question: Can someone tell us more about the use of artificial snow for winter protection?

Tom Pinney: Many years ago we tried a snow making machine and came up with the same problems: it's very slow and it only lasts as long as the temperature stays below 32F. It has not been economical so we cover our crops with a type of microfoam or insulating materials instead.

Bruce Briggs: Why not just cover with sawdust?

Tom Pinney: There would be a mess to clean up. Straw has been used also, but the mess and the weeds become a problem.

Doug Justice: We used to do it when we had very clean roads, but once you have three or four years of sawdust down you mess up the roads and trucks have a difficult getting in.

Roger Hollingsworth: Several years ago we had ice and snow and a retailer put sawdust over a small area of azaleas. To clean up he brought in a street cleaner with a vacuum cleaner and vacuumed the whole area.

Bruce Briggs: Water works beautifully for frost protection, but not for cold weather protection because you can't quit. The resulting ice can get so thick that the limbs break down. There's no protection from ice itself; it's just the release of heat from the water going on it.

Jeff Bohn: I have a question regarding the recycling of nursery containers. We in southern California have tried to find someone to accept nursery containers that are used or damaged for recycling. Has anyone had success in finding someone to accept those? There are logistical problems with dirty pots and things like that.

Eric Nelson: Susanne Foster has developed the pot re-use program in Seattle and that program is working very well. Those containers that can't be reused have to be cleaned up before they can be ground and used in any recycled plastic manufacturing application. One of the opportunities that does exist is the use of that sort of mixed contaminated plastic to make plastic lumber products. The companies that are in the plastic lumber business now are tending to use very clean material. They are able to get clean regrind material from plastic manufacturers and from bottle collection programs that collect very clean material like milk jugs that can be cleaned up very easily. Once those industries are developed further they will develop the ability to use more highly contaminated material. At this time there are very few people who are able to do that and I sympathize with your frustration trying to find somebody to take it. We hope to see those industries develop. There may be people out there who are trying it, but I don't know of any at the moment.

Bruce Briggs: Why can't we get somebody to grind it and use it as a heat source?

Eric Nelson: That's a capital idea. It's likely we will see that developing here. One of the big obstacles to recover BTUs is that in order to do that you have to burn it. If you are going to burn it you have to site a plant somewhere and no one wants to have a burner in their backyard so there's a great deal of education and even some technical development work that needs to be done before we can do that.

Tom Pinney: There's a community in Wisconsin that is successfully burning old tires along with fluidized coal.

Ron Amos: One thing we have looked at is construction companies. They use a lot of plastic for covering concrete and for putting under concrete. One person from a construction company looked at our plastics and said our grade of polyethylene is better once it's been used than the grade they buy. They were very enthusiastic and took a whole truck load and they have been using it ever since. I have another load waiting for them. I think if you talk to several different construction companies they use a lot of plastic sheeting and they use it in the winter time to enclose entire buildings during winter construction. That's a good use for it, but they have to find a way of getting rid of it after that.

Sharon Collman: I had a chance to go to Israel last winter and I think plastic is going to be a world-wide problem. They are using it there for mulch and water retention under drip systems and the plastic is being tilled into the field and it's blowing around the country. It's a significant problem that needs to be addressed.

Tom Pinney: How about grinding up the product and selling to asphalt plants?

Eric Nelson: This is what I do everyday. There are a number of things that can be put into aggregates and essentially disappear during road construction. Hundreds of thousands of tons of material will go into a road construction project. The big problem is that you build a road out of sand which you buy for $3-$4 a ton and in order to get a big pile of glass turned into something you can use in the road you will likely spend $30-$40 a ton. That cost is a lot less than the $90 a ton that you would spend on that material to put it into a sanitary landfill. Nevertheless, there is a big difference between $3 to $4 a ton and $30 a ton.

Terry Finnerty: Why not try to tie into non-profit organizations like Boy Scouts or fraternities to wash pots. This might be good public relations at the same time. The washing could be done on a donation basis or a penny a pot before the pots went to the recycling centers.

Native Woody Shrub Propagation Three Key Steps

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The increased demand for native, woody plant species in public and private landscapes has resulted in a renewed interest in native, woody shrub propagation. This poster presents a comprehensive approach for incorporating the large amount of information that is already available on many of the native, western, woody shrubs into existing propagation programs.

Facts are meaningful only when they can be attached to ideas. Unless students (people) are taught a system for learning or processing information, facts are of little use to them. (Wurman 1990, parentheses inserted by author.)

This poster presentation is a revision of a talk that was given at the Western Forest Nursery Association Meeting at Fallen Leaf Lake, California in September, 1992. It was later published as a paper in the Proceedings of that conference. (Finnerty and Hutton, 1993.)

While preparing the presentation I discovered that there was already a great deal of information available about many of the plants of interest. Much of the information about native shrub propagation was compiled from public and private sources in the late 1970s and 1980s as land management agencies and private industry responded to the challenge of land revegetation with native plant species.

I decided that more than simply describing the specific treatments used for a variety of species, it might be more beneficial to growers to show them some of the information that is already available for many of the native woody shrubs; and present it in a way that could help them use the information more effectively in their own propagation programs.

The three key steps, "**Know Your Plants**", "**Planning and Scheduling**", and "**Recordkeeping**" presented in the poster are the context in which the existing propagation information might be used more effectively. References for specific information about the plants or suggested methods for propagating them follow this summary.

- **Know your plants** includes acquiring some understanding of the ecological influences and plant characteristics that may affect plant growth; and becoming familiar with some of the pre-treatments necessary to improve germination.
- **Planning and scheduling** deals with setting up a propagation program based upon what is known about the plants, and how you, the grower, intend to produce the plants based upon your schedule and production capabilities.
- **Recordkeeping** emphasizes keeping good records to keep track of information about the plants, scheduling, and other useful information for increasing future propagation success and profitability.

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History of Ardmore Nurseries Ltd

Alen Beaumont
Ardmore Nurseries, Ardmore

Beaumonts Nurseries Ltd was started by our grandfather and father in 1933 at Manurewa as a growing and retailing concern. The emphasis was open ground growing and the location for the nursery was moved several times around Manurewa, until 1970, when a permanent area was purchased in Ardmore. In 1970 the company was divided, creating Beaumonts Garden Centre in Manurewa and Ardmore Nurseries in Ardmore. Ardmore Nurseries is owned and operated by Barry and Allen Beaumont.

BEAUMONTS NURSURIES LTD—THE OLD STYLE, HISTORY FROM 1933

We were introduced to the business in the years when you used clay pots for container growing, and when the plants were sold, they were knocked out and put into paper pots. Hence, most of the plants were grown in the open ground, lifted, and balled in hessian. We had made our own pot washer so we could keep the pots clean and free from disease before reusing. I remember my grandfather sterilizing soil in a 40-gal drum with a fire underneath. We built most of the buildings and glasshouses ourselves and the glasshouse walls were built from timber out of old railway cattle wagons. Some of the glasshouses had a fireplace at one end that heated water which then flowed along second-hand fibrolite pipes; so the first time the fire was stoked up as you can imagine one of the pipes burst. Seed and cutting trays were 1 m long × 60 cm wide × 25 cm thick timber. I could just pick them up by myself but any shorter arms and no chance!

We supplied the entire country by mail and rail plus direct sales to the public in Manurewa, Papakura, Papatoetoe, Pukekohe, Waiuku, and their surrounding rural areas. We had many people coming to the nursery on Saturdays and sometimes we would have over 50 cars parked down the road. Barry and I were the "ball boys", so every time a customer came in for plants, we were given the labels and went off and dug one peach, one apple, six roses, etc. As you can imagine we got tired of this and decided that during the week we would ball 10 of each evergreen and put them in sawdust beds. We would also dig 10 of each deciduous tree and heel them in bare rooted into sawdust. We made beds with concrete blocks to hold the sawdust, concrete paths for the customers to walk along, and a car park. All plants were labelled.

We, therefore, believe that Beaumont Nurseries started the first self-help garden centre just out of sheer necessity. The nursery was 30 acres and it was not all on the Great South Road. Some was half a mile behind, some in Takanini, and some opposite where the Botanic Gardens is now located. If you have read the September (1993) *Commercial Horticulture* magazine you will have seen that Masons Nurseries (in Te Awamutu) started in 1933, the same year as us. They also grew barberry and many other plants like us. We grew about 1000 types of plants, including apples, peaches, citrus, and many other fruit trees. We must have delivered a group of fruit trees to every section in Manurewa, Papatoetoe, and Papakura plus roses and a couple of hundred hedging plants. We grew hundreds of thousands of shelter plants for domestic hedging and farm shelter. We would have up to a hectare in barberry every year which was sown with a hand sower in hand raked soil. There were no herbicides so all weeding was by hand. We also grew pines, macrocarpa, cryptomeria, lawsons, gum, cupressus, boxthorn (*Lycium*), all the same way as barberry. Domestic hedging was abelia, escallonias, lonicera, privet, euonymus, eugenia, and feijoa. In 1940, prices were $3 per hundred for most hedging—barberry was 40¢ per hundred and $3 per thousand. Most shrubs were 2/6d (equivalent to 50¢[NZ]). I have a few photocopies of our 1940 trade list. For those old enough, you may be able to remember *Acacia baileyana* at 2/6d or 2-year-old *Cupressus macrocarpa* 12-15 in. at 9 lb per 1000. We ploughed the open ground with a single furrow mole plough and then we hoed for planting with walk-behind rotary hoes. Later on, when tractor hoes came, we had a contractor to do the hoeing.

This is a condensed history of some of the silly things we did. But I have told you this so you can see why we have carried on mainly with open ground production and are still going strong even if a bit older and wiser now.

THE SHIFT TO ARDMORE IN 1970

When we moved to Ardmore in 1970 it was hard to believe the difference in soil from that at Manurewa. Ardmore soil is a consolidated peat—25 m of consolidated peat before reaching anything different, and that was sand.

We started using a double farrow disc plough, ploughing about 50 cm deep and leaving the soil friable and mainly level. We hoed and topdressed, hoed again, and lined out the area to be planted with tightly stretched rope. Rows are 90 cm wide. We have tried mechanical planting but have found, because of the number of different plants and sizes we grow, it did not work very well. Cultivating plants was with a rotary hoe. After buying our first tractor we moved to cultivating with tines on mid-mounted hydraulics.

As we bought more tractors, we upgraded and bought a Farmall Super A and put on high clear wheels so we could cultivate taller plants and also use it for wrenching. We only started doing tractor wrenching when I started working full time. Previously, that was done by spade. Larger trees that cannot be straddle wrenched are cable wrenched. It might look old fashioned but it works. Some of our buyers have said that they prefer our plants to those grown under newer systems.

Bagging open-ground plants has been made quicker by the use of a sleeve. This system also has the advantage of retaining a larger amount of roots. The system was conceived by Vernon Harrison.

Propagation of Acacias and Eucalypts

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The old saying that "the only people who made money during the gold rushes were the storekeepers" had quite a bit to do with our decision to establish our shelter nursery partnership during the heady days of New Zealand's "horticultural boom years." Driven by the Kiwi Fruit successes, New Zealanders were charging headlong into growing anything and everything from babacos to lychees. One of the first things all these ventures needed was shelter, and that's where we came in with our container nursery. It's interesting to reflect that in the Wairarapa nearly every horticulture venture has foundered except for pip fruit which is steadily expanding. Fortunately our nursery has survived, widening its scope, and eventually being sold as a going concern a few months ago.

I am a keen farm forester and a soil conservator by training and this has given me a special interest in eucalypts and acacias. It's no surprise therefore that these species continued as one of the mainstays of our nursery. In this paper I will endeavour to pass on some of the techniques we used to propagate these species in our nursery.

SEED PROPAGATION

Seed Sources. Although seed is commercially available, we collected seed from local trees, and more recently from our own plantings on the property. Provenance is most important with eucalypts. *Eucalyptus obliqua* seed collected from trees growing at Rotorua or inland Southland is most likely to produce a good frost-hardy line of trees. Similarly the coppicing ability of *E. nitens* can vary depending on just where the seed originates in Victoria. The right source must be pursued if the intended use is for firewood production under a coppice system.

Collected eucalypt capsules can take some time to release their seed—warm dry conditions are required for release. Bagged seed put on top of the hot water cylinder always gave us good results. Eucalypt seed is very fine and is sown with the considerable amount of dross produced during drying.

Acacia seed is collected pods and all. Collection should not be delayed once the seed is ready as most pods can fall in one day of hot dry northwest wind. Hot dry conditions are again needed to release the seeds. Sieving is used to eliminate the chaff.

Stratification. The saying "some like it hot" certainly applies to acacias. We always achieved good results by covering seed with water that has just boiled and then leaving the seed to soak overnight —a total period of around 15 to 20 h.

Eucalypt stratification requirements are the opposite of acacias. Most require varying periods of cold-moist stratification to break dormancy and achieve an even germination. Generally the altitude at which the species naturally occurs relates closely to its stratification requirements. Higher altitude species, such as *E. delegatensis*, need up to 10 weeks while lowland/coastal species, such as *E.*

botryoides, require no stratification.

Such varying conditions require a planned stratification programme carefully worked backwards from late autumn when seedling growth slows, to pricking out, and back to sowing.

We achieved consistent results by stratifying eucalypt seed in coarse, damp river sand. After dusting the seed with Thiram, seed layers are alternated with sand in air-tight plastic containers. We put 15 g of seed per container and sow both sand and seed later in one large polystyrene seed tray. Containers should be carefully labeled with species and date for later sowing after stratification is completed. We apply masking tape to ensure containers remain air tight and then place in a refrigerator.

Sowing. We have always used a proprietary seed germination mix which is sterilised and has a low nutrient content. Trays are filled, well-watered, and left to drain.

Even sowing is most important with fine seeds, such as eucalypts. Use fine sand to ensure an even distribution. With stratified seed, sow with the sand used for stratification. Thinly cover the seed after sowing with a coarse grade vermiculite and lightly water.

With acacias, drain the seed and use vermiculite or dry sand to separate the damp seed for sowing. After sowing, cover with a 1 seed germination mix : 1 sand (v/v) medium, firm the mix, and cover with washed pea gravel. Pea gravel prevents crusting as the seedlings emerge.

Once placed in the glasshouse, the trays are each covered with white plastic that is held down with light battens. Each day the plastic is taken off , excess water shaken off, and replaced dry side down—this operation is repeated until seedlings emerge. We always avoided watering until germination to prevent damping off.

Pricking Out. Once the eucalypts and acacias have reached the first two-leaf stage above the cotyledons, pricking out into final containers occurs. Because they are Australian plants, high fertility is not a requirement,—phosphate must be particularly avoided. Our first efforts with acacias resulted in plants with a propensity to grow horizontally, the problem was overcome by leaving phosphate out of the mix. For both acacias and eucalypts our soil mix is a 7 stabilised granulated bark : 1 washed river sand (v/v) mix. Fertiliser was based on slow-release Osmocote and fritted trace elements. To ensure even mixing and resultant even growth of seedlings, we used a horizontal paddle mixer for mixing the soil mix and fertiliser.

After initially using peat pots, we made the change to Root Trainers with excellent results. The combination of root training and air pruning goes a long way to ensuring that each future large shelter and woodlot tree will have strong, well-balanced, multiple root systems. We used Shrub Trainers for the eucalypts and the deeper Hillsons for the acacias.

Careful pricking-out is essential. Seedlings must only be handled by the leaves—not the stem. This prevents subsequent stem breakage as the seedlings grow. Seedlings should be placed into a prepared hole with soil carefully "levered" against the roots. We used paring knives for this work. On no account should the soil be pushed downwards. This results in "S" shaped stems or stems with "pig tails" just below the surface. Trees with such weak points invariably break off below ground level within a few years of planting.

After pricking out and replanting, the small seedlings soon resume vigourous growth. We use shade houses and judicial hand watering at this stage. The plants are kept under shade until they are about 10 cm high. They can then be placed outside, with a careful eye on watering needs. Direct exposure to autumn changes and falling temperatures is needed to develop frost hardiness before the winter.

Disease Control. The main insect problem we encountered is leaf roller caterpillar which is readily controlled with Maldison at half the recommended rate. *Botrytis* can be a problem under very wet conditions, particularly in softer species such as *E. botryoides*. Benlate or Captan can be helpful although the best answer is to keep the base of the plants free from litter and make sure they are not in the shade and receive full sunlight.

Restoring a Lowland Forest Remnant

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BACKGROUND

In Nelson Province there has been a systematic destruction of the forest cover from the time of settlement. This destruction, particularly of the coastal and lowland forests and beech forests at lower altitudes on more accessible sites, has resulted from timber milling and farm development.

Forest clearance continued until recently in Nelson and Marlborough with the felling of beech forests and associated podocarps for the export of wood chips.

Extensive areas of forest have been set aside for protection in national forests, maritime parks, and other reserves. However, much of this protected land is mountainous beech forest with lowland coastal and wetland plant communities poorly represented.

Many landowners today recognise the value of the remaining bush remnants and wish to see them protected. This is possible through agencies such as the QEII National Trust or the Department of Conservation but legal protection alone may not be enough to ensure the survival of the bush and active management may be required.

MANAGING LOWLAND FOREST REMNANTS

The three main options for managing forest remnants are: natural regeneration, regeneration using nurse trees, and revegetation.

Natural Regeneration. Where livestock and fire are excluded, natural regeneration may be sufficient to ensure the survival of a forest remnant. The regeneration will occur through the growth of seedlings of trees within the remnant and to a lesser extent by birds carrying seeds in from nearby areas of bush. However, problems can arise where there are openings in the canopy or around the edges as these are sites likely to be invaded by weeds, particularly old-man's beard.

Providing that the remnant is largely intact and there are few openings in the canopy then natural regeneration is a realistic option.

Regeneration Utilising "Nurse" Plants. Nurse plants can be utilised for accelerating the natural process of regeneration by creating a favourable microclimate for the germination and growth of native seedlings. This approach is most useful on exposed sites where the nurse plants provide shade and shelter.

Examples of nurse plants, both indigenous and exotic, assisting regeneration can be seen throughout the Nelson region.

- Pine plantations at Spooners Range and Rai Valley are developing a strong understory of wineberry, kohuhu, karamu, mahoe, and fivefinger.

- Eucalypt plantations at Milnethorpe have created a favourable environment for regeneration on a harsh coastal site.
- Gorse throughout the region is being succeeded by native forest. There are good examples in Abel Tasman National Park.

Utilizing nurse plants to assist regeneration is one option to be considered but the technique does have limitations. In the case of pines and eucalypts, there is the problem of damage to the emerging forest if the trees are to be harvested, and with highly flammable nurse plants, such as gorse, there is always the risk of fire occurring before the new forest has become established.

Revegetation. Revegetation or restoration can be described as new or supplementary planting to accelerate the natural process of regeneration. This is often the best approach in managing small forest remnants where the bush has become open to sunlight and exposed to the wind because of milling, grazing, or windthrow. In these situations the natural process of regeneration may take a very long time even if browsing animals are excluded because the site will be invaded by grasses and other weeds such as old-man's beard.

Revegetation using quick growing trees that occur naturally in lowland forest communities will suppress the grasses and other weeds by excluding the light and allow the process of succession to proceed.

Revegetation may also make it possible to form a more complete plant community by including plants from nearby stands that no longer occur in the remnant being replanted.

REVEGETATION PLAN

Although different sites will have different solutions, the principles remain the same when preparing a revegetation plan.

Study the Brush Remnant. When preparing a revegetation plan, first study the bush remnant to understand its structure and composition. This will reveal not only the species that make up the forest but also how they are spatially arranged to form the canopy, understory, and ground cover.

Investigate nearby remnants to see if there are important species absent from the site to be planted. They may need to be incorporated in the plan.

Investigate Physical Characteristics. Investigate the site and learn something about its physical characteristics. Study the soil type, soil depth and drainage; exposure to the wind and to frost, and the general aspect. These factors which may vary across the smallest sites will help determine the siting of different species.

A Revegetation Project. Because of site variations, it is not possible to give a blanket prescription for all lowland forest revegetation. However, the next section describes in some detail a revegetation project at Waimea West that would apply to many Nelson Province sites.

Background—Revegetation at Titoki, Waimea West. Revegetation of a small remnant of lowland forest at Titoki, Waimea West has been underway for the past 6 years.

Typical of other forest remnants on the Waimea Plains, this 1.0 ha site was logged for kahikatea and matai in the early days of European settlement and then grazed until the present. The result is an open stand of totara and titoki together with scattered kowhai, ribbonwood, lacebark, mahoe, rohutu, and ngaio. Grazing has destroyed the understory and native ground cover which has been replaced by grass.

Revegetation Technique. Because of the open nature of the stand it was decided to plant quick growing species that would soon form a "closed canopy" and suppress the grass by excluding light. These quick growing species which all occur naturally in lowland forest throughout the Waimea Basin include:

Aristotelia serrata	wineberry
Cordyline australis	cabbage tree
Coprosma robusta	karamu
Dodonaea viscosa	ake ake
Hoheria angustifolia	narrow-leaved lacebark
Kunzea ericoides	kanuka
Melicytus ramiflorus	mahoe
Myoporum laetum	ngaio
Pittosporum eugenioides	lemonwood
Pittosporum tenuifolium	kohuhu
Plagianthus regius	lowland ribbonwood

Since planting, all the trees have established well and are growing quickly—in the case of wineberry and ngaio up to 1.0 m per year. In earlier plantings grass is already showing signs of suppression and will soon allow the second stage of revegetation to begin.

In the second stage plants will be chosen from species that occur naturally in the Waimea Basin and will include:

Alectryon excelsus	titoki
Beilschmiedia tawa	tawa
Dacrycarpus dacrydioides	kahikatea
Nestegis montana	narrow-leaved maire
Pennantia corymbosa	kaikomaka
Podocarpus totara	totara
Prumnopitys taxifolia	matai
Pseudopanax ferox	lancewood
Sophora microphylla	kowhai

They are planted at this later stage because they are mostly species that do not compete strongly with grass weeds and may not establish quickly in full light or when exposed to strong winds.

Natural regeneration will supplement this second stage of planting and the forest can be expected to develop further over time. Ultimately, it should become largely self-maintaining although weeds, such as old-man's beard, will continue to be a threat.

Revegetation Program. The revegetation plan will take many years to complete because of the scale of the project and the need to maintain the plants while they are becoming established. An annual program is followed and up to 500 trees are planted out each year.

1) Raising Plants . The plants are nursery raised and grown in containers called "Tinus rootrainers". Plants raised in containers and in an open growing environment transplant with less shock than wildings collected from the bush.

The seed is collected locally from lowland bush within the Waimea basin to ensure genetic purity. This seed, collected and sown in the autumn, will germinate and grow into seedlings 400 to 500 mm high which are ready for planting the following winter.

2) Site Preparation. The area to be planted is prepared in the autumn, first by hard grazing and then fencing to exclude stock. The planting sites are marked at 2.5 m x 2.5 m spacings and sprayed with the herbicide 'Permazol SDA' at 250 g/100 m^2. A sprayed circle of 0.5 m diameter is adequate and gives effective weed control for the first year.

3) Planting. Planting may be carried out anytime during dormancy providing soil moisture levels are adequate. However, planting in autumn is recommended if there is a risk of early summer drought.

4) Planting Pattern. The pattern of planting is determined by the characteristics of the site. Kanuka, akeake, ngaio, and kohuhu are dominant on the exposed sunny free-draining sites; lemonwood, mahoe, and karamu the more sheltered areas; and cabbage trees, flax, and kowhais along the flood channel.

5) Maintenance. Little maintenance has been required other than an annual herbicide spray to control weed seedlings such as old-man's beard.

In some years the young tree seedlings have been release sprayed with "Roundup" although the benefits have been marginal.

No promotion of tree growth from fertilizer application either at planting or later as a side dressing has been observed.

Blanking has not been necessary so far because of the high establishment rate. Any gaps will be filled in later years with the second stage planting or by natural regeneration.

LANDSCAPE DESIGN

Native bush remnants need not be considered in isolation from other farm plantings and uses. Rather, it should be possible through creative design to integrate the more "productive" land uses with the natural resource. How this is achieved will vary according to the site and land use—different solutions will be required for a hill country property compared with say, a property on the plains.

At Waimea West an 8 ha property is being developed as an economic unit by growing horticultural crops. Typical of many properties in Nelson Province the land was subdivided from a larger farm that had a long history of arable and pastoral farming. The land is flat and the natural features are the bush remnant, a river boundary, and good views of the mountains.

In developing the property the design philosophy has been to regard the bush as the central or "core" area and to create a series of enclosed fields throughout the farm by planting a network of shelterbelts that extend outwards from the bush.

These shelterbelts, necessary to provide shelter for the horticultural crops and to create pleasant working and living conditions, also form wildlife habitats and corridors. Furthermore by using trees that occur naturally in the area, species such as kanuka, ribbonwood, lacebark, kohuhu, karamu, and cabbage tree the landscape is enhanced and the character of the bush extended to the whole farm.

This planting theme can be developed further to include the homestead site where a bush garden can be created by using the same species to form the basic tree framework.

CONCLUSION

Although the site is small, a little over 1.0 ha, the same restoration principles could be applied successfully to a much larger project.

The first objective is to quickly establish a primary cover of native plants to suppress the weeds and to create a good environment for supplementary planting and for the process of natural regeneration. The best way to achieve this is to:

- Select quick-growing locally occurring, native species
- Raise the plants in containers, preferably "Tinus rootrainers"
- Exclude fire and browsing animals
- Control weeds before planting
- Plant in May after autumn rains have recharged soil moisture.
- Release plants from competing weeds until they have become established.

Second phase planting with supplementary species should be delayed until about the time of "canopy closure". At this stage natural regeneration will also play a part in the process of restoration and ultimately the bush will become largely self-maintaining.

The Design and Development of Seaview's Propagation Facility

Ashley Craig
Seaview Nurseries, Auckland

Early this year, the need arose to expand and modernise our propagation area with the following attributes:

- Where possible, existing structures to be utilised.
- Flexible/adaptable, where there is an ability to propagate a number of plant species under different temperature, water, and light regimes within the same structure.
- Easy to use/workable, whereby there is a central control unit without the need for constant monitoring, or adjusting of timers, throughout the day.

With these factors in mind it was decided to utilise an existing durolite house with vents, electricity, and water were already in place, and which required only a concrete floor. It was decided that a new work room (where cutting preparation, deflasking of tissue cultures, etc., are performed) would be built.

The workroom is fully lined and it utilizes both artificial and natural lighting. The floor is painted with epoxy resin to aid cleaning. Work benches are free standing, height adjustable, and the working surface is made of stainless steel—again for ease of cleaning and hygiene.

The growing area consists of 16 benches each with individual heating, misting, and lighting controlled from a central controller. In order to save space, the benches roll which reduces the need for walkways or paths between benches. The benches are at a comfortable height so staff do not have to squat, stoop, or lean in order to move trays. Movement is also helped by being able to pull the mist lines up when not in use, or if working with the cuttings. Bottom heat is supplied by thermostatically controlled heat boards, with nine used per bench. Each bench is capable of holding 52 hygiene trays. Mist is supplied overhead and four of the benches have fog.

Mist and fog are controlled by an 18-stage Sarnia controller with a wean selection. This enables mist cycles to be gradually omitted between the time cuttings begin to root and until they have hardened and are ready to be potted. Each bench is assigned to an individual stage on the mist controller. Mist cycles can range from 2 sec to 1 min. The mist controller is itself controlled through a light integrating meter which converts sunlight into calories/cm^2. The meter "counts" down the number of calories that pass until reaching zero—then the mist controller is activated. The more intense the sunlight, the faster the countdown occurs; the more cloudy the day is, the less frequently zero is reached thereby reducing the risk of over watering, or under watering. Night-time watering can be achieved through a standard time clock built into the mist controller. This control system is easy to set, requires little or no monitoring, and if adjustments are needed they can be done in seconds without having to change all the benches. The main goal which has been achieved is the flexibility of the facility whereby the microclimate within each bench can be altered, allowing different plant species with different requirements to be grown side by side without the need to build special houses.

The system after being in place for 9 mo was expanded with a further 16 benches added and a 34-stage controller installed. Rooting percentages were up and disease incidence down in the new facility.

The Flora of the New Zealand Subantarctic Islands

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The subantarctic islands include the Auckland, Antipodes, Bounty, Snares, and Campbell Islands. Geographically, these islands all lie between the subtropical convergence and the antarctic convergence. Most of the subantarctic islands were formed 1 million to 65 million years ago during the Cenozoic period.

Bounty Island (47°41'S; 179°02'E) is comprised of a cluster of weather-beaten granite rocks with no vegetation and no fresh water.

The Snares Islands (48°00'S; 166°35'E) consist of Main and Broughton Islands, some 20 to 30 seastacks and a string of rock islets (Herning, 1979).

The Antipodes Islands (49°41'S; 178°43'E) are the smallest of the New Zealand subantarctic islands. The islands consist of Antipodes Island, Bollons Island and a number of small islets and seastacks. These islands are remnants of one large and several subsidiary Pleistocene volcanic cones (Malloy and Dingwall, 1990).

The Auckland Islands (50°50'S; 166°00'E) are a small island group including Auckland Island and Adam Island. These islands were formed by Cenozoic volcanic activity associated with seafloor spreading and crustal plate movement. They are the remains of two coalesced volcanic domes.

Campbell Island (52°33'S; 169°08'E) is the most southerly of the New Zealand subantarctic islands. It is the 560 m high remnant of a miocene volcanic dome (Gamble et al., 1986).

Weather patterns of the New Zealand subantarctic region are characterised by strong, often gale-force winds, cool temperatures, infrequent sunshine, and high humidity. Rainfall occurs at 1000 to 5000 mm, 3 times per year, falling evenly throughout the year (Dawson, 1988). As a result of climatic conditions typical to the subantarctic islands wet soil conditions are prevalent. There is a slow decay of dead plant parts which forms a layer of peat that is characteristic of all the subantarctic islands.

Oceanic wet heath communities predominate on these blanket peats. These communities are characterized by dwarf shrubs, which are mostly less than 1 m tall, and tufted grasses all growing in a cryophyte or flowering plant mat (Wace, 1960).

Tussock communities are also characteristic of the subantarctic islands. *Poa* species are the most important dominants of maritime tussock. This tussock while found almost exclusively on well-drained ground close to the sea may also be seen on exposed slopes. The tussock is associated with penguin and seal habitats. The large growth form of tussock is well adapted to withstand animal movement (Wace, 1960).

Bogs are dominated by cushion-forming plants including *Gaimardia* and *Oreobolus* species. *Sphagnum* species are absent. Herbfield vegetation is dominated by large-leaved, perennial rosette plants, such as *Pleurophyllum* and *Stilbocarpa* species.

Feldmark communities of the subantarctic islands resemble the Raoulia and Haastia communities of the New Zealand Mountains. Species in these communities are either circumpolar or restricted to a small area (Wace, 1960).

The Auckland Islands are the only islands supporting forest vegetation. A narrow band of forest occurs approximately 50 m above sea level. The dominant species are *Metrosideros umbellatus, Dracophyllum longifolium* var. *cockayneanum* and *Pseudopanax simplex.*

A characteristic of the flora of the New Zealand subantarctic islands is the high level of endemism. Thirty-five species of flowering plants are confined to the area. This amounts to 20.3% of the total flora of seed plants (Lloyd, 1985). Endemic genera include *Pleurophyllum* and *Celmisia* (syn *Damnamenia*). The above two genera show characteristics which are typical of certain herbs found growing on the subantarctic islands. There is a tendency towards the aggregation of flowers into larger inflorescences than those characteristic of New Zealand herbs. *Anisotome, Pleurophyllum*, and *Bulbinella* show this characteristic (Lloyd, 1985).

Flowers are often coloured whereas mainland New Zealand species, of the same genera, have white flowers. *Hebe benthamii* and *Myosotidium capitata* have blue flowers. *Gentiana cerina* can be found growing on the Auckland Islands. Mainland gentian species have white flowers whereas *G. cerina* has red or striped flowers as well as white.

Bulbinella rossii has orange-yellow flowers. This summer green herb is dioecious whereas its relatives on the New Zealand mainland are hermaphroditic (Lloyd, 1985).

A number of subantarctic herbs have large leaves. All three species of *Pleurophyllum* are noted for rosettes—up to a metre or more across—of broad, longitudinally ribbed leaves. *Stilbocarpa* species can have leaf blades as much as 1/2 m across.

A number of theories have been advanced to account for the unique features of these herbaceous plants.

Lloyd (1985) states "Conspicuous flower displays are universally interpreted as adaptations associated with animal pollination, and unisexual plants must be cross fertilised. The occurrence of these outcrossing features on the outlying islands is puzzling in view of the low temperatures and frequent storms on these islands and their depauperate, pollinating faunas."

Lloyd (1985) suggests that the aggregation of flowers may reflect a greater reproductive expenditure for large herbs in a hyper-oceanic environment.

Wardle (1978) suggests that the coloured flowers of subantarctic species are non-adaptive, and that they represent primitive conditions in genera which have subsequently evolved white flowers on mainland New Zealand.

Godley (1979) suggests that the brightly coloured flowers, typical of some subantarctic plants, may reflect selection in an environment where every possibility of attracting insect pollinators needs to be exploited.

Because of maritime conditions, the subantarctic region was only lightly glaciated. Fleming (1976) believed that the high level of endemism is due to plants surviving throughout periods of glaciation.

Detailed studies are required, to further understand the unique features of the flora of the New Zealand subantarctic islands.

Acknowledgements. Thanks to Gillian Rapson, Bruce MacKay, Pamela Howell, Bill Lee, and Peter Johnson for assistance with the preparation and presentation of information in this paper.

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A Personal View on Staff Relations and Training

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INTRODUCTION

Often I think I'm incredibly lucky to be involved in a job that covers such a wide variety of skills and interest. On any given day I might be taking cuttings, organising staff, doing the books, weeding, or marketing. A great combination of earthy, people, and administrative skills. I'm sure life is similar for a lot of you.

The questions arise. How do we best manage time and staff? How do we create a good working atmosphere? Why are we in business? For the last question I suspect for most it's a love of plants and a decent way of making a living.

At the moment I have an apprentice working for me and this year I am the Nursery Representative for the Education Advisory Committee at Richmond Polytechnic, Nelson. This has given me the opportunity to look at training and the changes taking place.

To produce a quality product which is essential in today's environment, it's imperative to have a working environment where the employees are learning skills and are motivated, happy, and challenged. So I'd like to share some of my observations on staff relations and training.

EMPLOYER RESPONSIBILITY FOR THEMSELVES AND STAFF

Firstly, in a small business it's the boss who sets the tone for the working environment. He or she is ultimately responsible for what goes on. For me having interests outside my nursery has been critical for my sanity. I train regularly at Seido Karate and try to meditate at least 20 min per day. Having these disciplines enables me to look at my job in a reasonably clear and focused way. Crisis situations are easier to handle. I try to create a friendly and supportive working atmosphere.

Secondly, I have a responsibility for staff training whether it be encouraging my apprentice in her studies or making time for staff to go on relevant day courses, such as "growsafe chemical use" or the recent fertiliser workshops.

Thirdly, it is very important to set quality standards and it is my responsibility to implement and monitor them. For example, as a fruit tree producer we are in the process of implementing a standard quality assurance scheme for all fruit tree nurseries. A set of criteria which, if kept to, will result in certification. Customers will know they are buying a quality product.

A LOOK AT STAFF MOTIVATION

To ensure the highest level of employee performance, employers must motivate them. In my experience if you deal with people fairly, professionally, and honestly you'll be treated in the same way. So what motivates people? I've come up with 10 different factors.

1) **Make Work as Interesting as Possible.** A lot of nursery work can be boring

and repetitive. If this is the case take note and rotate jobs as required. Recognise people's differences. I have someone working for me who is happy desuckering apple rootstocks all day and does a very good job of it. Many people would get bored and quality decreases.

2) **Appreciate Your Staff**. Give praise for a job well done. A smile goes a long way. It helps people's self esteem and so they do a better job.

3) **Try to Make Staff Feel a Part of the Whole Operation.** This might mean giving special projects to people which they are entirely responsible for completing. I grow cyclamen so I could give one person the job of growing them from seed right through to sale. Share the decision making process sometimes and be open and informative on the way business is operating.

4) **Job Security.** Be clear about terms of employment. If there's only temporary work state within reason how long employment will run. For full time employees let them know that their job is secure. People like to know where they stand.

5) **Good and Fair Salary.** This is a difficult one. Many of us, me included are guilty of paying the minimum wage when perhaps an extra $1 per hour will make a lot of difference to the employee's pocket and attitude and so make more effort and do a better job. Provide fringe benefits where appropriate—free plants or a trip to the pub.

6) **Promotion and Growth Potential.** This does not really apply to my operation being quite small but in larger businesses it's important to reward effort with promotion and wage increases where deserved.

7) **Favourable Working Conditions.** Provide well-maintained tools. A conducive environment for bagging or taking cuttings. This is hard to do in a nursery situation as we all get wet and cold at times which is OK but be aware of it.

8) **Employer Loyalty to Staff.** A good staff member deserves the loyalty of his/her boss. If you have to lay someone off make a bit of effort to find them alternative employment.

9) **Assist with Personal Problems.** Allow time off if the situation requires it. Be flexible with working hours especially for women with young children. Offer advice if required and make yourself available to listen to problems from time to time.

10) **Tactful Discipline.** It's important to be firm and clear and make sure standards are being kept. Tell someone if their behaviour is unacceptable.

Many people leave or are unhappy in their job because of lack of involvement. It is important that employees are given the opportunity to grow as human beings. This in turn will benefit the efficiency of the business. Remember that a large part of life is spent at work. It must be fulfilling. Training, evaluation, praise and satisfaction make employees work for the business.

A BRIEF LOOK AT THE NEW TRAINING SYSTEM

Industry Training Organisations (ITOs) are being established and they consult with education institutes regarding training. The ITOs are writing units of learning for the new system. The new system brings together all the existing areas of training into one comprehensive system. There are eight levels with level 1 as basic, and could be studied at school, and level 8 as degree and beyond. Each of the 8 levels is broken down into units similar to university papers. A unit specifies the skills and knowledge required to reach a standard.

I have a draft copy of a landscape unit as an example. I'd like to show briefly the components of a level 3 unit.

Title "Select and plant trees and shrubs in landscape work."

Purpose. People credited with this unit will be able to select and plant trees and shrubs to a given planting plan and apply mulches and related materials to the requirements of a site specification. Then it has Elements 1-4.

1) Select specimens of specified trees and shrubs.
2) Handle trees and shrubs without damage.
3) Prepare and plant trees and shrubs.
4) Describe and apply mulches and associated covers.

Each element has subsections detailing performance criteria, e.g., 2.1 Lifting and carrying techniques used to move trees and shrubs. Minimise the risk of personal injury and damage to specimens. These units can be taken individually or in a package. Industry determines which units make a Qualification . UNITS can be cross credited, e.g., this one could be part of a forestry package. This new system is potentially very liberating as it does away with the notion of pass and fail. You might obtain some units at school, continue at Polytech, and move and get a job and study some units at the same time. Then you might go to a university. There is no repetition. The prospective employer can see the exact skill level of a potential employee. I gather that ITOs are working towards a National Certificate which will indicate levels of learning.

CONCLUSION

I hope in this brief presentation it might stimulate you to look at your working environment and the potential for training. A while ago someone pointed out to me that I was very successful. I thought, what? I don't have a flashy house or car, never have much spare money, how come? Then I thought, yes. I have a business that is operating, a healthy family, good working situation, friends, and outside interests. Yes! So appreciate your successes and keep pushing your potential.

Production and Propagation of American Ginseng (*Panax quinquefolius*) in North America—a New Zealand Perspective

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INTRODUCTION

Ginseng is an herbaceous perennial that is cultivated for its highly valued root. It is purchased as whole dried roots, pieces of root, powdered, or in capsules, and it is used in teas, soups, wines, and in a wide assortment of herbal and cosmetic preparations. Ginseng is used mainly in Asia, although its use is gaining popularity in other cultures. American ginseng (*Panax quinquefolius*) is a close relative to the Asian or Korean ginseng (*P. ginseng*). Both species are of economic importance and each has a distinct use in Chinese medicine. The main commercial production areas in North America of American ginseng are Wisconsin and Ontario with significant expansion in recent years in British Columbia. Interest in the production of this crop is high and expansion in North America is likely to continue.

GROWING CYCLE

Ginseng is propagated by seed which germinates after a lengthy stratification period. After germination 1-year-old seedlings produce three coarsely serrated leaflets joined at the top of a 5- to 10-cm stalk. In autumn the leaves senesce with the plant overwintering as a root similar in shape to a small carrot. In the second year plants produce two compound leaves at the top of a 10 to 20 cm long stem. Older plants may have three, four, and sometimes five compound leaves. Most ginseng plants flower after their third year, although flowers are sometimes found on two year old plants. The number of flower clusters and subsequent seed numbers increase as the plant ages but this is also dependent on plant vigour. The fruit ripens in late summer to a deep red colour and usually contains two hard-coated seed. In its native environment ginseng can grow for many decades. Each year when the plant senesces the dead stem leaves a bud scar on the tuberous root. By counting the scars the age of the plant can be determined. Older plants which are extremely rare command very high prices when sold.

SITE SELECTION

Careful site selection is essential for this crop. Factors to consider include climate, soil characteristics, aspect, slope, and previous land use.

Climate. American ginseng is a native of North American temperate hardwood forests from Georgia to Canada. The geographic range extends between 34° to 45° north latitude in eastern North America. This region generally experiences a continental climate with hot dry summers and cold winters. Two important factors to consider when choosing a climate suitable for growing ginseng include:

1) The need for a prolonged cold stratification period for both shoot emergence and seed germination.

2) Ginseng seems to have little resistance to diseases which thrive in cool wet conditions. The most notable, *Phytophthora* and *Cylindrocarpon*, can wipe out an entire crop over a period of days given the appropriate conditions. A comparison of climate data between New Zealand and the main growing areas in North America (Table 1) indicates that possible New Zealand sites are warmer in the winter and have fewer degree growing days in the summer. Given these constraints it follows that the most successful production of ginseng in New Zealand is likely to be in those areas that have cold winters and dry hot summers. Although not as cold in winter or as hot in summer, likely areas in New Zealand include parts of the central North Island and most of the South Island. Production in North America also includes areas that have high rainfall (see Table 1). Production in these areas is often carried out under a forest canopy. The forest soils rarely become waterlogged because excess water is absorbed by the high organic soils or returned to the environment by transpiration. This may increase the number of possible areas for ginseng production in New Zealand by including much of the 1.2 million ha of plantation forest.

Table 1. Climate comparisons between traditional ginseng growing areas in North America and potential New Zealand growing sites.

Site	Mean annual rainfall (mm)	Mean July temp. (C)	Mean January temp. (C)	Degree days (>10C)	Air frost-free days
New Zealand					
Hamilton	1201	8.3	17.8	1376	228
Nelson	999	6.3	16.7	-	-
Christchurch	666	5.8	16.5	1067	206
Alexandra	360	2.5	16.5	889	112
Dunedin	691	5.0	14.7	791	195
North America[1]					
Lytton (British Columbia)	411	-0.5	29.0	1409	186
Simcoe (Ontario)	888	-5.6	20.6	1240	155
Wausau (Wisconsin)	646	-6.4	21.7	-	-
Asheville (North Carolina)	1524	2.9	23.2	-	-

[1] The data for the North American mean July and January temperatures are transposed to enable more meaningful comparisons to be made between hemispheres.

Southern Ontario the most popular soil for ginseng production are the "Fox" soils. These soils are comprised mostly of loamy sands down to about 80 cm. Below 80 cm the soils are composed of strongly calcareous sand. This results in soils that are well drained and rapidly permeable. They also have a low water-holding capacity which makes irrigation desirable in dry years.

Aspect. In practice ginseng is grown on all aspects but because it prefers a cool shaded environment a northerly (southerly in New Zealand) aspect is preferred.

Slope. Slope is important to provide good air and water drainage which assists in disease prevention. Machinery access is also important so excessive slope should be avoided.

Previous Land Use. Ginseng does not grow well on sites that have grown ginseng previously. There are anecdotal reports of land being spelled for up to 40 years and still not successfully growing a second crop. Often the crop will germinate and grow for one or two seasons but usually not through to a third year. Disease is implicated but researchers do not yet fully understand the reasons for this decline. Other crops which in Ontario grow well under a similar climate and soil type to ginseng include tobacco, maize, cereals, and horseradish. In Wisconsin land used for ginseng is also used for corn, cereals, and potatoes.

GINSENG PRODUCTION

There are four methods of producing ginseng in North America:

1) **Wild Crafting**. Wild ginseng is harvested from the woods. Because prices are high, excessive harvesting has resulted in ginseng becoming endangered in some states.

2) **Wild Simulated**. Ginseng is cultivated in the woods using a low input system to produce roots resembling wild ginseng.

3) **Woods Grown**. An intensive production system using the shade provided by a forest canopy. Most of the management systems (e.g., fertiliser and fungicide applications) are similar to intensive cultivation.

4) **Intensive Cultivation**. Ginseng is grown intensively using wooden lath or shade cloth, to provide the shade.

Land Preparation. Land planned for ginseng production is usually sown in a cover crop such as lucerne or buck wheat. After an initial cultivation animal manure is applied at rates of around 60 tonnes/ha or more. The manure is well worked in and if the farm is on stony soil the stones are removed. In July or August (January and February in New Zealand) the soil is often fumigated. Although fumigation is usually carried out in Ontario, it is less common in Wisconsin. In Ontario Vorlex at 30 to 80 litres/ha is most commonly used. Other soil fumigants used include basamid and methyl bromide. After allowing at least the recommended time for the soil fumigant to work, lime or gypsum is added to achieve a soil pH of 5.5 to 6.0. Any basal fertiliser applications are also made at this time. If soil drainage is likely to be a problem some growers also installed tile drainage. After the lime and fertiliser have been well worked into the soil, the posts and support structures for the shade are laid out. The beds are then formed and groomed in preparation for planting in September (March in

New Zealand). Beds are approximately 30 cm high at the centre. They must provide adequate height to allow a harvester to pass underneath without cutting the root and to provide good drainage while at the same time not being so high that the foliage is damaged when a tractor passes overhead.

Propagation. Commercially ginseng is propagated by seed which is harvested in late August and September (February and March in New Zealand). The seed needs an embryo-ripening period to germinate and requires temperatures at about 20C as well as a period of cold stratification. Typically seed is harvested in late August or early September (February or March in New Zealand) with approximate seed yields of 300 to 350 kg/ha and 400 to 450 kg/ha from 3 and 4 year old crops, respectively. After harvest the seed would either be passed through a depulping machine which separates the pulp from the seed or the seed pulp is allowed to ferment for 2 or 3 weeks, before washing the seed from the pulp. Once separated from the pulp the seed is 'floated' or placed in water. Only those seeds that sink are regarded as viable and any that float are discarded. Seed is then usually treated to reduce the incidence of fungal or bacterial attack. Treatments differ from grower to grower with the soaking of seed in a formaldehyde solution for 25 min being one of the most common treatments. Seed is then mixed with washed mortar sand in a concrete mixer. The ratio of seed to sand varies from grower to grower but is usually around 1 : 2. The seed and sand mix is then placed into especially constructed subterranean seed boxes for one year. Again the box dimensions vary greatly from grower to grower, however, a typical box is about 3 m long, 1.5 m wide, and 0.5 m deep. Wire mesh is used for the base of the box to prevent the entry of rodents. This is then covered with 7 to 8 cm of sand followed by the seed and sand mixure. The last 10 cm is filled with sand only. Mesh for rodent protection and shade to keep the seed cool are then placed on top of the box. During the summer an additional layer of shade may be placed about 2 m above the box. Care needs to be exercised when positioning the seed box as excessive drainage will cause the seed to dry out while insufficient drainage will cause waterlogging and the seed to rot. The exact causes of seed rot or "milky" seed are not well understood but the problem seems to get worse the deeper the seed is in the seed box. Likely causes are insufficient drainage, lack of oxygen, or warm temperatures. The seed box also needs to be regularly monitored so that if it starts to dry out, water can be applied. After one year the seed is lifted, sieved, and washed to remove the sand. The seed is again floated to remove non-viable seed and treated to help prevent fungal attack. The seed is surface dried then stored, usually in a cool store prior to sowing.

Seed Sowing. Seed should be sown as soon after removal from the seed boxes as possible to ensure that seed viability is not lost through excessive drying or disease. Prior to sowing the seed coat is surface dried to ensure it does not jam in the seeder. If a precision sower such as the stanhay is used, the seed is also graded to remove the larger seed that may not fit in the belts. There is also a general perception that seed with a split seed coat has been sufficiently stratified and is ready to sow; however, many growers try to avoid sowing split seed because of the damage that can be caused to this seed when passing through the seeder. If split seed is sown the radicle should be less than 1 mm long. Seed is usually sown in September (March in New Zealand) although in Wisconsin some growers have sown with success as early as July (January in New Zealand) while growers sowing into the woods tend to sow later to avoid seed predation by rodents. Seeding is carried out using a variety of methods from precision sowers such as the stanhay, planet junior, or vicon down to manual hand-operated seeders such as the planet junior and sometimes for forest-grown ginseng seed is spread by hand. Often a precision sower is used for most of the beds with a manual push seeder being used to sow the top of the beds between the posts supporting the shade structures. Seed is sown at approximately 110 kg/ha onto raised beds. Eight to 20 rows can be sown per bed with 12 rows/ bed being the most common. After seed sowing, a mulch (usually oat straw) is applied. Germination usually occurs in the spring following sowing however some seed may take an extra year before emerging. Crop thinning was never carried out with crop spacing being achieved through a combination of seed sowing rate, seed germination percentage, and attrition through disease. In North America it is common for plant numbers to be reduced by as much as 60% to 70% between sowing and harvesting. For wild simulated ginseng the leaf litter is removed, seed broadcast sown, and raked in. The leaf litter is replaced and the crop left with little or no further inputs until the crop is harvested.

Mulching. After sowing, the crop it is covered with a mulch which insulates the ginseng seed from excessive temperatures and helps control weeds. Most growers reportedly use either seed-free straw or sawdust. The usual mulching rate is one bale of straw for every 3.6 m of row in the first year and one bale of straw every 7.2 m of bed in the second and subsequent years. Most growers in Ontario use seed-free straw with a preference for oat straw.

Nutrition and Soil pH. Little scientific field evaluation of fertiliser requirements has been carried out with growers generally relying on field officers working for fertiliser companies to make suitable recommendations. This coupled with little published fertiliser research has resulted in a wide variation in fertiliser usage. Most growers aim for a pH of between 5.5 and 6.0.

Shade. Ginseng requires shade and will not grow without it. In North America shade is provided by either wooden lath, shade cloth, or by growing the crop under a forest canopy. Besides providing shade, artificial shade structures must be able to be removed during winter to avoid snow damage, relocatable once the crop has been harvested, allow tractor access, and not promote high humidity around the plant.

Pests and Disease. One of the main constraints to production of ginseng in North America is disease. This problem is compounded by the long period required to produce a crop and the difficulty growers have in getting fungicides registered for use on ginseng. Generally ginseng grown under a forest canopy suffers far less from disease than when intensively produced. The main diseases are *Phytophthora cactorum*, *Alternaria panax*, *Phythium*, *Rhizoctonia*, *Fusarium*, *Rhizoctonia solani*, *Cylindrocarpon* spp. (*Ramularia*), *Botrytis cinerea*, and *Stromatinia panacis* (*Sclerotinia panacis*). While host to a wide range of diseases ginseng is not host to many pests. The main pests are root knot nematode (*Meloidogyne* spp.), slugs and snails, and voles.

Harvesting. Ginseng roots are harvested, using modified potato harvesters, after the tops have started to die down but before the ground has frozen. This usually takes place in October (April in New Zealand). After digging the exposed roots are bagged by hand ready for drying.

Post-Harvest Handling. After harvesting roots are washed in water. Various methods are used from simple washing with a high pressure hose to the use of more sophisticated tumble washers. Roots are then either placed directly into a drier or cool stored. Cool storing of the root (at 7C) primarily adds flexibility for the grower who can harvest when conditions are most favourable rather than when drying space is available. Roots can be stored for a maximum of 6 to 8 weeks. After washing and possibly coolstoring roots are dried. Generally modified tobacco kilns are used. All growers have their own drying recipes but as a general rule roots are dried at approximately 38C for 10 to 14 days. Usually the crop will be sold as a single grade to a buyer or broker. The firm on whose behalf the broker is operating would then be responsible for grading, packaging, and resale. Ginseng is sold and transported in cylindrical cardboard barrels capable of carrying 45 kg of ginseng.

Marketing. Between 1983 and 1987 over 86% of the North American ginseng crop was marketed in Hong Kong with most of the crop going into China. The final price to the grower is dependent on the following factors.

- World supply of ginseng
- Exchange rates
- Market manipulations by the major importers and exporters
- Market demand related mostly to stability and standard of living in China
- Product characteristics which can include disease incidence, root age, root size, shape, condition, and method of cultivation.

Summary of production in North America. Ginseng is a significant minor crop in North America with a high profit profile. The most valued ginseng root is one harvested from the wild, followed by wild simulated, woods grown, intensively produced ginseng. A price premium is also given to older roots. The main constraint on production in North America is disease.

Potential for New Zealand. American ginseng appears to be a crop ideally suited to production in New Zealand. Ginseng when dried properly stores indefinitely and commands a high price on world markets. The main problem for New Zealand producers is that it is unknown as a producer and will be competing with the rapidly expanding production of the well known North American and Chinese producers. One of the main constraints on production in these traditional areas is disease which has had the result of decreasing the size of the root produced as growers harvest younger and younger roots. New Zealand growers could well command a market niche if they were able to grow larger older roots. Ginseng roots grown in the forest also command a price premium because these roots resemble wild ginseng. Another market niche could also be developed if ginseng were able to be successfully cultivated under a Monteray pine (*Pinus radiata*) plantation.

Acknowledgments. This report is based on a visit made to North America in 1992. I am indebted to both the trustees of the Queen Elizabeth II Technicians Study Award for financial assistance and Dr. John Proctor from the University of Guelph. Without their support this project would not have been possible. Thanks also to Mr. J.A. Douglas for his critical review of this manuscript.

Propagation, Industry, and Education

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At present, I am studying for NDH (National Diploma in Horticulture specialising in nursery production). I have completed 2 years as a student at Aoraki Polytechnic and now have a full-time job as nursery propagator for the above nursery. I will discuss my experiences, thoughts, and facts on the present and future of education in horticulture especially in propagation.

At present we have diverse and fragmented forms of training and education within the industry. Starting with secondary education and working up:

- High schools: School Certificate in Horticulture and 6th Form Certificate in Horticulture
- Polytechnics and other providers: TOPS (Training Opportunities Programme). These are short-term courses up to 12 weeks on the basics.
- Trade Certificate Board: TCB (Apprenticeships). Training within the workplace.
- RNZIH (Royal New Zealand Institute in Horticulture). These qualifications are taught in various Polytechnics throughout New Zealand and include:

    CHT (Certificate in Horticulture Theory)
    NCH (National Certificate in Horticulture)
    NDH (National Diploma in Horticulture)
    NDH Honours

These courses, as in my case, can be done by correspondence and do require a certain amount of practical experience.

- Universities and Polytechnics: Advanced diplomas degrees and honours.

The present systems cover their area of qualification reasonably well, but as there are a number of authorities involved in administration they each have different sets of standards and criteria. As students, we have problems getting recognition of prior learning by other administrating bodies.

The industry has raised questions about the levels of tuition and qualification being taught by various institutions. In reading the transcripts of the meetings of the New Zealand Region of I.P.P.S. last year, there is record of some discussion on this topic and some concern. Also, the educationalists are looking to find a better system that provides them with more industry input and brings all qualifications and training into one aligned system.

A new group, called the ITO (New Zealand Horticulture Industries Training Organisation Inc.), has been set up to amalgamate all the qualifications, training, and education under one body. This organisation is to set standards of attainment for the students and trainees and also to set standards that the institution are to meet.

Firstly, institutions have to be accredited, that is, visited with inspection of facilities and student support systems checked, tutors' qualifications accepted and the general training programme approved. All this is done by the NZQA (New Zealand Qualifications Authority) which is made up of educators and industry representatives covering all facets of horticulture.

At the end of 1994, TCB, NCH, NDH, and CHT will cease to exist and there will be no more apprenticeships.

What will take its place is a set of units of learning standards from 1 through 8. There will be requirements to master to reach each standard.

Here is an example of the proposed future system along side the existing systems.

Present Systems	Proposed Future Systems Levels
High School Certificate	1
6th Form Certificate	2
TOPS	3
TCB	4
CHT	4
NCH	5
NDH	6
NDH Honours	7
University Degree/Diploma	8

As an example, there will be 200 units up to level 4 registered by November 1993 covering all facets of horticulture. Level 4 will be equivalent to the present NDH and levels above 6 will be advanced diplomas and degrees. Units for levels 5-7 are to be registered by June 1994.

All these units of learning are to be contestable and will be tendered for by the different institutions that are accredited to teach to the various levels.

Not only is theory instruction involved in these standards, but also a high proportion of practical experience and teaching. Registered practical assessors appointed by the ITO will monitor the progress of students through the practical on-job aspects of the components of their studies. These assessors will come from within the industry as people involved in the present running of a particular aspect of horticulture.

Also a cross reference or RPL (Recognition of Prior Learning) is to be put in place so that training at one institution can be accredited at another institution to enable further training or study without the risk of being penalised. Also everyone will be aware of what each standard module unit or level stands for and the qualification and teaching will be standard throughout all institutions or providers.

This in my mind should eliminate a lot of the confusion and frustration felt within the industry, by student trainees, and by educators/administrators.

Members of I.P.P.S. and those from within the horticultural industry can and should have involvement and input into this new direction in education. To ensure that the content, emphasis, and qualifications are what the industry needs and demands we should have an involvement. I feel that because propagation is such an important and integral part of every aspect of horticulture, its profile should be raised and covered adequately both theoretically and on a practical basis in this new form of education.

In the Aoraki region we have a General Advisory Committee to the Rural Studies Centre of Aoraki Polytechnic. Under this we have a subcommittee of horticulture. The membership is comprised of representatives from all aspects of horticulture, e.g.; turf, landscaping, floriculture, fruit production, vegetable production, nursery both open ground and container, and parks and reserves.

I have been a representative on this committee formerly as a student representative and presently as an industry representative. This committee provides support to the tutors and has a large input into what and how the students are taught in the course at Aoraki Polytechnic.

I have found this involvement stimulating, interesting, and rewarding, and I would encourage all members to seek out their line of involvement in the area of education. The students and trainees of today are the industry of tomorrow.

For the continuation of the good standing of I.P.P.S., for the development of horticulture as an industry, and propagation as an important part of horticulture let us uphold the motto we have "To Seek and Share."

Capillary Beds—My Experience

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INTRODUCTION

When planning to set up the nursery, the following criteria were laid down.

- It was to be a one-person operation.
- The production level was to be 6000 to 8000 saleable units per year.
- Use of electronic controls was to be kept to a minimum, mainly as a cost-saving measure on both equipment and power.
- Hand watering, being a time-consuming exercise, was to be kept to an absolute minimum and the use of overhead sprinklers was to be avoided because of its problems and wastage of water.

In this paper I would like to share with you my experiences with capillary beds. After looking at different methods of providing the needed water to the plants, it was decided that the Kinsealy Capillary Beds system was the best one to use. This system is outlined by Lamb et al. (1975).

Although certain measurements are given, it is not necessarily to adhere to them. The system is very adaptable and can be used with success on many different sites.

CONSTRUCTION

As the site was slightly sloping, the system was adapted to suit our requirements. The beds were built on levelled terraces to fit the site with a narrow path between the beds. Although we have some odd-shaped beds fit into the site, in general the width of the beds is about 1.5 m and the length 6 m. The sides and ends were constructed with 10-cm-wide timber and the area within the frame was leveled. A channel was constructed down the middle of the bed to take a 6- cm Nova-flow drainage pipe—this supplied water evenly throughout the bed. The bed was lined with heavy-grade black polythene, the Nova-flow drainage pipe was placed on this, and the bed filled with pumice sand. To control the water level in the bed, a copper toilet cistern and ballcock was installed on one end and the Nova flow connected to it. On the other end an overflow outlet was provided to keep the water level about 2.5 cm below the sand surface. The sand was compacted and plants were put on it and given a good watering to start the capillary action.

RESULTS AND DISCUSSION

The system worked very well in the first summer and no stress was apparent even on very hot days. Overall growth was very good with plants saleable in a shorter time than those grown with overhead watering. Spraying programs could be reduced as sprays were not being washed off. There was, however, one problem and that was weeds growing on the sand. To solve this problem we used weed mat on the sand. It works well and does not affect capillary action.

The first winter things did not go very well. When we had a period of cold heavy rain the plants were standing in water for a considerable time, consequently the mix was soggy and cold. At the time we were using a 1 peat : 1 pumice (v/v) mix. We did two things to solve this problem. First, we put in drainage at the base of the bed and made an L shaped piece of polythene pipe to fit the hole. This could be swivelled to whatever level of water we wanted in the bed. We decided that for winter we would drain the beds and that worked very well. Secondly, we changed the bagging mix as the one we were using held excess water. We changed to a 1 Punga fibre : 1 bark : 1 pumice (by volume) mix. This mix gave us more drainage yet the mix did not dry out. Even with the few problems we had, I was more than satisfied with the system. Apart from the minimum of hand watering, we used less fertilizer, less chemicals for spraying, and plant growth was more rapid.

A further development occurred the following summer when structures called "cropcovers" came on the market. Lyndale Nursery had put one up, Malcolm called it "his big umbrella". I was impressed and, after having a good look at it, I felt that this was our answer but there were two problems. It was too expensive and it would not fit on our property. Because of our situation the cover would have to be removed during the summer as temperatures would be too high and surely burn the crop. This called for some Kiwi ingenuity, or was it Dutch. A structure was designed and the cover put up before the next winter. The sides were left open as the sole purpose was to keep off the rain. We have now used the cover for three winters and I am more than happy with it. It keeps the plants and me warmer and drier during the winter months. I cannot give you scientific proof that this is the way to go. What I can say is that, from my observations and my bank balance, it works for me. I believe that with the use of capillary beds and the winter cover, I get the best of both worlds.

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Propagation of Rootstocks by Trench Layering

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INTRODUCTION

The trench layering method of vegetative propagation has endure the test of time. Its modern rival, tissue culture, has so far not been able to match it in terms of producing the first choice product nurseries require for the production of high-quality, high-performance trees. Rootstocks propagated by trench layering remain the most cost effective, meet the size specifications required, are easy to transplant and handle, and are available when required to take advantage of optimum planting conditions. In addition, rootstocks are not usually adversely affected by the vagaries of weather and in the event of a bad growing season are usually of a buddable size at planting time anyway.

WHAT IS TRENCH LAYERING?

Trench layering consists of growing a plant in a horizontal position in the base of a trench and filling in sawdust around the new vertical shoots as they develop. The shoot bases are etiolated by this procedure. Roots develop from the base of these new shoots and grow into the surrounding sawdust. Trench layering is used primarily for woody species difficult to propagate by mound layering (stool layering). I should point out here that my method differs from that outlined in Plant Propagation Principles and Practices by Hartmann and Kester in that I take two years to establish the mother layer instead of one as they outline.

TRENCH LAYERING PROCESS

Establishment Phase (Year One).

- Mother plants, after 1-year's growth in the nursery if from tissue culture or alternatively well rooted 9- to 11-mm rods from an existing trench layering bed, are planted in a straight line down the middle of a trench. Each plant is planted at an angle of 30° to 45°—this angle is critical. Too little and you will not get the desired growth the first 9 months, too great and you will never be able to pin the mother plant in the required horizontal position in the bottom of the trench. The plants are planted 65 to 70 cm apart down the row. This operation will take place in July to August.

  It is important that mother plants are not doubled up in the trenches. While it is tempting to do this to get higher production quickly, it is short sighted for it causes an early drop off in production and quality of stock produced.

- After the mother plants have become established and made some growth, usually by the following February, they are laid flat on the bottom of the trench and secured with wire fasteners. The mother plant must be kept completely flat. At the same time a moderate amount of lateral growth is also pinned down. The plants are then left to continue growing.

- During the first winter (June to July) the mother plants are repinned where necessary to ensure they are flat in the trench. The lateral shoots pinned down the previous February are thinned out as required and shortened. It is important to avoid over-crowding. All other growth is cut back to within 2 cm of the mother plant. This leaves two or three buds to grow the next spring. At this stage it is advisable to use a wound dressing or spray to guard against *Chondrostereum purpureum* (silver Leaf) a major pest of *Malus* species.

Production Phase (Year Two).

- In the second spring as the buds on the now established mother plants break and develop vertical growths, layers of sawdust (untreated) are applied at intervals to etiolate 5 to 7.5 cm of the base of the developing shoots. Apply the first 2.5 to 5 cm before buds swell. Repeat as shoots emerge and before they expand. Later coverings are less frequent and should only cover half the shoot at any one time. The final depth of sawdust should be 15 to 19 cm. In a large-scale operation it is not practical to apply frequent small applications. Usually two applications will suffice and produce good results. However, it is important that final application is completed by the end of November, and that you do have an adequate depth of sawdust. This will vary from cultivar to cultivar. As a general rule, within reason, the more sawdust the better, especially with M793 or harder-to-root culitvars.
- At the end of the second growing season (June to July) the sawdust is removed and the rooted layers cut off close to the original layered stock leaving a small stub for next year's growth. Layering by this process may be repeated annually from the same mother beds. Mother beds if well cared for could last for 15 to 20 years.

Establishment of Mother Plant Beds. As beds are a long-term capital investment and can be expected to produce for 15 to 20 years, thought should, therefore, be given to the following points.

Site Selection.

1) Soil should be fertile, well drained.
2) Free of soil borne diseases.
3) Free of perennial weeds.
4) Sheltered from wind—wind can move sawdust around.
5) Availability of irrigation water.
6) Warm and sheltered with good light, avoid shading.

Mother Material Selection. This is of the utmost importance.

1) Must be know to be FKV preferably from a single mother plant or plants that have been individually virus indexed.

2) Free from diseases, such as silver leaf and *Phytophthora* spp.

3) Good grade and size of mother plants—9 to 11 mm diameter, 500 to 600 mm long.

4) Must be in a juvenile form.

Bed Preparation.

1) Drain soil if necessary.

2) Eliminate weeds, especially perennial weeds.

3) Sterilise ground if likelihood of soil borne diseases exist or if sight previously grew apple or pear trees—likely to have been virus infected.

4) Conduct a soil test and correct any nutrient deficiencies.

5) Thoroughly cultivate area and level.

6) Form trenches. These should be 70 to 75 cm wide and 10 cm deep. Rows should be about 1.6 m apart. This will depend on management practices. The number of rows per block will also depend upon individuals management practices. I work on six rows and then a tractor bay.

Management of Beds

1) Fertilisation programme—fertiliser should be applied annually as site and beds dictate soil tests are helpful in determining amount.

2) Irrigation—depending on climate and season—should be applied to obtain maximum growth and to keep sawdust moist.

3) Weed control programme in place and working.

4) Must have a planned pest and disease control programme in place and working.

5) Application and mounding of sawdust must be done on time and accurately. Optimum time is October/November.

QUALITY CONTROL

QUALITY IS NEVER AN ACCIDENT; IT'S THE PRODUCT OF INTELLIGENT EFFORT.

Sadly, quality is often something which is left to chance. At best given lip service, at worst ignored, and usually thought about at dispatch time. Careful attention must be paid to the quality aspect right from bud burst to dispatch.

New Zealand Plant Collection Register: An Update

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New Zealand is very rich in both indigenous and adventive flora. It is important to know the extent of this resource, where specific species are located, and how vulnerable they are. This is especially true of plants in cultivation.

Since 1988 a small group of Institute members have been working on a register of plant collections of all sizes held in New Zealand. This work is a first step to documenting the extent of the plant genetic resource. As such it is simply a quantitative exercise, getting all the information together in one place. The register was initially compiled in March 1992 from returns received from a questionnaire sent out during 1991. Since that time two further updates have been published with the latest register containing details of 400 generic collections and 97 theme collections.

DETAILS OF REGISTER

The current register contains basic information on the collection, its size, and who holds it. It also indicates the status of records for each collection. It is best seen as an informal working list. Information recorded is that handed on by the owner. There has been no research on the collection, correct identification, etc.

The register contains information received from a publicity campaign run during 1992 as well as from the work of two other organisations:

1) The Herb Federation have done much valuable work and started publishing lists of national herb collections. These collections are detailed in the publication "Individual Plant Collections 1992."

2) Marion Mackay in association with the International Dendrology Society (IDS) carried out a survey of 17 tree genera which appeared in the publication "A survey and evaluation of selected exotic tree genera in private collections in New Zealand (1990)."

The initial survey shows the extent of the genetic resource and how much of it is in private hands. Clearly the survey is still far from complete and further important collections will be unearthed.

USES OF REGISTER

The register will have many uses. It will be of value to nurserymen and gardeners seeking plants new to their range. It will show what germplasm is already in the country, thus avoiding the importation of new plants and the associated risks of pest and disease importation. plant breeders will see it as a list for available germplasm for breeding programmes. Most importantly, however, it will act as a guide to the vulnerability of each species or cultivar.

For instance, in the IDS work it was found that some species existed in only one or two collections and there were only 2 or 3 plants in the country. Clearly action is needed to prevent these at risk plants from disappearing. This is especially so when you realise that many of the collections are in one arboretum, Eastwoodhill near Gisborne.

The Register will also draw attention to important collections and ensure that where collections are under threat action can be taken quickly to save or transfer them to a new owner.

FUTURE PLANS

The Register will never be complete as plant holdings change constantly. However, it is hoped that now it has been started it will prove a focal point and enthusiasts will see gaps and help us keep it up to date and as useful as possible. This stage, however, has really only given us a broad view of the extent of the resource. The next stage which we are starting is to gather much more qualitative information on specific collections. From there we can continue and set up some sort of simple national collection criteria, along the lines of the NCCPG Scheme in Britain.

Recently the NZ Lottery Grant Board made a grant to the RNZIH to investigate the publication of more detailed information. This work is currently being carried out by horticulture students at Massey University as a research topic. This work has two aims: (1) Assessment of suitable software for a national plant collections database, (2) More detailed survey of specific species and their collection holders. For instance, a survey of metrosideros species and current collection holders.

During 1994 an initial register will be published containing the basic information on each collection plus more detailed information on species. This is sure to throw up many more collections as well as bring up inaccuracies in the initial list. The best way to find out what's wrong is often to publish.

If a wide range of people connected with plants in New Zealand make a contribution, whether they be botanists, plant collectors, breeders, nurserymen or home gardeners, we can produce and maintain a working index of our plant resource which will benefit both ourselves and will help to ensure the continued existence of as many plants as possible.

If you have information to contribute to the Register please contact:

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Acknowledgements. Dr. Keith Hammett for his tremendous work in getting the Register up and running. Marion Mackay for organising the research project for students.

A Review of Kauri (*Agathis australis*) Nutrition and Assessment of Current Nursery Container Mixes

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INTRODUCTION

Kauri forests once covered much of the early land mass of New Zealand. Now only a remnant of the great forests remain—a mere 5% of the pre-European kauri forest has been spared from the axe and burning (Ahmed and Ogden, 1987).

Kauri is a large, long-lived tree which normally grows for more than 600 years with individuals exceeding 2 m d.b.h. (diameter at breast height) and often 1000 years of age (Ahmed and Ogden, 1987). Sale (1978) in his book, which reviews the history of the kauri in New Zealand, states that forest authorities consider this to be the tree capable of yielding the greatest volume of millable timber in the world. Sale goes on to explain the significance of this tree in the early maori history and European colonisation, including its uses and the wastage that has occurred. Fires were particularly common in logged kauri forests, many being deliberately lit by gum diggers (Ecroyd, 1982). Fortunately some great kauri giants have remained and are protected in reserves and parks. Many are seen as historic and notable trees and have been individually named (Sale, 1978; Burstall and Sale, 1984; Salmon, 1990). The kauri is therefore seen as having great historic and amenity value in New Zealand.

Recently there has been a new interest in it as a forestry tree. Early papers have recorded how the kauri is readily produced from seed (Morrison, 1955; Dakin and McClure, 1975; Barton, 1978) and also by vegetative propagation (Dakin and Mearns, 1975). Recent work by Graeme Platt and Jenny Aitken-Christie (Anon, 1993), funded jointly by the Forest Research Institute and Tasman Forestry, has involved the collection of seed and propagating material from outstanding forest trees. Selected clones have been raised using tissue culture, grafting, and cuttings. Plants grown from seed are reported to be very variable. The kauri is, therefore, seen as having potential in plantation forestry. It is a tree of great beauty and historically its uses have spanned from sailing ship masts to paving slabs, and more recently to furniture where the durable, short-grained, handsome, easily worked and lengthened nature of the kauri wood is used to an advantage (Sale, 1978).

SOILS AND HABITAT

Temperature appears to be an important determinant influencing the distribution of kauri. Pollen analyses are reported to show that the climate 4000 years ago was warmer than today (Kershaw and Strickland, 1988) and kauri were even distributed down to Otago, where fossil remains have been found (Oliver, 1953). They then receded and are now primarily found north of 38°07'S in the North Island and on many offshore islands (Ecroyd, 1982).

Soils are a key aspect in considering the nutrition of kauri, as well as their ecology and planting-out. Clayton-Greene (1978) has noted that kauri are particularly prevalent on greywacke, as well as on the younger andesitic and rhyolitic volcanic soils of the Waikato. He suggested that soil type has influenced kauri distribution and that the lack of suitable soils and terrain, rather than climatic limitations, has hindered extension further south. Platt (pers. comm.) has noted that kauri can grow in wet clays, peat, alluvial clays, and stabilised sand, but tends to be absent from recent volcanic soils and those based on limestone.

Molloy (1988) states that indigenous forest containing kauri once covered over 1 million ha of Northland and Coromandel. Most of these soils have now been cleared of kauri and he comments that today only 20,000 ha of state forest with a high proportion of kauri remain. There are 300,000 ha of kauri podzol soils which remain as a legacy of the original kauri vegetation. Kauri can grow on a wide range of soils, but under the influence of sufficient rainfall and the very acid litter of the tree species, on certain soil types, kauri podzols can form. These trees themselves are in fact a soil-forming factor, since where there is adequate rainfall the water combines with humic acids to dissolve and wash out most things including the clays. This results in a kauri podzol soil with a quartz rich E horizon (under the A horizon) which can be readily recognised due to its bleached and sandy nature. This type of impoverishment can also occur with other genera like *Nothofagus*, although the characteristic pale quartz layer of the podzol may not always develop.

Kauri trees can grow for hundreds of years on impoverished soils and may also establish on low fertility, and hilly or mountainous sites. It appears that this is not an indication of their need for low fertility but rather a tolerance of low fertility, which has given them a competitive edge compared to other trees that are less able to tolerate infertile soils. Mycorrhizal infection has been shown to markedly stimulate phosphate absorption in kauri (Morrison and English, 1967) which would be an added advantage for establishment. The kauri's ability to grow on ridges also indicates its relative wind tolerance compared to other species; it is among the most wind-firm of all trees (Ecroyd, 1982).

A further factor is their drought resistance once they are established at about one year old (Bieleski, 1959a), although young seedlings can die readily from desiccation (Mirams, 1957). So, therefore, this plant's adaptability allows it to grow on harsh, dry, ridge sites, although the largest specimens are usually found on flat relatively fertile locations. This is further borne out by the fact that kauri will often respond well to quite high fertiliser additions in potting mixes as discussed in the next section. Bieleski (1955) confirms this when he points out that the ridge-top habitat is the one normally occupied but that they grow readily on flat areas, and even in ground that is swampy for part of the year. Bieleski (1959 a,b) showed that the distribution of young kauri seedlings in the field can be limited by both low and high light intensities and it can, therefore, be concluded that not only are edaphic factors (soil and water regimes) important in governing establishment and distribution, but also light and temperature (Bieleski, 1959c) are strong growth factors. This was confirmed by Hawkins and Sweet (1989) who grew kauri in growth cabinets and found that maximum net photosynthesis was at 27C and with high light intensities.

NUTRITION RESEARCH

Peterson (1961) studied the effect of different tree characteristics on foliar nutrient contents in kauri. Peterson (1962) then grew kauri seedlings for 100 days in solution cultures with specific supplies of six macronutrients, N, P, K, Ca, Mg, and S, and six micronutrients. The NZ native tanekaha (*Phyllocladus trichomanoides*) was also grown in the macronutrient solutions to provide a comparison. Both species responded to the range of nutrient levels with kauri appearing to prefer slightly higher concentrations of N, P, and K. It was noted that both species had low foliar N and P contents in comparison to other species and therefore have relatively low physiological requirements for these elements.

The kauri was also shown to be less severely affected by Mn and Fe deficiencies than the tomato, which was grown as a second test plant. Foliar Fe content in kauri rose to as high as 0.035 % when P was deficient. Peterson (1962) concluded that the kauri had greater tolerance than tanekaha to deficiencies and that it would be expected to grow more successfully in soils of low N and P status than other species. These and other factors help to account for observations like that of Burns and Smale (1990) who noted that in a forest study the kauri were inhibiting the growth of their associates, especially the tanekaha.

Morrison (1955) carried out an experiment with open-ground nursery-planted kauri which were supplied with ammonium sulphate, superphosphate, and muriate of potash. These treatments were applied to 2-year-old trees and 2 years after application the N and P fertilisers were found to have significantly increased the weight of the trees. Fertiliser trials in a stand of kauri aged 130 years were carried out by Barton and Madgwick (1987), where they found that the trees responded well to N fertilisers but that this was slow compared to *Pinus radiata*.

ASSESSMENT OF NURSERY MIXES

Several nurseries were requested to provide details of their container mixes used for growing kauri. A summary of the details is provided in Table 1.

Total available nutrients (for N,P,K) in g/m^3 were calculated from the rates of fertilisers incorporated in each mix multiplied by the percentage of each nutrient in the fertilisers. For comparative purposes a monthly release figure (g/m^3/month) was estimated based on the release periods of the individual fertilisers used in each mix. This method was described by Thomas and Spurway (1975) and can be illustrated using the following example:

- Applied 2 kg Osmocote 23-0-0 (5-6 month release)/m^3
- Therefore total available N = 2000 x .23 = 460 g N/m^3
- And monthly N release = 460 ÷ 5.5 (5-6 month) = 84 g N/m^3 month

This method assumes the release of nutrients from the fertiliser is uniform and while it may be simplistic it does provide a useful method of comparing mixes containing differing types of fertilisers. An estimate was made of the monthly release for both the first 3½ months (as some of the mixes include a relatively short-term fertiliser component), and the remaining term of the mix.

The stated release period or term of the mix was based on the reported release period of the slow-release fertiliser component of the base mix, e.g., 12-14 month

Table 1. Analysis of nursery container mixes used for kauri.

		Nutrient total (g/m^3)			Nutrients (g/m^3) First 3 mo.			Nutrients (g/m^3) After 3 mo.					
Mix	Media	N	P	K	N	P	K	N	P	K	Term (mo.)	Lime kg/m^3	Side dress.
1	2 composted bark; 1 peat; 1 pumice	480	132	249	54	15	28	54	15	28	8-9	4	☑
2	2 composted bark; 2 pumice; 1 peat	1060	299	489	209	72	105	61	9	22	8-9	5.5	☑
3	2 composted bark; 1 pumice; 1 peat	260	114	216	29	13	24	29	13	24	8-9	3	☑
4	2 punga fibre 1 peat; 1 pumice	950	110	315	194	20	62	51	7	19	8-9	4.5	
5	2 composted bark; 1 pumice	900	210	546	69	16	42	69	16	42	12-14	2	
6	1 peat; 1 composted bark; 1 compost; 1 pumice; 1 soil	1080	126	546	83	10	42	83	10	42	12-14	5	☑
7	9 composted bark; 1 pumice	1010	265	455	132	39	35	58	13	35	12-14	4	☑
8	1 peat; 1 sand	876	229	360	117	50	42	117	11	42	8-9	4	
9	3 peat; 1 pumice	140	340	100	12	28	8	12	28	8	12	?	☑
10	composted bark	628	120	390	179	34	111	0	0	0	1-3	2.5	

Osmocote Plus, 270 day Nutricote. In some instances fertiliser side dressings were also applied although these tended to be done towards the end of this release period and have therefore not been included in the calculations.

As can be seen there is a wide variation in the nutrient levels of container mixes used for the commercial production of the kauri, and indeed native plants in general, as most nurseries did not have a specific mix for kauri. Several of the mixes contained a relatively quick-release component, e.g., calcium ammonium nitrate (CAN), PG mix, resulting in particularly high nutrient levels over the first 3½ months.

Past research work on a number of crops at Lincoln University (Thomas and Baird, 1985), and by other workers, has shown that, in general, nitrogen (N) has a greater influence on the growth of container-grown plants than any of the other nutrients. Based on their work, Thomas and Spurway (1975) have suggested a nitrogen level equivalent to 90 g N/m^3/month provided optimum growth for a range of general nursery stock. Levels of 30 g/m^3/month and 60 g/m^3/month have been recommended for phosphorus (P) and potassium (K), respectively.

From Table 1 it can be seen that several of the mixes are well in excess of or below this nitrogen recommendation, with extreme N levels of about 30 and 200 g/m^3/month being reported. Although the estimated N release for mix 9 was only 12 g N/m^3/month, plants are also regularly fed with liquid fertiliser.

Growers reported steady kauri growth at the lower levels of nitrogen applications. Early unpublished research on kauri by the authors indicated that optimum foliage growth and dry matter production for container-grown plants can be obtained at relatively low levels of N, possibly as low as 60g N/m^3/month. There was also a strong negative response to liming. Plants were superior in size when grown in nil lime which resulted in a pH of 4.5. These plants were greenhouse grown in 1 peat : 1 sand (v/v) medium.

Where higher levels of N have been incorporated into the commercial mixes, or when plants with low base N levels have been given a sidedressing of fertiliser, good growth response was observed by growers. This tends to indicate that while kauri are tolerant of and achieve reasonable growth with low N levels, under good growing conditions plants will respond to increased N levels. When plants are grown in less than ideal conditions and subjected to stress, e.g., hot or cold conditions, then nutritional growth responses will be limited.

From the results provided in Table 1, it can be seen that, in general, lower rates of P and K were supplied than for N. The application of low levels of these two nutrients is supported by the unpublished work of the authors who found that the kauri was less responsive to both P and K than N.

CONCLUSIONS

This review discusses the diverse soils and habitats in which kauri grow in the wild and under culture. They can be found growing in harsh conditions on soils of low fertility. Growers have reported steady growth of container-grown stock under relatively low nitrogen fertilisation. Unpublished work on kauri, by the authors, showed poor response to low nitrogen additions, although increasing lime levels strongly depressed growth. This tolerance of low fertility was also reported by Peterson (1962) and in an early New Zealand Forest Service bulletin (Anon, 1977).

Despite this tolerance, in the wild the largest specimens are normally found on flat, relatively fertile sites. Platt (pers. comm.) reports that container-grown kauri on his nursery in Auckland will normally put on four flushes of growth per year and he believes that the species responds dramatically to the correct nutrition. Some of the other growers observed good growth responses, when their plants were being grown in relatively low N base mixes, but had been given a supplementary feed. Research work by Morrison (1955), and Bartin and Madgwich (1987), on open-ground kauri, support the notion that they do respond to N applications.

Further research is required to clearly define an optimum N level for container-grown kauri. At present they are obviously being grown at a wide range of N levels. At low levels mild deficiency or at least sub-optimal growth is likely to occur, while with the very high monthly N release occurring in some of the mixes over the first 3½ months, there could be the risk of mild toxicity particularly in the first few months of potting up.

From what is known about kauri nutrition so far, and from work done on other species (Thomas and Baird, 1985), including two other native plants, a nutritional recommendation of nitrogen equivalent to about 90g N/m^3/month is suggested. Further research may well confirm that this level is higher than the optimum for most rapid growth. Low phosphorus and potassium levels, and nil or low lime is recommended. Kauri are usually grown in a general potting mix, and these nutrient levels should also be suitable for other container-grown natives although they may require a higher level of lime.

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The Production of *Robinia pseudoacacia* 'Frisia'

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The production of *Robinia pseudoacacia* 'Frisia' from start to finished product in 5 months, excluding growing of the rootstock, is discussed below.

ROOTSTOCK—JUNE

The rootstock (*R. pseudoacacia*) is one-year-old seedlings grown in open ground. These are harvested in June and the roots cut back to fit a 7-cm square tube. The stem is cut back to about 30 cm. Once potted they are put under cover (tunnel or glasshouse) without heating.

SCION WOOD—JULY

The scion wood after going dormant in winter (June - July) is harvested from the mature *R. pseudoacacia* 'Frisia' trees. The wood that is selected is one year old. Trees can be grown especially for this purpose and each year pollarded to produce good scion wood. The wood is then cut into 30 cm lengths and each end dipped into hot petroleum candle wax to seal it. The wax can be heated in boiling water to melt it. The wax floats to the surface of the water and the cuttings are dipped into it. Once the ends have been sealed they are wrapped in damp sphagnum moss and placed in a plastic bag. The bag is then put into a fridge at a temperature of 2 to 4C.

GRAFTING—AUGUST

Once the rootstocks have started to break bud and the sap flow has commenced, grafting can be started. We use a grafting machine which produces a "V" graft. Because the rootstock is in 7-cm tubes they are much easier to handle than bigger containers. The graft is made about 10 cm above the tube and the scion is cut so there are two buds left. One-bud scions can be used if there is limited bud wood. With two buds the strongest shoot can be selected. It is important to select the thickness of the scion wood to match the thickness of the rootstock. Matching the cambium layers is not that critical as long as they cross somewhere on the graft. Once the graft is completed and tied, the whole graft (rootstock shoot and scion) is dipped into melted wax. This protects the graft and buds from drying out. As the buds swell—3 to 4 weeks later—they crack the wax. At this stage suckers from the rootstock need to be removed as they grow.

POTTING—SEPTEMBER

Once the scions have grown 15 to 20 cm the grafts are potted into 10-litre buckets and put outside on the container block in a sheltered spot. The new shoot is tied to a 2-m stake and at this stage needs tying every 2 weeks as the shoot grows. The 10-liter container has two major roles:

- Allows good root growth.
- Provides blow-over support for 2 m trees.

By the end of December trees should be 1.5 to 2 m high. Once shoot growth is 2 m high it is topped; this causes the tree to start branching at a good height. Lower branching is not always desirable as the branches can have large thorns and be hazardous.

Grafting *Ilex dipyrena*—How to Repeat Beginners Luck!

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BACKGROUND

Ilex dipyrena is a rather distinctive and handsome species among the many in our collection of 40 plus holly species and cultivars at Cannock Wood Nursery. This large shrub to small tree species, is native to the Himalayas. Although it is not a great garden centre plant there is a demand for it from plant collectors who have seen it growing in the wild, as well as those who see it in our collection. We grew our plant from cuttings taken from Eastwoodhill in April 1976. That attempt involved about 12 cuttings which produced about 4 to 5 trees. At that time I was a novice so records were non-existent except for the labels on the bench. One tree was planted in our garden and has grown to approximately 3 m by 1993. Further attempts at propagation have been fruitless, or maybe I should say plantless, which is frustrating as the cutting material looks perfect. The cuttings just sit and callus but no roots! Hence my paper title of how to repeat beginners luck! As with all my holly propagation, I use Seradix No.3 - Hardwood and have also tried Liba 10000 at 1 part to 3 parts of water. Some cuttings have gone on bottom heat, some without, and some outside behind the shed—but no plants.

THINGS I HAVE HEARD

Two thoughts come to mind before I carry on. First, years ago I read—I do not know where—about a strange habit which hollies have that appears to make them different from other plants. The second is a belief that older trees give better cutting material than very young trees. This second idea came from a fellow nurseryman. I had given him some cuttings and 2 years later he offered me a plant. I said that I had a tree, I just wanted to know how to grow more. His observation was that all the cuttings with flower buds failed, while all that succeeded had none. So this year I have tried again with all this in mind. Cuttings were taken in mid June with particular attention to flower buds. Four months later some have callused, most are green, and in basic language they are looking good. However, roots have not been forthcoming in time for the I.P.P.S conference. They will not hurry for propagator or publisher so maybe I should give some more cuttings away.

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Populus wilsonii and *Populus lasiocarpa* —Root Grafting Trials

Steuart Welch
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BACKGROUND

Populus wilsonii is native to southwestern China. To be more precise, the Chinese record it growing on the Southern slopes of the Qin Ling Mountains, Shannxi Province and down into the Sichuan Province. The Chinese do not appear to use it in either their planting or hybridising programs and it remains rare in cultivation. The extent of wild populations is unknown to the author. *Hiller's Manual of Trees and Shrubs* describes it as a highly ornamental, medium-sized species and it is from Hillier's Nursery that New Zealand's only recorded accession originated.

Also noted in literature is the belief that all *P. wilsonii* in Western cultivation are a single female clone due to them being uncommonly uniform in habit. *P. lasiocarpa* also comes from southwestern China and is best known as the Chinese necklace poplar. Hillier's describes this tree as a magnificent, medium-sized tree with leaves sometimes up to 30 cm long and 23 cm wide which are bright green with conspicuous red veins and stalks.

THE PROBLEM

Populus wilsonii and *P. lasiocarpa* seem to break all the propagation rules relating to the *Populus* genus. Whereas most poplars can be grown easily from either hardwood or root cuttings, these two cannot. The following cases of successful propagation by cutting are in contradiction to the common belief about these trees. Douglas Cook imported a grafted tree of *P. wilsonii* from Hillier's for Eastwoodhill Arboretum (Gisborne). Cuttings were given to Bob Berry who succeeded in growing at least one tree by cutting for his arboretum at Hackfalls. The original tree at Eastwoodhill died so Bob gave some cuttings back to Eastwoodhill curator Gary Clapperton who then grew one tree. At time of writing, the Eastwoodhill tree is doing well but Bob Berry's tree has succumbed. Gary Clapperton used the recommended method of lying his cuttings down in vermiculite to allow the auxins to increase on one side of the cutting, then standing it up to plant. I could say here that cutting propagation is keeping *P. wilsonii* in cultivation, with the help and expert propagation skills of the two tree enthusiasts mentioned above but the population is not increasing. My source of cutting material and introduction to*P. wilsonii* was a tree in Palmerston North that was grafted from the Eastwoodhill tree onto *P. yunnanensis* rootstock. This was after attempts of both cutting and tissue culture failed at the DSIR Aokoutere near Palmerston North. Their tree is now very healthy. *Populus lasiocarpa* is more common in New Zealand as we have trees which produce viable seed. Cuttings are known to be difficult or impossible, according to which source of information is believed.

THE PROPOSED SOLUTION

During the winter of 1993, I obtained some cuttings of *P. wilsonii* and already had three trees of *P. lasiocarpa* growing so the scene was set for a grafting trial. Scions of both poplars were grafted onto roots and also field grafted to trees. Table 1 lists the scion and rootstock combinations used.

Table 1. Effect of rootstock on growth of *P. wilsoni* and *P lasiocarpa*.

Scion	Roostock	Grafted (no.)	Comments
Populus wilsonii	*P. tremula*	6	2 dead
" "	*P. szechuanica*	7	2 fresh, 5 sitting
" "	*P. angustifolia*	8	most look doubtful
" "	*P. lasiocarpa*	9	2 leafing, 7 fresh
" "	*P. maximowiczii*	3	1 leafing, 2 fresh
" "	*P.* x *eridano*	4	all sitting
" "	*P. yunnanensis*	3	1 dead, 2 sitting
" "	*P. trichocarpa*	7	1 leafing, 6 sitting
P. lasiocarpa	*P. tremula*	5	5 sitting
" "	*P. szechuanica*	6	5 leafing, 1 sitting
" "	*P. yunnanensis*	5	4 leafing, 1 sitting
" "	*P. lasiocarpa*	16	3 very fresh, 13 sitting
" "	*P. maximowiczii*	4	2 leafing, 2 very fresh

EARLY CONCLUSIONS

After 7 weeks, of the 42 *P. wilsonii* grafts three have died, eight look doubtful, 17 are the same as when grafted and the rest are either freshening up or coming into leaf (Table 1). *Populus lasiocarpa* grafts are responding in approximately the same ratio. At this time several other things are obvious. (1)Three *P. lasiocarpa* rootstocks are suckering below the grafts which makes grafting of this species not important. (2) *Populus maximowiczii* and *P.tremula* are also suckering. The latter, especially, has a reputation for this making it a most unsuitable rootstock. (3) Grafts on *P. maximowiczii* rootstocks appear the most advanced. Our trees of this species are in full leaf already while many others are just starting to leaf, so this is probably the cause.

I cannot say that I have *P. wilsonii* trees just yet but remain very hopeful that this tree can become more common through my efforts. Regarding *P. lasiocarpa,* I may just use this as understock—either way I can't lose.

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Regeneration of Sweet Pepper (*Capsicum annuum* L.) from Axillary Bud Induction in Vitro

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Donor plants of 10 cultivars of sweet pepper were produced in vitro from seeds. Having been excised from the donor plant, nodal segments were placed on a modified half-strength Murashige and Skoog (MS) medium. The axillary shoots induced from the explants were transferred to the rooting medium. Benzyladenine (BA) in the medium for culturing of donor plant was not effective on the induction of axillary buds from the nodal segments. Rooting of the axillary shoot was promoted by 0.2 mg/liter indoleacetic acid (IAA) in the medium. Cultivar difference in potential for plant regeneration was observed, which was mainly attributable to the difference in rooting ability among these cultivars. The plants propagated by nodal segment culture developed normally in the greenhouse as well as those grown from conventional seedlings.

INTRODUCTION

Sweet pepper is widely used as an important fruit vegetable. In Japan, the amount of its production has been increasing, and has now reached 200,000 tons per year. Most growers use the seeds of a F1 hybrid cultivar which are expensive. Moreover, they have to nurse the seedlings for transplanting in a greenhouse. By using tissue culture two advantages are expected. One is supplying a good cultivar which is genetically stable. The other is labour saving for growing seedlings in a greenhouse. Up to now, several investigations have been reported on plant regeneration of sweet pepper from various explants, cotyledon (Gunay and Rao, 1978; Sripichitt et al., 1987), hypocotyl (Fári and Czáko, 1981), embryo (Agrawal and Chandra, 1983), and leaf disc (Phillips and Hubstenberger, 1985). In general, axillary bud induction from the node explants is often used in some horticultural crops. In this case, promotive effects of benzyladenine (BA) on axillary bud induction have been reported (Kantharajah and Dodd, 1990; Ni and Wetzstein, 1990; Xiao-Shan Shen et al., 1990). In our preliminary experiment using sweet pepper, it was also observed that 0.5 mg/liter BA in the medium for culturing of donor plant had positive effect to some extent on plant regeneration from the node explant (Yamamoto et al., 1991). In sweet pepper, however, the effect of BA has to be ascertained using a number of cultivars. The present paper describes the effect of BA in the medium for culturing of donor plant (BA pre-treatment) on organogenesis of nodal explants, cultivar differences in potential for plant regeneration, and the growth of the regenerated plants in greenhouse.

MATERIALS AND METHODS

Ten cultivars of sweet pepper used are shown in Table 1. After being sterilized with 1% sodium hypochlorite solution, seeds of these cultivars were placed on a half strength MS medium without hormones. After two weeks plantlets which germinated were transferred to a medium with 0.5 mg/liter BA or without BA,

Table 1. Axillary bud induction and rooting of ten *Capsicum* cultivars.

Cultivars	BA pretreatment (mg/liter)	Bud induction (%) 3 (Days)	Bud induction (%) 10 (Days)	Rooting (%) 15 (Days)	Rooting (%) 30 (Days)[1]
Kyounami	0	33.3	94.3	18.2	37.5
	0.5	53.8	93.5	17.2	31.2
Hokuto	0	64.2	94.0	22.4	33.8
	0.5	57.4	93.6	10.6	19.1
Tokahikari-D	0	19.0	95.2	7.5	33.3
	0.5	37.5	94.6	10.7	16.1
Tosakotobuki	0	39.1	95.7	0	39.1
	0.5	33.3	77.8	0	7.4
Tosokatsura	0	45.0	95.0	0	30.3
	0.5	34.3	91.0	2.9	5.7
TM-5	0	33.3	97.2	2.8	20.8
	0.5	43.0	84.8	5.1	22.8
Shinsakigake	0	41.5	80.5	2.4	19.5
	0.5	43.2	75.7	0	5.4
Golden Bell	0	56.8	91.9	0	2.7
	0.5	26.7	46.7	0	0
Wonder Belle	0	10.0	33.3	0	3.3
	0.5	13.6	27.3	0	4.5
California Wonder	0	12.5	33.3	0	0
	0.5	0	18.8	0	0
Mean	0	35.5	81.0	5.3	22.0
	0.5	34.3	70.4	4.7	11.2
S.D.	0	17.9	25.6	8.3	15.2
	0.5	17.5	28.8	6.2	10.5
C.V.	0	0.50	0.32	1.57	0.69
	0.5	0.51	0.41	1.32	.94

S.D. standard deviation; C.V. coefficient of variation.
[1] Days of culture in the rooting medium.

and cultured for two successive weeks. Nodal segments taken from the donor plants were placed on the half strength MS medium. Axillary shoots induced from the explants were cultured on the rooting medium. Cultures were kept at 25C and 16 h photoperiod. After acclimatization for one week the regenerated plants were grown in pots (18 cm in diameter). When the plants attained about 30 cm in height, these plants were transplanted to the soil in the greenhouse. The growth period in the greenhouse was approximately 10 months.

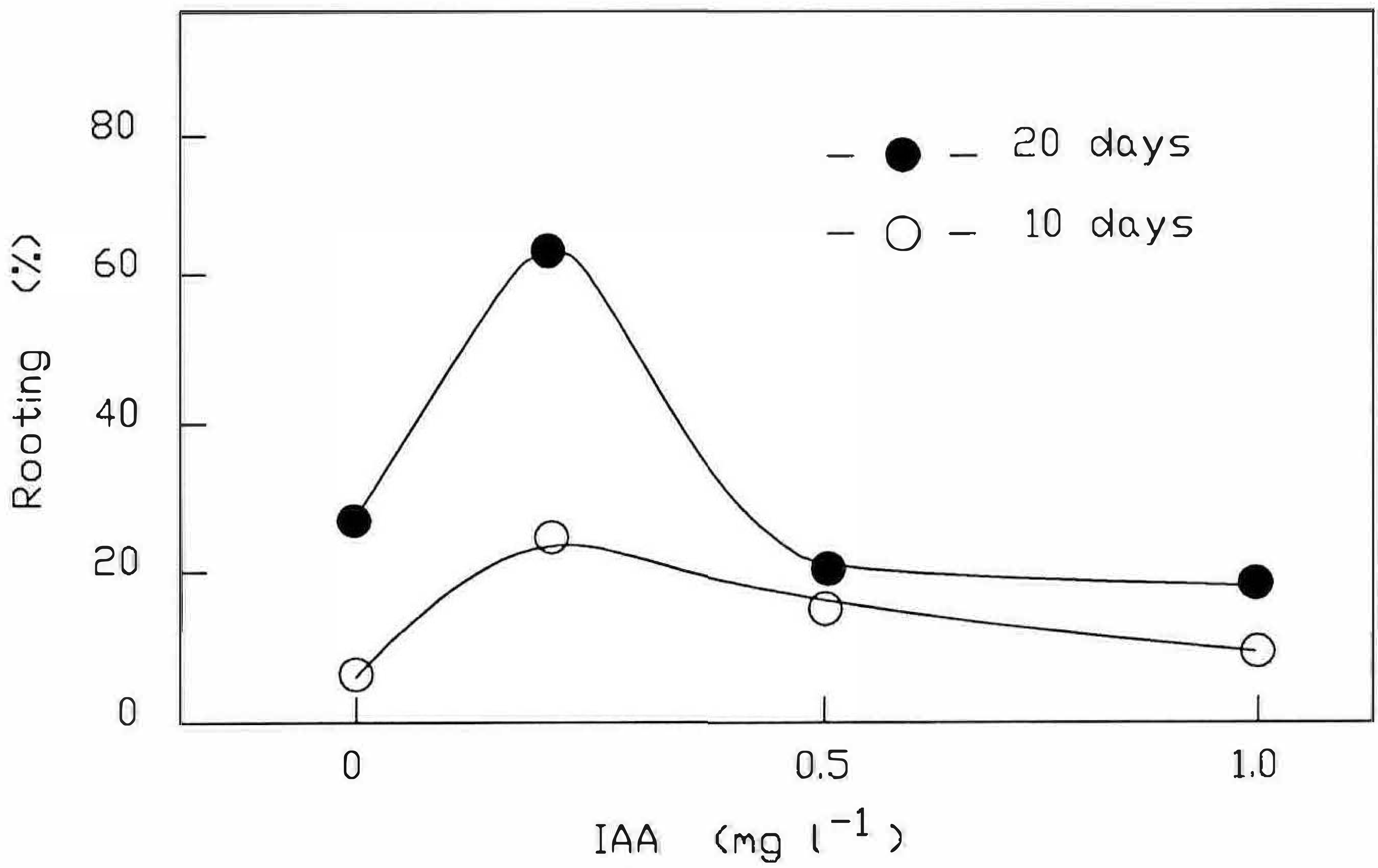

Figure 1. Effect of IAA concentration on rooting of axillary shoots.

RESULTS AND DISCUSSION

Table 1 shows axillary-bud induction and rooting from the node explants of 10 cultivars. After 20 days of culture without BA more than 80% of axillary-bud induction was observed in the eight cultivars except for Wonder Belle and California Wonder. The rooting of Golden Bell, Wonder Belle, and California

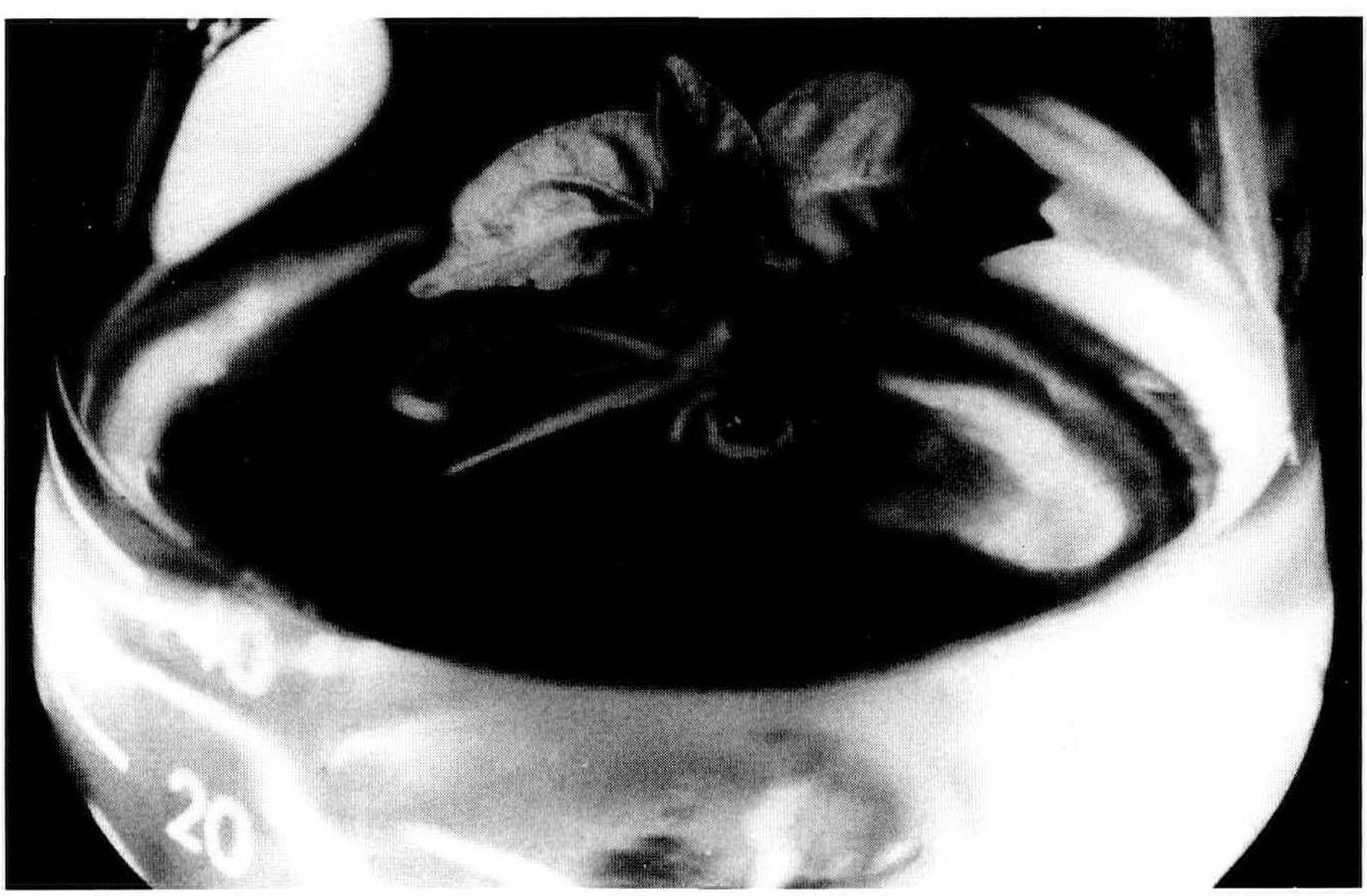

Figure 2. A plant regenerated by nodal segment culture.

Figure 3. Growth of the regenerated plants in greenhouse

Wonder were very low compared with the other seven cultivars. On the whole, BA had little effect on the axillary-bud induction but a decreasing effect on the rooting. The coefficients of variation for rooting were considerably higher than those for axillary-bud induction. This indicates that cultivar differences in rooting are larger than that in axillary-bud induction. The results can be explained from the difference in the mode of organogenesis between the axillary-bud induction and the rooting. The former is considered to be outgrowth of bud primordia which had been already formed on axillary meristem. In contrast the rooting is a new differentiation occurring during the in vitro culture. From the data shown in Table 1 it can be also concluded that the 10 cultivars can be divided into three groups with regard to potential for plant regeneration which is mainly attributable to the difference in rooting ability. 'Kyounami', 'Hokuto', 'Tokahikari-D', 'Tosakotobuki', and 'Tosokatsura' have higher potential for plant regeneration, while the lowest were 'Golden Bell', 'Wonder Belle' and 'California Wonder'. TM-5 and 'Shinsakigake' are intermediate. Figure 1 shows the effect of indoleacetic acid (IAA) concentration on rooting of axillary shoots. The rooting was maximum in the half-strength MS medium supplemented with 0.2 mg/litre IAA. A typical example for the plant regenerated by the nodal segment culture is shown in Figure 2. At this stage, the plants were transferred to small pots in a plastic box for acclimatization. After acclimatization for one week, the plants were grown in the pots (18 cm in diameter). When the plants attained about 30 cm in height, these were transplanted to soil in the greenhouse. Figure 3 shows the regenerated plants grown two months after transplantation in the greenhouse. The plants propagated by the nodal segment culture developed comparable to those grown from conventional seedlings in the greenhouse.

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Summary of Evaluation of New Containers For Nursery Production

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INTRODUCTION

Since nurseries began using containers as a major production tool in the early 1960s, there has been a constant struggle to overcome some of the problems inherent in this type of production. A few of these include maintaining adequate availability of water throughout the day and the season, reducing labor requirements, minimizing water runoff, reducing turn-over problems, moderating temperature extremes in the root zones. This paper discusses results of five research/demonstration projects evaluating these ideas.

The research evaluated sub-irrigation, Environmental Friendly Containers™, Poly-Jacket/Insulator™ and the Poly-Jacket/Water Saver™ containers, pot-in-pot above ground containers, and the Soil Sock™.

The project that started our interest in container design was one that evaluated the effects of subirrigation or collecting leachate in 2-in. saucers at the base of a container vs traditional irrigation. We discovered that live oaks grown with a constant reservoir of water at the bottom of a container had a significant increase in growth (1.5 ft) over traditional drip irrigation. Shumard oaks showed no difference in either of the treatments. (Tilt et al., 1990).

METHODS AND MATERIALS

A follow-up project to this evaluated effect of growing pecan (*Carya illininoensis* 'Melrose') and pear (*Pyrus calleryana* 'Bradford') trees in 20-gal (76 liter) containers including soil sock, low-profile, and traditional containers with drip irrigation and traditional and Soil Sock containers in 2.5-in. deep reservoirs. EFC was the sixth container in the study.

Twelve trees of each treatment were transplanted into the containers in May 1991, and grown for two years. Data for plant height, caliper, root number, root weight, and soluble salts were taken.

Average calipers of pears ranged from 1.8 in. (EFC) to 1.3 in. (low profile). Average heights ranged from 8.8 ft (EFC) to 7.7 ft (soil sock with drip irrigation). All subirrigation treatments (soil sock subirrigated, traditional subirrigated, and EFC) were significantly larger trees than drip-irrigated trees (low profile and traditional containers and soil sock with drip irrigation). Drip irrigation containers were more difficult to water effectively, especially with the large evaporative surfaces of the Soil Sock foam containers. There were no differences in root numbers/in.^{2} visible in the bottom of low profile, Soil Sock drip, EFC, and traditional drip containers for pear trees. The two treatments with constant standing water had no visible roots. Fresh root weight of roots extending from the original preplanted root ball was highest in the EFC. Soluble salt levels, measured by saturated paste extract method in August, in traditional containers with subirrigation (1.39 mmhos) were higher than traditional containers with drip irrigation (0.85 mmhos) indicating a tendency for salt accumulation in subirrigated containers. There was no difference in soluble salts for the other containers. No difference was found for any of the growth parameters for pecan trees that could be attributed to container design.

Weekly temperature data indicated that the Soil Sock did offer a reduction in extreme summer temperatures over traditional containers but provided no insulation effect against low winter temperatures. Subirrigation treatments also resulted in lower summer temperatures but not as low as the Soil Sock. Average August temperatures were 101, 96, and 91 F for traditional black containers, subirrigation black containers, and the Soil Sock container, respectively.

Speculation of the attributes of EFC's indicated a possibility of reduced irrigation requirements and reduced leaching. We initiated a study in the greenhouse evaluating 40 fashion azaleas *(Rhododendron* 'Fashion') in 1-gal (3.8 liter) containers. Half the plants were in EFC and the other half in traditional containers. We potted the plants in pine bark medium screened to 3/8 in. and took the weight of the containers at container capacity (watered until saturated and allowed to drain for 1 h). Each container was weighed daily and watered when the container reached 90% of container capacity. This target was switched to 80% in June. The difference in weight (g) of the container and the container at container capacity represented the amount of water (ml) to add to the container to bring it back to container capacity. Days between watering and volume of leachate were recorded at each watering. Soluble salts were measured in April and August during the experiment. The study was terminated in August 1992, and top growth was measured and a growth index calculated. There were no differences in soluble salts in April but August measurements showed a build up of salts in the EFC container over the traditional containers (Virginia Tech Extraction Method). There was almost a two-fold increase in leachate from the traditional container (10.9%) compared to the EFC (5.9%). EFCs require 26% (910 irrigations - EFC, 1234 irrigations - traditional) fewer irrigations than traditional containers.

Another experiment conducted at Auburn's Experiment Station in Mobile, AL evaluated the effects of EFC and traditional containers with and without copper coating on shelf life of plants in the garden center or interiorscape. Nikko blue hydrangea (*Hydrangea macrophylla* 'Nikko blue') and Natchez crapemyrtle (*Lagerstroemia* 'Natchez') were potted in 3-gal EFC and traditional containers. Half the containers were treated with copper. Plants were potted in April and allowed to grow until roots had contacted the copper and fully exploited the containers. Top growth measurements were taken and plants were moved to the greenhouse. Water was withheld and time was noted when plants wilted. Water was withheld for different periods of time to determine permanent wilting point (data is still being analyzed for this variable). No differences were found in growth as a result of the two containers or two copper treatments for the two plant species tested. There were also no differences in time to wilting suggesting no practical benefit of the treatments on shelf life.

The final two experiments evaluated five container types on growth of five plants. The experiments also studied the effects of container design on media temperatures and stability of containers. In experiment 1, three ornamental species (*Buddleja davidii* Franch 'Black Knight'; *Myrica cerifera* L.; *Viburnum* ×*pragense* Hort.) were potted in the five container types (traditional, above ground pot-in-pot, EFC, Poly Jacket Insulator, and Poly Jacket Water Saver) at Greene Hill Nursery Inc., Waverly, AL. Plants were potted in an 8 pine bark : 1 peat moss (v/v) medium. The second experiment was located at Auburn University and evaluated two azaleas— 'Fashion', and 'Delaware Valley White', in the same five container types. These plants were grown in a 100% pine bark medium.

All plants were grown in 3-gal (11.6l) containers for one growing season. There were 20 replications of each container type for each species used. A growth index was taken for each plant at the conclusion of the experiment and comparisons were made. Media temperatures taken 1 in. (2.54 cm) in from the side of the pot and 3 in. (7.62 cm) deep.

Plants (waxmyrtle, viburnum, and butterfly bush) in the standard and pot-in-pot containers grown at Greene Hill Nursery were consistently larger than plants in the other container types. There were no differences in growth among the containers for the two azalea cultivars. Temperatures in the media were more extreme in the standard container and lowest in the pot-in-pot containers. The lower temperatures and possible evaporation of water from the reservoir in the pot-in-pot containers can possibly explain the equivalent growth with the traditional containers. Pot-in-pot containers did not exhibit media temperatures above 120F (49C) which are noted as damaging. They also did not exhibit media temperature fluctuations of the magnitude observed in the other containers tested. This could be significant in terms of root damage from temperature extremes or from more efficient release of fertilizers, many of which are temperature sensitive.

Poly Jacket Water Saver containers were the most stable followed by the Poly Jacket Insulator, pot-in-pot, raised, hole, and standard containers, respectively. The Poly Jacket containers exhibited almost four times the resistance to turnover recorded by the traditional containers.

RESULTS

All of these containers have positive attributes. Evaluate new technology as it becomes available to see if it solves problems in your nursery or improves the efficiency of your production and the quality of your product.

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Minimizing Loss in *Rhododendron* and *Pieris* Production

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RHODODENDRON

We begin taking our cuttings between 20 October and 20 November. We start with a clean cutting, one that has been sprayed regularly all summer. The benches are sprayed with a mixture of 1 Clorox : 9 water (v/v).

We cut the hardened growth off about 2 to 3 in. from the top. Next we strip all the leaves off the cutting except three or four, then wound one side about 1½ in. from the bottom of the cutting. About ¼ in. of the base is quick dipped in a rooting solution of 7500 ppm IBA in 50% wood alcohol. The cutting is stuck about 2 in. deep in a peat cup filled with a mix of 1 perlite : 1 peat moss (v/v). The cups have already been placed in a heated bench. We use a mist system over the top that activates for 15 sec every 10 min during 8 h of daylight until rooting begins. We then cut down the misting time a little each day.

After the roots have formed, we spray the benches in the greenhouse with Alliette every 21 to 24 days until they are potted in the spring. We use Subdue at the recommended rate when we pot them in the middle of May, then continue to spray with Alliette. On or around 20 June we use Alliette at the high rate because it is only a preventative for *Phytophthora* and other wilts. We look for dieback at least twice a week. If we see dieback, we carry the plants out of the nursery.

We try to grow our plants to a salable size in 2 years. We repeat the same treatments the second year.

PIERIS

We take pieris cuttings when their new growth has just fully matured, about 5 July to 15 July. They are cut off about 3 in. from the top, and the leaves are stripped from about 1½ in. of the bottom of the cutting. The cuttings are then dipped about ¼ in. deep into a rooting hormone with fungicide. We use the same misting system for the pieris as we do for the rhododendron.

Update on Fungicides

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Although I am not a plant pathologist, I hope my practical experience from custom spraying and exchanging information with nurserymen and researchers for more than 18 years have given me enough knowledge to make my presentation worthwhile. I especially want to thank Dr. Ron Jones at North Carolina State University and Dr. Jerry Walker with the University of Georgia for their help over the years and their suggestions for this update.

Integrated pest management (IPM), or Integrated Crop Management (ICM), and record keeping should be foremost in our plans for plant protection.

INTEGRATED PEST MANAGEMENT (IPM)

Many practices a grower can follow will reduce the likelihood of severe disease problems. The philosophy of IPM is to apply any pesticide (fungicide, insecticide, or herbicide) only when justified and to integrate its use with all other cultural practices that could reduce the conditions favoring pest development. This does not necessarily mean to avoid preventive fungicide applications. It does not mean fungicides should be applied according to a calendar schedule. Use fungicides protectively on small populations rather than spraying everything. Use mixtures with residual properties, and alternate fungicides from different classes of compounds to help reduce resistance buildup.

INTEGRATED CROP MANAGEMENT (ICM)

ICM describes practices that I recommend better than does IPM. ICM and IPM include such things as 1) practicing sound sanitation, 2) avoiding sites that would increase disease pressure, 3) using cultivars that are disease resistant, and 4) optimizing nutrient levels rather that trying to maximize growth with high nitrogen.

RECORD KEEPING

How many times have you wished you had recorded how, when, and what you did so that you could avoid doing the same thing again or so that you could repeat a past success? For once maybe the regulators have done something that will help us. Effective 10 May 1993, certified private pesticide applicators have been required to keep records of federal restricted-use pesticide applications. I encourage you to keep the same type records for <u>all</u> pesticide and fertilizer applications, whether restricted-use or not. Here is what is required:

- The **brand or product name** of the federal restricted-use pesticide and its EPA registration number.
- The **total amount applied.** Amount does not refer to percent active ingredient. It means pints, ounces, or pounds of product, however the label directions are stated.
- The **size of the area treated.**

- The **crop or site** on which the pesticide was used. It is best to refer to the label for guidance to record this information. If the label is broad and says ornamentals, then you should use this term; but if the label itemizes cultivars and species, then so should you.
- The **location of the application.** Maps, charts, or the legal property description are acceptable.
- The **month, day, and year** of the application.
- The **certified applicator's name and certification number.**

In addition to these requirements you should record weather conditions, including temperature, wind speed and direction, cloud cover, and rainfall or irrigation before and after application.

FUNGICIDE RESISTANCE

Following the ICM and IPM practices mentioned above is the best way to reduce the possibility of fungicide resistance. I especially want to emphasize the importance of alternating fungicides and using mixtures with good residual action.

COMBINATION PRODUCTS

When there appears to be more than one disease problem or if the pathogen is not positively identified, use a combination product that will give control of a broad spectrum of pathogens.

- **Banrot** controls a broad spectrum of stem and root-rot diseases. It combines the effectiveness of Truban (Terrazole) against pythium and phytophthora with the systemic activity of thiophanate methyl (SysTec 1998, Domain, and Cleary's 3336) against fusarium, rhizoctonia, and thielaviopsis.
- **Zyban** or **Duosan** combines thiophanate methyl and mancozeb (Dithan M45, Dithan DF, Fore 80w, Manzate 200DF). Mancozeb is good against a variety of leaf-spot diseases, stem and twig blights, mildews, scab, and rust.
- **A Tank Mix** of mancozeb and copper hydroxide (Kocide) has proved to be very effective against most leaf-spot diseases, including bacterial leaf spot and fire blight, as well as scab, mildew, and rust.

OTHER GOOD FUNGICIDES

Banner gives broad-spectrum and systemic control of powdery mildew, rust, scab, black spot of roses, and anthracnose.

Daconil 2787 has been around a long time but still is excellent against a variety of leaf spot diseases including entomosporium, scab, and rust.

DORMANT SPRAY

I think that dormant sprays are the most important preventive sprays in the year's program. Dormant oil plus a fungicide will eliminate or minimize many early season pest problems, insects as well as diseases. The fungicides I use most often in dormant sprays are Dithane DF or Kocide 101. Oil, as well as the fungicide, kills or suppresses development of the overwintering stages of the pathogens.

NEW OR DIFFERENT

Dr. Jerry Walker sent me a reprint of an article by Horst et al. (1992) who reported effective control of powdery mildew and black spot of roses with a combination of oil and sodium bicarbonate. Their effectiveness was good when applied singly but improved when used in combination. On sales yards or other areas where re-entry may be a problem with conventional pesticides, this could be of interest. Additional work needs to be done to determine if other pathogens are controlled with baking soda. Hagan et al. (Hagan et al., 1991) found two ergosterol biosynthesis inhibitor fungicides, Nova and Flusilazol, that were as effective as Daconil 2787 (chlorothalonil) and better than Funginex (triforene) in controlling black spot of roses. To my knowledge these EBI fungicides are not labeled for ornamentals as yet, but we need additional systemic fungicides such as these.

Ronilan and Ornalin have been excellent for control of *Botrytis* spp. and *Sclerotinia* spp. In March 1993 Hammer et al. (1993) reported that pyrrolnitrin, an antibiotic isolated from *Pseudomonas cepacia*, a bacterium, gave comparable control of botrytis.

Dr. Ron Jones at North Carolina State University told me about Mycostop, a biofungicide, that now has a full federal label for a wide range of floral and foliage crops as well as azaleas, other rhododendron, fir, and several other woody ornamental species. It controls seed rot and root and stem rots such as fusarium, alternaria, and phomopsis and suppresses botrytis, pythium, and phytophthora.

Mycostop can be used as a drench; dip for transplants, seeds and cuttings; or as a foliar spray. It is a streptomyces, and the commercial product from Finland is *distributed by Ag-Bio Development, Westminster, Colorado. Many streptomyces* have been the source of antibiotics used in medicine.

Terragard, from Uniroyal, now also has a full label. In addition to Banner, Ciba expects to have another new fungicide in 1993. New from ISK Biotech, is a product with the common name fluazinam. It is labeled for a wide range of crops, including turf and poinsettias.

SUMMARY

I would like to emphasize the importance of using ICM or IPM practices extensively but also to remind you that even well-managed crops often need treatments with fungicides. It would be a dangerous gamble for a grower to let any disease get a headstart.

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Using Copper Compounds to Modify Roots on Container-grown Trees

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INTRODUCTION

Girdling roots—roots which grow around tree stems and other roots—may shorten a tree's life span if they constrict the vascular system and restrict water and nutrient movement or if they fail to anchor the tree adequately (Gouin, 1984; Holmes, 1984; Whitcomb, 1984). Girdling roots generally start in one of three ways:

1) Plants may be put in planting holes with glazed clay walls that restrict structural development and cause roots to circle;

2) new lateral roots may develop behind the ends of primary roots that are cut during field-grown nursery stock harvesting (Watson et al., 1990);

3) or roots may circle on the outside of the medium root ball for container-grown trees.

A common planting recommendation for circling roots resulting from container production, has been mechanical disruption, slicing or "butterflying," of the root ball (Flemer, 1982; Gouin, 1984). The value of these practices, however, is questionable, according to limited and contradictory research conducted primarily using shrubs (Blessing and Dana, 1987; Wade and Smith, 1985; Wright and Milbocker, 1978).

REDUCING CIRCLING ROOTS USING MODIFIED CONTAINERS

A variety of modified containers have been developed in an effort to solve the problem of circling root formation during production. Conventional plastic containers, which generally have rigid, straight, and smooth walls; have had ribs, holes, baffles, and other root deflecting or air-pruning devices designed into their walls to reduce or eliminate circling root formation.

These various wall modifications, and a flexible poly-bag container, have significantly reduced circling root formation on many species of plants (Appleton, 1989; Warren and Blazich, 1991; Whitcomb, 1984; Whitcomb and Williams, 1985), although sometimes with conflicting results relative to shoot growth (Newman and Follet, 1987; Whitcomb, 1984). Once planted in the landscape, Warren and Blazich (1991) found the effectiveness of the modifications in enhancing new root generation to be species specific.

Privett and Hummel (1992) found that a porous-walled container with pin-hole perforations randomly punctuating the container walls produced roots superior to those in nonporous smooth and nonporous ridged containers. Air root pruning behind the perforations prevented circling root formation except where the plastic was denser and container air porosity was limited.

Although trees generally cannot be grown in the ground in single plastic containers due to drainage problems, a rigid plastic container has been developed with rows of small holes around the container sides and bottom to minimize these problems. No comparative tests have been reported as yet, but the potential for circling root formation appears minimal (personal observation).

Another new development is an above-ground container that combines a porous foam-rubber liner with wire baskets used to protect field-grown tree root balls (Tilt, 1992). Called the "Soil Sock" (Better Bilt Products, Inc., P.O. Box 559, Addison, IL 60101-0559; 1-800-544-4550), the foam-rubber liner insulates the roots against temperature extremes while allowing air penetration, which air-prunes the roots and prevents circling root formation. The container sits above ground for production but is reported by the manufacturer to be entirely plantable. It is currently being tested by the author for transplantability and circling root reduction.

REDUCING CIRCLING ROOTS USING COPPER-COATED CONTAINERS

A new approach to the reduction or elimination of circling root formation is the use of rigid plastic containers with copper-coated interior walls (Struve and Rhodus, 1990). The copper in a liquid carrier is painted or sprayed on the walls and is absorbed by the root tips. The copper acts as a growth regulator, inhibiting root tip growth and stimulating branching.

A currently available copper product is SpinOut™ (Griffin Corporation, P.O. Box 1847, Valdosta, GA 31603-1847; 1-800-237-1854). The manufacturer claims that root tips are not killed by the copper as they are with air-pruning.

The effectiveness of the copper has been demonstrated on a large number of trees

Figure 1. Left. Root ball of a lacebark elm (*Ulmus parvifolia*) grown in a copper-coated container. Note that no roots are visible on the outside of the medium. Right. Fibrous root system of a lacebark elm grown in a copper-coated container, medium removed.

Figure 2. Left. Root system of a sawtooth oak (*Quercus acutissima*) grown in an uncoated container. Note major circling taproot at the bottom of the root ball. Right. Root system of a sawtooth oak grown in a copper-coated container. Note taproot has been eliminated and root system is more fibrous and evenly distributed throughout the entire root ball.

and shrubs (Arnold, 1992; Arnold and Young, 1991; Beeson and Newton, 1992; Flanagan and Witte, 1991, 1992; Struve and Rhodus, 1990). Results range from virtually no visible roots on the outside of root balls to roots whose tendency to circle is stopped after one to two inches of growth. No impairment of root growth into the surrounding soil has been reported for trees and shrubs after copper-coated container removal and field transplanting.

The only containers thus far developed with copper incorporated into the container walls are fiber (peat/paper) containers (Root Works[R], Keiding, Inc., 4545 W. Woolworth Ave., Milwaukee, WI 53218; 1-800-346-0898). Appleton and Salzman (1993) reported that these containers have been very effective at preventing roots from matting on the outside of azalea root balls, but thus far no reports have been published on their effect on tree roots.

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Making Profit from the Swamps

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My topic, "Making Profit from the Swamps" might be made more general by calling it "Wetland Mitigation."

As a child I grew up in a floodplain area that had drainage ditches, springs, marshes, pot holes and spring floods. I hunted and fished these areas and became quite familiar with the plants that would grow under those conditions. Back then we called these areas swamps; today they have acquired the name wetlands. Tidal marshes, creek banks, and general bay and ocean shore lines are wetlands with a completely different type of plant life.

For the most part the nursery industry has concentrated on the obligate upland species for such things as soil erosion, windbreaks, and strip mining revegetation. The plants used most are natives. They are fast growing, adapted to a wide spectrum of soils and microclimates.

A nursery can specialize in three separate groups of plants--obligate upland plants, obligate wetland plants, and facultative species that lie in between.

As more environmentalists became involved in and concerned about landfills, highways, developments, fish and wildlife conservation, and air and water quality, they began to call for plants I remembered as a child. Plants like cattails, jack-in-the-pulpit, elderberry, alder, willow, skunk cabbage, wild rice, Virginia creeper, sumac, and the list goes on and on.

Nurserymen, including us, had calls for plants that were not readily available in our trade. The hard part, as always, was getting seedlings or liners and getting them in production.

As in any industry, to make a profit, you must know your field. You must know which seedlings to buy and which cuttings and seedlings you can produce yourself. You also need to know how many plants can be done from cuttings and have a projection of the numbers you will need to grow. This I call the "crystal ball."

Some of the native trees we now grow as ornamentals are willow, maple, birch, ash and oak. We also use shrubs such as blueberry, red twig dogwood, holly, and viburnum. Most of these are wetland plants.

To get started as a wetland mitigation supplier, I estimate you should grow 75 to 100 types of plants and have a good knowledge of suppliers who are growing others. Most growers have ponds, river-bottom land, sandy places, or low spots in their fields where nothing seems to grow well except weeds. Always remember to plant plants that will grow for you, not plants you want to grow.

We at Bobtown Nursery do some seedlings. We found that picking our own seed was the fastest way to get into production. We gather most of our seed from Virginia and Maryland areas. We treat these seed the same as we do seeds of Japanese maple, sweetbay magnolia, and dogwood.

In the fall we make the beds, then fumigate, add seed, cover with 1 in. of sand and a layer of pine needles. We top the bed with snow fence, which is removed when seed germination occurs.

Around December 15 we take cuttings from plants on our ditch banks, ponds, and marshes. Two specific plants we propagate this way are black willow, *Salix nigra*, and Elderberry, *Sambucus canadensis*. We take cuttings that are 24 in. long and about 1/2 in. thick. The cuttings are placed in unsterilized topsoil in 1-gal containers. The cuttings are not sterilized or dipped in any rooting compound. They are maintained in a greenhouse at a minimum of 35F. Under these conditions, we have good root production and some top growth by February 15. By May 25 the plants are 18 to 24 in. tall, well rooted, and ready for shipment or transplanting. Alder and sumac are the next plants I will try using this method.

Most growers are slow to change their growing operations, saying, "It was good enough for my father, so it's good enough for me." This leaves little room for change. With the growing demand for native plants and the ever-changing economy, take a hard look at the swamps—I mean wetlands. These plants could be a good addition to your ornamental lines.

What's New In The Biology Of Adventitious Root Formation

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INTRODUCTION

The First International Symposium on the Biology of Adventitious Root Formation was held in Dallas, Texas, 18 April through 22 April 1993, with over 140 participants, representing some 25 different countries. It was a unique opportunity for researchers from industry, government, and many different academic disciplines to get together and focus on the basic and applied aspects of adventitious root formation. The Southern and Western Regions of IPPS helped sponsor the symposium.

No participant had a magic bullet or quick solution to rooting problems, and more questions were raised than answered. Inability to agree on a model system was probably a healthy sign and points to the complexity of adventitious root formation.

COMMERCIAL IMPORTANCE OF ADVENTITIOUS ROOT FORMATION

Vegetative or clonal reproduction is the most important propagation method of many horticultural crops. United States of America horticultural industries comprise one of the largest combined commodity crops in agriculture. In fact, the USDA reported that in 1991 export value of horticulture crops exceeded all other agricultural commodities, including forestry and agronomic crops (USDA, 1991). The 1991 United States of America wholesale value of ornamental crops (nursery crops, greenhouse, floriculture, foliage and bedding plants) was $8.9 billion, while total consumer expenditure for ornamental crops was $40 billion.

ADVENTITIOUS ROOT FORMATION IN HORTICULTURAL CROPS

Over 70% of the propagation systems used in the ornamental horticulture industries depend on successful rooting of cuttings. The large international floriculture industries such as poinsettias, carnation, and chrysanthemums rely exclusively on asexual propagation by cuttings.

In southern and western U.S. ornamental nurseries, seed propagation typically accounts for less than 10%; division from 5% to 15%, and graftage, spores and tissue culture liners less than 1% of the propagation systems utilized, compared to 70% to 90% propagation by cuttings. Ornamental shrubs are usually asexually propagated by cuttings, whereas shade trees are propagated by seeds due to difficulty in rooting. Easy-to-root plant materials are much more widely propagated as tissue-culture-produced liners than are difficult-to-root species. Even though tissue culture can enhance a difficult-to-root woody species' ability to be cloned, poor adventitious root formation often limits their commercial production through tissue culture systems.

LIMITATIONS OF ASEXUAL REPRODUCTION

Adventitious root formation is a prerequisite to successful clonal regeneration of propagules, with possible exceptions of apomictic seed, and graftage and budding systems on seedling rootstocks. Poor rooting continues to be a serious commercial limitation in the asexual propagation of many woody horticultural crops. Propagation systems commercially utilized to improve rooting success such as mounding, stooling, layering, division, separation, graftage, budding, tissue culture, manipulation of stock plants through etiolation and banding are costly and labor-intensive.

Labor costs contribute to 30% to 65% of ornamental crop production expenditures and more than 80% of propagation costs, which gives considerable financial incentive to streamlining techniques and improving rooting. Direct sticking cuttings into small liner pots as opposed to sticking into conventional flats uses personnel and materials more efficiently. The additional production step of transplanting rooted cuttings is eliminated, and the potential transplant shock due to a disturbed root system is avoided. However, hard-to-root species cannot be stuck directly into pots since rooting must be 80% or better to justify the additional space required. The inability to induce adventitious root formation seriously limits our ability to propagate many potentially valuable horticultural crops, particularly mature woody species.

GENETIC AND BIOCHEMICAL IMPLICATIONS TO ROOTING

Auxin is frequently not the limiting factor to successful rooting. So will magic chemical formulations for industry to use be available in the near future? Probably not. So we need to know what makes a cutting difficult to root. We know that many woody plant species are much more difficult to root when they become physiologically mature. Ability to form new cells, to respond to certain chemical stimuli, and to develop root initials are the most critical parts of the rooting process. A cell's ability to form new cells or remain meristematic, even while other cells are becoming specialized, or differentiated, may be determined during a stage of development when rooting would not ordinarily occur. The later development of root primordia and their elongation are rarely a limiting factor in rooting.

So what controls cells' meristematic ability? Much of the rooting research to date has relied on the chemical events and responses after genes have triggered the production of proteins or enzymes. Research needs to concentrate on the genetic processes controlling the production of proteins, some of which serve as important enzymes in the initiation and development of adventitious roots. Molecular studies at the DNA transcriptional and translational level have the greatest potential for revealing the control of rooting. Researchers in Wes Hackett's laboratory at the University of Minnesota have identified some biochemical markers for rooting such as polyamines, peroxidases, and flavenoids with the juvenile and mature forms of English ivy.

To date no current gene marker is clearly defined for rooting. There are phenylpropenoid genes (PAL, CHS, DFR), cell wall protein genes, and genes regulating cell division, but researchers do not agree that these genes are clearly defined for rooting.

Spano et al. in France worked with leaf explants of hairy root tobacco that were genetically transformed with the bacterium *Agrobacterium rhizogenes.* They were able to isolate different genes in the agrobacterium. They demonstrated that spontaneous rooting of the transformed tobacco plants was not due to auxin-producing genes or a substantially altered balance of endogenous hormones, but rather to those genes that increased the sensitivity of the tobacco to the presence of auxin. This has important implications in difficult-to-root woody species that have lost their rooting ability and will not respond to applications of auxin. The ramifications of this are that in the future, genes that enhance tissue sensitivity to auxin could be inserted into genetically transformed woody plant species.

ANTISENSE TECHNOLOGY AND ROOTING

The idea here is to switch genes on and off. When a plant undergoes changes from juvenile, to transition, to mature phase, its genome genes do not change. However, there are specific genes that are turned on or off change during the maturation process. These epigenetic, or nonpermanent genetic changes can negatively influence rooting since certain enzymes may or may not be produced. Antisense technology is currently being used in fruit ripening and in flower pigmentation where changes in flower color can be genetically induced. If an enzyme negatively affected rooting then an antisense DNA or RNA could be used to turn off the gene that produced the enzyme. What genes or gene groups affect rooting has yet to be determined.

POTENTIAL FOR EMERGING NEW PROPAGATION TECHNOLOGIES

Biotechnology includes whole-plant engineering using traditional plant breeding and selection, cellular engineering with cell culture and cell fusion and molecular engineering at the genetic level. Development of somatic embryos, called embryoids, from vegetative rather than reproductive cells holds promise for synthetic seed technology. A somatic embryo encased in a synthetic seed can be used in fluid drilling systems. Clonally regenerated plants are being propagated as seeds that will produce offspring identical to the parent. The bedding plant industry is highly interested in this technology. Calgene produced somatic embryos of celery, which can be fluid drilled into the soil, are being commercially used in Mexico. The forestry industry is very much interested in this process because it circumvents the maturity phase of the plant, when rooting is reduced, and the plant material can be handled as seedling transplants even though they are clones.

STOCK PLANT MANIPULATION

So until this "new" technology is available, propagators can use more conventional techniques. Brian Howard from the East Malling Horticultural Crops Research Center presented results of some excellent applied research on stock plant and stock block manipulations, such as hedging and pruning systems, for rejuvenating plants and enhancing rooting.

CONCLUSION

Successful rooting of species that are currently uneconomical to root by cuttings will give the industry new plant products and markets. Using biotechnology to manipulate genes to improve tissue sensitivity to auxin, as well as to improve tissue culture systems may be the way these species can become important in the ornamental industry. Successful rooting and acclimation of tissue-culture produced plants will need to be improved if biotechnology is to be commercially incorporated into the propagation and production of ornamental horticulture crops.

Meshing Perennial Plant Production with Woody Plant Production

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INTRODUCTION

Growing a mixture of woody ornamentals, perennials, and annuals is our response to the public's desire for year-around color. By broadening our product line, we have been able to increase sales, extend our shipping season, and use our labor resources and growing area more efficiently.

We are growing upright hollies, unusual conifers, and small trees in about 100 acres of field production. In 15 acres of container production, we have an assortment of woody ornamentals, perennials, water plants, annuals, and ornamental grasses. In contrast to most nurseries, we do not raise any azaleas, Japanese hollies, or junipers. We strive to offer a mix of varieties that add color and excitement to the landscape all year long.

This paper will summarize some of the efficiencies and challenges of meshing perennials and woody ornamentals during propagation, planting, growing, selling, and shipping.

PROPAGATION

The same propagation facilities are used to root softwood perennial cuttings in the spring and woody cuttings in the fall. The greenhouses are equipped with raised benches, a mist system, bottom heat, and a fan for ventilation.

Our philosophy for rooting perennials is to stick the softest cuttings available, root them quickly, and pot them up without letting them lose growing momentum. To accomplish this, cuttings are made from vigorous shoots from the crop already in production. This practice not only generates strong, healthy cuttings but also helps promote branching and uniformity in the crop about to be sold. Wiss Quick Clip finger snips are ideal for cutting the small tender shoots. The cuttings are quick dipped in a .25% solution of KIBA and stuck 50 each in a 1020 flat. The trays are filled half full with rooting medium and then topped off with 1/2 inch of perlite. The perlite helps reduce the infection and spread of fungus by forming a sterile barrier between the medium and the tender foliage. Once rooted, the plants are shifted from the flats to pots with a hand trowel. A clump of rooting medium is moved with the new plants so fewer roots are disturbed and transplant shock is minimized.

Woody cuttings are direct stuck into 3-in. peat pots or plastic trays in the fall, rooted during the winter and planted in the spring. Often three cuttings are placed in each pot to produce a heavy liner more quickly.

Ornamental grasses, hosta and daylilies are propagated by division from stock in the nursery. This helps ensure the divisions will be fresh, true to name, and available when needed.

Propagation of these three crops is scheduled around peak shipping times, thus spreading the work load and requiring fewer people on the payroll.

In January ornamental grass is forced in a greenhouse so it can be divided during cold wet weather and be ready to plant in the spring. We have found a short-blade handsaw with coarse teeth is a safe and effective tool for cutting the tough fibrous roots. Once separated, the divisions are potted into 3-inch peat pots and grown in a heated house (65F) until spring planting.

Hosta divisions are made two times during the year. The majority of the crop is divided in June and July, just after the preceding crop has been shipped and space is available. This works well because the same growing area is used for the next year's crop and the crew can work in the shade during hot weather.

Containerized plants from our production are divided using handsaws and knives. In early spring the largest plants are selected and set aside as stock. It is a challenge to keep the sales manager and shipping crew out of them! If the eye is very large, it is cut in half and pulled apart to yield another division. The tops are left on the divisions to keep the plants growing so they fill the pots with roots by fall.

Since they do not grow as well in the heat, the large-leaved cultivars like *Hosta sieboldii* are divided in the winter. It is also easier to cut the crowns without foliage. Whenever the weather is too unpleasant to work outside, the divisions are separated, packed in bulb crates, and stored until spring when they are planted.

Daylilies are divided immediately after the hosta. The stock is grown on raised beds in soils that are too poorly drained to raise other field stock. The beds are drawn and fumigated with methyl bromide before planting. After two growing seasons, the daylilies are lifted with a U-blade and brought to the container area to be divided. This also is done in the shade to give the crew some relief from the summer heat.

Propagation of woodies and perennials is scheduled so there is a progression of crops to be planted from spring to fall.

PLANTING

For most crops the pots are filled and laid out in beds during slow shipping times. Later, when the liners are ready, hand trowels are used to plant the pots. This takes advantage of available labor and makes planting much easier and faster. The type of crop dictates the pattern in which the pots are set. Pots for most woodies are set jammed, pots for ornamental grasses are set in hedge rows, and pots for fast growing perennials are set spaced.

The same medium is used for almost all the container-grown plants. It consists of 6 aged pine bark : 1 coarse filter sand (v\v) and 4 lb dolomitic lime per cubic yard. The potting machine built by the nursery mixes the medium as it fills the pots.

Planting is scheduled throughout the year to take advantage of growing areas as they become available and to provide the sales department with a constant fresh supply of blooming plants. Multiple crops of the same plant are grown to mature at different times of the year.

GROWING

Herbicide compatibility, water requirements, and fertilizer needs determine where we locate crops in the nursery. Several herbicides used on woody ornamentals are not labeled for and are not safe to use on many perennials. Woodies and perennials are generally not grown in the same zones. Some perennials cannot stand as much water as other plants in the nursery, so they are grouped and watered less or grown in drier wind-swept areas. Heavy feeders and light feeders are grown and fertilized separately to accommodate their needs.

The nursery is liquid fed with VT 1 and VT 3 almost every time it is irrigated. These two formulations, developed by Virginia Tech, are used to supply all the macro- and micronutrients. Most of the runoff water is caught in ponds, chlorinated, and recycled. To keep fertility at the desired level, soluble salts are monitored, and the injector is modified often. During some times of year lighter feeders like hosta receive enough nutrients from the recycled water and do not require additional fertilizer.

Like woody ornamentals, certain perennials require spreading and trimming to develop good quality plants. The difference is that perennials tend to grow faster and are less patient when they need more room. Good air circulation and adequate space are the keys to producing stocky, healthy plants.

Grouping plants with similar needs helps to coordinate tasks and manage growing condition.

SELLING

Having a combination of perennials and woody ornamentals in the product mix has allowed the sales department to offer our customers color almost all year.

Every week a "Looking Good List" is sent out highlighting the plants which are in bloom for that week. Buyers from several departments of large companies are often involved. Their combined needs usually add up to a larger order that can be delivered at one time.

The expanded product line has increased sales and improved service to our customers by encouraging more frequent deliveries.

SHIPPING

The nursery owns semitrailers, which are fitted with removable shelves. By varying the configuration of the shelves, a mixture of different sized material can be shipped without being stacked or crushed. Large B & B material is often laid down so several layers of perennials and other small plants can be shelved on top of it. At times it is a puzzle to figure out how to fit the orders together. With more plant material on a truck, the delivery cost per plant is reduced for our customers.

CHALLENGES

One of our greatest challenges is providing the ideal growing conditions for such a broad range of plants. Often the needs of one plant are compromised by the needs of another.

We must constantly monitor demand in the marketplace to keep production in line.

Combating weeds is another challenge. Several preemergent herbicides are being tried on our combination of crops, but a lot of hand weeding is still required.

The greatest challenge to our industry is helping our customers learn to combine perennials with woody ornamentals in the landscape.

CONCLUSION

Meshing perennials into our production has expanded our customer base and increased our sales, especially into the summer months. It has helped us offer our customers better service and has increased the efficiency of our production and labor resources.

My only frustration is with so much to do in the winter, I barely have time to go snow skiing.

Vegetative Propagation of Three Plants with Commercial Potential, *Averrhoa carambola* L., *Gevuina avellana* Mol., and *Hillia valerii* Standl.

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INTRODUCTION

The biodiversity programme has been conducted at Invermay since 1989 (Halloy, 1992). One of the objectives is to introduce a range of new plants into New Zealand agriculture and horticulture, thus decreasing the dependence on a relatively narrow range of plants. The majority of plants has been introduced from areas of South America that correspond geographically and climatically to parts of New Zealand.

Averrhoa and gevuina are not new introductions to New Zealand, but their production potential has not been fully evaluated. Hillia may be a new introduction to New Zealand. The purpose of this paper is to describe research focused on determining propagation requirements for new plants from the biodiversity programme.

MATERIALS AND METHODS

***Averrhoa carambola* L. Oxalidaceae.** Commonly known as carambola tree, star fruit, or oxalis tree it occurs naturally in Asia with a distribution across the continent from India into southern China. An evergreen tree reaching 5 to 10 m, it has pinnate leaves that close when touched. The pendant, fleshy, ribbed fruit is up to 10 cm long and yellowish brown in color.

Its uses in Asia are well documented (Queensland Department of Primary Industries, 1984). It is grown in tropical regions and parts of the United States, including Hawaii. One accession was tested.

***Gevuina avellana* Mol. Proteaceae.** Commonly known as gevuina, Chilean nut and Chile hazel, the indigenous name is guevin. Gevuina is an attractive evergreen tree from the Valdivian forest in Chile. Tolerant of some frost to -8C, it produces a nut with an edible kernel similar to macadamia and is the source of cosmetic oils. The timber is used for joinery and turnery. It was apparently first introduced into New Zealand in the 1940s. Four accessions were tested.

***Hillia valerii* Standl. Rubiaceae.** A small tree from the cloud forest of Costa Rica with attractive glossy dark green leaves and creamy white flowers similar to plumeria (frangipani), it could have potential as a container plant because of the attractive foliage and compact habit. Under glasshouse conditions at Invermay it has not exhibited any pest or disease problems. One accession was tested.

MATERIALS AND METHODS

The facility used for propagation was a structure covered with rigid, twin-skin, polycarbonate material. Concrete benches support heating cables imbedded in sand. Two thermostatically-controlled electric heaters in the ridge provide air heating to a constant 18C. Two domestic fans, one at each end, provide ventilation. An intermittent mist system on each end is controlled by an electronic leaf.

The greenhouse used for growing on and holding the more tender plants is also covered with twin-skin polycarbonate. In winter heat is maintained at a minimum 12C and maximum 18C. Summer minimum and maximum are 17C and 25C.

Accession 63 of gevuina was planted outside in the nursery trial site. The remaining stock plants were maintained in containers in the structures described above.

Table 1. *Averrhoa* rooting. Accession 617.

Acc. no.	Cut date	No.	Pot date	No. rooted and (%)	Medium	Cutting type
617	11/2/91	2	6/3/91	1 (50)	—	—
617 2-91/1	10/11/62	4	30/6/93	only 3 with callus	peat/sand	tip, soft-tips out 150 mm
617 7-90/1	10/11/92	6	23/3/93	4 (66)	peat/sand	tip, soft-tips out 150 mm
617 7-90/1	14/1/92	9	23/3/93	1 (11)	peat/perlite	tip, semi-hard wood 150 mm
617 2-91/1	14/1/93	3	23/3/93	3 (100)	peat/perlite	softwood side shoot with hardwood heel 150 mm
617 2-91/2	14/1/93	3	23/3/93	1 (33)	peat/perlite	semi-hard 200 mm
617 7-90/1	31/3/93	7	30/6/93		peat/sand	semi-hard 150 mm
617 2-91/1	31/3/93	6	30/6/93	2 small roots 4 callused	peat/sand	semi-hard 150 mm
617 2-91/2	31/3/93	3	30/6/93	3 small callus	peat/sand	semi-hard with hardwood heel 150 mm

Six-inch (150 mm) tip and basal cuttings of side shoots were taken of averrhoa. The basal cutting included part of the main stem. Softwood and semihardwood tip cuttings 6 to 8 in. (150 to 180 mm) long were taken from side shoots of gevuina. Leaf-bud cuttings are being tried. Tip cuttings 3 1/4 in. (80 mm) long were taken from side shoots of hillia. Cuttings were dipped for 5 sec in 5000 ppm indolebutyric acid (IBA), K+ salt formulation and stuck in either 3- or 5 1/2-in. (80- or 140 mm-) rigid plastic pots with bottom drainage, containing a 1 : 1 mix of either 1 peat : 1

horticultural sand or 1 peat : 1 perlite (v/v). Pots were bedded into sand of the cutting bench to ensure heat transmission.

RESULTS AND DISCUSSION

Grafting has been the most common method of propagating averrhoa since cutting propagation has been mostly unsuccessful (Campbell, 1970; Tidbury). The completed trials in this study gave an overall success rate of 43% (Table 1). The first entry was work done by Ralph Bungard.

Table 2. *Gevuina* rooting. Accessions 546, 557, 545, 63.

Acc. no.	Cut date	No.	Pot. date	No. (%)	Medium	Comment
63	17/1/91	26	19/3/91	24 (92)	—	—
545	18/1/91	1	5/2/91	1 (100)	—	well rooted
546	18/1/91	1	5/2/91	1 (100)		
63 7-89/1	04/2/92	7	16/5/92	7 (100)	peat/sand	well rooted
557 7-91/1	14/1/93	2	23/3/93	2 (100)	peat/sand	well rooted
557 7-91/6	14/1/93	5	23/3/93	5 (100)	peat/sand	well rooted
63 1-91/4	14/1/93	1	23/3/93	1 (100)	peat/sand	well rooted
63 1-91/19	14/1/93	1	23/3/93	1 (100)	peat/sand	well rooted
557 7-91/6	31/3/93	3	20/5/93	3 (100)	peat/sand	well rooted
557 7-91/1	31/3/93	5	20/5/93	5 (100)	peat/sand	well rooted

Three batches of cuttings are still in the propagation house. Root balls of cuttings that rooted after 50 days were small. Often roots arose from large masses of callus tissue. Removing the callus and resticking the cuttings may have some merit.

Several growers overseas and in New Zealand have reported difficulties with propagating gevuina from seed (Halloy, 1992; Queensland Department of Primary Industries, 1984). While germination did occur, 70% or more of the seedlings died at an early stage. Recently obtained seed has been sown individually in separate containers to avoid handling at what may be a critical stage. At a late stage, the application of Aliette (80% fostetyl-aluminum), 5 g/l, at 28-day intervals stopped the sudden collapse and death of plants. R. Appleton, another grower, reported this in personal conversation (1992). Table 2 gives details of cutting information. The first three entries are results of work by Ralph Bungard.

All gevuina cuttings rooted in nine of 10 trials and gave transplants with well-developed fibrous root systems. The potted plants were placed into the heated house along with the stock plants and showed no detrimental effect from the potting disturbance. Number of days from sticking cuttings to potting varies from 18 to 71. Initial rooting occurred within 18 days. Cuttings were left longer to develop more roots, and at 50 days root balls had good root systems and had to be soaked in water to allow easy separation. The 71 days was determined by work load.

Hillia cuttings were all well rooted at 40 days. Work on this species is at the initial stage and more cuttings need to be tested. Rootballs were soaked in water for easy separation when they were potted two months later. Based on these results, I suggest potting at 50 days.

Table 3. *Hillia* rooting.

Acc. no.	Cut date	No.	Pot. date	No. rooted (%)	Medium	Comment
601	14/1/93	8	23/3/93	8 (100)	peat/perlite	excellent root system

CONCLUSION

Averrhoa results indicate that rooting is possible. I believe the trial warrants continuation.

Gevuina rooting was excellent. Performance of cuttings from other accessions will confirm whether or not this result is typical.

Hillia rooted easily, and further trials should confirm this observation.

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Propagation of ×*Cupressocyparis leylandii* and *Magnolia grandiflora*

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Rooting ×*Cupressocyparis leylandii*, Leyland cypress, and *Magnolia grandiflora*, southern magnolia, requires totally different approaches. Leyland cypress is more likely to root than southern magnolia; therefore, I will start with the leyland cypress.

At Powell Propagators and Nursery, approximately 91,000 Leyland cypress cuttings were direct stuck starting in January and ending in March 1993. Three thousand of these were stuck in 4-in. square pots, about 30,000 in 3-in. round pots, and the remainder in 2 1/2-in. pots.

A solution of 6000 ppm of KIBA and 1500 ppm of KNAA in water was used on one half and a solution of 6000 ppm of IBA and 1500 ppm of NAA in alcohol was used on the other half. Each cutting was given a 5-sec quick dip.

Cuttings were taken from stock plants at the nursery or from apartment complexes in the area. Terminal cuttings were prepared by cutting to about 6 in. The bottom leaves were removed and the tips were trimmed. However, cuttings for the 3000 4-in. pots were not cut into smaller pieces nor were the tips cut. These were terminals about 12 in. long. All cuttings were from the previous season's growth and were showing red or brown at the base of the stems. Green stems were not used.

The medium was 4 pine bark : 1 part coarse sand (v/v) plus 10 lb lime, 8 lb. Osmocote 18-6-12, and 1 lb of minor elements per cubic yard. A Phytotronic mist controller and a day-night clock were used for misting, starting at 10:00 a.m. and stopping at 5:00 p.m., with 10-sec mist every 16 min. The interval between misting was lengthened to 32 min after a few weeks. Cuttings were placed in a 30- × 96-ft or a 35- × 144-ft poly greenhouse. No heat or shade were used during rooting. Results are as follows: The large cuttings rooted best. These were stuck in early January with the KIBA/KNAA water mix hormone. These rooted almost 100% by June. Rooting was slow due to the cloudy weather during the winter of 1993.

The other Leyland cypress cuttings that were stuck in January with the KIBA/KNAA water hormone rooted after warm weather arrived in March. Most, but not all, had good roots by June, and the crop was removed from the greenhouse in July. The cuttings that had only callused failed to survive.

Cuttings stuck in February and March using the IBA/NAA alcohol hormone mix also rooted after the weather became warmer.

A few were well enough rooted by July to be shipped. More of the cuttings dipped in the hormone in alcohol had large callus formations than those dipped in hormone in water.

In summary, the larger cuttings stuck in January into larger pots gave the best transplants. The larger tip cuttings gave the best results of the remaining cuttings.

The time of sticking in 1993 did not seem to matter because of the cloudy days. Usually cuttings root in March and are ready to be removed from the greenhouse by May. The rooting hormone mixed with water seemed to produce a better liner because most of the cuttings rooted without forming a callus. The final rooting percent for the 6-in. cuttings was about 70%. When leyland cypress cuttings have rooted, they will put out new growth. If they remain green for months but do not put out new growth, they have usually only callused.

When I spoke on Leyland cypress in 1985, I reported that 8000 ppm IBA was used. Since then I have found that the lower concentration of IBA does not produce the big callus, which means a better rooted liner.

ROOTING *MAGNOLIA GRANDIFLORA*

Rooting southern magnolia is an art. Timing, temperature, the right hormone, the right soil mix, and proper watering are the keys to success.

Procedures for rooting. Eight-inch terminal cuttings from the current season's growth should be taken in August or early September. Care should be taken to keep them from drying out. The base of the cutting should be cut approximately 1/4 in. below a bud. Wound each side of the base of the cutting about 1/2 in. long.

Cuttings are dipped into half-strength Woods Rooting Hormone for 10 sec. If mixing your own or using another brand, it is important that the solution contain NAA. I suggest using a water solution of 6000 ppm KIBA and 3000 ppm KNAA. I have noticed that the alcohol seems to burn the base of the cutting.

Cuttings are direct stuck in 4-in. or larger pots filled with well-drained medium such as 100% aged pine bark.

Cuttings are put in a white plastic-covered greenhouse. The doors are kept closed so that the house gets very hot.

The most important part of rooting magnolia is the watering. Cuttings in the hot greenhouse are hand watered only a few times during the day. They are watered as needed to keep the humidity very high and the leaves slightly wet without overwetting the medium.

CONCLUSION. I have watched this procedure and have found that the high temperature is a very important ingredient. This past year I stuck my southern magnolia cuttings in October hoping for a normal sunny winter to keep the greenhouse hot. This did not happen. The magnolia cuttings sat until spring before they started to root. By then a lot of them had rotted. I believe that for best results that magnolia cuttings need to be in a separate greenhouse so that the necessary conditions can be maintained just for them.

Variation in Sensitivity of Azaleas to Herbicides

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Azaleas differ in their susceptibility to pre- and postemergence herbicides. Treflan (trifluralin) and Surflan (oryzalin) reduced shoot and root growth of certain cultivars. Surflan decreased stem diameter and strength of 'Hino Crimson' and 'Snow'. Image caused foliar injury on the cultivars tested, whereas Poast and Vantage, sethoxydim formulations, did not. Damage caused by other herbicides was cultivar dependent.

INTRODUCTION

Azaleas differ in their susceptibility to herbicides. Many cultivars have been screened for tolerance to the postemergence herbicides Ornamex (fluazifop) and Vantage (sethoxydim) (Derr, 1987; Frank et al., 1987). Certain red-flowered cultivars are sensitive to Ornamec (Gilliam, 1987). Thus, differential susceptibility exists among red-flowering cultivars as it does among all azaleas. Plants generally recover from foliar damage caused by postemergence herbicides such as Ornamec (Derr, 1987). Increased flowering in the spring following application of Ornamec has been reported for the sensitive cultivar 'Hino-crimson' (Gilliam, 1987). All cultivars tested are tolerant to Poast/Vantage (sethoxydim) (Derr, 1987; Frank et al., 1987).

Some ericaceous plants are sensitive to dinitroaniline herbicides. High rates of Surflan and Treflan girdled the stems of *Leucothoe* (*L. fontanesiana*) (Ahrens, 1979). High rates of Surflan and Barricade (prodiamine) restricted growth, root development, and marketability of azaleas (*Rhododendron* 'Kirin' [syn. 'Coral Bells'] and *R.* 'Formosa') (Singh et al., 1981).

Due to differential plant tolerance, Casoron (dichlobenil) is labelled for use only on kurume, mollis, hardy hybrid types, and hardy native azalea species (Ahrens, 1966).

MATERIALS AND METHODS

Screening of pre- and postemergence herbicide products was conducted for a number of years at several sites in North Carolina. Herbicides were applied three times at 8-week intervals, with final evaluations in October of each year (30 days after third application). Granular herbicides were weighed out on a per plot basis and applied manually with a shaker jar. Liquid treatments were applied over the top with CO_2 backpack sprayer and 8003LP nozzles delivering 25 gpa at 20 psi.

RESULTS AND DISCUSSION

Some dinitroaniline herbicides decreased shoot and root growth of certain azaleas (Ruff, 1989). Surflan decreased stem diameter and strength of 'Hino

Crimson' and 'Snow' and affected cellular organization of stems at the groundline. These abnormalities may be involved in the phenomenon known as groundline breakage.

Image (imazaquin) caused moderate to severe foliar injury on the cultivars tested. Damage caused by Pursuit (imazethapyr), Basagran (bentazon), and EC and DG formulations of pendimethalin was cultivar dependent. Poast with or without crop oil and Vanatage were not injurious. Flame azalea (*R. calendulaceum*) was more susceptible to herbicides than evergreen and semi-evergreen types (Skroch et al., 1991).

Due to the diversity among azaleas, tolerance to a particular herbicide must be determined for each cultivar individually.

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Storage and Production of Selected Conifers from Hardwood Cuttings

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Many propagators have collected, stored, and rooted *Thuja*, *Taxus*, and *Juniperus* from hardwood cuttings without supplement bottom heat (Bailey, 1967; MacKay, 1962; Wells, 1967). Briefly, cuttings are taken in the fall or winter (Carville, 1979; Rigby, 1981), sealed in polyethylene bags, and stored at 28 to 32F for up to 4 months. They are then removed and stuck in outdoor beds without supplemental heat.

COLLECTION AND STORAGE OF CUTTINGS

The initial collection of cuttings is conveniently done after two or three frosts (Cross, 1971; Holmes, 1967; Schultz, 1983), but in practice it is best to wait until January or February (Regan and Robesting, 1988). Cuttings can even be taken as late as March provided they have not broken bud and cool weather prevails. It is not entirely necessary for conifer cuttings to be exposed to hard frosts (Shugart, 1989). Experience has shown that if a period of cold night temperatures between 35 and 40 precedes the taking of cuttings by 5 to 10 days, the cold requirement can be met. Extended storage of cuttings between 28 and 32F also will probably supply the necessary cold conditions to allow for satisfactory rooting and subsequent bud break (Miller, 1982; Rigby, 1981).

The techniques outlined here apply to most *Thuja* species, *J. virginiana* such as 'Hetzii Glauca', and cultivars of *T.* × *media*, such as 'Densiformis' or 'Wardii'. In the case of *Thuja* and *Juniperus* wood is selected so that at least ½ in. of the basal end is from 2-yr or older wood. Newly hardened previous-season's growth is normally avoided. The reason for selecting 2-yr wood is the presence of preformed root initials, which can often give rise to adequate rooting without extensive efforts. *Taxus* cuttings do not share this attribute, but in general the thicker the cutting the more likely the stored food reserves are to be adequate for rooting.

Cuttings are collected from field-grown plants, cut to 6 to 8 in., and placed loosely in polyethylene bags, as outlined by Behrens (1984). Once the bags are full, they are sealed and placed in cold storage (Bailey, 1967; Cross, 1971; Rigby, 1981) and held between 28 and 32F. No supplemental water is added to the sealed bags in order to avoid the possibility of botrytis or other types of mold formation (Behrens, 1984; Cross, 1971). Cuttings remain in the bags from January to April (Thomsen, 1978; Wells, 1967). Miller's work (Miller, 1982) with Fraser fir showed that chilling requirements for rooting could be met in 6 to 10 weeks under these conditions.

STICKING CUTTINGS

The stored cuttings are removed from the cooler and allowed to warm to room temperature. It is not good to begin work immediately handling cold cuttings. Once the cuttings have warmed and become flexible, they are trimmed lightly, wounded 1/2 in. on two sides, and treated with rooting chemicals. Wounding accelerates cell division that leads to rooting and also increases the surface area for the adsorption of the root-inducing chemical. Studebaker (Studebaker et al., 1988) indicated that wounding definitely contributes to the rooting of taxus. Once properly prepared the cuttings are stuck directly into pots.

The pots are filled with a 1 sand : 1 peat (v/v) mixture or in some cases such as *Taxus baccata* 9 sand : 1 peat (v/v). It is always advisable to have at least 10% peat in a rooting medium but it is also prudent not to exceed 50% as too much moisture will interfere with the rooting process. Most conifers will root best when the soil is kept towards the dry side (Carville, 1979; Regan, 1988). Conifer cuttings rooted in pure sand usually have large brittle roots that break easily when transplanted. In a peat and sand mix a much finer and more branched root system develops.

CULTURAL CONDITIONS

Full trays of cuttings are placed out of doors (Studebaker et al., 1988; Wells, 1967) directly upon gravel beds or on pallets, which ensures constant drainage. The cuttings are normally exposed to the full sun and watered for 10 to 15 min daily. The water is set to come on during the warmest part of the day. No water should remain on the foliage during the night as this could give rise to disease problems.

Cuttings are left in this environment till they are rooted. In the Philadelphia area this is usually mid-June to July. The warmer the weather, the faster the rooting. Previous work has shown that a cold medium that warms up gradually benefits the rooting process (Davis, 1988; Thomsen, 1988). It is not unusual for the cuttings to break dormancy and put on some growth during the rooting period or before they start to root. This does not seem to interfere with the rooting nor does it appear to harm the cuttings even though they may yellow and look chlorotic. Once the cuttings are rooted, they can be fertilized lightly with 75 to 100 ppm N from a balanced fertilizer. The intent is to reestablish the nutritional balance of the cuttings, not to give rise to large amounts of new growth. The cuttings will root enough by August to plant out or pot.

SUMMARY OF TECHNIQUE

- Cuttings are taken from January to March, preferably after a period of cold.
- Cuttings are collect from field-grown plants and placed in polyethylene bags.
- Cuttings are removed and processed around mid-April. They are trimmed, wounded, treated with hormone, and stuck.
- Cuttings are direct stuck in containers in peat/sand.
- Trays of cuttings are placed on pallets or gravel to provide adequate drainage. They are watered twice daily, 10 to 15 min each time.
- Cuttings are fully rooted by mid-June to July.

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Cultivar Introductions of *Ilex*, *Pyracantha*, and *Rhus* from Rutgers University

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ILEX OPACA

Initial work in the woody ornamentals breeding program at Rutgers University was with plants of *Ilex opaca*. The first introduction was 'Jersey Knight', originally selected from the wild at Locust, New Jersey, by the late Dr. Charles Connors and tested as Brown No. 9. Plants of 'Jersey Knight' are vigorous and exhibit a dense habit of growth with large, semi-glossy, green leaves. More than just a good pollen producer, progeny tests of seedlings from hundreds of controlled crosses showed that 'Jersey Knight' was the best of the male parents utilized. 'Jersey Knight' is fully winter hardy at -15F, and is widely regarded as the best staminate cultivar of *I. opaca* in the trade today.

'Jersey Princess' is a seedling selection from a controlled cross of an unnamed pistillate plant × 'Jersey Knight'. Plants of 'Jersey Princess' develop a narrow to medium conical habit, are winter hardy at -15F, exhibit high vigor and the darkest glossy, green foliage of any plant of *I. opaca* that this holly hybridizer has ever seen. The red fruit of this pistillate cultivar are not particularly showy, but the superior foliage characteristics fully compensate for any deficiency in this regard.

'Dan Fenton' originated as a seedling selection from a controlled cross of 'Maurice River' × an unnamed male, two clones grown by the late Daniel G. Fenton, a vigorous promoter of plants of *I. opaca* and a co-founder of The Holly Society of America. Plants of 'Dan Fenton' develop a broadly conical form and exhibit dark green, semi-glossy leaves of a rather distinctive shape (square). This pistillate cultivar produces good crops of attractive red fruit and is fully winter hardy in U.S.D.A. Plant Hardiness Zone 6a (-5 to -10F). This cultivar is exceptional for the quality of the foliage and the characteristic that rooted cuttings develop readily in containers to yield upright, well developed plants with minimal pruning or staking.

The cultivar 'Jersey Delight' originated as a seedling selection from a controlled cross of 'Old Heavyberry' × 'Isaiah' (a glossy-leaved staminate cultivar). The hybrid exhibits the heavy leaf texture of 'Old Heavyberry' and the "shine" of 'Isaiah'. Plants of 'Jersey Delight' develop a narrow conical form, produce heavy crops of showy, red fruit, and are fully winter-hardy in Zone 6a.

DECIDUOUS HOLLIES

After initiating crosses within *I. opaca*, hybridization efforts were extended to crosses between our native winterberry holly, *I. verticillata*, and its Asiatic counterpart, *I. serrata*. This work led to the introduction of the first known interspecific hybrids of these two species: namely, *I.* 'Harvest Red' and 'Autumn Glow'. These cultivars combine the vigor of *I. verticillata* and the diminutive form of *I. serrata*, and provide pleasingly low and compact plants with excellent, dark green foliage, and heavy crops of showy fruit that usually persist about five months. The hybrids are fully vigorous but do not develop the tall, open habit so typical of many plants of *I. verticillata*. Plants of 'Harvest Red' grow to 7 ft tall × 12 ft wide in 12 years with horizontal to slightly pendulous branches and dark green leaves that completely mask the multi-stemmed nature of the plants. Plants of 'Autumn Glow' are slightly taller but less spreading than those of 'Harvest Red' and the fruit are orange-red rather than dark red as with 'Harvest Red'. The fruit become fully pigmented about September 1st in central New Jersey and provide an attractive display of foliage and fruit until the first hard freeze of autumn "knocks" the leaves from the plants. The spectacular display of the leafless fruited branches typically persists into January or February. When these hollies were introduced in 1972, there was very little interest in deciduous hollies. However, with virtually no promotion, 'Harvest Red' and 'Autumn Glow' have become very popular in the commercial trade.

A staminate hybrid [*I. verticillata* × (*I. serrata* × *I. verticillata*)] named 'Raritan Chief' was introduced as a pollinator for 'Harvest Red', 'Autumn Glow', and other deciduous hollies. The original seedling was selected for its low, compact habit and excellent summer foliage characteristics which make it easy to incorporate into most any landscape. 'Raritan Chief' is particularly useful as a pollinator as the period of flowering extends over a period of two weeks. A major factor in the failure of deciduous hollies to be of ornamental value in the landscape is the lack of available pollen at the time the pistillate plants are flowering

ILEX CRENATA

Ilex crenata is a popular bread-and-butter item in the nursery industry, plants of this species being used in nearly every type of landscape, be it residential, commercial, industrial, institutional, or municipal. 'Beehive' is a new cultivar that is receiving wide acceptance. Selected out of a population of 21,000 seedlings resulting from a cross of 'Convexa' × 'Stokes', the original plant of this cultivar was selected after 15 years testing in the field. Prior to the introduction of 'Beehive', plants of this clone were intensely evaluated in both container production and field production studies along with 5 plants each of 39 other seedling selections from the cross, and with 5 plants each of 10 prominent cultivars in commerce. Destined to become a standard in the trade, 'Beehive' is rated high for its attractive form and winter hardiness, being fully winter hardy in Zone 6a. The plants exhibit tiny leaves medium green in color, and develop a dense, symmetrical habit of growth. The plants are vigorous but require no pruning, a 12-year plant from a rooted cutting being approximately 3 ft tall × 3½ to 4 ft wide.

'Dwarf Pagoda' and 'Green Dragon' are siblings selected from a cross of *I. crenata* 'Mariesii' × *I. crenata* 'John Nosal'. Both parents are relatively dwarf, with short internodes and exhibit rather rounded, dark green leaves. The cross was made with the hope that the resultant progeny would include seedlings that were truly dwarf with more attractive, or artistic, habits of growth. This goal was achieved with both 'Dwarf Pagoda' (pistillate) and 'Green Dragon' (staminate). Plants of 'Dwarf Pagoda' grow approximately 1 to 2 in. per year, exhibit small, rounded, dark green leaves and a tiered habit of branching. They are hardy to 0F and are widely used as bonsai and in tray gardens, as well as in rock gardens. 'Green Dragon' is slightly more vigorous in growth and the plants exhibit slightly larger, dark green leaves. Plants of 'Green Dragon' have been widely distributed, for use primarily as bonsai and in rock gardens.

No upright form of *I. crenata* has achieved the wide acceptance throughout the country that 'Helleri' receives as a low, spreading form. 'Jersey Pinnacle' is a new contender on the scene. A seedling selection from a cross of 'Green Lustre' × 'John Nosal', 'Jersey Pinnacle' is outstanding for its naturally upright habit of growth and attractive, dark green foliage which remains attractive in the spring of the year when the leaves of most other cultivars of *I. crenata* exhibit winter burn in Zone 6a and are not salable.

'Midas Touch' is an attractive, upright selection of *I. crenata* with yellow variegated leaves. This cultivar originated as a budsport (observed as a single lateral branch with yellow variegated foliage) on a 1-year seedling that resulted from a cross of a yellow-fruited clone (P.I. #231948) × *I. crenata* f. *microphylla*. The yellow sectors of the leaves are most brilliant on plants grown in full sun.

INTERSPECIFIC HYBRID

Ilex 'Rock Garden' originated as a seedling resulting from hybridization of a pistillate plant of *I.* × *aquipernyi* × *I.* 'Accent' (male *integra/pernyi* introduction by the late WIlliam F. Kosar).

It is a welcome addition to the listing of evergreen plants suitable for use in rock gardens or in other settings where diminutive plants are favored. It has a very dense, dwarf, low spreading habit and typical holly-type foliage. Seven years from a rooted cutting, the plants will average about 6 in. high and 12 to 15 in. wide. If appropriate pollinators (*I.* × *aquipernyi* or blue-holly males) are present, the plants will set nice crops of bright red fruit. 'Rock Garden' is fully winter-hardy in zone 6a.

PYRACANTHA

The cultivar 'Rutgers' originated as a seedling from a controlled cross within *P. coccinea* and was selected for its low habit of growth, excellent dark green foliage, heavy flowering and fruiting, and high resistance to the bacterial incitant of fire blight and to the fungal incitant of scab disease. 'Rutgers' has nearly replaced 'Lowboy' in the nursery trade. 'Lowboy' was popular for its low, spreading habit but plants of this cultivar are very susceptible to the fungal incitant of scab. Plants of 'Rutgers' are fully winter-hardy in Zone 6b (0 to -5F).

'Fiery Cascade', a seedling selection resulting from a controlled cross of *P.* × 'Watereri' × *P. crenulata* var. *kansuensis*, is exceptional for its dense, low habit with pendulous branches bearing heavy crops of brilliant red fruit that contrast markedly with the small, slender, dark green leaves. Plants of 'Fiery Cascade' are highly resistant to the incitants of fire blight and scab. The plants are exceptionally winter-hardy for a red-fruited selection of *Pyracantha* [Zone 7a (0 to 5F)].

RHUS CHINENSIS

The first and only cultivar of *R. chinensis* was introduced from the woody ornamentals breeding program of Rutgers University under the name 'September Beauty'. This clone was brought to my attention by the late Edgar G. Rex, who was serving as Executive Secretary of the New Jersey Federation of Shade Tree Commissions. Unusually strong limbed for a member of the genus *Rhus*, plants of 'September Beauty' are extremely vigorous and typically develop a single trunk with three or four major branches originating 1 to 3 ft above ground. A 14-year plant at Rutgers University is 20 ft tall and 40 ft wide with a very symmetrical form. It is densely foliaged with glossy, dark green leaves. The plants are exceptionally showy for two to three weeks in early September. Thousands of creamy white flowers are borne on the compound panicles that average 24 in. wide and 22 in. in length. Root suckers become a problem if the plants are included in mulched beds; however, when grown in sod, routine mowing eliminates the problem. This cultivar is a welcome addition to the short list of small trees that produce a dramatic floral display in September. The plants are fully winter hardy in Zone 6a.

An extensive program of intra-and inter-specific hybridization with many different species of*Ilex* is currently in progress at Rutgers University. We anticipate that new and superior cultivars will be introduced in the near future.

Effects of Growth Stage, Branch Order, and IBA Treatment on Rooting Stem Cuttings of 'Yoshino' Cryptomeria

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INTRODUCTION

Little research has been published on vegetative propagation of Japanese cedar, *Cryptomeria japonica* (L.f.) D. Don, and its cultivars by stem cuttings. The objective of this study was to investigate the effect of growth stage, branch order, and indolebutyric acid (IBA) treatment on adventitious rooting of stem cuttings of 'Yoshino' cryptomeria.

METHODS AND MATERIALS

Forty 10-in. tips of first-order laterals with second-order laterals attached were taken from each of six 10-year old trees growing in the North Carolina State University Arboretum, Raleigh, on five dates, representing four different growth stages: 7 August 1992 and 9 July 1993, softwood; 6 November 1992, semi-hardwood; 15 January 1993, hardwood; and 12 March 1993, prebudbreak. Budbreak occurred about mid-April 1993. Cuttings were taken throughout the entire crown of a tree.

Treatments were as follows:

A) Tips, terminal 8 in. of first-order laterals;

B) Distal halves, terminal 4 in. of tips of first-order laterals;

C) Proximal halves, basal 4 in. of tips of first-order laterals; or

D) Tips, terminal 4 in. of second order laterals. Lower branches were removed from the basal 1.6 in. of cuttings, and each type of cutting was treated with 0, 3000 (0.3%), 6000 (0.6%), or 9000 ppm IBA dissolved in 50% isopropyl alcohol.

Cuttings were inserted in a 4 peat : 3 perlite (v/v) medium in a raised greenhouse bench and maintained under natural photoperiod and irradiance (light intensity) at day/night temperatures of 75/60F. Intermittent mist operated 6 sec every 3.3 min from 7 a.m. to 7 p.m. daily. Cuttings were sprayed initially and weekly thereafter alternating benomyl and captan.

Cuttings were arranged in a randomized complete block design with a factorial arrangement of treatments (4 branch orders × 4 IBA levels) and six blocks. Five cuttings made a treatment combination for each block.

Cuttings were harvested after 12 weeks for each growth stage. Percent rooting, number of primary roots >0.04 in., root area, root length, and root dry weight (dried at 158F for 72 h) were recorded.

RESULTS AND DISCUSSION

Stem cuttings of 'Yoshino' cryptomeria can be rooted at any growth stage. However, the branch order from which a cutting is prepared is critical. Regardless of growth stage, rooting of cuttings from distal halves of first-order laterals and tips of second-order laterals never exceeded 55% and 35% (Fig. 1). However, for cuttings from tips of first-order laterals and the proximal halves of first-order laterals rooting ranged from 59% to 87% and 68% to 78% (Fig. 1).

Hardwood cuttings taken 15 January 1983 from the tips of first-order laterals and proximal halves of first order laterals exhibited the highest overall rooting with a mean of 79%, followed closely by softwood cuttings taken on 7 August 1993 with a 77% mean (Fig. 1). Softwood cuttings of 9 July 1993 gave similar results. Cuttings taken on 6 November 1992 and prebudbreak cuttings taken on 12 March 1993 rooted in lower percentages. Mean rooting exceeded 63% and 72% for the same two branch orders. Branch order generally influenced all measurements of rooting (Table 1).

Table 1. Effects of branch order on the overall rooting response of hardwood stem cuttings of 'Yoshino' cryptomeria taken 15 Jan 1993.

Branch order	Rooting (%)	Root area (cm^2)	Root dry wt (mg)
First-order[z]	86.7 a[y]	4.3 a	64.2 a
Distal half	55.0 c	1.1 c	17.7 b
Proximal half	71.7 b	3.4 b	53.0 a
Second-order	12.5 d	0.2 d	4.6 b

[z] First-order = tips (terminal 8 in.) of first-order laterals, distal = distal halves (terminal 4 in.) of first-order laterals, proximal = proximal halves (basal 4 in) of first-order laterals, and second-order = tips (terminal 4 in.) of second order-laterals.

[y] Mean separation within columns by LSD, p = 0.05. Data averaged over all IBA levels.

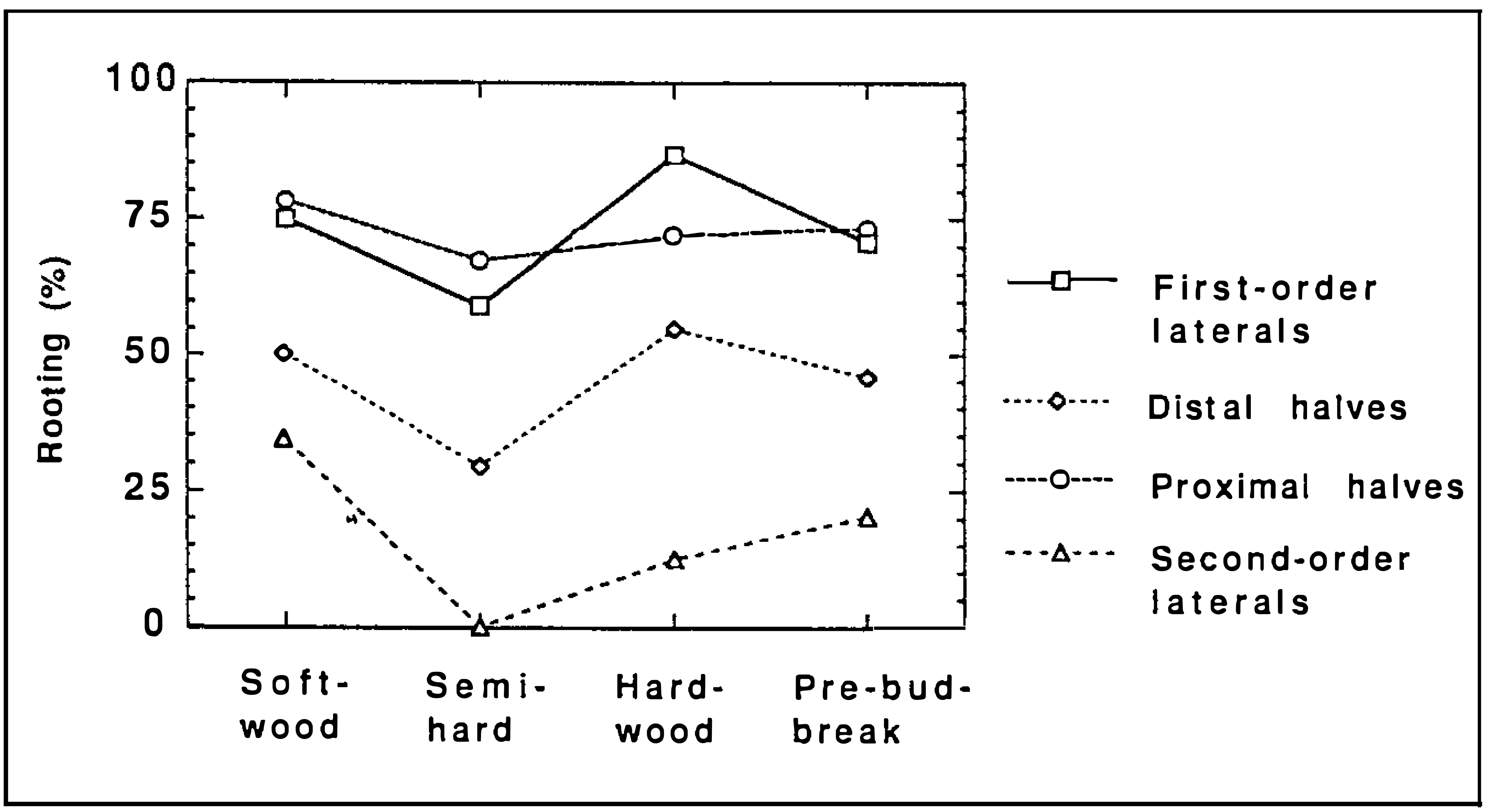

Figure 1. Effect of growth stage and branch position on mean percent root of stem cuttings of 'Yoshino' cryptomeria. Each symbol represents a mean of 24 observations. Percent rooting was averaged over all IBA concentrations.

IBA increased rooting percentages for all growth stages except softwood cuttings. Contrary to current recommendations for rooting stem cuttings of Japanese cedar (Dirr, 1990; Doran 1957; Mitsch, 1975; Nakayama, 1978), 3000 ppm IBA produced maximum rooting percentage with hardwood cuttings (Table 2). For root area and root dry weight, the pooled IBA mean was significantly greater than the cuttings not treated with IBA. IBA increased root area by 35% compared with nontreated cuttings (Table 2). Root length, except for tips of second-order laterals, was linear with increasing concentrations of IBA.

In summary, stem cuttings of 'Yoshino' cryptomeria rooted at any time of year. Hardwood cuttings taken in January gave 72% to 87% rooting when tips of first order laterals or proximal halves of first-order laterals were treated with 3000 ppm IBA. However, 9000 ppm IBA gave the maximum root length and number of roots.

Table 2. Effects of IBA concentration on the overall rooting response of hardwood stem cuttings of 'Yoshino' cryptomeria taken 15 Jan 1993.

IBA conc. (ppm)	Rooting (%)	Root area (cm^2)	Root dry wt (mg)
0	43.3	2.0	33.9
3000	63.3	2.4	37.6
6000	56.7	2.3	34.1
9000	62.5	3.4	50.4
Significance [z]			
Linear	NS	NS	NS
Quadratic	NS	NS	NS
IBA vs Control [y]	***	**	*

[z] NS, *, **, *** nonsignificant or significant at $p \leq$ 0.05, 0.01, and 0.001, respectively. Data averaged over all branch orders.
[y] Linear contrast.

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Movement, Dissipation, and Impacts of Isoxaben (Snapshot TG) in Nursery Runoff Water

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Granular preemergent herbicide formulations are preferred by the nursery industry because they are easy to apply. These materials are broadcast applied over the top of containerized crops and then activated by irrigation. Much of the applied herbicide may land on the surface surrounding the target pots where it is available to move offsite in runoff water and into containment ponds used for water recycling (Gilliam et al.,1992).

Concern over the fate of herbicides in the environment and their potential for accumulation, especially in surface andgroundwater supplies, is justified (Mahnken et al, 1992; Keese et al., 1991, 1992; Mangus et al., 1985). This issue is particularly important in nurseries that recycle their irrigation water.

The objectives of this study were to determine the movement of isoxaben from Snapshot TG formulation (DowElanco) in irrigation runoff water and to monitor its dissipation in the containment-pond water. The influence of residual concentrations of isoxaben in irrigation water on container-grown plants was also evaluated.

MATERIALS AND METHODS

Runoff Events. A 5-acre (2 ha) container nursery production area containing a diversity of plant species was treated with Snapshot TG (0.5% isoxaben + 2.0% trifluralin) at 100 lbs product/acre in August 1992 and May 1993. The area drains into a 1.25 acre (0.5 ha) containment pond through a single storm drain. Overhead irrigation (0.5 in.) was applied following herbicide application, and water samples were collected from the runoff water before it entered the collection pond. Runoff sample collection times were 0.25, 0.5, 1.5, 2.5, and 3.5 h after water began to enter the pond and also 2 and 5 days after treatment. Pond water samples were also collected near runoff entry point and the point of water exit before herbicide application, after the first runoff event, and at 2, 5, 8, 14, 21, 29, and 60 days after treatment in order to monitor isoxaben dissipation.

Irrigation Experiment. Spring-rooted liners of snow azalea (*Rhododendron* 'Snow'), buccaneer azalea (*R.* 'Buccaneer'), and Heller's Japanese holly (*Ilex crenata* Thumb. 'Helleri') were potted in 4.5-inch plastic containers, and freshly harvested root divisions of daylily (*Hemerocallis* 'Hyperion') and dwarf gardenia (*Gardenia jasminoides* 'Nana') liners were potted in one-gal containers using 100% fine pine bark. Fountain grass (*Pennisetum rupelli*) was seeded into the same medium. Potted liners were fertilized twice after potting with 16-4-8 fertilizer and placed in a glasshouse for the duration of the experiment.

Plants in 4.5-in. containers received 120 ml and plants in 1-gal containers received 240 ml of isoxaben-fortified irrigation water 2 to 3 times per week as needed. These quantities approximately equal 0.5 in. irrigation water. The treatments included 1.0 ppm and 10.0 ppm isoxaben in irrigation water obtained from Gallery 75 DF. Experiments continued for 6 weeks beginning the fourth week of March. However, daylilies were irrigated for an total of 11 weeks. Active ingredient received varied by species as shown in Table 1. All experiments were in randomized complete block design with six replications. Data were processed using analysis of variance and means separated using a protected least significant difference at p=0.05.

Table 1. Amount of isoxaben received by each plant species for the experiment duration.

Species	No. irrigations/time (no./weeks)	Total ai applied (mg)	
		1 ppm	10 ppm
Daylily	19/11	4.56	45.6
Dwarf gardenia	9/6	2.16	21.6
Fountain grass	12/6	1.44	14.4
Heller's Japanese holly	9/6	1.08	10.8
Buccaneer azalea	14/6	1.68	16.8
Snow azalea	14/6	1.68	16.8

RESULTS AND DISCUSSION

Runoff Events. Runoff studies indicated that 7.4% of the applied isoxaben was lost in the irrigation runoff water during the first runoff event. Nearly 3.0% was lost 2 days after treatment (DAT), and 0.9% was lost 5 DAT.

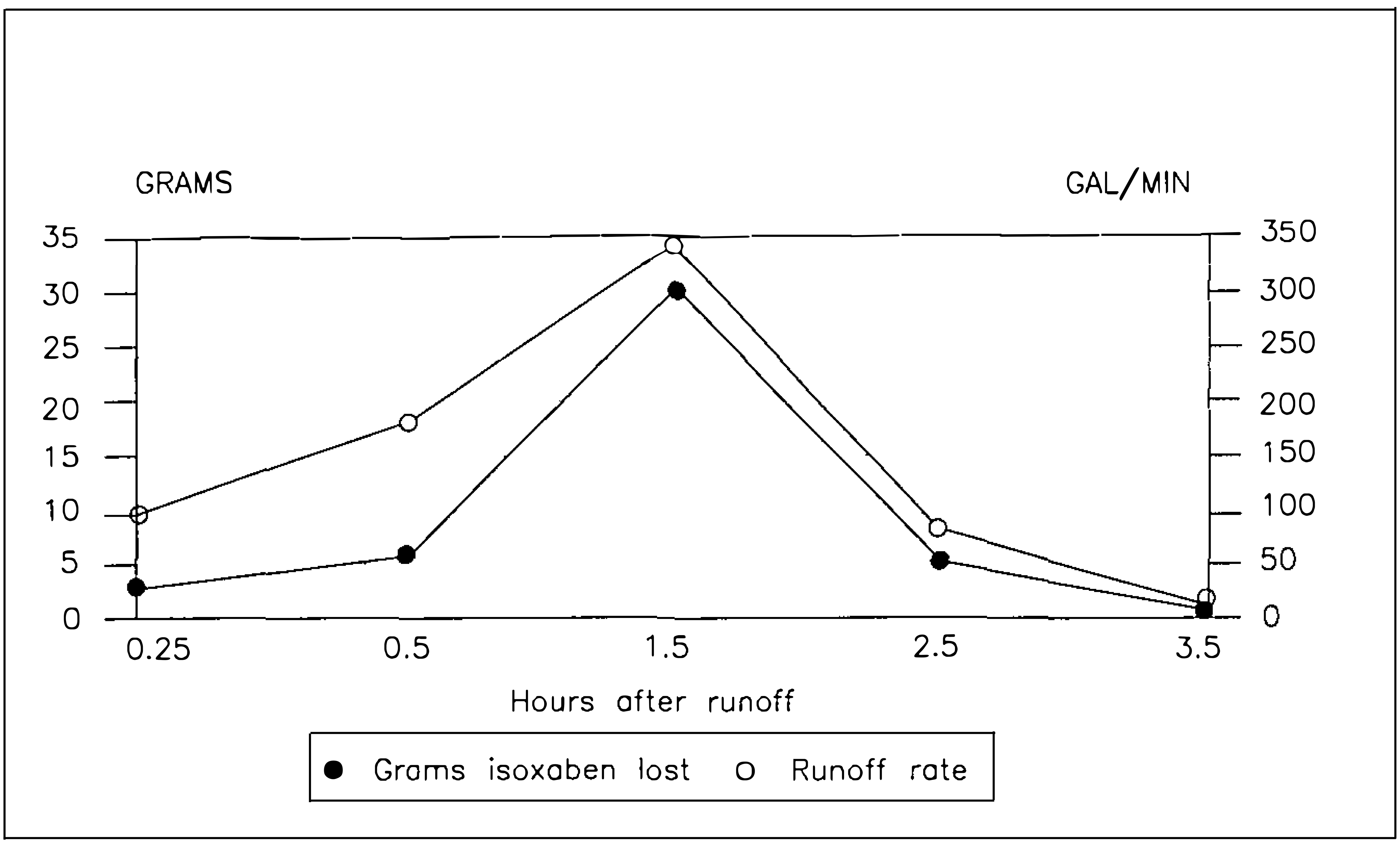

Figure 1. Isoxaben lost during first runoff event.

Approximately 38 g of isoxaben was detected during the first 1.5 h following herbicide application. Minimum quantities of 2.9 and 0.26 g were lost at the 0.25 and 3.5 h sampling periods (Fig. 1). These data correspond to results for agricultural and grass studies reported in the literature (Caro and Taylor, 1971; Bovey et al., 1978).

Isoxaben concentrations in the containment pond were much lower in 1992 than in 1993. However, the reverse was true at the site where water exits the pond. (Fig. 2).

Irrigation Experiment. Isoxaben-fortified irrigation water did not affect the growth index of dwarf gardenia, Heller's holly, or buccaneer azalea (Table 2) but reduced the growth index of snow azalea at both 1 and 10 ppm.

Table 2. Growth parameters measured for each species. Growth index = (height + 2 perpendicular widths)/3.

	Growth index (cm)				Shoot fresh weight (g)			
Species	0 ppm	1 ppm	10 ppm	LSD	0 ppm	1 ppm	10 ppm	LSD
Daylily	142.1	131.1	130.5	9.6	59.3	57.7	55.5	ns
Dwarf Gardenia	134.5	132.2	130.0	ns	0.52	0.54	0.45	ns
Fountain Grass	260.2	268.8	244.2	ns	10.6	9.1	8.6	1.3
Heller's Holly	122.1	123.8	124.7	ns	12.2	12.3	11.8	ns
Bucaneer Azalea	120.3	119.6	121.8	ns	24.7	24.6	25.5	ns
Snow Azalea	117.7	109.9	112.4	4.3	17.7	18.4	17.7	ns

ns = not significant at p = 0.5

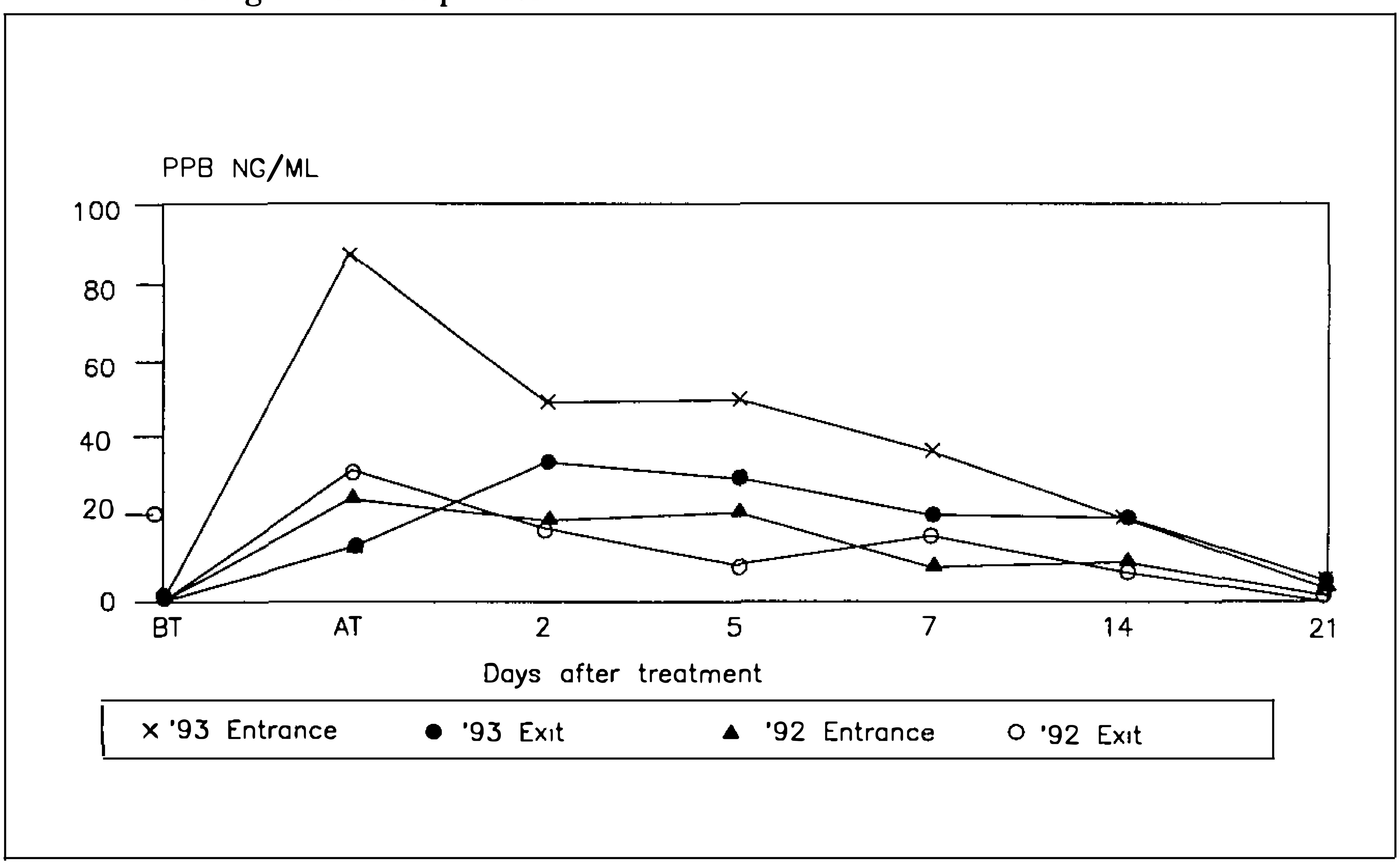

Figure 2. Isoxaben concentration in containment pond water near entry and exit points.

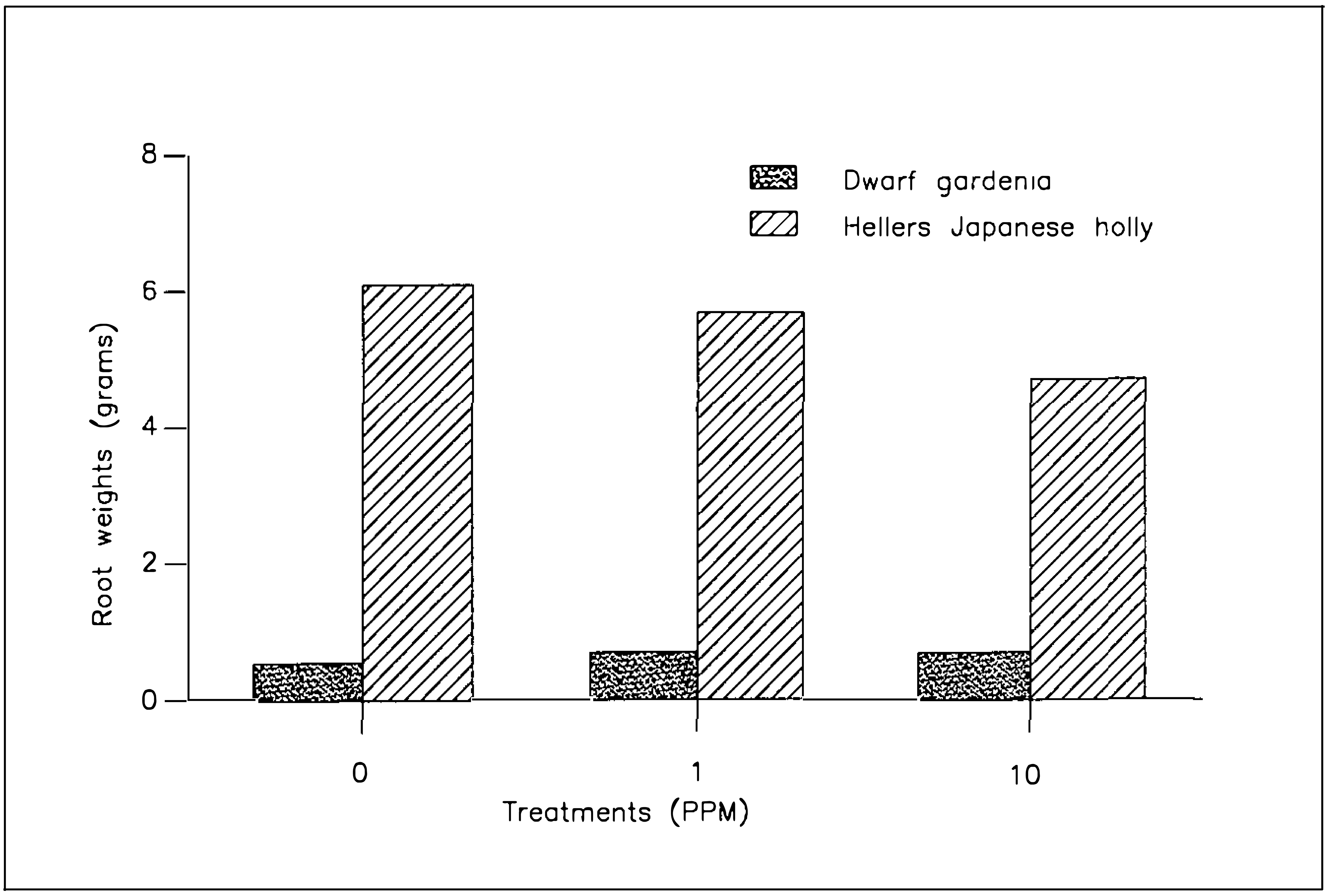

Figure 3. Root weights.

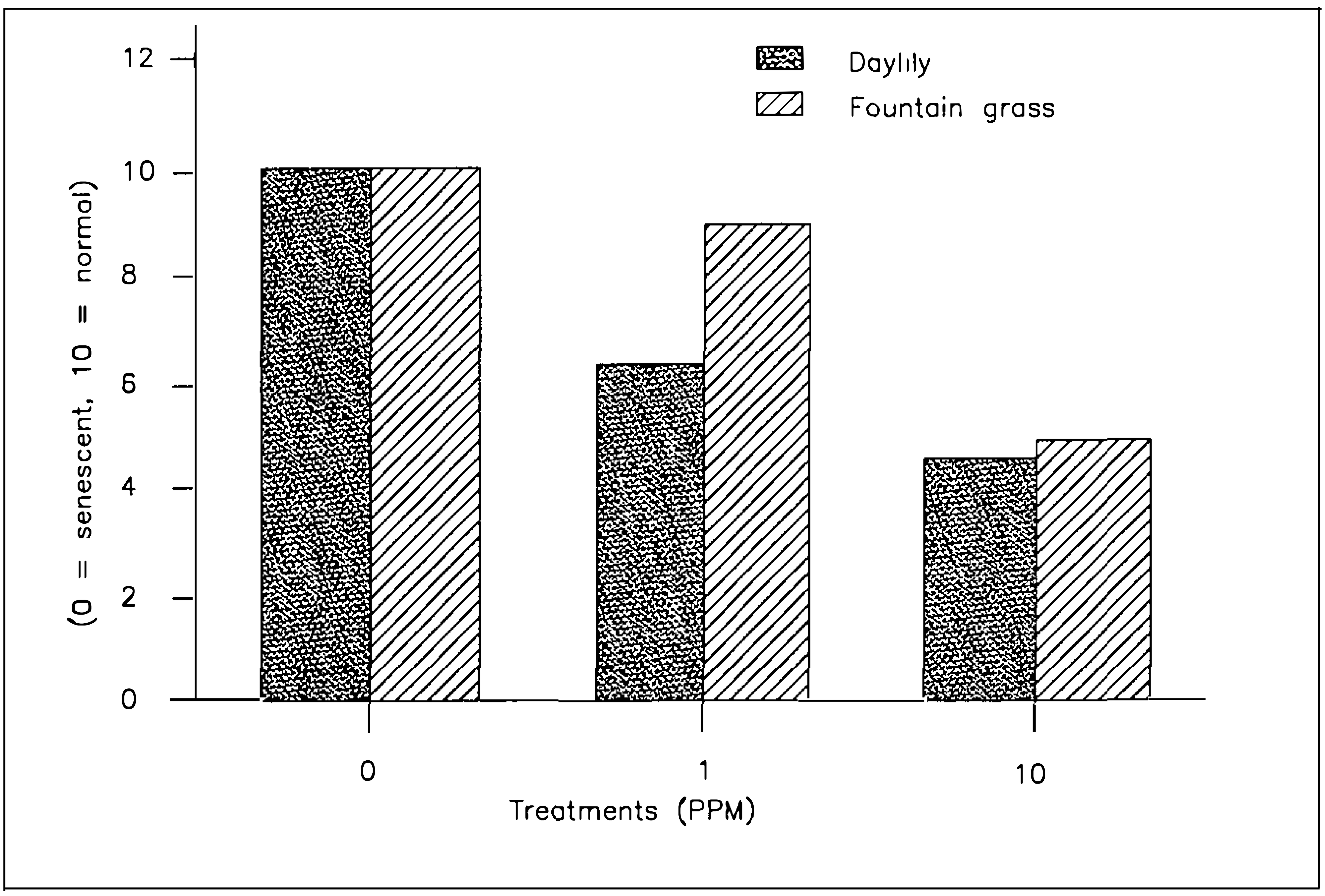

Figure 4. Root quality ratings.

No differences were observed in shoot growth index for Heller's holly, dwarf gardenia, or buccaneer azalea (Table 2). However, the 1.0 and 10.0 ppm reduced the shoot fresh weights of fountain grass. Isoxaben-fortified irrigation water produced no observable reductions in root fresh weight for dwarf gardenia but did reduce the root fresh weight of Heller's holly (Fig. 3). Root quality of both daylily and fountain grass was reduced by the 1.0 and 10.0 ppm treatment levels (Fig. 4).

This study shows that isoxaben moves from the application site in runoff water shortly after application and that it does not accumulate in the containment pond. However, some ornamental species may be injured by isoxaben residues in irrigation water. Growers can reduce the risk of plant damage from irrigation water by holding water for a period of time in a containment pond.

Acknowledgment. Special thanks to DowElanco for funding this research. Trade names and companies are mentioned with the understanding that no discrimination is intended nor endorsement implied.

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Propagation in School and Out—Myth and Reality

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INTRODUCTION

This is indeed a special privilege for me to be surrounded by four of my former students, all graduates of Sandhills Community College, offering a 2-year curriculum in applied horticulture. These former students today represent a total of 49 years of "real world" employment since they graduated. The exposure to propagation from both the theoretical and practical approach will undoubtedly be reflected here today as we discuss the knowledge and experience they received compared to their expectations and actual needs when they graduated to positions involving propagation.

DISCUSSION

Jeff Cred—Speaker One.

Hello, I am Jeff Cred one of three partners of Greensboro Shrub Nursery, Greensboro, North Carolina. I have been in the nursery business for 14 years. Before college the only experience I had came from working with my father in our backyard. We started a small propagation area where we stuck cuttings in cold frames. The high school I attended did not offer any type of horticulture classes; therefore, my interest came from what my father taught me and the little hands-on experience we acquired together.

After making my decision to study plant propagation, I enrolled in the landscape gardening program at Sandhills Community College. I knew everything learned would someday be helpful in my nursery business. There we were shown all aspects of the horticulture business. I feel that college gave me a great foundation to build on, but in no way did I learn everything I needed.

In order to graduate each of us was required to take an apprenticeship in the area we were most interested in. My special interest was in propagation; therefore, I chose Greenleaf Nursery in Oklahoma as I felt it would offer me a wonderful learning experience.

My apprenticeship at Greenleaf Nursery was for 10 weeks. The first 5 weeks I helped load and unload trucks, weed, fertilize, set up plants and spread plants. I did everything there was to do in the field. I then moved to the propagation area where I spent the next 5 weeks. I then learned about propagation in a large nursery. For example, in college we stuck 100+ cuttings at a time, and at Greenleaf I stuck thousands at a time in open beds. I watched how they took care of their cuttings before and after they were stuck. I learned how to set up mist systems and bottom heat systems using hot water. At Greenleaf Nursery I learned how a real nursery operated.

After the apprenticeship I felt I was ready to start my nursery. That was when reality set in. Sandhills and Greenleaf Nursery had only given me the building blocks to begin my work. Not having the perfect propagation means available to me, I decided to take a combination of both methods, Sandhills and Greenleaf, to set up my propagation greenhouses.

Today we have six greenhouses, with a mist system, bottom heat with hot water in concrete, and a fog system. We rotate two crops a year in these houses. It seems we work on this propagation area a little each day, making small improvements as we go. This year we will propagate well over 500,000 liners in these houses.

Sandhills Community College and Greenleaf Nursery gave me great experience to begin my work. Without it, it would have taken extra years and a great deal more cost to have the nursery we have today. We are very proud of our nursery. There is still a lot we will learn while in the nursery business, but to me, this is the most satisfying job or occupation I could ever want.

John Hoffman—Speaker Two.
I am John Hoffman and am president of Landscapes by Hoffman, Inc. in Rougemont, North Carolina. Our corporation does both nursery and landscape work. I began in the landscaping end of the business before graduating from Sandhills Community College in 1980. I had already graduated from Wayne Community College with a Forestry Degree but could not find any jobs in forestry. I started my career in the landscape business at Goldsboro Nursery in Goldsboro, North Carolina. At Goldsboro Nursery, Martin Casey showed me how the landscape industry really worked and gave me a taste of the nursery business. I was working with plants and realized that this could be the line of work I would like to do for the rest of my life. I realized that I needed to understand more about plant materials and design. Sandhills Community College gave me a good start in learning all the parts of landscaping and a little bit about the nursery end of the business.

I interned with Morris Newlin at New Garden Landscaping and Nursery, here in Greensboro. It was an excellent experience. I made new contacts, learned more about new plant material and learned how to put it all together in a real business situation. I was doing landscape installations from start to finish. Since I had some work experience, I was able to handle my own job designs and sales. Morris was always there to answer my questions. The only regrets I have about my school and intern experiences are that I did not ask enough questions. Looking back now, I wish I had spent more time with Morris at New Garden. You just do not realize what it takes to run a business until you actually own your own business.

I started my business in 1981 after graduation and internship. The real learning begins when you run your own business. I started in Greensboro doing landscape design and installations. I also did some maintenance work. Business was slow for me in Greensboro. After two years, a big apartment complex installation job in Chapel Hill, and my family, encouraged me to move to the Raleigh area. Since then the landscaping end of the business has improved each year. Profits from the landscape business financed the purchase of an old tobacco farm in North Durham County in 1986. This was the beginning of my dream to have a nursery. The landscaping end of the business continued to prosper until 1991. The recession in the Triangle and my interest in spending more time in the nursery contributed to a decrease in landscape sales.

The one thing that I have found lacking in my education and experience was business training. As long as things are going well, most business owners do not realize whether or not they are good businessmen. The real test arises when the tough times hit. A business owner needs to know how to spend money wisely and how to make the most profitable business decisions. If I had it to do over, I would take more business courses and ask more questions about the business where I worked. Now I am learning the hard way—I am trying to learn on the job. I am making mistakes, but I am learning from them, and I do not make the same mistake twice.

I am currently putting most of my energies in Hoffman Nursery, the newest part of the corporation. Hoffman Nursery is a specialty nursery that grows the new plants we believe will be winners, ornamental grasses and aquatics. The nursery has grown tremendously since its inception in 1989 and has now become the major contributor to the corporation. The nursery has been challenging and exciting from deciding what plants to grow, to learning how to grow them, to learning how to sell them, to learning how to run a successful nursery. I will never stop learning about the nursery business. I have found that talking to other people is very important. Experienced nursery businessmen can help with propagation, selling, and general problems intrinsic to owning a nursery. Persons in the peripheral green industry can be a limitless source for ideas on items to grow and who might use them.

Sharing information increases professionalism in the green industry, increases public appreciation for plants and their role in the environment, and increases respect for those who can help the public enjoy their environment.

Sandhills Community College and my internship spurred my interest in the horticultural field. Individuals currently in the Landscape Gardening Program at Sandhills or in other horticultural and landscape programs need to realize how important it is to learn about the business end of the nursery or landscape business as early as possible and to cultivate a good network of people in and out of the industry whom they can talk to for new ideas and solutions to problems. Mastering these objectives will help you be successful both professionally and personally, will help make the green industry more professional, and will help the nursery person enjoy what he or she loves best—the plants.

Mike Marshall—Speaker Three.

I am Mike Marshall from Chesapeake Nursery, Salisbury, Maryland. I grew up in the nursery where I now work. My first job ever was working with the cutting crew, stripping leaves and cutting to length the cuttings that were brought in from the plants growing at the production farm.

I was 10 years old when I started this work. My work at the nursery in the following 10 years increased from being on the cutting crew in summers to working at the greenhouse areas and at the production farm. I worked full time for 2 years after completing high school. I then also worked in propagation and in field production. Tasks included digging, loading trailers, pruning, and raking pine needles in the middle of winter for mulching the production beds. Thank goodness someone discovered pine bark for mulching! Propagation tasks included preparing cuttings and sticking cuttings, mixing media for flats, transplanting rooted cuttings to wider spacing, building greenhouses, and pulling weeds. Pulling weeds is definitely the basic horticultural experience.

After 2 years of full-time work, I decided I wanted to go to college so I could better understand the way we grew plants. I felt this step was necessary to progress beyond the level of work I was doing at the time.

College covered some of our nursery operations and much more. College provided a foundation of horticultural knowledge in a relatively short time. It would take many years on the job to acquire the information I obtained in a few years at school, even though I grew up in a nursery where many questions were answered and many important points were explained. An employer would find it difficult to present what I learned at school, even an employer with the best intentions.

During internship, any questions I had about the work we were doing were answered with insight and clarity. The intern period was a good time to see how the ideas we learned held up in the production setting.

In the ten years since college, the ideas and procedures taught have continued to be important in every day procedures. Some of these practices are sanitizing areas for plant production, keeping accurate records, applying pesticides accurately and at the proper time, and staying active in educational seminars and meetings.

These procedures and much of the information I gained in college will be just as important 10 years from now.

In summary, the ideas taught at college give a person a foundation to enter into the field of propagation since a propagator must spend a full year following one growing cycle, keeping records, observing and learning different procedures all of which are important practices learned at college that will make a person a productive propagator.

Alan Salmon—Speaker Four.

I am Alan Salmon, I graduated from the Landscape Gardening Program at Sandhills Community College in 1981. I had not had any propagation experience before enrolling at Sandhills. Fred Garrett gave me a broad overview of both seed and cutting propagation. I completed my required apprenticeship at Angelica Nursery's 2000-acre nursery on the eastern shore of Maryland. During my 3-month stay I worked in all parts of production. I worked in the landscape industry for 3 years until I met my wife. She was already producing container herbs in a sideline business. We married and decided to go into the herb business full time.

When we started Wildwood Herbal Flower Farm in Weaverville, North Carolina, we found there was very little information about commercial production of herbs. Most books about growing herbs were written for the hobbyist or homeowner.

We started propagating in the traditional manner, using seed and cutting flats, mist systems, and heat cables. We soon found that our labor cost and efficiency needed to be improved. We began experimenting with direct sowing and sticking methods. After 11 years of trial and error we now produce 85% to 90% of our plants with the Direct Propagation Method (DPM).

Fred asked me to express my views on how the Sandhills program can better prepare students in propagation. I feel that all the program can do is give students an overview of the basics and arrange many field trips to different propagation nurseries to view their techniques. When the students graduate and start working in the propagation field, they will continue to learn in the job setting and fine-tune their skills on the plants they are producing.

CONCLUSION

Propagation is not an exact science. There are many different techniques used and many more yet to be discovered that ultimately may achieve acceptable results in all aspect of propagation. You do not have to take formal courses in propagation to be successful. However, formal courses, such as in a college curriculum, may help shorten the time required in gaining some knowledge of the techniques and theory without having to rediscover already known procedures. College courses in propagation at best are only an introduction, in a brief period of time, to a profession that will take a lifetime to perfect. As we complete this session, I propose that acceptance of a philosophy much like that of medicine be considered—we teach the practice of propagation in school—you in industry employ the practice of propagation daily. When we begin to realize that what we thought we needed to know was only part of what it takes to be successful, we see the reason for being members of this fine organization.

In closing, I would like to quote from Alice Through the Looking Glass—said Tweedledee—"If it was so, it might be; and if it were so, it would be; but as it isn't, it ain't." We must always continue to look for the was so's, the might be's, the would be's, and the ain'ts.

Growth of Three Species Produced in a Pot-In-Pot Production System

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INTRODUCTION

Production of trees and shrubs in containers offers a number of production, marketing and establishment advantages compared to field-grown plant material. A problem associated with the production of container-grown plants is exposure of the root system to extreme temperatures. Roots are not as hardy as foliage and stems, and extreme temperatures limit the production of container-grown plants. Root systems of plants growing in the ground are insulated by the surrounding soil and are not exposed to the large fluctuations in root-zone temperature that occur in containers.

To address some of the problems associated with container production, the idea for a "pot-in-pot" (PIP) production system was developed (Parkerson, 1990). With this production system, a holder pot is permanently placed in the ground. The container-grown plant is then placed inside the holder pot. Using this production system, roots are protected from extreme temperatures, and windthrow problems are reduced.

The purpose of this study was to compare the growth and field establishment of three southeastern landscape plants grown in a PIP system compared to a conventional above-ground container production system.

MATERIALS AND METHODS

The experiments were conducted outdoors over a 2-year period under full sun at the University of Georgia Coastal Plain Experiment Station in Tifton, Georgia. For experiment one, uniform liners in #1 containers of *Ilex* × *attenuata* Ashe 'Savannah', *Lagerstroemia* 'Natchez' (*L.indica* × *L. fauriei*) , and *Magnolia* × *soulangiana* Soul.-Bod. were potted into #7 containers (#070, The Lerio Corporation) on 18 March 1991. Potting medium consisted of 4 milled pine bark : 1 sand (v/v) amended with micronutrients (Micromax, Grace/Sierra) at 1.5 lb/yd^3 and dolomitic limestone at 6.0 lb/yd^3. Plants were top-dressed with High-N 24-4-7 (Grace/Sierra) at the rate of 1.5 lb N/yd^3 on 25 March and 3 June 1991. Holder pots (Lerio #070) were placed in the ground with the top 1 inch of the container above grade. Plants were irrigated daily with 160^o low volume spot spitters (Roberts Irrigation Products, Inc.) at the rate of 1.0 gal per container. The experiment was a randomized complete block with three species, two container production systems (PIP and conventional above-ground) and 10 replications. On 1 July 1991, container medium temperatures from 10 containers in each production system were measured using a thermocouple thermometer. The thermocouple probe was placed 1 in. from the container wall on the north, south, east, and west quadrant and in the center quadrant of the container to a depth of 6 in. Temperatures were recorded between 4 to 5 p.m. EST.

The study was terminated in October 1991, and measurements of shoot dry weight, root dry weight, and root dry weight between the holder pot and the planted container were taken for five replications. Root growth in the north, south, east, and west quadrants (n=5) was rated as follows: 1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, and 5 = 81-100% of the rootball covered with white roots. *Magnolia* final height, caliper, and branch number measurements were taken. Growth index measurements of *Ilex* and *Lagerstroemia* were taken.

In experiment 2, four replicate plants of *Ilex* and *Lagerstroemia* from each of the treatments in the container study were planted in the field on 12 February 1992, as a randomized complete block. The container-grown plants were planted in augered holes measuring 24 in. across and 12 in. deep in a Tifton loamy sand. Plants were fertilized on 12 February, 1 April, and 1 June at the rate of 50 lb N/A over a 24-in. circular area with Sta-Green 12-6-6. Plants were watered at the rate of 1.0 inch using drip irrigation when less than 1.0 in of rainfall had occurred during the previous week. In October 1992, final growth index and shoot dry weight measurements were made. The root system of each plant was manually excavated to the diameter of the original planting hole. All roots extending past the original rootball were removed and were weighed separately to obtain a dry weight for roots that regenerated into the surrounding soil as well as a dry weight for the rootball. Data for both experiments were subjected to analysis of variance using SAS. Mean separation is by Waller-Duncan K-Ratio t-Test or mean ± standard error.

RESULTS AND DISCUSSION

In experiment 1, production system had no effect on the height or caliper of *Magnolia*. *Magnolia* plants grown in the PIP system had more branches (22.8±0.6) per plant compared to the conventional production system (20.0±0.8). Height and growth index of *Ilex* were not affected by production system. While the growth index for *Lagerstroemia* was not affected by production system, height of plants grown in the conventional production system were taller (46.8±1.6 in.) than in the PIP system (40.9±1.2 in.).

Shoot dry weight and the root : shoot ratio of *Magnolia* were not affected by production system. Root dry weight inside the planted container, total root dry weight, and total plant biomass were all greater for plants grown in the PIP system (70%, 74%, and 65%, respectively) compared to the conventional production system. Production system had no effect on the growth of *Ilex* in this experiment.

Shoot dry weight and total biomass of *Lagerstroemia* were not affected by production system. Root dry weight inside the planted container, total root dry weight and root : shoot ratio were all greater for the PIP system compared to the conventional production system. Root dry weight inside the planted container increased 47% while the root : shoot ratio increased 87% for plants grown in the PIP system. The percentage of roots on a dry weight basis found outside of the planted container but within the holder pot were 2.1%, 0.4%, and 3.6% for *Magnolia, Ilex,* and *Lagerstroemia*; respectively.

The temperature of the medium in the western quadrant of containers in the conventional production system was approximately 13C (23F) warmer than containers in the PIP system between 4 and 5 p.m. Mean container medium temperature across all quadrants was 39C (102F) for the conventional production system in contrast to 33C (91F) for the PIP system.

The root ratings for all three species were influenced by interactions between production system and quadrant of solar exposure. For all three species in the conventional production system, the south, west and east quadrants had less root coverage compared than the north quadrant. There were no differences between quadrants for species grown in the PIP system.

This study demonstrates that *Lagerstroemia indica* × *L. fauriei* 'Natchez' and *Magnolia* × *soulangiana* benefit from being grown in a "pot-in-pot" (PIP) production system, producing more root dry weight and more uniform root systems. Improved root system development was related to lower container medium temperatures during the growing season. Species with vigorous root systems like *Lagerstroemia* and *Magnolia* root-out through the planted container, through the holder pot, and into the surrounding soil. Periodic rotation of planted containers within the holder pot or use of fabrics and root pruning compounds such as Spin Out™ (Griffin Corporation) or Biobarrier™ (Reemay, Inc.) may be helpful (Ruter, 1994).

In experiment 2, the only measurable difference in growth for *Ilex* after several months in the field was in root regeneration beyond the original rootball. *Ilex* grown in the conventional production system had 57% more root dry weight beyond the original rootball than plants grown in the PIP system. Production system had no effect on the root and shoot growth of *Lagerstroemia* in the field. Root regeneration from plants grown in the conventional production system were less uniform around the circumference of the rootball than plants grown in the PIP system. We hypothesized that lack of root regeneration was caused by high temperature damage to the rootball while in the container. While production system influenced root-system development of *Lagerstroemia*, the initial advantages were not evident after one growing season in the field.

The added expense of producing plants in a PIP system needs to be weighed in terms of the limited benefits seen for field establishment in this study. For a fast-growing species such as *Lagerstroemia*, the initial benefits of being grown in a PIP production system were not evident after being placed in the field. With a slower growing-plant such as 'Savannah' holly, production system had little or no effect on plant growth and establishment. Future research on different species, different container designs, rooting-out control, water management, and fertilizer use efficiency are needed for the PIP production system before large-scale recommendations can be made to growers.

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Wetting Agents And Gels—Where They Have A Purpose

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A series of experiments were conducted over a period of 7 years to determine the benefits of using wetting agents and hydrogels in horticultural substrates. A summary of observations, results, and conclusions of these studies are presented in this paper.

INTRODUCTION

Water shortages and attempts to reduce waste-water runoff may require nurserymen to adjust substrate components and mixing, as well as cultural practices such as irrigation, and fertilization. Materials that increase water retention in containers might help growers reduce irrigation frequency or the volume of irrigation required during each irrigation.

MATERIALS AND METHODS

A synthetic moisture-extender gel (Terra-Sorb AG) and a wetting agent (Aqua-Gro) were evaluated in two separate studies. The effects of these additives on water-air relationships, nutrient levels in container substrates, plant nutrient levels, and plant growth were measured (Bilderback, 1989). In the first study, *Pyracantha coccinea*, *Ilex* 'Nellie R. Stevens,' and *Rhododendron* 'Hinodegiri' were potted into pine bark alone. In the second study, *P. koidzumii*, *Cotoneaster dammeri* 'Skogholm', and *R.* 'Sunglow' were potted in a mix of 4 pine bark : 1 sand (v/v).

Control plants in pine bark with sand and pine bark alone were compared with wetting agent and hydrogel treatments. Dolomitic limestone and Sta-Green ProStart 13-6-6 with minors were incorporated in all substrates at a rate of 8 lb/yd^3. At potting, TerraSorb was incorporated at a rate of 2 lb/ yd^3. Aqua-Gro granular was incorporated at 1.5 lb/yd^3. and monthly using 700 ml of Aqua-Gro L (2500 ppm) as a drench over containers that received the wetting agent. One teaspoon of Sta-Green Nursery Special 12-6-6 was applied to the surface of each container each month beginning 1 month after initiation of the studies. Containers were irrigated by Dramm ring trickle irrigation with 700 to 1000 ml each irrigation applied at 1- to 6-day intervals. Moisture retention characteristics, nutrient levels, (Wright, 1987), top and root dry weight, and tissue nutrient levels were measured.

A third study was conducted in the horticultural substrates laboratory at North Carolina State University on the hydrogel to resolve discrepancies related to moisture characteristics in substrates in the previous studies.

RESULTS

The hydrogel held more water in the containers but less water was available than in other treatments.

Hydrogel did not affect nutrient retention. The wetting agent increased the amount of water available to plants in the bark medium but decreased the amount of water available to plants in the bark and sand mix.

The wetting agent reduced the nutrient levels in both media. In the bark medium, both materials contributed to greater shoot growth of *P. coccinea*, *I.* 'Nellie Stevens' and *R.* 'Hinodegiri'. In the bark and sand mix, the amendments increased root growth for all plants but did not affect shoot growth.

Irrigation frequency had a significant effect on plant growth and nutrient levels. In the bark and sand mix, drought-sensitive species such as *P. koidzumii* and *C. dammeri* 'Skogholm' grew less with each decrease in irrigation frequency.

In the bark medium, growth of 6 'Nellie R. Stevens' and 6 'Hinodegiri' was not affected until irrigation was reduced to 4- or 6-day intervals. Although both amendments did improve plant growth somewhat compared with control plants, the treatments did not compensate for less frequent irrigation.

Two possible physical explanations for variable results when using hydrogels in potting media are (1) inconsistent incorporation of dry granules during blending and (2) reduced hydration of hydrogels in media.

When hydration of hydrogel cubes in distilled water was compared to hydration of hydrogel cubes in pine bark medium, results indicated that pine bark contained substances that reduced water uptake. Although this explanation provided some insight into the reduced hydration, it did not account for the increased growth responses seen in the plant container studies. Further investigation showed that standard physical property techniques to determine moisture content of potting media were not adequate for measuring water content of media containing hydrogels. Standard techniques assume that tension is maintained uniformly in samples during moisture content measurement.

Study three results indicated that the moisture gradient between the hydrogel cube and the surrounding medium is broken during measurement. The cubes contained moisture that was not accounted for during measurement. Our results indicated that hydrogel cubes achieved approximately 55% hydration by weight when incorporated in a pine bark and sand medium but approximately 92% to 95% of this volume would be available at tensions exerted by plant roots.

Hydrogel cubes apparently served as an oasis for roots of established plants that grow into the cubes. However, newly planted liners would likely derive little benefit unless they were in direct contact with the hydrogel.

CONCLUSIONS

Wetting agents appear to be useful in nursery production. In the container studies, wetting agents increased available water content in the pine bark. This result indicates that more thorough wetting occurs in the medium with the use of the wetting agent.

If fresh pine bark or pine bark that lacks 20% to 30% fine particles (<0.5 mm) is used as a potting medium and no other fine particle component such as sand or peat moss is included in the mix, rapid movement of water, or channelling, through the container may occur. Even with frequent irrigation newly planted nursery crops may suffer in very coarse potting media. Use of a wetting agent could be beneficial under these conditions by enhancing lateral movement of water and reducing the infiltration rate of water through the container.

Wetting agents may also be useful for nurserymen that store pine bark at the nursery so they have a ready source for potting. Dry pockets frequently develop in pine bark inventory piles.

Many nurserymen are currently evaluating the use of cycled irrigation. Considerable research is also being conducted to compare leaching of interval applications of water with the amount leached each time. Interval or cycled irrigation creates a wetting front in containers between irrigation intervals. Leaching does not occur as with one extended irrigation application. After each irrigation interval is completed, limited free drainage occurs; and water moves laterally across the container. The medium above the wetting front is wet more thoroughly. Sand or other fine particle components have a similar effect. Wetting agents could enhance this flow even more, but presently no such studies have been reported.

Further study may show hydrogels to have greater value as nursery irrigation practices change in the future.

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Propagation Medium Moisture Level and Rooting of Woody Stem Cuttings

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INTRODUCTION

Intermittent mist systems are commonly used to reduce transpirational water loss from cuttings during propagation. A problem with this system is maintaining a wet leaf surface without overwetting the rooting medium. Water and air compete for pore space in a medium (Loach, 1985), and oxygen availability may be reduced as the volume of water in the medium is increased. Propagators face a dilemma in providing adequate but not excessive moisture to stem cuttings both above and below the medium surface. The objective of this study was to determine the influence of a range of moisture levels in the propagation medium on the cutting water potential, adventitious rooting, quality, and survival of stem cuttings of 'Blue Rug' juniper, 'Hino-crimson' azalea, and 'Helleri' holly.

MATERIALS AND METHODS

Stem cuttings of 'Blue Rug' juniper (*Juniperus horizontal* Moench 'Wiltonii') 'Hino-crimson' azalea [*Rhododendron* (Lindl.) Planch 'Hino-crimson'], and 'Helleri' holly (*Ilex crenata* Thunb. 'Helleri') were propagated in 1 peat : 1 perlite (v/v) at one of five moisture levels based on medium dry weight (125%, 250%, 375%, 500%, or 625%). Under normal intermittent mist situations, a peat/perlite medium would be at 400% to 500% moisture. Thus, the 625% treatment contained excessive water compared to a "normal" propagation situation. Please consult the *Journal of the American Society for Horticultural Science* 116:632-636 for more details of this experiment.

RESULTS AND DISCUSSION

Stem cutting quality and rooting percentages. In most cases, percent survival and adventitious rooting of stem cuttings were highest in the wettest propagation medium and lowest in the driest medium (Tables 1 and 2). Survival was high in juniper at all medium moisture levels, with 77% of cuttings in the lowest medium moisture level (125%) alive and green 8 weeks after insertion (Table 1). It is possible that the surviving cuttings may have rooted later, since juniper cuttings may take 12 weeks to root. Generally, survival of azalea and Japanese holly cuttings was low at the lowest moisture treatment.

The variability in rooting percentages between species was expected. Stem cuttings of juniper are generally slower to root than those of either 'Helleri' holly or 'Hino-crimson' azalea. However, the repeated experiments with 'Helleri' holly illustrated that rooting success can vary with time of year or growth stage of the stock plants (Table 2). It usually is recommended to take these cuttings between the periods of shoot growth (Dirr and Heuser, 1987).

In no case was the incidence of basal rot significantly related to the percentage of moisture in the propagation medium (Tables 1 and 2). Instead, basal rot in this study seemed related more to the growth stage of the cutting. For example, basal rot of 'Helleri' holly cuttings taken in August was much more severe than on cuttings taken in March or April (Table 2).

Table 1. Survival, basal rot, and rooting percentages of stem cuttings propagated in a peat/perlite medium at five moisture levels. Data are shown as actual percentages.

Medium moisture (%)	Survival (%)	Basal rot (%)	Rooting (%)
		'Blue Rug' juniper	
125	77[z]	43	0
250	95	24	0
375	100	43	10
500	100	43	5
625	100	33	48
Significance (P values of components)			
Linear	0.01	0.99	0.05
Quadratic	0.03	0.99	0.40
		'Hino-crimson' azalea	
125	13	0	0
250	19	0	0
375	81	0	19
500	100	0	38
625	100	0	75
Significance (P values of components)			
Linear	0.04	0.99	0.02
Quadratic	0.70	0.99	0.33

[z] Percentage data transformed via arcsin [square root (proportion)] prior to statistical analysis. For 'Blue Rug' juniper, n = 20; for 'Hino-crimson' azalea, n = 16.

Water uptake by stem cuttings. Stem cuttings in the wettest medium generally showed the greatest amount of water uptake (Table 3). This result is in agreement with the findings of Grange and Loach (1983) that water uptake by stem cuttings is limited by the availability of water to the cut stem base. Our data also show that water uptake by cuttings is greatest during the first 4 days of propagation, followed by a period of lower water absorption from the propagation medium until adventitious rooting formed. The later increase in uptake by 'Helleri' holly cuttings occurred between the 3rd and 4th weeks after insertion, corresponding to the period in which rooting was noted.

Table 2. Survival, basal rot, and rooting percentages of 'Helleri' holly stem cuttings in a peat/perlite medium at five moisture levels. Data are shown as actual percentages.

Medium moisture (%)	Survival (%)	Basal rot (%)	Rooting (%)
		31 Mar. - 22 Apr. 1989	
125	0[z]	0	0
250	74	0	26
375	96	0	74
500	91	0	74
625	100	0	92
Significance			
(P values of components)			
Linear	0.05	0.99	0.02
Quadratic	0.18	0.99	0.18
		27 Apr. - 26 May 1989	
125	30	0	20
250	80	20	60
375	90	0	60
500	100	20	90
625	100	20	70
Significance			
(P values of components)			
Linear	0.01	0.42	0.10
Quadratic	0.12	0.99	0.23
24 Aug. - 21 Sept. 1989			
125	79	50	0
250	75	75	0
375	75	71	4
500	83	88	4
625	88	83	8
Significance			
(P values of components)			
Linear	0.04	0.09	0.05
Quadratic	0.06	0.37	0.91

[z] Percentage data transformed via arcsin [square root (proportion)] prior to statistical analysis. For 31 Mar., n = 22; 27 Apr., n = 10; 22 Aug., n = 24.

The high initial water uptake by cuttings may be due to the continued transpirational water loss through stomata that have not yet responded to the stress of propagation. The application of greater quantities of water to stem cuttings during this period could help reduce water stress. Our results indicate that the wetter medium, which may result from heavy water application during propagation, does not necessarily adversely affect rooting

Table 3. Water uptake by 'Helleri' holly stem cuttings from a peat/perlite medium at five moisture levels (cuttings inserted 27 Apr.).

	Water uptake (g)[z]					
	Days after sticking (%)					
Medium moisture (%)	4	8	12	16	23	27
125	0.16	0.12	0.11	0.06	0.02	0.03
250	0.28	0.17	0.16	0.06	0.32	0.42
375	0.34	0.18	0.12	0.07	0.31	0.42
500	0.20	0.20	0.20	0.05	0.31	0.42
625	0.41	0.35	0.21	0.08	0.17	0.53
Significance						
(P values of components)						
Linear	0.08	0.02	0.12	0.79	0.18	0.03
Quadratic	0.94	0.37	0.83	0.82	0.01	0.32

[z] Mean uptake of 10 cuttings, over previous 4 days. Linear and quadratic P values for uptake data over time were <0.05 except for the 125% treatment..

An increase in contact between the cut stem base and the water in the medium probably accounted for greater water uptake by stem cuttings in the higher medium moisture treatments (Grange and Loach, 1983). The duration and extent of this contact could control stem cutting water potential and adventitious rooting.

The level of moisture in a propagation medium influences the ability of stem cuttings to absorb water and produce adventitious roots. The availability of moisture in a propagation medium at least partially controls the ability of a stem cutting to absorb enough water to offset transpirational and nonstomatal water losses. A standard 1 peat : 1 perlite medium under intermittent mist may contain 400% to 500% moisture on a dry weight basis. We found that stem cuttings inserted into a relatively wet propagation medium (625%) exhibited greater water absorption, less negative water potential, and greater adventitious rooting percentages than cuttings propagated at lower percent moisture levels. Cuttings in a finer textured medium may have exhibited basal rot and reduced rooting under conditions of excessive moisture. However, within the range of moisture and species tested here, a reduction in stem cutting quality due to basal rotting was not a direct result of high moisture levels in the propagation medium, even when the cuttings were at least partially submerged in water. The basal rotting of stem cuttings appeared to be more closely linked to the growth stage of the cutting tissue.

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Plant Product Trends

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Many different direct and indirect forces create plant product trends. Our industry was once controlled by the production end of the business, but now it is more market driven. The ultimate consumers' perceived value of our product has always been the basic control of what sells and what we need to produce. Most often these values have been determined by experience with our product. In recent years more information has been available for consumers, including product availability.

Presently, the ultimate consumer for plants is the retail customer, a homeowner, and usually a woman. Just a few years ago a high percent of the plant material was sold to large commercial jobs with a much different ultimate consumer with a different perceived value. The plant product trends of the future will depend on the ultimate consumer.

The retail segment of our business will always use a high percent of our product. Color has been a major selling feature for retail sales for one reason—it is visually gratifying to the consumer. The question is can visual gratification continue to create enough perceived value to allow color to remain the hot trend it has been. To determine this, let's understand the meaning of perceived value.

Perceived value is defined as plant benefits less costs. The greater the benefits, the higher the perceived value, unless costs also rise. Costs include more than just money paid. They also include maintenance costs, replacement costs, and opportunity cost of time involved with the product.

What happens to color's perceived value if the homeowner cannot control certain pests, or the retail store price is doubled because the grower's and retailer's costs double? This is important because it is exactly what is beginning to happen in our industry due to the legislation that has or will be passed in the next few years.

- **Worker Protection Act**
  Increased labor costs
  Elimination of many effective pesticides
- **American Disabilities Act**
  Increased labor costs
- **Clean Water Act, Coastal Zone Management Act**
  Increased labor costs
  Increased facility costs
  Increased fertilizer and pesticide costs
- **Universal Health Insurance Legislation**
  Increased labor costs

What is the perceived value of our product and how can we increase that value? To increase the value of our product, we must provide more than something that is pretty. To reach millions of people who place little value on aesthetics around the home, we must convince them that plants positively affect their lives in many ways other than providing beauty for the world.

- Plants are a major source of oxygen.
- Plants filter pollutants, both air and water.
- Plants screen out noise and sights.
- Plants cool the summer days.
- Plants slow the cold winter winds.
- Plants offer shelter and food.

Plant product trends for the future will be determined by our industry's ability to convince ultimate consumers that plants are really valuable to them.

What do I think are the plant product trends over the next three years?

- Continued expansion of color
- Increased awareness of low maintenance plants, not necessarily natives
- Multiple-use plant products
- Unique products

Foreseeing trends is especially important for producers as they must start production well in advance of the increased demand in order to provide what consumers want when they want it.

Trends in Plant Product Mix: A Retailer's Perspective

Larry Newlin
New Garden Landscaping & Nursery, 5888 Old Oak Ridge Road, Greensboro, North Carolina 27410

I would hate to be a grower trying to figure out what New Garden Landscaping and Nursery is going to buy in 5 or 10 years. We are fickle. But, alas, so are our customers. For every generalization I might make, there is buying-pattern evidence that contradicts it. We are operating in a time when trends are difficult to discern, and we find ourselves as a company swept up in a dynamic environment of customer lifestyle- and buying-habit shifts, government regulation, radical weather patterns, and a variable economy.

We have three landscape designers, a landscape architect, six landscape crews, four landscape management crews, and a nursery-stock buyer who spends half his time purchasing plants for retail sales and landscaping and half in retail sales. He and several department managers purchase about one million dollars wholesale value of green goods. A few buying facts:

- Twenty percent of the cultivars of woody ornamentals used in our landscaping and sold in retail were not in our inventory five years ago.
- Eight years ago the largest residential landscape job we had done was $10,000. In the past two years we have taken on two residential jobs in the neighborhood of a quarter million and two exceeding $100,000. We have completed a score of residential jobs in the $25,000 to $50,000 range right here in the dirt-poor South. Our mix has shifted from 50/50 residential to commercial to 90/10 residential to commercial. In these larger landscape jobs we are using a broad mix of plant material, but we require a large quantity of any one plant. We used to stock over 30 cultivars of junipers, 80 azaleas, 50 dwarf conifers, and 30 hollies. We have made a major effort to limit our inventory to the best performers; and while we may try new cultivars, we are looking for plants that are distinctively different from the ones we carry and that appeal to our retail/landscape customers.
- We try to carry all of the National Arboretum crapemyrtle, but the best seller for us continues to be the standard red, 'Carolina Beauty'.
- We generally try to carry improved cultivars in trees such as *Acer rubrum* 'October Glory' or 'Red Sunset', but in other instances we have found new cultivars to be less desirable than the old standbys. We find 'Bradford' pear to be less susceptible to fire blight than 'Aristocrat'. There is growing interest in other trees that offer seasonal appeal.
- We are finding a renewed interest in plants that help folks reconnect to their past. We call nandina, lacecap hydrangea, weigela, lilac,

peony, delphinium, dahlia, spirea, and magnolia "Granny Plants". In a recent newsletter I asked, "Do you have a tree of childhood memories?"

- We also find ourselves turning back to old workhorse plants like *Osmanthus fortunei, Ligustrum japonicum,* and *Ilex* 'Nellie R. Stevens'. Nevertheless, we have a special retail display of improved plants from the North Carolina State Arboretum. We find growing acceptance for new plant material, especially if the plants are recommended by our landscape designers or retail salespeople.
- We find we have to limit our designers' use of certain plants, such as cephalotaxus and zabel laurel, because the availability is poor.
- Five years ago 50% of the shrubs and trees we purchased were from out of state. Today we purchase 80% from nurseries within a 200-mile radius. We find excellent quality and a wide variety. Local purchases also help us with just-in-time inventorying and allow us to reduce or eliminate transportation costs. Some plants, camellias, for example, have fallen out of favor with local growers, and we have to go out of state to bring in the size and variety we require.

While we have pulled in the reins on some of the variety we offer in woody ornamentals, our herb, annual, and perennial selection has quadrupled in the past two years. We offer over 30 cultivars of impatiens, 25 culitvars of geraniums, and 30 cultivars of hosta. If it is blooming, it will sell in retail; and if a plant is blooming when it is installed on a landscape project, it increases our customers' satisfaction manyfold.

THINKING LIKE OUR FICKLE CUSTOMERS

The rule in marketing today is, "Think like customers." What do we know about them?

- Customers tell marketing gurus that the major reason they shop today is not price, selection, or any of the stuff they've been telling us for years; it's to solve problems. Our customers are building huge houses on postage-stamp lots, and they want instant privacy. They've lost plants to the worst drought and worst winters, the rainiest springs, and the most insect-infested summers. They are tired of climbing up ladders to prune foundation shrubs, and they hate to spray. They want their plants cold hardy, drought tolerant, compact, evergreen, free of disease and insects with blooms in the spring, colorful foliage in the fall and pretty berries in the winter. They are stressed out and pressed for time, and they want a maintenance-free landscape with a lot of inspiration . If we can figure out what their problems are (just ask them!), then we can figure out what plants to grow for them.
- They tell marketing gurus that climbing the ladder to success is no longer their highest priority. When asked, "What's most important in your life?" they respond, "Family, health, and happiness."

What about family? Increasingly we are seeing retail purchases and landscaping decisions made jointly by couples. It used to be that the women gardened and the men landscaped, but now we are adding perennials to the foundation planting, herbs to our patio garden, and bulbs in our azalea bed. Moreover, we are seeing a big push towards kids' gardening. We don't sell a lot of kids' merchandise, but we do have a Kids' Club with over 1,000 kids between 4 and 12. We also host a Garden Festival in May and a Harvest Festival in October to offer families a fun-filled Saturday of hayrides, straw mazes, face painting, and the like.

Maybe the exponential growth in herb sales can be attributed to the increased interest in health. Two Lowe's superstores, two Wal-Marts, and one Home Depot have come to town in the past two years, but none of them offer the competition for our customers' discretionary dollar like health spas, jogging, tennis, and hiking paraphernalia, and all the other health-craze expenditures. Somehow we need to find other avenues to capture the health interest of our customers. Maybe we can even interest them in edible landscape plants again. We are planning a special edible landscape display next spring and have touted in our newsletter the exercise provided and the calories expended through gardening.

Isn't happiness what our industry is about? Don't they have flowers at weddings and funerals, in hospitals and at parties, on anniversaries and holidays? Aren't those public gardens that are jampacked on weekends with picnickers, joggers, and strollers? Isn't that why Disney invests a small fortune in its grounds—to make us happy? Shouldn't our retail locations be designed to invite folks to browse and enjoy a relaxing afternoon? When stress is a major personal obstacle in many folks' lives, can't we invite them, "Don't worry, be happy?"

If I were a plant propagator, I'd hang around the local garden center and even volunteer my services occasionally as a salesman to find out what customers are thinking. Although our salespeople don't have the knowledge and skills of a Michael Dirr or a J. C. Raulston, we are providing training opportunities through conferences and in-house that will better equip them to value and, therefore, to sell new plants available to us.

Our industry has changed radically in recent years and is apt to change even more in the years ahead. The chain stores have taken over many of the product lines we used to sell like gallon azaleas, bags of mulch, and grass seed. That leaves us with what we like best—plants. It means we have more time to merchandise them, to develop signs that include a bit of plant lore, and to share our enthusiasm and knowledge with our customers.

Plant Product Trends from the Salesman's Viewpoint

Jack Lowry
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Customer opinions can tell us how well we are really doing. I felt a recent customer comment to me reflected a trend in today's market. "Our industry needs to move into the 20th Century." The customer wasn't even asking for the 21st Century.

Another customer said, "Maybe we are going back to the way it was some years ago when most of the industry relied on the wealthy and the people interested in large, unusual specimen material. The average homeowner will not be able to afford landscaping."

Today there is a very different approach to buying from previous times. Customers are not in a hurry. They are waiting much longer after they buy a home before they buy plants. And they are buying more carefully. Many contractors are watching their inventories. Some do not carry inventory but buy when they get the jobs.

Retailers are thinking turn-over. Trade show business has been slow in the early part of 1993. We hope business at the winter shows will be brisker.

Many growers who used rewholesale yards as their major customers are now selling directly to retailers and contractors and providing them timely delivery.

More nursery sales representatives are on the road now than ever before. Some growers who never before had salespeople now have several covering the same territories.

I suppose my job was easier in the eighties. I didn't think it could get any harder, but it has.

In various areas where I sell, the popularity of some plants is waning. Black and Austrian pines are two examples.

Some varieties are losing favor because of bad press. Dogwood and hemlock have both suffered. Damage from deer is slowing the sales of taxus. Other animals also cause damage that results in slow sales of their favorite plants. Overproduction and poorly grown and improper varieties have cut rhododendron sales. Homeowners get tired of losing expensive plants.

These are not our only problems. We need to sell our plants! We have been very fortunate. Plants tend to sell themselves. Just think how well we could do if we had trained, enthusiastic sales people on the retail level instead of uninformed uninterested help. I hope our future is not selling through the mass merchandisers. I doubt they will ever have adequately trained help. Our independents must do better than that. The mass merchandisers would not be in the position they are with our products today if growers had not overproduced.

Predictions are that by mid-1994 there will be a building boom and that more households will have more money to spend than in the past several years. We shall see!

The future for growers, retailers, and landscape contractors depends on their proceeding with an up-scale attitude. This is the only way.

Quality <u>will</u> sell. Businesses that do not believe so and do not furnish their customers quality plants are doomed.

Growers who produce quality plants for this market will draw the better retailers and contractors. The upper-scale customers usually pay better also.

The public is better educated about our products than ever before, and consumers are going to demand plants that have better quality and provide lasting beauty.

Growers who are doing well now are those with excellent quality, a good variety mix, and quick delivery response.

We all hear that color is selling. Retailers tell us that they make more profit per square foot from annuals and perennials. We must help develop ways to make sales turn over faster at the retail level.

We need to improve tagging on our plants. More information on colorful, interestingly shaped plastic tags large enough to be visible would help.

Signage at the retail level must improve. Area signs giving location of plants according to use or flowering characteristics are categories that could be used.

How about more color charts? We have them for shade trees, crabapples, and rhododendron. How about some for azaleas, crapemyrtles, and Japanese maples?

How about usage charts indicating good screening materials, ground covers, winter gardens, or small ornamental trees? Or, to increase summer traffic, summer-blooming plants and fall planting charts to help customers plan ahead.

Growers in the lucrative eighties produced easy-to-grow, fast-growing varieties in large quantities. In many cases these were not the most desirable plants.

Today growers are looking at production differently. They are lining out slower-growing, hard-to-find plants.

I see a market for plants suitable for the smaller gardens of plant fanciers. Screening materials, NOT white pine, and quality trees, NOT Bradford pear, will be in demand.

An idea to expand the fall market is to include berried hollies in nice containers with distinctive shapes for late fall and Christmas sales.

Other items that have rarely been pushed are:

- Azalea cultivars that extend blooming time or have dwarf growing habits.
- Crapemyrtles in blooming sizes in containers. There are several new cultivars that would be suitable.
- Boxwood in assorted sizes and shapes such as pyramids, columns, spreaders, and even topiary.
- Fir cultivars that are not now on the market. Try to buy a Nordmann fir.
- Camellias in good cultivars and good sizes.
- Deciduous hollies. These need to be shown and promoted to the public.
- Espaliered plants more suitable than we have offered in the past.
- Witch hazels, yews, magnolias and atlas cedars might be worth trying.
- Nandinas are selling well but could do better with the newer cultivars. They add a great deal of interest and are underproduced.
- *Cercis canadensis* hybrids are coming on the market and are selling. 'Flame' and 'Silver Cloud' are examples.
- Southern magnolia cultivars, including 'Bracken's Brown Beauty,'

'Edith Bogue', 'Victoria', and 'Little Gem' are great plants and are selling well. When some of the new deciduous magnolias, including the new yellows, become available, they will sell.

- The new red or pink kousa dogwood can't miss, if there really is one.
- Japanese maple varieties are in very limited supply although there are many varieties that could be grown.
- Other little-grown plants that could add variety and interest to the product mix include: *Clethra barbinervis*, *Acer griseum*, *Stewartia*, and *Pterocarya*

Trends. Many of my retail buyers tell me women are their best customers. To attract women, plants must be clean, easy to handle, and transport.

If we do our part as growers and provide top-quality plants, retailers who have enthusiastic, informed, people-oriented employees in a well-groomed marketplace with timely advertising and reasonable prices can succeed in today's more challenging sales environment.

Basics of Propagation by Cuttings—Temperature

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Proper control of air and root zone temperatures is critical for rooting of stem cuttings. The optimum air temperature for growing the crop is probably the best for propagation. Bottom heat should be manipulated in two phases, with a higher temperature for root initiation, then a somewhat lower temperature for root growth and development.

INTRODUCTION

Propagators routinely regulate the temperature of both the air and the medium when rooting cuttings. It is clear that as temperatures increase (within limits) cuttings metabolize faster and root better. Improper control of temperature can result in slow rooting, low rooting percentages, poor development of the root system, damage, or death of cuttings. Daily monitoring will alert a propagator if there is a failure in the heating system, especially the source of bottom heat. Aspirated thermometers housed in white (to reflect light) boxes are the most accurate way to assess air temperature. Soil thermometers should be placed at multiple locations within a propagation bed with their temperature sensors at a depth equal to the bottom of the cuttings. A written record of daily temperatures can be used for trouble-shooting and to help a propagator repeat past successes.

AIR TEMPERATURE

Within limits, as temperature rises, plant metabolism, including respiration, increases. Respiration has a temperature coefficient (Q_{10}) of approximately 2. This means that for every 10C (16F) increase in temperature the amount of CO_2 given off doubles. Respiration is necessary for the process of rooting cuttings because it is the method by which plants release energy to support growth. Photosynthesis is also temperature sensitive, but to a lesser degree than respiration. Therefore, as temperature rises, the rate of respiration will tend to increase faster than photosynthesis. This can cause cuttings to lose weight and possibly even die (Kester, 1970). Evans (1951) reported that *Theobroma cacao* (cacao) cuttings placed under low light and high air temperature (32 to 33C or 90 to 91F) showed "starvation symptoms within a week" because of loss of carbohydrates. When the air temperature was lower, (27 to 28C or 81 to 82F), however, cacao cuttings were successfully rooted. Rooting will be slow or success will be limited if temperatures are too low because the cuttings will not be metabolizing at a sufficiently rapid rate for optimum rooting.

The relationship between day and night temperatures is also important. Photosynthesis does not occur in the dark, but respiration continues. Lower night temperatures will slow this respiration, conserving food reserves while higher night temperatures will tend to cause the plant (or cutting) to burn this energy (Preece and Read, 1993).

The relationship between air temperature, and light (for photosynthesis) is important. Howard (1965) reported that under conditions of very low light, *Humulus lupulus* (hop plant) cuttings rooted at 15.5C (60F) had higher root dry weights than those rooted at higher air temperatures. Yue and Margolis (1993) found that as air temperatures rose around *Picea mariana* (black spruce) cuttings, there was an increase in the light compensation point (the level of light at which the CO_2 fixed by photosynthesis equals the amount of CO_2 released by respiration). Black spruce cuttings rooted at 10C (50F) required about one-third the amount of light as cuttings rooted at 30C (86F). This would primarily be a concern if cuttings are rooted under heavy shade.

The system for controlling water loss by the cuttings must be considered along with air temperatures. When leaves and cuttings are illuminated, the leaf temperature generally exceeds air temperature (Loach, 1988); this effect would be negligible if cuttings are rooted under shade. When cuttings are misted, the cooling effect of the water and its subsequent evaporation can reduce leaf temperatures to below that of the air temperature (Loach, 1979, 1988). Evaporative cooling will be greatly reduced if the mist system is enclosed in a plastic tent; in fact it can be warmer within a tent than in the greenhouse that houses the tent (Loach, 1988).

Fog systems are also used to reduce transpiration from cuttings and to lower air temperatures, especially in the summer (Press, 1983; Torn, 1989). Torn (1989) used two layers of 40% white shade cloth and fog to lower the air temperature in his propagation house and combined this with intermittent mist (10 sec/h). He reported that cuttings rooted faster and at higher percentages with this system.

Plants can be classified as cool-season crops, intermediate-season crops, or warm-season crops (Preece and Read, 1993). With respect to rooting cuttings, the best procedure is to use the same air temperature that optimizes growth of that species. For most species, this is in the range of 18 to 32C (64 to 90F) during the day and about 5C (10F) lower during the night (Hartmann et al., 1990).

ROOT ZONE TEMPERATURE

It is easier to control the temperature of the rooting medium than the air temperature. Propagators have been aware of the importance of bottom heat for more than 100 years (Bailey, 1896). Bailey felt that an important reason for using bottom heat was to speed rooting of cuttings and to increase root growth before shoot growth began. However, Hartmann et al. (1990) caution that excessive root growth in leafless hardwood cuttings can deplete carbohydrate reserves needed for bud outgrowth.

Root initiation involves the formation of root primordia and is largely dependent on cell division. Root development (elongation) is dependent on both cell division and cell elongation. Within a temperature range, root development increases as temperatures rise. Burholt and Van't Hof (1971) showed that *Helianthus annuus* (sunflower) roots elongated faster at progressively higher root zone temperatures from 10 to 25C (50 to 77F). However, at temperatures above 25C, roots elongated at a much slower rate and at the highest temperature tested (38C or 100F) root growth virtually ceased.

Dykeman (1976) reported that root initiation and root development have different temperature optima based on experiments with cuttings of *Dendranthema* × *grandiflorum* (chrysanthemum) and *Forsythia* × *intermedia*. At higher temperatures (up to 30C (86F)), more roots initiated and emergence through the stem was faster than at lower temperatures. Root development was improved if root zone temperatures were reduced after emergence. Dykeman (1976) recommended that the optimum root zone temperatures for root initiation was 30C (86F) and for root development was 20C (68F). This system of using a higher temperature for root initiation than root development should be modified for each particular species regarding the timing at each temperature and the optimum temperature for each phase of rooting.

There are some interesting relationships between auxin applications and root zone temperature. Carpenter and Cornell (1992), working with *Hibiscus rosa-sinesis*, showed that the amount of indolebutyric acid (IBA) required to elicit 100% rooting decreased as root zone temperature increased. Higher temperatures did not completely replace the benefits of auxin in this study.

A negative aspect of increasing the temperature of the rooting medium can be increased disease. As the rooting medium temperature increased from 15 to 25C (57 to 77F) the incidence of leaf, bud, and stem rots increased on cuttings of hybrid rhododendrons (*Rhododendron* spp.), even though they had been drenched regularly with Captan fungicide after placement in the rooting medium (Whalley and Loach, 1977). Disease outbreaks can be reduced through strict sanitation procedures in the propagation area. If sanitation does not solve the problem, it may be necessary to treat the stock plants with fungicides and/or dilute liquid chlorine bleach one or two days prior to taking cuttings.

CONCLUSIONS

Clearly both air and root zone temperatures have major effects on rooting of cuttings. Higher temperatures will increase respiration of the cuttings, depleting stored reserves, and reduce rooting. If temperatures are low and metabolism is too slow, rooting may be slow with percentages below desired levels. Optimal air temperature will vary depending if cuttings are rooted under sun, shade, humidity tent, mist, or fog. Root zone temperature can be controlled thermostatically through recirculating water systems, heating pads, or heating cables. To obtain the best rooting in the shortest time, it is probably best to maintain the same air temperature that results in optimal growth of the species. A high root zone temperature should be maintained until roots begin to emerge then the temperature should be lowered for best root development.

Acknowledgements. I thank Paul Henry and Carl Huetteman for critical review of this manuscript.

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RAY BLEW: What work have you done with white shade cloth?

JOHN PREECE: I have done none, however, I see more and more growers using it.

BRUCE BRIGGS: We use the white poly with our tissue cultured plants in the summer. It keeps the air cooler. Harvey Tempelton, who was an engineer and published in past Proceedings, published many principles that we are using today. It would be valuable reading to go back and review his work. Dr. Dinkle also published work on temperature and his work is also worth reviewing.

DICK BUR: We did a white vs. black shade cloth comparison in a nursery and found no significant difference when the same percentage of shade was used.

Basics of Propagation by Cuttings: Light

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INTRODUCTION

No one would deny that the amount or type of light reaching a cutting is important to the success of plant propagation. There is ample evidence that light profoundly affects the formation and growth of roots. Why is it then that the level of light, and the sources of light are mentioned so rarely in reports and studies of propagation methods? In the industry it has become a matter of course to provide 50% shade, or to whitewash the propagation greenhouse. Beyond these measures little attention is given to manipulating the light level around the cutting to increase rooting. Not that it is all that difficult to vary the amount of light a cutting receives. Shading in a variety of forms and densities is available from most grower supply firms. Also, easy-to-use light sensors are available that will measure irradiance in footcandles (FC) for as little as $50 to $250. Understandably, however, much of the attention given to light is directed toward its frequent byproduct—heat. Ventilation, mist, fog, and shading all are used to maintain the air temperature in the propagation bench within a reasonable range. In this brief treatment of light and rooting, I will concentrate on several ways by which light interacts with cuttings rooting in the propagation bench.

Light shines in several ways—the strength or level of irradiance, the photoperiod or duration of light exposure on a 24-h time scale, and the spectral quality of light. Each of these factors has been studied on a variety of crops, and each has the potential to affect the initiation and growth of roots on cuttings. The reader who desires a more in-depth discussion of how light affects rooting is directed to several fine treatments published in recent years (Davis, 1988; Hartmann et al., 1992; Loach, 1988; Moe and Andersen, 1988).

HOW LIGHT LEVELS AFFECT ROOTING

Adventitious root formation is a metabolic process, and as such requires energy and is responsive to environmental factors such as water (e.g., irrigation) and temperature (e.g., bottom heating). The energy used in rooting comes from respiration, which in turn relies on supplies of carbohydrate (sugars, starch, etc.) stored in the leaves and stems of the cutting. Remember also that the act of taking a cutting severely wounds the plant stem, and so other metabolic processes besides those leading to rooting figure highly in the energy budget of the cutting, for example, the compartmentation of the wound surface by callusing and formation of wound-response chemicals. Cuttings of some species even continue to grow in the propagation bench, also drawing on stored energy reserves. All of these processes together draw from the one or a few available pools of carbohydrate. Each metabolic process, including root initiation and elongation, competes for energy, and likely is regulated by the extent to which it can commandeer this finite supply. Higher intensities of light have been correlated, in a number of studies, with the production of more roots (Moe and Andersen, 1988). This could be expected if carbohydrate levels were limiting root initiation or the growth of initiated roots. Of course, leafless hardwood cuttings depend entirely upon stored carbohydrates, which may be why winter cuttings of some species, replete with starch and energy stored for spring growth, root better than cuttings taken earlier or later in the year.

Cuttings with leaves intact have the potential advantage of manufacturing new carbohydrates while in the propagation bench. However, their capacity to do so will depend on several factors. One factor common to all leafy cuttings is water stress, a big killer of unrooted cuttings. Cuttings become severely water stressed following harvest from the stock plant, and often remain stressed until new roots form (Grange and Loach, 1983). A consequence of cutting stress is the closure of the stomates, by which further water loss is reduced. Herein lies a problem, however, because while water is being conserved, carbon dioxide, the building block of photosynthesis, is being excluded from the leaf (Davis, 1988). Unable to take up carbon dioxide, the leaves of stressed plants can not photosynthesize very well, and can not benefit from lighting supplied for that purpose. It has been proposed that measures such as overhead mist and fog are beneficial because they reduce cutting stress and permit higher rates of photosynthesis. Rates of photosynthesis typically rebound following the formation of new roots, presumably because water stress in the cutting has been relieved and stomates re-open (Davis, 1988).

Another means of reducing cutting stress is shading. Shading at a level of about 50% is very common in propagation facilities, but the need for shade varies with the crop and time of year. Many propagators focus, understandably, on the foliar heating and water stress that can result from high light levels reaching the propagation bench. This is because, in the short-term, drying of the cutting or burning of the foliage can easily break a production schedule. In his recent treatise on light and rooting, Loach (1988) suggested maintaining lower light levels until roots have formed and then increasing light levels to promote growth of the new root.

Other speakers today have addressed remedies for overheating and water stress. From our perspective, suffice it to say that light and heat are one and the same—energy—differing only in its wavelength. A major influence of light on the leaf is to increase leaf temperature. Heating also is a byproduct of inefficiency in photosynthesis, particularly if the leaf receives more light that it can use—i.e., if photosynthesis is "overdriven." One of the functions of transpiration—the movement of water through plants—is to cool the leaf. Cooling prevents damage to the leaf and preserves the efficiency of photosynthesis. When heating is too great, as under excessive light levels, the ability of transpiration to cool the leaf may be exceeded—resulting in damage. Simply the fact that cuttings are limited in their ability to cool themselves, by taking up and distributing water, is enough reason to reduce light levels in the propagation facility.

In their popular plant propagation textbook, Hartmann, Kester, and Davies (1992) define an optimal light level for rooting leafy cuttings that falls in the range of 20 to 100 W/m^2 (~ 200 to 1000 FC; or between ~ 50% and 95% shade on a sunny day). Below 20 W/m^2, rooting is reduced in a variety of plant species (Loach and Whalley, 1975), probably because photosynthate becomes limiting.

While full sunlight can reach 1000 W/m^2 (~10,000 fc), it is usually less due to the angle of the sun, cloud cover, dust/air pollution, etc. (Loach, 1988). The process of photosynthesis in the leaves of many woody plants saturates in the range of 100 to 500 W/m^2 (~1000 to 5000 fc), or somewhere between 1/10 and 1/2 full sunlight. Photosynthesis in cuttings may saturate at even lower levels because of stomatal closure or a limited "sink" capacity for carbohydrates in the cutting (Loach, 1988). In general, the leaves of herbaceous cuttings can handle higher light levels than those of woody cuttings, because they have a high saturation point for photosynthesis (Larcher, 1980). The compensation point of many plants, i.e, the light level at which the loss of carbohydrates through respiration exceeds the formation of carbohydrates through photosynthesis, lies in the range of 3 to 15 W/m^2 (~30 to 150 fc).

What these numbers tell us is that recommended light levels will generally exceed the light compensation point of the cutting, even when shading is used. This means that some extra carbohydrates will be manufactured which can go towards supporting root initiation and growth. At 100 W/m^2, the high end of recommended light levels, photosynthesis may even be running full tilt for certain species.

Our best shot in manipulating light levels to promote rooting may be to strike a balance between having enough light to yield a net gain in the products of photosynthesis, and maintaining an environment that minimizes cutting stress. In all likelihood the practice of shading with 50% saran shade cloth does this, though we remain ignorant of the actual degree to which we are achieving each of these antagonistic objectives. There would be considerable commercial value in research directed towards measuring the balance of carbohydrate production and cutting water stress. However, there are means of promoting photosynthesis without further stressing the cutting. For example, carbon dioxide enrichment of the atmosphere surrounding the cutting could be used to increase the efficiency of photosynthesis, thereby increasing carbohydrate production and rooting (Moe and Andersen, 1988).

HOW PHOTOPERIOD AFFECTS ROOTING

The length of the day, or more accurately, the length of the night, has long been known to influence plant growth. Photoperiod is routinely manipulated to control the growth and flowering of greenhouse crops, and has been studied in various woody plant propagation systems.

In many plants longer photoperiods promote bud break and shoot growth, and the resulting succulent growth oftentimes roots more easily. Short days (long nights), conversely, reduce shoot growth and stimulate bud set. Woody plants in this semi-hardwood or hardwood stage of growth often are more difficult to root. Longer photoperiods also produce higher levels of carbohydrates and auxins in cuttings—resulting perhaps from longer periods of photosynthesis and more active shoot growth. Some propagators have argued that promoting bud break or shoot growth on cuttings in the propagation bench may reduce rooting by using up stored energy. Indeed, Whitcomb has proposed that shoot growth is favored over root growth in plants having limited supplies of carbohydrates (Whitcomb, 1984). One should be aware also of the antagonism between flowering and rooting, and avoid rooting cuttings under photoperiods that promote flowering or dormancy (Moe and Andersen, 1988).

However, promoting the active growth of rooted cuttings, either in the bench or soon after rooting, may be critical to the overwinter survival of many species. A flush of growth after rooting improves the overwinter survival of cuttings in several genera, including *Acer*, *Betula*, *Cornus*, *Corylopsis*, *Hamamelis*, *Magnolia*, *Rhododendron*, *Stewartia*, and *Viburnum* (Smalley et al., 1987). A long photoperiod or night break is often the key to stimulating this secondary flush of growth. The caution in using this technique is to ensure the new growth is hardened off before winter weather sets in, if liners are to be overwintered out of doors.

It has been suggested that higher carbohydrate levels in roots and stems are responsible for the increased survival and growth of liners that grow on after rooting. Yet, it simply may be a matter of having enough to make it through the winter and meet the demand for carbohydrates when shoot growth resumes in the spring (Loach and Whalley, 1975). Principles of Accelerated Optimal Growth (AOG), which strive to achieve the most growth in the first year of production, also call for long photoperiods (Hanover, 1976). Some AOG systems even go so far as to use 24-h days to keep plants growing.

HOW LIGHT QUALITY AFFECTS ROOTING

The influence of light quality on rooting has received more attention relative to preconditioning stock plants for good rooting, rather than increasing rooting in the propagation bench. Exposing stock plants to blue light and cuttings to red light have both been shown to improve rooting (Hartmann et al. 1993). Using lighting that gives more red than far-red light appears to increase rooting in many greenhouse crops (Moe and Andersen, 1988). Though it is probable that root initiation, like many other plant growth processes, is regulated somehow by red and far-red light through the phytochrome molecule, this is not an easy area of study, varies among species, and may be limited in commercial application.

THE INHIBITION OF ROOTING BY DIRECT LIGHTING OF THE CUTTING BASE

Considerable evidence exists that light directly inhibits root emergence. The most often cited study is that of Shapiro (1958) who used stem cuttings of Lombardy poplar to show that preexisting root initials would not grow out in the presence of light, and that red light was more inhibitory of root emergence than far red light (an implication of involvement by phytochrome), green or blue light. Indeed it is generally accepted that a role of rooting media is to shield the base of the cutting from light (Hartmenn et al., 1992). The direct inhibition of root initiation or elongation is not well understood on the molecular/biochemical level. It has been proposed that light is destroying auxin, changing the ratio of promoting/inhibiting phenolics, activating auxin oxidases or enzymes that conjugate auxin and phenolic compounds, etc. Many biochemical processes kick in when a cutting is separated from its root system. Light also affects numerous events in plant growth and development, from seed germination to flowering. Determining what conditions in the rooting bench are most responsible for the control of root initiation and elongation is beyond our scientific abilities at present. The answer to these questions may lie in the exciting fields of molecular biology and genetic engineering. In the mean time, keep those cuttings cool on top and warm below!

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PETER VERMEULEN: Has any additional work been done on light interruptions of the dark period since the work of Dr. Cathy?

BRIAN MAYNARD: The most recent is by Smalley and Dirr that I am aware of in relationship to restarting growth.

Basics of Propagation by Cuttings—Timing: Age-Related Effects on Adventitious Root Formation

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INTRODUCTION

The observation that some plants have a greater potential to form roots on cuttings was known to the earliest horticulturists and recorded by Theophrastus (300 B.C.). Today, root formation in cuttings can be categorized based on their response to auxin. Cuttings are **easy to root** if application of auxin is not required for rooting. Cuttings can be classified as **difficult to root** if they require auxin to root at high percentages. Finally, cuttings that fail to root even after auxin application are considered **recalcitrant**. In many cases, a species' ability to form roots is modified as an individual plant ages. Species with cuttings that are easy to root are not affected considerably by plant age. However, age-related influences must be considered a major limiting factor for cuttings that are difficult or recalcitrant for rooting.

The basic influence of plant age on root formation can be illustrated in red pine (*Pinus resinosa*) (Gardener, 1929). Red pine is considered a recalcitrant species for rooting. However, Gardener demonstrated that one-year-old seedlings of red pine rooted at 62%. Two- and three-year-old seedlings rooted at less than 10% and in subsequent years, the ability to initiate roots on cuttings was lost. This suggests that rooting potential is linked to the chronological age of the plant.

Unfortunately, the concept of plant age is not as straight forward as this example provided by Gardener for red pine. We must be careful not to bias our view of plant age by our observations of animals as they grow older. Superficially, age is similar in plant and animal systems. Following germination (birth), the individual grows through a juvenile period, then matures to a reproductive stage. The difference is that chronological age (years) does not equal biological age (maturity status) for plant systems. Theoretically, there can be portions of the same plant that contain a juvenile, mature, and a transitional phase at the same time. The chronologically newest portion of a tree is located at the growing tips, while this portion of the tree is biologically oldest. The biologically youngest (juvenile) portion is located at the base of the tree. This is termed the "cone of juvenility" (Hartmann et al., 1990). Therefore a working definition for juvenility is the stage of plant development where the tissue lacks the ability to flower under environmental conditions that normally induce flowering (Hackett, 1985). Also, for many species the ability to form roots on cuttings is inversely related to plant maturity.

With this in mind, it may be more appropriate to illustrate the influence of plant age on the rooting potential of cuttings by the study by Porlingis and Therios (1976) working with olive (*Olea europaea*). They demonstrated that the rooting ability for cuttings decreased as the distance the cutting was taken from the base of the tree increased. Therefore, it was the position on the plant that determined maturity status, rather than simple chronological age. This study also suggests that a cutting taken from a particular position "remembers" its maturity state.

The other important concept about plant age that influences rooting potential is that the stage of plant maturity is reversible (often stably). Methods to induce and/or maintain a juvenile stage of plant development are included in Table 1. The objective of this communication is to illustrate horticultural practices related to plant age that have the greatest potential to influence rooting potential in cuttings. This is not meant to be an exhaustive review of the literature and readers are recommended to the reviews by Hackett (1985, 1988) and the general discussion in Hartmann et al. (1990) for additional references.

Table 1. Methods to induce juvenility.

- Hedging
- Stump sprouts
- Root cuttings
- Tissue culture
- Serial grafting/cutting
- Embryogenesis
- Chemical induction

HEDGING

If shoots that arise from around the base of a tree have the potential to be juvenile, then pruning a plant to induce shoot formation from within the "cone of juvenility" is a logical treatment to maintain a pool of easier-to-root cuttings. This has been demonstrated convincingly for a number of species. Libby et al. (1972) used this technique to hedge radiata pine (*Pinus radiata*). They concluded that hedging arrested the normal decline in rooting potential by rejuvenating cuttings. Subsequent rooted cuttings grew faster and more characteristic of seedlings. They estimated that 100 upright, straight cuttings could be obtained per square meter of hedge. In a similar study, Black (1972) hedged mature Douglas fir (*Pseudotsuga menziesii*) and compared rooting percentages for 24-year-old trees. Cuttings from non-hedged plants rooted at only 5%, while hedged plants produced cuttings that rooted at 45%. Hedging represents the simplest treatment to maintain a large number of cuttings in an apparent juvenile stage of development.

STUMP SPROUTS

Many deciduous tree species have the potential to form adventitious shoots from the stump left after the bole of the tree has been removed. The best evidence that stump sprouts could be a useful technique to produce cuttings with a higher rooting potential comes from work with a 12-year-old American elm (*Ulmus americana*) by Schreiber and Kawase (1975). They showed a 45% increase in rooting for cuttings taken from shoots arising from stumps cut at 0.3 mm above the ground.

ROOT CUTTINGS

It is generally assumed that roots do not proceed through a maturation period and remain in a juvenile state. Stoutmeyer (1937), in a classic paper, made the observation that shoots arising naturally as root suckers on crabapple had the morphological characteristics of seedings. He demonstrated that root cuttings could be taken from mature crabapple trees and that the shoots arising from these root cuttings had a high rooting potential when taken as softwood cuttings. Robinson and Schwabe (1977) recorded a similar response in a difficult-to-root apple (*Malus* 'Lord Lambourne') but also observed that the rooted cuttings flowered in only two years following propagation. The combination of root cuttings to induce a juvenile state and hedging to maintain juvenility offers an attractive opportunity to produce a stock block with a high number of easy-to-root cuttings.

TISSUE CULTURE

The final technique with the potential to commercially alter the rooting ability of a large number of cuttings is through shoots regenerated in tissue culture. It has been documented many times that microcuttings have a higher rooting ability compared to the parent plant. Sriskandarajah et al. (1982) showed that the rooting ability in microcuttings of apple increased with increased time and subculturing in tissue culture. Additional morphological changes (i.e., leaf shape) associated with juvenility have also been observed in tissue culture. Commercial growers have found that some plants derived from tissue culture maintain a high rooting capacity as young liners. This enables growers to successfully root a crop of softwood cuttings harvested from these liners. Struve and Lineberger (1988) demonstrated that softwood cuttings of birch (*Betula papyrifera*) derived from micropropagated liners rooted at a high percentage (75%) similar to seedlings. Apparently, in a situation similar to root cuttings, micropropagated plants can attain a mature state (flowering) faster than would be expected for seedlings (Hackett, 1985). This suggests that the high rooting potential of micropropagated plants would be lost quickly in a stock block unless a technique to retain juvenility (i.e., hedging) was employed.

BIOLOGICAL VS. SEASONAL AGE

An additional factor related to age is demonstrated by species that are easy-to-root during one part of the year and difficult or recalcitrant for rooting at other seasons of the year. This well-documented phenomenon drives the cutting production cycle in all commercial nurseries. Some species show a dramatically short seasonal window for rooting. Stoutmeyer (1942) demonstrated that *Chionanthus retusus* would only root during a 2-week period in the spring. Lamphear and Meahl (in Hartmann and Kester, 1983) showed convincingly that andorra juniper cuttings rooted at higher percentages from November to April compared to summer cuttage.

Seasonal differences observed for root formation in cuttings is not well understood and probably involve a complex association between environmental and physiological factors including nutrition, carbon to nitrogen ratio, and anatomical changes in the stem. Recently, Blakesley et al. (1991) working with *Cotinus* cuttings suggested that seasonal changes in plant hormones could be an important factor contributing to seasonal rooting in this species. They found that the IAA to ABA ratio was inversely related to rooting ability with higher auxin ratios favoring rooting.

CONCLUSIONS

Root formation in cuttings is a complex, integrated phenomenon responsive to environmental, nutritional, and physiological factors. For some species, age-related effects can be the major factor limiting successful root formation in cuttings. Many of the horticultural treatments employed by propagators have taken advantage of the plastic nature of plant age. However, our understanding of plant maturation at the biochemical and molecular level is only beginning. Advances in our understanding of maturation holds the potential to provide a chemical or genetic basis to further manipulate plants to produce cuttings that are easy-to-root.

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VOICE: A comment on the use of plastic right on top of the cuttings for rooting. We have had real good success, especially with the ground covers that root in 3 to 4 weeks. We lay 50% white poly right on top of the cuttings that are under 55% shade. This procedure allows us to use houses that do not have mist, and we do not have to move the plants around.

PETER ORUM: A word of warning. You need to know how much light you have or you can burn up the cuttings. You need a lot of clouds as they have in northern Europe or additional shade to be successful.

The morning session was reconvened at 10:30 a.m. with Dr. Deborah D. McCown serving as moderator.

Using Compost on Liner Beds

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We all know that organic matter improves soil. There are several materials we can use to accomplish this. Manure, cover crops, leaves, peat, and nursery and yard waste are examples. More recently in several areas of the country, commercially composted materials have become available. These come in the form of composted yard waste, municipal sludge, and even municipal garbage. Getting enough organic matter to replenish our soils is a continuing problem and looking into these composted alternative sources became a reality over 3 years ago when we started testing the use of composted municipal sludge from the city of Akron, Ohio.

As we looked into the use of composted material we found some interesting facts. The composting process ensures that nutrients normally lost through leaching from uncomposted materials will be retained due to their altered chemical state in mature composts. We also found that applying composted material to our fields gives us a far greater amount of organic matter than if we were to use uncomposted raw materials. In fact, composted material can deliver 10 to 20 times the organic matter that will be found in raw material. For example, a cover crop such as Sudan grass can give us about 10 tons of material per acre. This is good except that 90% of it is water leaving only 1 ton of dry material as a potential soil amendment. After the crop is plowed under and decomposes another 50% is lost reducing the amount of material to 1/2 ton. If only half this material is organic, we are left with only a 1/4 ton per acre of organic material. By comparison, applying 1-in. compost per acre gives us about 62 tons of material. If 30% of the compost is water, that leaves 43 tons of dry matter per acre. If the material is 70% organic this provides 30 tons of organic material per acre (Tyler, 1991).

The most obvious benefit of composted organic material is its ability to break up clay soils and add moisture retention to sandy soils. Other benefits include a source of nutrients, improved cation exchange (CEC), disease suppression, and the enhancement of healthy soil microflora to name a few.

We found an initial application of 2-in. compost per acre would be the most beneficial to amend our fairly heavy soils for bed production (refer to Table 1 for application rates). We accomplished this by applying 1 in. of material to the area with a manure spreader and working it into the top 4 to 5 in. of soil with a rototiller. We shaped our beds with a bed maker and planted them. After planting, we applied another 1 inch of material as a mulch. After harvesting the beds, we cover crop the area when possible and start the process over again. After the first planting we do not add the initial 1 in. to the area, but simply mulch the new beds as a supplement to the organic matter already present.

Since we have begun using the compost we have noticed a significant change in our soil composition and significant improvement in certain crops such as ornamental grasses and *Buxus*.

Not all commercial composts are created equal. Know your source and the composition of the material you are going to try. Maturity is important, the compost should be stable, and consistent from batch to batch. Organic content can vary with the source, ranging from 30% to 75%. Be aware that potential variables between composts exist and ask for test results that can show if heavy metals or other inert contaminants such as glass, metal or plastics are present and that EPA guidelines for eradicating pathogens have been followed. Watch for safe levels of soluble salts. The pH should be between 6 and 8.

Table 1. Cubic yards of compost required for various depths of compost desired.

Area	Inches of compost to be applied[1]				
(ft^2)	1/4	1/2	1	1.5	2
5000	4	8	16	24	31
10,000	8	16	32	48	62
15,000	12	24	48	72	93
20,000	16	32	64	96	123
25,000	20	40	80	120	154
30,000	24	48	96	144	185
35,000	28	56	112	168	216
40,000	32	64	128	192	246
Acres	1/4	1/2	1	1.5	2
1	33.5	67	134	201	268
2	67	134	268	402	536
3	100.5	201	402	606	804
4	134	268	536	804	1072
5	167.5	335	670	1005	1340
6	201	402	804	1206	1608
7	234.5	469	938	1407	1876
8	268	536	1072	1608	2144
9	301.5	603	1206	1809	2412
10	335	670	1340	2010	2680

[1] Suggested amounts of compost for liner beds. Numbers indicate cubic yards of compost; for instance, applying a 1-in. layer of compost to a 5000 ft^2 area requires 16 yd^3 of compost. Applying 1 in. to an acre requires 134 cubic yards (Tyler, 1993).

The initial cost of the material and application can seem high—about 1 to 2 thousand dollars per acre—but the results have been obvious to us and well worth the investment especially where high intensity crops are produced.

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Important Considerations for an Arboretum Propagator

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When one considers what is unique about an arboretum, the wide array of interesting plants quickly comes to mind. These plants are often unusual or very rare—frequently they are magnificent old specimens with a character all their own. Although the types of plants being grown and tested at an arboretum may vary with the institution's mission or region of the country, displaying a wide diversity of plants is central to most.

Because of the richness and diversity of arboretum collections, the propagation and production of these plants frequently present special challenges to the propagator. In many ways, propagating plants at an arboretum is unique. The work is:

- Highly diversified: a large variety of different plants are grown, although the number of plants per lot is typically rather small.
- Specialized: often plants are unique or rare, possessing unusual characteristics, such as variegated foliage or dwarfness.
- Challenging: often stock plants are aged and frequently in a declining condition; seeds may vary significantly in their trueness-to-type and viability.

Some of these challenges may also be encountered by the commercial nursery propagator who grows "specialty" plants. The purpose of this paper is to highlight the unique characteristics of arboretum plant propagation and production, and propose methodologies and practical solutions to help the propagator to be more successful.

DIVERSITY OF PLANTS

Diversity is both a blessing and a curse of propagating at an arboretum. Growing a wide variety leads to professional enrichment, but it also leads to an array of challenges and hurdles to overcome. Using The Morton Arboretum as an example, in the production facilities we are currently growing 152 different genera and 504 different species, varieties, and cultivars of woody plants. This breakdown is probably typical of many arboreta.

One of the challenges presented by this diversity is that, because of space limitations, plants that have different cultural requirements, e.g., watering frequency and type of potting media, must be grown close to one another. To be successful the propagator must be keenly observant; it is particularly important to understand the conditions under which the plant thrives and the conditions under which the plant fails. The failures can be the most telling and educational—make special note of what treatment did not work. Try not to make the same mistake twice!! (The cause of failure in production may also be helpful information to be used when the successfully propagated plant is sited in the collections).

Another important culture-related challenge is associated with their use of pesticides. Plants vary significantly in the tolerances to pesticide exposure.

Extreme caution is needed when trying a pesticide for the first time. Read the label carefully and search for warnings regarding the potential for phytotoxicity. Legal application of a pesticide requires that either the plant name must be included on the label, or the pesticide must be labeled for the particular insect, mite, disease, or weed to be controlled. Very few of the plants grown at arboreta are listed on pesticide labels. As a result, the problem to be controlled is usually the basis for which a particular pesticide is selected. Consider spraying a small number of different plants to get a "reading" on the potential for the pesticide to be phytotoxic. Several of the trifoliate maples, e.g.,*Acer griseum* and *A. triflorum*, have proven to be highly sensitive to miticides. In considering insecticides and miticides specifically, the new flowable formulations have proven to be much safer than either wettable powders or emulsifiable concentrates.

SPECIALIZED—RARE/UNIQUE PLANTS

One of the challenges of growing rare/unique plants is that their propagation methods have not been well documented, or in fact, have not yet been determined. This is a special (and often interesting) challenge to the propagator. To be successful there are several avenues that should be pursued. First, one should review the literature that addresses the propagation of specific plants such as *The Reference Manual of Woody Plant Propagation* (Dirr and Heuser 1987), and the *Combined Proceedings* of the International Plant Propagators' Society. In the 42-year history of the Society, it is likely that plants related to the plant being investigated have been propagated.

It is important to keep accurate and thorough records of each propagation attempt. Record both successful and unsuccessful treatments. These records will eventually become an important source of information. Studying the unsuccessful treatments may help to determine which other treatments should be tried.

Botanical relationships can be a particularly useful aid in understanding what propagation methods to use. Oftentimes, related plants have similar requirements. The *Manual of Cultivated Trees and Shrubs* by Alfred Rehder (1990) is particularly useful in reviewing and understanding botanical relationships. For example, the seeds of cold-temperate members in the olive family (Oleaceae) such as *Chionanthus*, *Fraxinus*, and *Syringa* require warm stratification, followed by cold stratification, before they will germinate. The legendary Alfred Fordham, former propagator of the Arnold Arboretum, frequently took this approach—studying common propagation requirements of a family or genus for clues to the treatments required for a certain species. Studying taxonomic literature can also be helpful in determining which rootstock might be compatible with a rare plant being grafted. Generally, the closer the plants are genetically linked, the more likely they can be successfully grafted.

To be successful in propagating unique plants (e.g., plants bearing an unusual form, foliage type, or color), the propagator needs to have a good knowledge of the plant being propagated. It is important to be able to recognize the "true" plant from a mutation or reversion. This is particularly important for dwarf conifers; these plants are frequently known to produce branches that revert back to the parent-type. If one is not an astute observer, a more vigorous reversion, for example, one which produces more scion or cutting growth, could "replace" the original cultivar selection.

Other unique plant characteristics need special attention; these include leaf variegations and the physiological property of topophysis. Understanding the basis of the variegation can be critical in producing offspring that are true-to-type. For example, the leaf variegation of *Weigela florida* 'Aureo variegata', is successfully reproduced when the propagation method includes terminal and axillary buds, such as with stem cuttings. Methods that involve adventitious bud formation, such as root cuttings or some micropropagation techniques, may result in plants that are not true-to-type.

Topophysis is the inherent characteristic of a propagule to continue to grow in the same orientation as the branch from which it was taken. This problem has long been recognized by propagators—first being described in 1904. The practical implication of this is that a plant which is rooted or grafted onto a seedling rootstock will continue growing in the same orientation in which it was positioned before being propagated. It is particularly common in gymnosperms (e.g., *Ginkgo*, *Picea*, *Pinus*, and *Taxus*), but has also been recognized in some angiosperms, such as cultivars with a columnar or fastigiate growth form. We have experienced form differences based on the original position of the cutting on propagules of *Alnus glutinosa* 'Pyramidalis'. Only the cuttings from the very top produced fastigiate plants resembling the parent. The propagator should recognize which plants might express topophysis and be prepared to manage it. For some plants, staking young grafted plants may solve the problem; with others care may be needed to select cuttings or scions from vertically oriented shoots.

AGED AND DECLINING PLANTS

Often the most important plants for an arboretum propagator to produce are those that are aged; unfortunately, these plants may often be in a state of decline. Propagating plants of this type presents special problems. While seed may be the easiest method, it may not be a viable option due to the possibility for hybridization to occur. This will be discussed in greater detail later. To preserve genetically identical plants, asexual propagation methods, i.e., cutting and grafting, are required. Incompatibility is a potential problem with grafting, particularly since the plant being propagated may be uncommon, and its compatibility with various rootstocks may not be well understood. Also, from a "purist" standpoint, the resulting plant is not a true clone because it is growing on a genetically different root system. Ideally, the plant would be propagated via cuttings (either traditional methods or micropropagated) to produce an identical plant.

With most woody plants, particularly trees, cuttings from older specimens are significantly more difficult to root than cuttings from young plants. Entire books have been written on the biological basis of this phenomenon. As a plant "matures" it is believed that cellular and hormonal changes occur. These changes are described as the transition from the juvenile growth phase to the mature growth phase. Morphological changes, decreased rootability of cuttings, and the ability to flower and fruit are signals of this growth phase transition.

To be successful the propagator must be able to recognize and select cuttings in the juvenile growth phase, and also know how to rejuvenate a mature plant, thus allowing it to be successfully propagated. Selecting juvenile cuttings requires care—it may involve taking cuttings from near the base of a plant that shows a juvenile leaf form and does not flower. Different leaf forms of juvenile and mature plants are frequently observed on *Euonymus fortunei* and *Hedera helix*. Selecting juvenile cuttings may involve collecting material from root suckers (as long as the plant was not grafted) or water sprouts. These have proven to root more readily.

The importance of juvenility has been recognized for years. Many commercial propagators maintain hedged stock blocks or drastically cut back a plant to help maintain or reintroduce juvenility; an arboretum propagator usually does not have this option. Often the parent tree or shrub is the only specimen; it cannot be destroyed or significantly altered.

One method that has proven successful in propagating own-root older and declining plants is serial grafting. This involves grafting the desired plant onto a seedling rootstock and testing the subsequent new plant for its rootability. If it does not root satisfactorily, then scions of the new grafted plant are collected and again grafted onto seedling rootstocks. This process is continued until success is achieved. Although this procedure may require several trials and take several years to be successful, it does preserve the genetic material of the parent tree while the attempts are proceeding. Serial grafting has been used successfully at The Morton Arboretum with old specimens of *Malus* and *Magnolia*.

SEED—THE IMPORTANCE OF SOURCE

Seeds are received through several different avenues. These include collecting trips to natural areas; collecting from arboretum collections; and seed exchange with other arboreta. (The seeds may be collected in their collections or in natural areas.) Where the seeds were collected is important. When seeds are collected in cultivated collections, there is an increased chance that hybridization may have occurred. Hybridization may be positive if new genetic combinations are desired, but it is undesirable if true-to-type plants are desired. Plant genera with only one species (monotypic genera), such as *Abeliophyllum*, *Cryptomeria*, *Ginkgo*, and *Oxydendrum*, can be grown from arboretum-collected seeds because the chance of hybridization is remote. In our experience, arboretum-collected seeds have resulted in hybrid offspring with the following genera: *Acer*, *Corylus*, *Crataegus*, *Fraxinus*, *Gleditsia*, *Malus*, *Morus*, *Populus*, *Pyrus*, *Quercus*, and *Tilia*.

The freshness of seeds is also very important. Although the seed viability percentage may vary with type of plant or particular year, some degree of success is usually achieved when the seeds are collected fresh and then cleaned, stored, and handled properly. With seeds received from exchanges, the success rate can be much more variable and is often species or genus specific. With some genera, e.g., *Aesculus* and *Quercus*, it is unusual to receive viable seeds from Europe or Asia. For other plants, such as *Acer*, *Crataegus*, *Cotoneaster*, and *Tilia,* there is often a "deeper" dormancy that may require two or three years to overcome. This "deeper" dormancy may be due to severe dehydration or other improper storage condition.

Because of reduced viability and the long period required to determine if the seed will germinate, many seed lots may be needed before the plant is successfully acquired.

IN CONCLUSION

Due to the diversity, uniqueness, and age of many plants produced by an arboretum propagator, special considerations are necessary. To be successful the staff must be knowledgeable and interested in learning more about plants. They also must be highly organized and possess strong observational skills. Propagating plants at an arboretum is as unique as the plants in its collections.

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Fern Propagation from Spores

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I was born in Western Canada and moved to the states and established a nursery in western Tennessee, about 40 miles northeast of Memphis. My facilities include 155 polyhouses, all 20 ft × 96 ft. Most polyhouses have 5 ft side walls. Six houses are gutter-connected greenhouses with Ambirad radiant heat, fertilizer injectors, raised benches, cool cell pads, and cooling fans. This is where we start the ferns from spores. We also have 40 propagation houses without heat—we move the ferns into this area after being potted into 2-1/4-in. rose pots.

Ferns are easy to grow and they are profitable. This year the theme for the I.P.P.S. is back to basics. There is not much more basic than growing ferns from spores. There are many good fern books available which list more taxa than you will care to grow. Edgar T. Wherry, Ph.D. , Professor of Botany, Emeritus, University of Pennsylvania put together a very fine book on ferns which I often use. Most books have a couple of paragraphs telling how to propagate ferns from spores.

We have stock blocks for fern spores just as we have stock blocks for *Spiraea japonica* 'Little Princess' or *Euonymus alatus* 'Compactus'. The fern stock blocks are located in a heavily wooded area of deciduous trees. I have planted from 10 to perhaps 100 of about 20 types of ferns that I am interested in propagating.

Depending on fern species, fern spores are ready to pick from late May to early autumn. The exact time of a particular species varies with each year. I walk through the stock blocks and watch for when the spores are about ready to pick. When I think the spores are ready, I will pick a tip with 2 or 3 spore cases on it, take it to the office, and put it on a white piece of paper. If spores are dropping the next day, then we start picking leaves of that particular type of fern. We pick large quantities of fronds and place them immediately on a white, 8-1/2 in. × 11 in. sheet of typing paper that has been creased down the middle. We then spread these papers out so they touch edge-to-edge on the office floor where the wind, heat, or air conditioning will not blow them away. Usually within 48 h, all of the spores have dropped that will drop. Then we remove the old fronds, gently tap the spores to the crease in the middle of the paper, and tap the spores into a black film canister like 35-mm slide film comes in. We type the name and date the fern was picked and tape this to the black canister. The canisters are stored in the refrigerator. I have used fern spores as old as 6 or 7 years and had very good results.

We use 1020 flats without holes in the bottom, place one inch of Metro Mix in each, and carefully shake spores from the end of a small plant stake. The soil is barely covered with spores—perhaps like putting pepper on mashed potatoes. Then lightly mist—like a "dew"—the spores with non-chlorinated water applied with a spray bottle. The spores produce male and female haploid structures and the moisture allows them to "swim" together and pollinate. The flats are covered with clear plastic domes. The tops and bottoms are ordered from A.H. Hummert Seed Co. in St. Louis.

When the small ferns are 1/2 to 3/4 of an inch tall, it is time to slowly prick them out and replant in a 288-plug tray. We also use Metro Mix in the plug trays. The ferns remain in the plug trays for 2 to 4 months. We apply Peters 20-10-20 fertilizer at 100 ppm through an injector system when the ferns are growing in the 288-plug trays. From the plug tray we transplant to a 2-1/4-in. rose pot in June or July. At this stage the potted ferns are moved from heated to unheated houses. They remain in the unheated houses until they are finished and sold or transplanted into a 1-gal container.

From the 2-1/4-in. pot liner to a 1-gal container in late spring you will have a very well established fern in 4 months.

Our gallon container mix is 9 pine bark (screened to 1/4- to 3/8-in. pieces): 1 red sand (v/v). We mix 10 yards at a time and add 50 lb of Sta-green prostart with minors and 50 lb agricultural lime.

Ferns are profitable for me to grow. I have figured my cost at 38¢ to produce each fern to the finished 2-1/4-in. pot. If you want to be friendly with a group of plants, then be in the friendship business with ferns.

PETER VERMEULEN: What do you mean by low temperatures, and what is the minimum you would go to?

KENNETH O'DELL: The houses can freeze. I imagine that they could go to zero degrees. We are interested in keeping the plants dormant when we ship in the spring so we want them to remain cold.

VOICE: What is the time to a salable plant from the time you put that spore into the flat until you have a salable plant? We can produce a 2-1/4-in. potted liner in 8 to 9 months. We start the germination of the spores at 55F in a greenhouse after the pointsettia crop is finished.

SUNDAY MORNING 5 DECEMBER 1993

The morning session was convened at 8:00 a.m. with Dan Studebaker serving as moderator

Side Shearing to Increase Shade Tree Quality

James Peckosh
A. McGill & Son, P.O. Box 70, Fairview, Oregon 97024

E.B. Gee, III
Heartland Nursery, 311 Main Street, New Madrid, Missouri 63869

In the spring of 1988 a box of 500, 3-in. tall, tissue-cultured trees—two hundred fifty each of *Acer platanoides* 'Crimson King' and *A. rubrum* 'Autumn Flame'—was purchased from A. McGill & Son and split between James Peckosh and E.B Gee, lll.

Because of the limited space, James Peckosh planted his trees in root-control fabric containers, side by side. His trees grew very fast in height ad became whippy and top heavy. To reduce top weight, and avoid having to stake the trees, he sheared the side branches back to two sets of leaves. The tops were never cut back. The results were enhanced stem taper, increased caliper, increased overall growth, and elimination of staking.

E.B. Gee's trees were grown in a more conventional manner. He planted his trees 4 ft apart and 10 ft between rows. The trees that were side sheared were twice as large in 2 years as those that were not. Both groups were watered and fertilized in the same manner. Heartland Nursery has successfully used this technique of pruning since the spring of 1989 on the following trees: *Acer palmatum, A. palmatum* 'Oshu-beni', *A. platanoides* cultivars, *A. rubrum* cultivars, *Cercis canadensis* cultivars, *Malus* culitvars, *Nyssa sylvatica*, *Prunus* cultivars, *Pyrus calleryana* cultivars, and *Quercus* species.

Heartland Nursery prunes once in mid-May, once in mid-June, and once in January.

How We Root *Taxus baccata* 'Repandens'

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Over the past 25 years we have successfully rooted *Taxus* × *media* cultivars. However, *T. baccata* 'Repandens' has been a real challenge for us. We were producing inconsistent numbers from year to year and never caught up with our production or marketing goals, which have been on the increase.

Taxus baccata 'Repandens' is a consistent performer not only for the grower, but the landscaper and owner as well. Even though not extremely cold tolerant, it is shade and drought tolerant, and is one of the finest low-growing taxus for the landscape. We like growing this plant in the field to its perfect form.

For about the last 3 years we have made a switch from raised benches with bottom heat, to ground beds with root-zone heat. We have been very pleased with this change for our hardwood production. Along with our *T.* × *media* production, our *T. baccata* 'Repandens' were included in our new rooting beds.

Timing and Preparation. After several hard frosts, usually between November and December in our area, cuttings are taken and collected into poly bags and stored at 35 to 40F. Handwork includes removal of 3 to 4 in. of green from the stem, bottoms recut, and tops trimmed for uniformity. We then place cuttings in plastic lined flats in preparation for sticking.

Hormone. Prior to sticking we use Woods Rooting Compound 1% IBA, dilute (1 : 5, v/v) with water, as a 2-sec dip.

Rooting Environment. Our propagation houses are 16 ft × 100 ft and covered with 4-mil clear poly. We try to shade sometime after April 1st and water only as needed for a damp, dry environment. The ground beds are 42 in. wide and 8 in. deep, and are filled with #300 concrete sand. Temperature is kept at 60 to 65F and may be lowered to 55 to 60F after callusing. The heat is provided by circulating water from a 50-gal water heater (50,000 btu) with a circulating pump controlled by a remote bulb thermostat. Pipes are 1/2 in. PVC spaced 6 in. apart and 8 in. under the medium.

Comments. As noted previously, with our old raised bench method, we targeted May as our planting date for lining out our cuttings into field beds. But, our *T. baccata* 'Repandens' never seemed to be ready. We felt there were many pre-finished cuttings not suitable for open field production.

As our *T. baccata* 'Repandens' progressed in our new production beds, we were pleased to observe earlier callousing on all cuttings—usually after 3 weeks, and when rooting progressed—full root development.

Even though this new process missed our May planting schedule, we had increased our rooting to the 85% to 90% range from about 60%. So we are now using a fall planting schedule for all taxus—not only for a bit less to do in May, our busiest month, but to further develop the roots and tops.

We are also taking a closer look at a small cross section of *T. baccata* 'Repandens' we rooted with reduced amounts or no added rooting hormone. This avenue showed great potential for expanded work in the current year's crop of taxus cuttings.

This combination of new and old have helped us to produce some of the nicest 2 and 3 year *T. baccata* 'Repandens' liners. Along with them, we have higher quality plants for our other taxus production.

Sexual Propagation of *Taxus cuspidata* 'Capitata'

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INTRODUCTION

The typical form of *Taxus cuspidata* now has the cultivar name of 'Capitata'. The species is indigenous to Japan (four islands), Korea, and Manchuria. Many nurseries propagate this cultivar sexually for two basic reasons. First, unless upright terminal cutting wood is used the progeny will maintain the same growth habit as if they were attached to the mother plant. Secondly, a cutting-grown *T.cuspidata* 'Capitata' does not have the full basal branching that one observes in a seedling-grown plant. Therefore at Zelenka Nursery, Inc. all *T.cuspidata* 'Capitata' is sexually propagated.

The frustrations in sexual propagation of *T.cuspidata* 'Capitata' are sporadic germination, and poor quality in seedling height and caliper. We shall share with you seed source, stratification, culture, and transplanting practices.

SEED PROPAGATION

The manual, "Seeds of Woody Plants in the United States" (Schopmeyer, 1974) recommends stratifying 90 to 210 days at 60F and follow with 60 to 120 days at 36 to 41F. I have used this practice with more negative results than positive. Dirr and Heuser (1987) suggest 4-months warm stratification followed by 4-months cold, or 8-months to 1-year warm followed by 3 months of cold. Their first recommendation will not provide economic germination. The frustration is finding seeds germinating in a 3-0 seed bed. That seedling is worthless!

Our seed source is a seed brokerage company in Japan. We have the seed shipped to arrive prior to March 1 (mid-February). We stratify upon arrival, using equal parts of sand to seed, in an outside stratification box for 12 months. We think this is the key for uniformity in germination. We remove the seed after stratification and wash the sand away from the seed on screens. The seed is then sown in well-drained, ground beds, in 100-ft poly houses. These houses are covered with 55% white poly until early June at which time we remove the poly and cover the house with 55% Saran shade cloth. We sow 75 pounds of seed per 2000 sq ft of seed beds. Doors are closed to provide high temperatures and humidity during germination.

CULTURE

Regarding culture, we water by hand because this genus is extremely sensitive to over-watering. Our normal preventative fungicide program is employed, and insecticides are used when needed for grub control. After germination, 6 to 8 weeks after sowing, we apply liquid fertilizer (10-52-10) at the rate of 3 lb/100 gal. The last feeding is in October. The major weed problems we encounter are the mosses, and we have used Goal 2E at one-half label rate. It has done a satisfactory job. This herbicide can only be applied after the removal of the poly. This is important!

TRANSPLANTING PRACTICES

After three years in the seed beds, the plants are harvested and graded. At grading, any one-year seedlings and "J" rooted plants are culled. At our seed bed density we are producing 1500 to 2000 seedlings per pound of stratified seed. The graded seedlings are then transplanted in nine-row beds at our liner farms for three additional years. In August of the second transplant year (now 3-2), all beds are root pruned vertically and horizontally with a Fobro root pruner. Culture at the liner farms is similar to the seed beds with respect to the greenhouse pesticide program, however irrigation is via overhead sprinkler heads. Once again, it is mandatory that we utilize well drained transplant beds.

After three years in the transplant bed the plants (now 3-3), are harvested in the spring and planted into the field, at a 44-in. spacing between rows and 18 in. in the row. This yields 8000 plants per acre. Up to this point the plants have not been top pruned. After the second year in the field, the plants are hand sheared annually the first two weeks in August. After 4 years in the field, the plants are now 10 years old from seed. We start field harvesting 12/15 in. and a few 15/18 in. plants.

IN REVIEW

- Seed shipped direct from Japan.
- Seed stratified for 12 months in sand, outside.
- Seed sown, ground beds, in houses poly covered from November to May. Saran covered June to October. Held for 3 years (3-0).
- Seedlings transplanted for 3 years (3-3).
- Transplants to the field for 4 to 7 years (10 to 13 years from seed).
- No top pruning as a seedling or transplant. Field-grown plants pruned by hand annually during the first 2 weeks of August.

In reviewing the literature, Tony and I found over 15 references regarding this cultivar. The earliest found in our beloved Proceedings was 1954. After almost 40 years, we all are constantly seeking and sharing!

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Rooting Second-Generation *Syringa vulgaris* Cultivar Microcutting

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Rooting second-generation microcuttings means taking a cutting off a rooted microcutting that was produced by tissue culture and rooting that cutting.

The rooting of second-generation microcuttings of *Syringa vulgaris* culitvars is just an additonal means of propagation for us when we have shortages of certain cultivars. We do not count on it yet as a major means of propagation.

We began rooting tissue-cultured cuttings a few years back. Through a little trial and error and help we developed a simple system for rooting these cuttings. We treat the second-generation cuttings the same as the microcuttings we get from the tissue culture lab.

Currently we are sticking all of our microcuttings in a Techniculture tray. This tray is a 12-1/2 in. × 12-1/2 in. × 1-1/8 in. styrofoam tray that holds 400 plugs. The plugs are made from peat with a polymer holding the peat together. We do not use rooting hormone on any of our microcuttings. Once a tray is planted, it is covered with a clear plastic dome. Planted flats are placed on a cart that has overhead lighting. The cuttings receive 16 h of light per day. The carts are put in a small poly chamber where we keep the temperature around 70F. The cuttings are hand misted three times a day for about a week and then weaned off the mist. After about 2 weeks they receive no mist. We usually start seeing roots after 7 to 10 days.

A liquid fertilizer program with 100 ppm of a 20-10-20 balanced fertilizer is started after about 3 weeks. Whenever the cuttings need water, we liquid fertilize.

After about 5 to 6 weeks the first generation microshoots have enough growth on them and we start taking cuttings. The cuttings are about 1 in. long when we start cutting. After all the cuttings are taken we move the flats of rooted cuttings to the greenhouse where they are acclimated to greenhouse conditions for a few days. The rooted cuttings are then transplanted and grown on in the greenhouse until they are planted in the field or put in cold storage for spring planting

We are now also taking third-generation cuttings and rooting them. All of our second- and third-generation cuttings are taken from rooted cuttings that are still in our rooting chamber—not in the greenhouse.

Fog and Air Circulation Techniques to propagate *Aesculus parviflora* and Trifoliate Maples

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INTRODUCTION

In the 6 years that our firm has worked with fog propagation, we have undergone a metamorphosis of technologies and techniques. A short explanation of our present system should clarify the factors necessary for the propagation of these very desirable plants—*Aesculus parviflora* and trifoliate maples.

PROPAGATION ENVIRONMENT AND FOG SOURCE

Our present production greenhouses are 30 ft × 60 ft and have a 14 ft height. We find the height extremely important in controlling temperature. It allows the heat to rise away from the cuttings and allows us to maintain the desired humidity within the lower 6 ft of the house. The temperature is often 8 to 10F cooler at the cutting height. The houses are covered with a white 3-year poly as well as a white shade tarp. The white 45% shade lowers our house temperature 5F at the cuttings height when compared to the same 45% shade provided by black shade cloth. These few degrees can become crucial when ambient air temperatures reach 89F and above. At such temperatures, maintaining the desired level of fog becomes difficult if not impossible. Our combined shading equals 70%+ of available sunlight. Many fellow nurserymen have commented that this is "near coal mine conditions". A quick check of propagation references (Dirr and Heuser, 1987) shows that cuttings which are 100% efficient in photosynthesis can use only 10% of the available sunlight at any given time. I have found that the direct rooting of difficult genera in a peat-based soil medium is challenging enough without teaching the cuttings to swim the back stroke due to over watering.

The houses contain a standard mist system using Naan Irrigation, Cerritos, California 327112 nozzles supplying 0.33 gpm at 55 psi water pressure. I should note that a mist system is required to cool the cuttings during hot weather because the fog supplies humidity without large water droplets which can settle from the air. A true fog type propagation system should never be considered a stand alone means for rooting cuttings. A standard time clock is used to deliver 8 to 10 sec of mist every hour from 11 a.m. to 3 p.m. during the propagation period. Our first notion was to utilize a fog system which was both economical and workable with our poor water quality. Although we have a plentiful water source our iron content can exceed 9 ppm. This prohibits any fog system utilizing fine nozzles which would wear excessively without expensive water treatment prior to use. Our experience with the Humidifan by Jaybird Inc., Centre Hall, Pennsylvania, has been good, although the early models exhibited excessive water fallout and wet zones near the fans. We did notice excellent results in temperature control and reduced disease problems due to the high amount of air movement as noted by Milbocker (1980, 1983). Although not inexpensive, the fans and oscillators supply superior fog movement and air mixing in conjunction with a our present fog nozzle.

Our present fog source is the AIRJET fogging nozzle produced by Spraying Systems, Wheaton, Illinois. The nozzle produces 3.1 gph of atomized water when supplied with 60 psi water pressure and 2.2 scfm of air at 35 psi. The fog droplets are produced by the shearing action of the air source against the water and do not utilize high pressure or fine nozzles as other systems do. The initial recommendations we followed were to use a nozzle for each 130 ft^2 of greenhouse space to be humidified. Sets of nozzles need to be zoned so that the volume of air required can be economically supplied. Although the system utilizes low pressure, a high volume air source is necessary. A 30 ft × 80 ft house as described previously can be operated by a single stage 2-hp compressor which will run almost constantly. This constant load will be a strain on the compressor, although the lack of on-off cycling will enhance the life of the electric motor. Large compressor units of high horse power as well as direct drive units are not recommended for this reason. A large volume storage tank of 100 gal+ will eliminate surging in the air supply. A second compressor, as a back up, will eliminate propagator anxiety.

The fog is controlled by a time clock opening the valves feeding both air and water at the same time. A humidistat was used at first but was found to keep the cuttings to "happy". During our first attempts we were throwing out cuttings with 2 to 3 in. of new growth and no rooting. I feel a slightly stressed cutting roots faster and better than our first pampered attempts. Humidity is controlled at about 75% to 80% from 9 a.m. to 7 p.m. during propagation. The fog is increased as flagging becomes apparent with a normal 85F sunny day clock setting of 2 min on time per 8 min. The houses are not vented and the humidifans are on to circulate air within the house during all daylight hours and 45 min to 1 h after dusk.

PLANTS UNDER PRODUCTION AND PROPAGATION PROCEDURE

Aesculus parviflora
A. parviflora f. *serotina*
A. parviflora 'Rogers'

Timing: Cuttings taken 5 June to 4 July (Chicago) when there is 10 in. to 2 ft of new growth on stock plants. Sucker growth or terminal growth from older wood—both root; however, sucker growth will root faster.

Preparation: Cuttings are taken in the field and then prepared at the farm prior to sticking. New wood of 18 to 24 in. is removed and bundled using rubberbands. If a long period may elapse prior to cleaning, the cuttings are iced in transport and held in loose bundles under refrigeration. Leafy single node cuttings with 1 in.+ of stem tissue and two leaves are used. Leaves are cut to 1/2 to 1/3 of original size to allow placing more cuttings in trays. Tip cuttings are made with the terminal shoot left intact. A clean basal cut is made on all cuttings with a pruner.

Fungicide: Zyban dip and allow to dry.

Hormone: Woods 1 : 8 (1 : 5 if wood is hardening) (v/v)

Medium: Containers are Growing Systems Inc. Milwaukee, Wisconsin, 38-deep tube trays 2-1/4 in. × 5-3/4 in. prefilled with Fison Sunshine Mix #1 cut 35% with coarse perlite and prewet prior to sticking. Trays are placed on the greenhouse floor on a pea gravel base. Cuttings are inserted with buds set at or below soil line.

Results. We have not found cutting age to be extremely important in rooting success. Sucker cuttings will root in 10 to 15 days and older growth will take 10 to 20 days longer at the minimum. **The cuttings will not root under wet soil conditions.** Cool temperatures and/or late sticking (20 June +) will lengthen the rooting time up to 5 weeks. A 70% rooting rate can be achieved with a higher success obtainable if sucker cuttings alone are used. Once the cuttings are rooted they must be potted or weaned from the fog to retain good foliage. We have rooted 2000 to 3000 plants for several years using this system.

Aftercare: We find it necessary to repot the plants to 1-gal containers to keep the plants in active growth. Plants 18 to 24 in. can be grown in a single season in this manor. All plants are held a 32F during the first winter.

Acer griseum
A. maximowiczianum [syn. A nikoense]
A. maximowiczianum × *A. griseum,* Rochester hybrid
A. mandshuricum
A. triflorum

Timing: June 1st to 12th (Chicago) after 6 to 10 in. new growth three nodes produced. No terminal growth is removed. We stick a one- to three-node cutting 1-1/2 in. to 7 in. long, depending on cutting availability. Wood is from sources with ages of: *A. triflorum*, 42 years; *A. maximowiczianum*, 20 years; *A. mandsuricum*, 4 years;*A. griseum* 4 to 23 years.*Acer griseum* appears to require juvenile wood to obtain higher rooting percentages when compared to the other species listed.

Preparation: Cuttings are field cleaned and bundled. The bottom two leaves are removed. A clean basal cut is made with a pruner. Fungicide, medium, and container used are as with *Aesculus*.

Hormone: Woods 1 : 5 (1 : 3 older wood) (v/v).

Results: Rooting percentages with 2- to 5-year-old stock plants average in excess of 75%.*Acer triflorum* as old as 45 years rooted 70% plus in two attempts with 1000 cuttings each on 2-successive years. With the exception of *A. griseum* the hardness of the cutting seemed far more important than stock plant age as long as vigorous cuttings were available. Young stock plants yield cuttings that can root in as little as 20 days. Older cutting sources can cause cuttings to take as long as 6 weeks to root. We are presently rooting from 500 to 2100 plants of each of the above trifoliate maples. Cuttings are overwintered in their rooting container and held at 32F until spring. **We have found all species with the exception of *A. griseum* to be severely prone to verticillium root rots. A well drained growing on mix is essential.**

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Reducing Plant Stress with Shading

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Nurserymen use a wide range of materials and methods to minimize the adverse effects of sunlight and wind. Lath structures, shading compounds, white plastic, poly shade fabric, and planted windrows are all tools that can be used to reduce direct sunlight and slow wind currents. Utilizing these methods will allow the grower more control over plant transpiration.

Poly shade fabric has been used by the nursery industry for decades. It can be purchased in various degrees of opacity such as 30%, 50%, 70%, and 90%. It can be installed for the entire growing season when working with a light sensitive crop, or for short-term use to minimize desiccation.

Conditions that might warrant the use of shade fabric include: transplanting, trimming, or general changes in the growing environment.

At D&B Plants, weather conditions and the sensitivity of plant material are taken into consideration at the time of transplanting. Shade fabric is placed over the plant material, and removed in stages as required. For example, bare root *Berberis thunbergii* f. *atropurpurea* in full leaf, coming from a high humidity propagation structure can be very temperamental to transplant. A 90% light reduction is often implemented for 3 to 5 days, followed by a week of 70% shade, and finished for an additional 2 weeks at 30%. Weather conditions and cutting appearance dictate the timing and opacity required.

Trimming on certain types of plant material can shock leaf tissue that has been shaded by the overstory. Trimming can be timed to coincide with cloudy weather to minimize plant stress. When this is not feasible, 30% shading, for 2 or 3 days, will prevent sunburning the remaining leaves.

During spring shipping season, plant material is removed from various growing areas and placed in a staging area. When conditions warrant, a light shade (30%) is placed over the entire order for 2 or 3 days to help the plants acclimate. Ideally, the plants will then be exposed to full sun for an additional 7 to 10 days.

With any of the temporary conditions described, monitoring weather conditions as well as plant response will eliminate damage from over shading, such as stretched growth or fungal disease.

Shade fabric can be used to fit the adjusting light requirements of plant material. Combining various opacities allows increments of higher light levels as tarps are removed individually.

Increasing light levels gradually has resulted in more favorable plant vigor and higher percentages of survival.

The second part of the morning session convened at 10:30 a.m. with Timothy Brotzman serving as moderator.

Fertilizers: Interactions and Overwintering—A Review

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INTRODUCTION

Plant nutrition plays a critical role in the rooting of cuttings. Research (Andersen, 1986) has shown that essential nutrients are calcium, nitrogen (in very limited amounts), potassium, and phosphorus. Important trace elements are zinc and boron but it is difficult to ascertain what the exact requirements are. Nitrogen is by far the most complex and difficult to use and prescribe. While it is apparent that it is essential for such things as cell division and new root development, nitrogen can also place many demands upon the plant energy systems. The supply of nitrogen is complicated by simultaneously trying to meet but not exceed what is required.

EFFECTS OF NITROGEN ON ROOT DEVELOPMENT

The rooting of many plants has been shown to be sensitive to nitrogen. Investigators have found that a lowering of nitrogen increases rooting potential and a lowering of calcium decreases rooting potential. Others have found the rooting of cuttings could be increased by applying phosphorus and potassium while simultaneously lowering nitrogen (Haissig, 1986).

TEMPERATURE

Another factor in root development is temperature. While higher temperatures promote rooting they also cause a reduction of carbohydrate accumulation.

A review by Haissig (1986) noted that starch buildup in cuttings occurs at 15C but not at 25C. Most cutting however root best at 25C. In *Camellia,* rooting is directly related to temperature with more rooting occurring at higher temperatures.

One suggestion to increasing overwintering survival of cutting is to root them as early in the season as possible at the higher temperature, and then move them to a lower temperature regime to allow for more carbohydrate accumulation.

ENERGY CONSUMPTION DUE TO NITROGEN

Nitrogen plays an important part in the nutrition of a plant but it has another role affecting carbohydrate assimilation (Barker and MIlls, 1980). The nitrogen requirements for root growth is insufficient for shoot growth. In some instances there is direct competition between the rooting and the subsequent growth of the cutting for the same nutrient. This can lead to an energy deficit in the whole plant (Bryan, 1976). It should be remembered that the roots must expend energy in order to facilitate the incoming nitrogen. Waxman (1965) suggests that for some plants overwintering difficulties are possibly due to low carbohydrate level and/or an inability to harden tissue. Both of these factors appear to have a relationship to nitrogen balance.

In plants, introduced nitrogen (from fertilizer) has to be metabolized in a very highly specific process. Once nitrogen is introduced into the cellular system, it is normally metabolized by conversion to amines and amino acids. In order to do this conversion the plant must provide the necessary carbon skeletons to form the compounds. The plant uses the same enzyme systems and sources of energy to form amines as it does carbohydrates (Barker and Mllls, 1980; Bryan, 1976). Ammonium ion is known to curtail sucrose formation in *Chlorella* (algae) (Bryan, 1976), inhibit photosynthesis, and damage chloroplasts. The relative toxicity of nitrogen, either as ammonium ion (NH_4^+) or nitrate(NO_3^-), to plant cells calls for rapid detoxification at the expense of carbohydrate (Bryan, 1976). The higher the nitrogen input the lower the reduction of carbon dioxide and consequently the lower the production of carbohydrate (Salisbury and Ross, 1978).

Another aspect of nitrogen metabolism is temperature related. When roots are cold, nitrate ($N0_3^-$) will be transported directly to the leaves and stems and will not be metabolized. It will accumulate until sufficient warmth is attained and then it is rapidly converted to amine (Salisbury and Ross, 1978). This is a third energy drain upon a plant system at a time when energy reserves are already low, i.e., late winter or early spring.

Light appears to be a factor in nitrogen metabolism and ammonium ion may accumulate during darkness when the necessary carbon sources are not available (Stimart and Michael, 1985).

The conversion of nitrogen into nitrogenous metabolites is a two-step process and requires carbon sources at both steps (Bryan, 1976; Stimart and Michael, 1985).

NH_4^+	+	light	+	CO_2	=	CH_xNH_2COOH
nitrogen				carbon dioxide		amino acid

CH_xNH_2COOH	+	NH_4^+	+	energy	=	$XCH_x(NH_2)_xCOOH$
amino acid		nitrogen		energy		more complex amino acid

In the above sequence more and more energy is consumed to make use of and to detoxify the ammonium cations. Ammonium is also released during the senescence of leaves (Salisbury and Ross, 1978) where it again requires the use of ATP (energy) to be converted into the amino acid, asparagine. Trees are known to convert this resultant amino acid to storage proteins found in stem tissue. The metabolism of sulfur also results in the formation of ammonium and, as indicated, before results in an energy consumptive process (Salisbury and Ross, 1978).

AMMONIUM TOXICITY

Most modern day fertilizers contain two forms of nitrogen, nitrate (NO_3^-) and ammonium (NH_4^+). Plants evolved with the predominate form of nitrogen being nitrate. They did not have ammonium ion as a common source for nutrition. While many plants can utilize ammonium cation they cannot tolerate its accumulation and its transport within the cellular system is harmful (Bryan, 1976).

Joiner (1983) states that the use of ammonia-based fertilizer can lead to the pathological condition known as ammonia toxicity. Salisbury and Ross (1978) suggest that ammonium ion is directly toxic because it interferes with the production of ATP (energy) in mitochondria and with the photosynthetic electron transport system. Ammonia toxicity manifests itself as restricted root growth, chlorosis and necrosis of leaves, stem lesions, and epinasty (Bryan, 1976). Ammonium ion appears to present itself in ways which are not directly toxic but do much to alter the plant's nutritional balance. Deterioration and loss of leaves is one of the more dramatic aspects of ammonium toxicity (Bryan, 1976). Another symptom of nitrogen toxicity is the delay in the maturation process of fruits and nuts (Shear and Faust, 1980). Poinsettia grown on ammonium fertilizers as opposed to nitrate are stunted, chlorotic, and exhibit leaf abscission (Joiner, 1983). Ammonium sulfate has been shown to be toxic to potatoes on acidic soils and the use of urea and ammonium fertilizer on acidic soils has had deleterious affects on citrus and leather leaf fern. Ammonium toxicity is pH dependant, the more acidic the soil the more pronounced the symptoms. Alternatively, alkaline soils exhibit little or no ammonium toxicity problems (Bryan, 1976).

The adverse affects of ammonium occur after absorption into the plant. One of the most dramatic affects of ammonium intake is through the displacement of potassium (K^+) in the plant. Roots will selectively admit ammonium ion into the plant at the expense of potassium and the situation can become advanced enough to lead to potassium deficiency (Bryan, 1976). Tomatoes have such a preference for ammonium ion that they will absorb it to the point of direct toxicity (Korcak, 1988). Roses are particularly affected by ammonium ion, especially when potassium is limited (Joiner, 1983). Low levels of potassium can in turn lead to phosphorus toxicity (Wright and Niemiera, 1987). Ammonium will eventually reach a level in plants that will decrease root and total plant growth. This can be reduced by the presence of nitrate in the fertilizer, but others (Titus and Seong-Mo, 1982) have indicated that ammonium ion will inactivate nitrate reductase enzyme which leads to a reduction in nitrate metabolism.

In addition to the reduction in the uptake of potassium and nitrate, ammonium ion also reduces the absorption of calcium and magnesium (Bryan, 1976). The reduction of these two ions is proportionally greater than that of potassium; every ion of ammonium absorbed will eliminate two ions of calcium or magnesium. A particular dramatic impact of the exclusion of calcium is that calcium is essential as a co-factor for the metabolism of iron and calcium also plays a very important part in the exclusion of sodium (Salisbury and Ross, 1978). Haissig (1986) asserts that calcium has multiple roles in the rooting process including that of an important role in nitrate reductase enzyme. It is apparent that a reduction or limitation of calcium due to ammonium ion can have serious consequences for plant development.

OVERWINTERING

One of the most significant influences of fertilizer use is in respect to overwintering survival. Stimart (1985) showed that cuttings of *Viburnum*, *Stewartia*, *Cornus florida*, and other species died when treated with fertilizer containing 200 ppm of nitrogen after rooting. Although it was not specified as to the source of the nitrogen there is reason to believe ammonium ion may have played a part in the death of the cuttings.

Smalley and Dirr (1986) gave a definitive review of the overwintering problem in cuttings. Their recommendations centered on fertilizer as being a culprit in the overwintering losses. Specifically they advised that cuttings should not be fertilized after rooting unless the cuttings had broken bud. Then and only then can fertilizer be of benefit to a newly rooted cutting. They also demonstrated that fertilizer cannot be used as an instrument to promote bud break in cuttings, and, in fact, when used in this capacity fertilizer usually leads to the death of the cutting. Stimart (1985) attributed losses in *Acer palmatum* and *C. florida* cuttings to nitrogen delaying vegetative growth and lack of cold acclamation. In particular he attributed a substantial cause and affect to ammonium ion.

Wright and Niemiera (1987) suggested that excess fertilizer applied late in summer may prolong growth and cause freeze damage. Baldwin apples treated with ammonium nitrate in October exhibited severe stem splitting. Pellett and Carer (1981) offered that nitrogen-deficient plants accumulate carbohydrates and are capable of hardening upon exposure to cold temperatures. Stimart's (1985) observations were that ammonium sensitivity varied as a function of physiological state, time of year, and climatic conditions.

CONCLUSIONS

In general the survival of cuttings during the first winter after rooting is best if they are not fertilized (Smalley and Dirr, 1986; Stimart and Michael, 1985). Actions taken to increase winter survival can be accomplished by the use of light (Waxman, 1965); however, subsequent hardening of the cutting can be a problem. Evidence clearly shows that ammonium forms of fertilizer can be particularly harmful to established plants as well as newly rooted cuttings (Pellett and Carter, 1981). Further, the proper timing for ammonium fertilizers is best during spring and early summer (Pellett and Carter, 1981; Stimart and Michael, 1985). Plants are naturally more tolerant of nitrate and are highly intolerant of ammonium (Bryan, 1976).

Clearly the use of the proper source of nitrogen at the right time of the year will do much to alleviate problems associated with overwintering.

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New Father Fiala Crabapple Introductions: Field Production of Own Root Crabapples from Liners to Finished Stock

Roy G. Klehm
Klehm Nursery, Rt. #5 Box 197 Penny Rd., South Barrington, Illinois 60010-9390

About 20 years ago, while visiting Brother Charles and working with him on tetraploid daylily breeding, I noticed a few small ornamental crabapples that he had previously budded in a near-by row. These trees had excellent foliage retention, attractive small berries, and neat sales appeal names like 'Christmas Holly', 'Garnet', and 'Egret'.

When I asked "Charlie" about the origin of these, he simply said that another priest friend of his from Ohio had sent him the buds a few years ago for him to try. Brother Charles said that a Father John L. Fiala of Medina, Ohio, had been breeding and evaluating crabapples for sometime and thought that these may have commercial value.

Well, of course my interest was piqued and little did I know at the time where this all would lead.

This morning I'd like to show these on their own roots and then go into a few of the better selections as we presently value them.

Plants shown included:

The lilacs: *Syringa vulgaris* 'Albert F. Holden', *S.* × *hyacinthiflora* 'Blanche Sweet', and *S. vulgaris* 'Aloise'.

The crabapples: 'Red Peacock' PP 7022, 'Leprechaun', 'Serenade' PP 6957, 'Satin Cloud' PP 6956, 'Amberina' PP 6942, 'Little Troll', 'Golden Galaxy', ×*zumi* 'Wooster', 'Luwick', 'Cranberry Lace', 'Christmas Holly', 'Autumn Glory', and 'Red Swan' PP 6974.

New Plant Forum

Compiled and moderated by Jack Alexander.

PRESENTERS:

Jack Alexander, Arnold Arboretum, Jamaica Plain, Massachusetts

Clethra alnifolia 'Anne Bidwell'

Vern Black, Bailey Nurseries, St. Paul, Minnesota

Berberis 'Tara' Emerald Carousel™

Bruce Briggs and **Steve McCulloch**, Briggs Nurseries, Inc., Olympia, Washington

Magnolia 'Butterflies'

Pieris japonica 'Cavatine'

Rhododendron "P.J.M. compact form"

Ruth Dix, U.S. National Arboretum, Washington, D.C.

Viburnum × *burkwoodii* 'Conoy'

Gary Koller, Arnold Arboretum, Jamaica Plain, Massachusetts

Xanthoceras sorbifolium

Rob Nicholson, Smith College, Northampton, Massachusetts

Prunus pumila var. *depressa* 'Gus Mehlquist'

David Schmidt, Royal Botanical Gardens, Hamilton, Ontario

Forsythia ovata 'Dresdner Vorfrühling'

Sidney Waxman, Storrs, Connecticut

Acer 'Cinnamon Flake'
Pinus strobus 'Shaggy Dog'
Sciadopitys verticillata 'Foxtail'

***Acer* 'Cinnamon Flake'** originated as a chance seedling among hundreds obtained from the Rochester Parks 30 years ago. It appears to be an *A. griseum* hybrid and is more vigorous than the species having attained a height and width of approximately 33 ft. It was named 'Cinnamon Flake' because of its unusual cinnamon colored bark which is finely and vertically fissured with thin paper-like flakes.

Its summer foliage is a rich green and its fall coloration is a spectacular red. In winter its cinnamon-colored bark is quite attractive. 'Cinnamon Flake' can be grafted onto *A. saccharum*, the sugar maple. Our oldest grafts, now 8 years old, are vigorous and show no signs of incompatibility. They have grown to a height of 14 ft with a 12-ft spread and have a trunk diameter of about 5 in. All of these selections can be seen at the Horticulture Research Farm at The University of Connecticut.

Berberis 'Tara' Emerald Carousel™

There has always been a need for a good hardy barberry that doesn't sucker. Korean barberry is certainly hardy enough and has a nice floral and fruit display along with gorgeous fall color, but suckers badly and can only be utilized in a limited situation. Japanese barberry has a good compact form and again nice floral and fruit display, but is not consistently hardy enough for this area. Emerald Carousel™ barberry is a happy marriage between the two types and seems to have gained the good qualities of both parents without the drawbacks.

Beginning in the spring, pendulous butter-yellow lily-of-the-valley blooms hang suspended along the arching branches. The medium to dark green foliage sets off the color without hiding the flowers. During the summer the same emerald foliage on a 4 to 5 ft round plant serves as a beautiful backdrop for bright colored perennials. Autumn changes the leaves to an outstanding red to reddish-purple which color early and remain well into the fall before dropping. The cardinal red fruit is persistent into spring making this plant a true carousel of color for all seasons.

The original plant, selected in 1985, has shown no winter dieback, no signs of suckering, and no disease or insect problems. It should be adaptable to almost all soil types. It has proven to be hardy in USDA Zone 4, and is currently being tested in harsher environments. The USDA Cereal Rust Laboratory has tested Emerald Carouse™ and found that it does not act as a host for blackstem rust and is on their approved list. It therefore can be sold throughout the United States, and should be a great alternative to Japanese green barberry for all landscape uses.

The name Emerald Carousel™ is trademarked (royalty is 30¢). We will license others. On approved barberry list as *B. thunbergi* × *B. koreana* 'Tara'.

Clethra alnifolia 'Anne Bidwell'

It is as if *C. alnifolia*, the summer-sweet or sweet pepperbush, has just been discovered by gardeners. Ten years ago, most gardeners and nurserymen thought of it simply as a good plant for wet places, available in white and pink. Now, there are at least eight obviously unique cultivars.

In 1983, Mrs. John Bidwell of Cotuit, Massachusetts invited me to see a *C. alnifolia* that she had grown from seed purchased from F.W. Schumacher, Seedsmen, Sandwich, Mass. One of her seedlings was obviously different. It had flowers that were arranged in a panicle rather than the more usual raceme. The size and habit of the plant were not unlike the wild plants that grow along the Massachusetts roadsides, maybe a little shorter and more compact than usual, but the inflorescence was unique. I had never seen any *Clethra* quite like it.

Mrs. Bidwell gave to the Arnold Arboretum the right to introduce the cultivar, hoping that we might derive some income from it. We have named it *C. alnifolia* 'Anne Bidwell' in her honor. Our oldest plants are grown from cuttings taken in

1985. They are now about 5 ft high and 5 ft wide. The inflorescence is usually a 4 to 6 in. panicle made up of 5 to 7 racemes. In Boston, it blooms about the third week of August, 2 to 3 weeks after the species.

Unfortunately, at least under our conditions, the whole plant does not bloom at the same time; and although this extends the season, bloom at any one time may appear to be sparse. This shortcoming was sufficient to keep us from patenting the cultivar, but it is still an attractive plant and may perform better under other conditions. While preparing this presentation, I found photos of the original plant growing in Cotuit, on Cape Cod and it appears to be covered with bloom.

Forsythia ovata 'Dresdner Vorfrühling' is from Sastzucht, Germany and was introduced to the trade there in 1973. The literature reference is from Beitrage Zur Geholzkunde p. 73-74. The main advantage of this forsythia is the very early appearance of abundant pale yellow blossoms from top to bottom of the shrub 4 to 5 days earlier than cultivars such as 'Lynwood'. Even during sudden cold spells in spring this cultivar can be in full bloom 2 to 3 weeks before any other cultivar.

The plant was received at the Royal Botanical Gardens in 1982. Today it measures 9 ft high by 12 ft wide and has a very upright and dense growth habit. The flowers appear in dense clusters, open up to seven per flower bud. Our 1-year liner plants which are 20 in. high by 15 in. wide flowered heavily the first spring. The actual flowers fare usually only half open, 3 to 4 cm wide. The tops are somewhat twisted.

This cultivar is not recommended for cutting and forcing but, because of the long and generous flowering time, it is quite effective in the landscape.

As with most forsythia cultivars, this one roots nearly 100% from softwood cuttings in June or July. Any one interested in hardwood cuttings can contact David Schmidt, Royal Botanical Gardens, Hamilton Ontario, Canada L8N 3H8 (Tel 1-905-527-1158; fax 1-905-577-0375)

***Magnolia* 'Butterflies'**

Magnolia acuminata 'F.M.' (not introduced) × *M. denudata* (K. Sawada - Semmes, Alabama)

Hybridized by Phil Savage, Bloomfield Hills, Michigan

Propagation and distribution by Klehm Nursery, Barrington, Illinois; Briggs Nurseries, Olympia, Washington; and licensed growers.

A neatly shaped magnolia with deep yellow flowers (darker than 'Elizabeth'), truly a precocious bloomer. Blooms are 3 to 4 in. in diameter, 10 to 14 tepals with red stamens. This magnolia blooms before leafing out—blooming late (first week of May in Illinois). Flowers sit on the branches like yellow butterflies. A 5 ft plant may have 20 to 30 blooms while a 6 ft plant may display 80 or more flowers. Plants are bushy and hardy to at least USDA Zone 5a. Plant is patented.

***Pieris japonica* 'Cavatine'**

Selection from wild collected *Pieris japonica* seed at high elevations on Yakushima Island in Japan.

Seed collection by R. de Belder - Kalmthout, Belgium 1970

Propagation and selection by Firma Esveldt Nurseries, Boskoop, Holland, 1978-83.

Esveldt Nursery grew 6000 seedlings of this select seed and initially selected 50 *Pieris* plants to evaluate, of which 15 compact forms have been named. These selections have more upright instead of drooping flower trusses and a spreading rather than upright plant habit. Plants bloom profusely in Washington. Flowers are white and held upright. Plants are hardy (at least USDA Zone 5b), very bushy (requiring little to no pruning), and vigorous. Plants normally may reach 2 to 3 ft tall and 3 to 4 ft wide in 8 years.

These plants appear to be definitely hardier than other *P. japonica* selections, and their compact stature should increase their value in the landscape.

***Pinus strobus* 'Shaggy Dog'** originated as a witches'-broom seedling. Its twice as wide as high and has an annual growth rate of approximately 6 in. 'Shaggy Dog' looks like a shaggy dog. Its new shoots tend to grow slightly upward and then curve down a few degrees lower than horizontal. As a consequence there are dense layers of branches closely overlapping other branches, all with shoots inclined towards the ground.

Its form is irregular and has grown to a height of 3-1/2 ft and a width of 6-1/2 ft in 12 years. The new shoots are relatively thick and are easily grafted.

***Prunus pumila* var. *depressa* 'Gus Mehlquist'** is a new cultivar with interesting landscape possibilities as a woody, deciduous groundcover. This cherry is native form New Brunswick, Quebec, and Ontario south to Massachusetts and New Hampshire. Hortus lll treats it as a separate species, *Prunus depressa*, while Krussman treats it as *Prunus pumila* var. *depressa*.

This cultivar was selected by Rob Nicholson of the Smith College Botanic Garden and Dr. David Boufford of the Arnold Arboretum from a stand along the banks of the Connecticut River in New Hampshire. It was growing on a sand and gravel bar in full sun. At flood stage the mother plant would be fully submerged while during low water in August the plant endures almost desert like conditions. It is probable that the entire stand may be a single plant, spreading and layering over the centuries.

This cultivar has rooted well from cuttings and is a rapid spreader growing 3 ft in a year once established. It is entirely prostrate, forming a dense mat that stands 6 to 10 in. above the ground. It flowers are small, with five white petals. It has a strong scarlet fall color.

The Smith College Botanic Garden is pleased to name this selection in honor of Dr. Gustav Melquist, renown teacher, hybridizer and propagator. Those interested in propagules can contact the Smith College Botanic Garden, Northampton, MA 01063 (413-585-2748)

***Rhododendron* "P.J.M. Compact Form"Tetraploid form**

Unnamed as yet; origin—induced polyploid.

Flowers have greater substance and are much larger (2 to 3 in. diameter) than the diploid hybrid. Trusses have 4 to 5 flowers and the truss is 4 in. wide × 2-1/2 in. high.

Plants bloom in mid-March in Olympia. Flowers are lighter in color than the "P.J.M. Compact Form" and are in the purple group, 77B fading to 77C in the center. Foliage is broadly elliptic and is thicker and wider than the diploid form. Stems are stout, erect, and thick. The plant habit is upright and spreading, and plants are bushy, and hardy. Plants bloom at the same time as `P.J.M.'

Performance testing is in process.

***Sciadopitys verticillata* 'Foxtail'** was selected because it is so different from other umbrella pines.

'Foxtail' was so named because of the unique development of its branches which are heavily foliated with short densely-arranged lateral shoots. Another unusual characteristic is its branching habit. Arising from a single leader and widely spaced, each branch is distinctive.

Along with its asymmetrical form, 'Foxtail' is in sharp contrast to the "typical" tree which is usually densely branched, sparsely foliated, and symmetrical in form.

***Viburnum* × *burkwoodii* 'Conoy'**. 'Conoy' has a compact growth habit, fine-textured, extremely glossy evergreen foliage and abundant, bright red fruit which colors in August and ripens to black in October. The shrub is a spreading, dense, evergreen shrub that has reached 5 ft in height with a width of 7 ft in a period of 17 years. In winter, the dark green foliage will take on a dark maroon tinge, but will revert to green with the advent of warm weather. The slightly fragrant flowers appear with the young leaves in late April; the buds are dark red opening to a cream white. Reliably evergreen to Zone 7 and perhaps Zone 6, it is hardy though deciduous in Zone 5.

***Xanthoceras sorbifolium*, yellowhorn**

With the decline of the American dogwood (*Cornus florida*), due to anthracnose, nurserypeople and landscape designers have been using alternate trees to fill the flowering niche of the dogwood. One such tree is the yellowhorp. Native to northern China the tree was first introduced to western gardens by Pere David, who sent a seedling to the Paris Museum in 1866 with first fruit production recorded in 1873.

Yellowhorn develops into a large shrub or small tree 15 to 20 ft in height with an upright pattern. With age it tends to be stiff and open causing it to become more picturesque than many small trees. In the Boston area flowering occurs, annually, in mid-May. Flowers are borne in terminal racemes 6 to 10 in. in length. Individual blossoms are five petalled, approximately 1 in. in diameter, white to creamy white with a color blotch at the base of each flower which gradually ages from yellow to carmine. Fruit occurs as leathery, three valved capsules which ripen in late August to early September. As they ripen the capsule opens allowing the seeds to drop to the ground. At the Arnold Arboretum a grove of four plants, 14-years old produces an abundant crop of seeds each year from which we have started and distributed many young plants. Seeds are edible and said to have the flavor of Macadamia nuts.

The foliage is pinnately compound, moderate green throughout the summer and becoming greenish-yellow prior to autumn defoliation.

With the hot dry summers of North America the plant seems to harden off and be tolerant of low winter temperatures. Mike Dirr tells of a nurseryman in Blair, Nebraska, who has successfully grown this out of doors where winter temperatures dip to -25 to -30F.

Jack Alexander, plant propagator at the Arnold Arboretum, tells us that the plant is easy to propagate. Seeds germinate after 2 months of cold stratification at 40F. He related that seedlings bought by the Arnold Arboretum had long thick roots. In order to get the seedlings into pots he removed the bottom four inches of root. So as not to waste the root pieces he potted them up allowing the top quarter inch to show above the soil line. Quick shoot proliferation resulted in another crop of strong, healthy plants.

In order for you to locate sources for trial at your location I offer the following sources and apologize to those I have missed! Large quantities of seedlings are being marketed by Lawyer Co., 950 Highly 200 West, Plains, Montana 59859. Mail order plants, for trial and testing are available from Forestfarm, 990 Tetherow Road, Williams, Oregon 97544-9599.

MONDAY MORNING 6 DECEMBER 1993

The morning session was convened at 8:00 a.m. with Dale Deppe serving as moderator.

New Large-Bracted Dogwoods from Rutgers University

Elwin R. Orton, Jr.
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INTRODUCTION

During the first 5 years of the woody ornamentals breeding program at Rutgers University, hybridization studies were limited to intra- and inter-specific hybridization of plants of the genus *Ilex*, and of the genus *Pyracantha*. Starting in 1965, plants of the various cultivars and numbered selections of *Cornus florida*, *C. kousa,* and *C. nuttallii* available in the trade were assembled in a performance trial as the starting point for interspecific hybridization between these three species of large-bracted dogwood. Such a field trial of tree species is essential to a long-range hybridization program: first, the trial allows one to observe the degree of genetic variability available within the various species and thus obtain a measure of the potential improvement one can expect to achieve via a program of controlled crosses; secondly, the performance trial provides the parent material used in making the crosses; and thirdly, the trial provides the current standards of excellence for evaluating plant material from the breeding program. It is not enough that seedlings from controlled crosses be good; rather, the various progenies must include plants superior, or novel, to those in commerce if the program is to be successful.

GENETIC VARIABILITY IN *C. FLORIDA* AND *C. KOUSA*

Early in this work, it was discovered that all the plants of *C. florida* and *C. kousa* exhibited a very high level of self-incompatibility. Thus, the plants are obligately cross-fertilized in nature and would be expected to exhibit a high degree of both phenotypic and genetic variability. This, of course, was true of the plant material available as cultivars in the trade. The trial included plants of dwarf, pendulous, or fastigiate habit. Some had floral bracts of various color (white, pink, red), some exhibited floral "doubles" or various foliage variegations. Various clones showed different levels of vigor and winter hardiness, and floral bracts of widely different size, shape, and texture.

Variation in plant vigor was particularly high in *C. kousa* and is believed to result from the introduction of a small sample of germplasm from the wild and subsequent inbreeding (Orton, 1985). Also, variability in the size, shape, and texture of the floral bracts was particularly high in the case of *C. kousa*.

Close examination of the floral structures in plants of *C. florida* and *C. kousa* revealed why plants of the latter species flower a month later than plants of *C. florida*. It is common in the nursery industry and in horticultural literature to refer to the true flowers in flower heads of *C. florida* and *C. kousa* as being protected in the overwintering floral buds by the enclosing floral bracts. While this is true for *C. florida,* it is not true for *C. kousa*. In the latter species, the floral bracts are minute, feathery structures clasping the tiny, developmentally immature flowers and the flower head is enclosed by two opposing pair of vegetative bracts at the base of the very abbreviated peduncle. These homologous structures are clearly visible in *C. florida*, being 1/4 to 1/3 in. in length near the base of the 1/2 to 1 in. peduncle of the overwintering flower buds. As growth resumes in the spring, the floral bracts enclosing the true flowers of *C. florida* unfold and enlarge to provide the showy floral display. The deciduous vegetative bracts enclosing the true flowers of *C. kousa* drop as growth resumes in the spring but the developmentally immature floral bracts and true flowers mature a month later than in *C. florida*. This is to be expected when one considers that the peduncle of the nearly sessile flower head of the overwintering bud increases to a length of 2 1/2 to 3 in. by the time of flowering and floral display.

In *C. nuttallii*, the true flowers are well developed, but are naked in the relatively large overwintering flower buds. Neither the vegetative bracts nor the floral bracts subtending the flower heads enclose the true flowers. As with *C. florida*, the floral bracts subtending the true flowers in the overwintering buds of *C. nuttallii* are developmentally more mature than in *C. kousa*. Thus, flowering and the ornamental display of the floral bracts occur about the same time as in *C. florida*.

No cultivar with good pink or red bracts has been found in *C. kousa*. Several clones said to exhibit pink or red bracts are in the trade and were acquired as they became available. The clones tested exhibited white floral bracts with just a trace of pink at the margins of the bracts when grown in a greenhouse in late winter and early spring.

Work with *C. florida* showed the pink- or red-bracted characteristic is conditioned by a single recessive gene in the homozygous state (Orton, 1982). One could speculate that the reported [red- or] pink-bracted clones of *C. kousa* may be heterozygous for a single recessive gene conditioning bract color. Such heterozygotes in *C. florida* often produce "apple-blossom pink" bracts during a cool spring. If such is the case, one could assume that a gene homologous to the gene in *Cornus florida* does exist in *C. kousa*. If true, progeny resulting from crossing such a heterozygote with a plant of *C. florida* homozygous for the recessive gene conditioning anthocyanin pigmentation of the bracts should segregate 1:1 for pink- or red-bracted seedlings and white-bracted seedlings.

These crosses were made and all of the seedlings with cotyledons exhibiting anthocyanin pigmentation—a trait associated with pink- and/or red- bracted segregates in *C. florida* (Orton, 1982)—were small and weak and seldom survived as long as a year. Thus, this researcher doubts that a reliably good red-bracted form of *C. kousa* will be found in nature. The pink-bracted plants observed among hybrids of *C. kousa* × *C. florida* are known to be heterozygous for the single recessive gene conditioning pink or red bracts in *C. florida*. As is true with the heterozygotes in *C. florida*, the intensity of the anthocyanin pigment in the floral bracts of the hybrids varies from year to year depending on seasonal factors.

CULTIVARS INTRODUCED

The two cultivars described below resulted from intraspecific hybridization within *C. florida*.

D376-15, PP 8214, Red Beauty®. Plants of Red Beauty® are semi-dwarf, with dark green leaves, and a densely branched, unusually symmetrical form. The floral bracts are bright red and showy early in the season.

D184-11, PP 8213, Wonderberry®. Plants of Wonderberry® are unusually vigorous, with large, thick, dark green, leathery leaves. Each white floral bract has a spot of red at the tip and the showy display is rather typical of the species. The trees are unusual for their display of large, tubular, bright red fruit nearly twice the size typical of the species.

Six F, interspecific hybrids of *C. kousa* × *C. florida* have been patented and introduced to commerce as Rutgers University's Stellar® series. Plants of all six hybrids exhibit more vigor than is typical for plants of either parent species and all exhibit large, flat leaves of a rich, dark green color. Similarly, all of the hybrids are highly resistant to infestation by the common dogwood borer. Additionally, the hybrids have moderate to high resistance to *Discula destructiva*, the incitant of dogwood anthracnose. Plants of the Stellar® series are highly floriferous, and the period of floral display is intermediate to that of plants of the parent species. The over-wintering floral buds are also intermediate to those of the parent species: the true flowers on the flower heads of each hybrid are enclosed to varying degrees by both the two opposing sets of floral bracts and the two opposing sets of vegetative bracts immediately subtending each flower head. All of the hybrids exhibit some flower heads in which a few of the true flowers are not enclosed by any of the subtending floral or vegetative bracts. However, plants of all six hybrids consistently have provided a good floral display in Zone 6a. U.S.D.A. Plant Hardiness zone 6a (-5 to -10F).

The hybrids of the Stellar® series are listed below in the order in which the floral display of each hybrid commences in the spring.

***Cornus* 'Rutlan', PP 7732, Ruth Ellen®**. Plants of Ruth Ellen® are similar to plants of *C. florida*. They are low and spreading rather than upright as with young plants of *C. kousa*. At 19 years, the original seedling was 18 ft tall, had a uniform spread of 22 ft, and was densely branched close to the ground.* The period of floral display of Ruth Ellen® slightly overlaps the last day or two of the floral display of most plants of *C. florida*. At the peak of the floral display, the trees are brilliant white in appearance and very showy even from a distance.

***Cornus* 'Rutfan', PP 7206, Stardust®**. Plants of this cultivar are similar to the *C. florida* parent as the general form is low and horizontal but they are much smaller than plants of Ruth Ellen®. The plants are heavily branched to the ground like a hedge. At 19 years, the original seedling was 11 feet tall with a uniform spread of 19 feet.* The floral display of Stardust® typically starts one day later than that of Ruth Ellen®. The white floral bracts of Stardust® are obovate with an acute tip. The bracts are distinctly separate and do not overlap. Although plants of this cultivar are low and densely foliaged, evidence of infection by *Discula* has not been observed.

***Cornus* 'Rutcan', PP 7210, Constellation®**. Plants of Constellation® are erect in habit and much more vigorous than plants of *C. kousa*, but do not exhibit the vase-shaped habit typical of young plants of *C. kousa*; that is, the plants branch low and are uniformly wide from base to top. The floral display commences two days after that of Ruth Ellen®, and is quite spectacular even when viewed from a distance. At 19 years, the original seedling was 21 ft tall and 17 ft wide.* The white floral bracts are obovate with an acute tip. Both the inner and outer (lower) floral bracts are separate with no overlap and are significantly longer than are the floral bracts of Stardust®.

***Cornus* 'Rutdan', PP 7204, Celestial™**. This hybrid is vigorous and erect in habit, exhibiting a uniform width rather than the vase-shape of a young plant of *C. kousa*. The floral display commences four to five days after that of Ruth Ellen®. The expanded floral bracts are white with a tinge of green and form a small cup early in the season. However, the bracts flatten and become pure white in a few days. Bracts are obovate to nearly rounded with an acute tip and a base broadly tapered. Margins of adjacent bracts often touch but do not overlap. At 19 years, the original seedling was 17 ft tall and 14 ft wide.*

***Cornus* 'Rutban', PP#7205, Aurora®**. Plants of Aurora® are very vigorous, erect in habit, and uniformly wide throughout. They are also very floriferous. The period of floral display is about the same as that of Celestial®. The floral bracts are white and provide a heavily textured, velvety appearance, and become creamy-white as they age. They are nearly rounded to obovate with a broad, tapering base and an acute tip. The margins of the basal one-third of adjacent bracts typically overlap. At 19 years, the original seedling measured 18 ft tall and 18 ft wide.*

***Cornus* 'Rutgan', PP#7207, Stellar Pink®**. Plants of Stellar Pink® are very vigorous and erect in habit. They branch low and are uniformly wide throughout, as opposed to the vase-shaped habit typical of young plants of *C. kousa*. The period of floral display of the floral bracts is similar to that of Celestial™ and Aurora®. The rounded, overlapping bracts are a soft pink in color and have a nice textured appearance. From a distance, the pink bracts are not as showy as the dark red bracts of good clones of *C. florida*. However, they provide a very attractive display when viewed more closely. At 19 years, the original seedling was 20 ft tall and 19 ft wide.*

The six hybrids of the Stellar® series listed above represent Rutgers University's answer to "dogwood decline". New intra- and inter-specific hybrids of the large-bracted dogwoods will be introduced from Rutgers University in the next two to three years.

*For purposes of comparison, 26-year-old plants of *C. florida* 'Springtime' and 'Sweetwater' in the performance trial measured 10 ft tall by 16 ft wide and 12 ft tall by 19 ft wide, respectively.

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Container Nursery Plant Culture in Waxed Corrugated Cardboard Media

Calvin Chong

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Media containing 25% or 50% by volume of uncomposted waxed corrugated cardboard mixed with 25% or 50% of spent mushroom compost and(or) sawdust were evaluated for container culture of four woody shrubs. The shrubs used were: dogwood (*Cornus stolonifera* 'Flaviramea'); forsythia (*Forsythia* × *intermedia* 'Lynwood'); ninebark (*Physocarpus opulifolius*); and weigela (*Weigela florida* 'Aureovariegata'). There were two fertilizer regimes: liquid (20-20-20); slow-release (Sierra 17-6-12 plus minors, 3-4 month release time). Shoot growth data showed that all four shrubs supplied with liquid fertilizer grew better than those with slow-release fertilizer. Among the media tested, certain waxed cardboard blends supported growth of dogwood, forsythia, and ninebark equal to a bark control medium and a commercial nursery mix.

INTRODUCTION

With many urban landfill sites approaching capacity and with scarcity of new sites, it is becoming more difficult to dispose of organic and industrial wastes (Davie, 1993). Landfills are now more selective of the wastes they will accept, while at the same time increasing their tipping fees. In Ontario, a tipping fee of over $100 per tonne is not uncommon. In Toronto the fee is even higher.

The Ornamental Nursery Research Programme at Vineland has been evaluating the use of organic waste by-products as growing media or as substitutes for traditional organic products such as peat and bark. At the 1991 International Plant Propagator's Society Eastern Region meeting, I described the successful recycling and reutilization of spent mushroom compost, papermill sludge, and composted municipal waste as amendments in container culture of several nursery crops (Chong et al., 1991a). My presentation generated significant interest from members attending the meeting, and from others that contacted me later.

Ontario discards annually about 70,000, 350,000, and 500,000 tonnes of waxed corrugated, non-waxed corrugated, and non-corrugated (post-consumer) cardboard, respectively (Anonymous, 1992; Ciepiela, E.J., personal communication). In addition, other cardboard products are brought in via shipping, but tonnage is unknown. As an introduction to the recycling of cardboard, this investigation was conducted to determine the suitability of uncomposted, waxed, corrugated cardboard wastes as amendment in container culture of selected nursery crops.

MATERIALS AND METHODS

In early June 1992, plug-rooted cuttings of dogwood (*Cornus stolonifera* 'Flaviramea'), forsythia (*Forsythia* × *intermedia* 'Lynwood'), ninebark (*Physocarpus opulifolius*), and weigela (*Weigela florida* 'Aureovariegata') were planted in #2 (6 liter) nursery containers filled with eight experimental media (Table 1). The media were:

1) Composted pine bark (control)

2) 16 bark : 3 peat : 1 soil (by volume) (a commonly used nursery mix)

3) 1 spent mushroom compost : 1 sawdust (v/v)

4 to 6) 50% uncomposted waxed corrugated cardboard plus sawdust and(or) spent mushroom compost

7 and 8) 25% cardboard plus sawdust and spent mushroom compost. Before blending with other ingredients, the cardboard was shredded through a hammermill producing pieces that were generally 10 cm × 4 cm.

Containers were arranged by species in separate split-plot designs: main plot, 8 media × 5 replications; subplot, 2 fertilizer treatments, i.e., liquid (200 ppm N) supplied as 20-20-20 with micronutrients 3 times weekly through drip irrigation, and slow-release (6 kg/m^3 Sierra 17-6-12 plus minors, 3-4 month release) incorporated before potting. Each subplot treatment consisted of four plants. Plants received 1 litre of water/container/day during the growing season. All media were sampled at planting and analyzed for selected macro- and micro-nutrients (duplicate samples) and physical (triplicate samples, air dry weight basis) properties (Table 1). Mid-August leaf samples were analyzed for N, P, K, Ca, Mg, Fe, Mn, and Zn. Top dry weight of all plants was determined in late September (Table 1).

RESULTS AND DISCUSSION

Compared to medium #1, all other media had pH of 7.0 or above at planting (Table 1). The 1 cardboard : 1 spent mushroom compost : 2 sawdust (by volume) (medium #7) and all cardboard-based media with 50% spent mushroom compost (media #3, 5, 8) had salt levels that were substantially higher than the 3.5 dS/m optimum threshold value and were due primarily to the presence of K, Ca, SO_4, Cl, and to a lesser degree, NO_3 in media #3 and 8 (Table 1).

Notwithstanding the above results, there was no apparent abnormal or detrimental symptoms observed on plants that could be attributed to initially high salts in the media. Unlike weigela which had lower top dry weight in all media compared with the 100% bark control medium #1, dogwood, forsythia, and ninebark grew equally well in control medium #1, nursery medium #2, and all the cardboard media, except the 1 waste cardboard : 1 sawdust (v/v) medium #4 (Table 1). Previous studies indicated that high or potentially toxic initial salt levels are quickly leached to low levels under these cultural conditions (Chong et al., 1991b). Similarly, media with initial pH up to 8.2 showed no negative effect on plant growth. Medium #4 consistently yielded the poorest growth in all species and was the medium with the highest (40%) aeration porosity (pores filled with air) and, conversely with the lowest (23%) moisture retention capacity (pores filled with water) (Table 1). All other cardboard media had aeration porosities (17% to 32%) and moisture retention (34% to 40%) in more acceptable ranges (OMAF, 1992).

Except for weigela, all species grew significantly better with liquid than with slow-release-fertilizer (data not presented) and, the leaves of slow-released fertilized plants tended to be slightly yellow. Chemical analysis revealed significantly lower contents of N, P, K, and Mn in leaves of all four species grown with slow-release fertilizer (data not presented). The unusually cool temperatures which prevailed during the summer of 1992 apparently resulted in inadequate nutrient release, which is temperature dependent.

Table 1. Chemical and physical properties of waxed cardboard and other media at planting and end-of-season top dry weight of four nursery crops grown in these media.

	Medium (by volume)							
	1 (Control)	2	3	4	5	6	7	8
Ingredient								
Bark	1	8						
Cardboard				1	1	2	1	1
Peat		1.5						
Sawdust			1	1		1	2	1
SMC[z]			1		1	1	1	2
Soil		.5						
Chemical Properties								
pH	5.2	7.0	7.7	7.6	7.7	7.8	7.8	7.5
Soluble salts(dS/m)[y]	0.6	3.0	7.2	3.7	7.0	3.4	5.9	9.3
NO_3[x]	3	3	122	8	9	2	5	96
P	14	2	2	2	1	2	2	3
K	138	587	1585	762	1638	817	1410	2058
Ca	15	206	401	207	348	221	283	455
Mg	12	65	172	80	159	84	118	216
SO_4	20	300	800	800	800	550	800	800
Na	18	109	272	213	277	155	252	391
Cl	27	428	784	384	786	380	837	1204
Fe	0.2	<0.1	0.5	0.3	0.4	0.2	0.5	0.1
Mn	1.9	0.5	<0.1	<0.1	<0.1	0	0.1	0
Zn	<0.1	0.6	0	0.8	0	<0.1	<0.1	0
B	0.2	0.1	0.4	0.4	0.6	0.3	0.7	0.4
Physical Properties								
Bulk density(g/liter)	330	239	497	216	352	372	287	352
Total porosity (%)	60	55	63	63	62	64	66	63
Aeration porosity (%)	14	22	17	40	22	23	32	22
Moisture retention(%)	46	33	46	23	40	41	34	40
Top dry wt (g/plant)								
Dogwood	99	107	89	52*	98	70*	98	75*
Forsythia	92	101	100	55*	109	91	99	91
Ninebark	101	106	105	56*	112	98	110	92
Weigela	30	20*	20*	15*	18*	17*	23*	18*

[z] SMC = spent mushroom compost.
[y] Low 0-0.75; acceptable 0.76-2.0; optimum 2.1-3.5; high 3.6-5.0; very high 5+, saturated paste procedure.
* Significantly different at $\underline{P} = 0.05$ from the 100% bark control (medium #1) according to LSD test within row (species).
[x] All macro- and micro-nutrients are expressed in ppm.

CONCLUSIONS

In this study, the cardboard was not composted before mixing with other medium ingredients. Also, the cardboard pieces were relatively large due to lack of availability of smaller-sized material. Despite this "worst-case scenario", the results showed that certain blends of waxed corrugated cardboard media supported growth of three of the nursery species equal to the control and(or) the nursery mix.

There were high levels of certain nutrients in some of the media at the start of the experiment, but no visual symptoms of nutrient toxicity was observed in any of the plants during the growing season. Analysis further confirmed no abnormally high buildup of any elements in the leaves.

While this experiment was in progress, it was brought to my attention that Cu and B may be present in high quantities in waxed corrugated cardboard (Anonymous, 1992; Davie, 1993; Ciepiela, E.J., personal communication). Analysis of selected leaf samples from all media indicated low (3 to 6 ppm) and average (36 to 48 ppm) contents of copper and boron, respectively. There was only a very low level of boron in the cardboard media (0.1 to 0.7 ppm) (Table 1). Copper was not analyzed in the media.

Presently, studies have been initiated to investigate the composting of various blends of waxed cardboard media using smaller-sized material. The comparative response of nursery crops grown in these composts will be evaluated.

Acknowledgements. This research was supported jointly by Waterdown Garden Supplies Ltd. (also known as Evergreen Sod Farms Ltd.), Troy, Ontario, and the Industrial Research Assistance Program (IRAP) of the National Research Council (NRC) of Canada. Technical support was provided by June Graham, Nicole Martin, Debbie Norton, and Bob Hamersma. Plant material (unrooted cuttings) was donated by Willowbrook Nursery, Fenwick, Ontario.

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Establishing and Maintaining a Seed Orchard

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Our company supplies tree and shrub seed for the nursery trade to produce seedlings for ornamental uses, reforestation conservation uses, mine reclamation, and understocks. Most recently we have begun to produce and collect seed for use in wetland programs.

From our beginning in 1973 we have tried to respond to the needs and requests of our customers. Our customers told us in the beginning that their primary concern was a reliable, consistent seed source. We realized the only way to address this challenge was to establish our own seed orchards. Today, 60% of seed we sell is produced from our orchards and more production is coming on line each year. Certain species such as the oaks take many years to reach bearing age. Therefore establishing seed orchards is a long-term project requiring considerable up-front investment.

REASONS FOR PRODUCING SEED IN ORCHARDS

1) To have a consistent seed source from known parentage.

2) To insure a quality product that is grown, collected, processed, and handled properly.

3) To have the seed crop where it can be closely monitored so collection timing is correct and chances of losing the crop to birds, deer, rodents, and unusual climatic conditions are minimal.

4) To facilitate harvesting.

5) To manage for maximum production by applying latest techniques in weed control, fertilization, watering, and pruning.

6) To facilitate our program of seed improvement through selection, breeding, and culling.

POINTS TO CONSIDER WHEN PLANNING A SEED ORCHARD

Site Selection. Probably the single most important consideration. Many species we grow tend to flower very early in the spring, making them highly susceptible to spring frosts, hence a high site affording good air drainage should be used. We also prefer a south-easterly exposure in our area to give protection from the harsh winters and summer heat and wind exposure common to our midwestern climate.

Soil. A deep well-drained native soil much the same as commercial fruit growers like.

Natural or Established Barriers. Since many species grown are wind pollinated, barriers are necessary to prevent unwanted cross-pollination. Where rolling terrain is available this can be solved by planting on opposite sides of ridges or by keeping a natural stand of timber between plantings. Natural timber stand can also prove valuable as wind breaks for both winter and summer protection.

Orchard Plant Spacing. Most of our production is in hedge row plantings with row spacing of 12 to 20 ft and 5 ft spacing used within the row. The spacing varies with the size and training techniques of the various species.

Basic Sod Crop. We establish a sod crop a minimum of 2 years prior to establishing an orchard on a given site. We prefer bluegrass in our area because of ease of maintenance and less competition during stress periods.

Strips are sprayed at the proper row spacing with Round-up herbicide to establish planting rows in the sod crop. Spraying is done immediately prior to planting. After plants are established the planting strip is maintained weed free by using Round-up in combination with select pre-emergence herbicides. Since a wide range of species are involved, the specific pre-emergence herbicides need to be individually researched.

Selection of Planting Stock. Since seed production is of such major importance, great care should be exercised in the selection of planting stock. Where at all possible, selection should be based on known parentage, improved selection, and breeding improvement. A literature and history search can be the best investment one can make. Botanical gardens, arboretums, plant material centers, and knowledgeable individuals are all invaluable sources of information.

KRIS BACHTELL: Why the southeast facing direction?

ROB LOVELACE: To get the warmth of the sun in the spring of the year.

KRIS BACHTELL: Just a comment on the use of clones as seed parents. Seed from them will not be the true clone and will show variability.

JOHN PADUA: With *Cornus alternifolia*, have you had any problems with canker. We have a real problem in Vermont.

ROB LOVELACE: I have never seen it on any of our plants.

Evaluation of a Chlorophyll Meter to indicate Relative Growth Rates of Similar Plant Material

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INTRODUCTION

Technological advances in electronics have provided us with new equipment to enhance our ability to quantify treatment differences in plant material. One such instrument provides a non-destructive evaluation of leaf chlorophyll levels. Early testing and present use of this instrument focuses on nitrogen fertility of grasses (usually grain crops). The work has resulted in a rapid determination of nitrogen crop fertility levels that identifies fertilization needs for the crop.

This study was initiated to determine if a chlorophyll meter could be a useful tool for production of woody nursery stock. Preliminary information indicated a possible relationship between perceived growth and chlorophyll readings within species. Verification of a correlation between chlorophyll levels and growth of related plant material could allow plant breeders to use information as early indicators of plant performance.

This report is the result of 2-years' data that measured chlorophyll levels in leaves of similar plant material. Initial work during 1992 monitored 12 types of deciduous trees. Data was collected from at least two cultivars within each species of four genera to allow for comparison. During the summer of 1993, a database was developed for six cultivars of *Cornus kousa* × *C. florida* cultivars bred by Dr. Elwin Orton and grown under nursery conditions. A comparison of chlorophyll readings and evaluations by growers of the relative growth rates was also completed.

MATERIALS AND METHODS

During this experiment, chlorophyll levels were determined with the use of a Minolta SPAD-502 chlorophyll meter. Calculations of relative values are based on the amount of light transmitted by the leaf in two-wavelength regions in which the absorption of chlorophyll is different. These correspond to the red area where absorption is high and unaffected by carotene, and the infrared area where absorption is extremely low. Two light-emitting diodes (LEDs) provide illumination in the 650 and 940 nm wavelength areas, which are transmitted through the leaf to a silicon photodiode (SPD) receptor. A ratio between the two light intensities is calculated and is compared to a calibrated value which results in a value that is displayed.

Twelve cultivars of shade trees were evaluated during the summer of 1992. Those evaluated included *Acer plataniodes* 'Crimson King', *A. plataniodes* 'Summershade', *A. rubrum* 'Red Sunset', *A. rubrum* 'Northwood', *A. rubrum* 'Autumn Flame', *Fraxinus americana* 'Autumn Purple', *F. americana* 'Rose Hill', *F. americana* 'Skyline', *Tilia cordata* 'Greenspire', *T. cordata* 'Olympic', and *Zelkova serrata* 'Green Vase' and 'Village Green'. During the summer of 1993, six cultivars of *C. kousa* × *C. florida* hybrids were evaluated. The cultivars tested were 'Rutgan'

Stellar Pink®, 'Rutban' Aurora®, 'Rutdan' Celestial™, 'Rutcan' Constellation®, 'Rutfan' Stardust®, and 'Rutlan' Ruth Ellen®.

All readings were taken from intact mature leaves. Shade trees were randomized within five complete blocks and planted in the spring of 1991. Five treatment plants of each variety were included in each block. Readings were taken from five leaves on each of the treatment plants. Chlorophyll level evaluation took place on 1 June, 15 June, 1 July, 14 July, 31 July, 18 August, 1 September, 15 September, and 1 October 1992. Dogwood selections were planted in block form, with data taken from plants in complete rows. Seven replications of each variety were evaluated, with five leaves from each plant being averaged. Dogwood data was recorded on 16 July, 17 August, and 17 September 1993. Data was statistically analyzed using the Fisher's PLSD test. Separations were at the .05% level (95% probability).

RESULTS

Overall shade tree leaf chlorophyll levels increased as the season progressed from the first test date on 1 June through 18 August (Fig. 1). After that date, chlorophyll levels gradually decreased through the last test date on 1 October. By 1 October, some species exhibited early fall leaf coloration so data was recorded from leaves representative of the total tree leaf area.

Trees were evaluated within species to determine if differences in chlorophyll levels existed. There were significant differences in mean chlorophyll ratings for all but the *Tilia* species (Table 1). Also indicated in Table 1 were the peak mean chlorophyll levels recorded by species and the date on which the peak levels occurred. The species with the highest annual mean chlorophyll reading was consistent with the latest date for the peak mean chlorophyll reading for *Acer*, but that relationship did not exist for the other genera tested.

Acer plataniodes 'Summershade' was observed by growers to gain in size faster than *A. plataniodes* 'Crimson King'. Data from this study indicated 'Crimson King' had significantly higher rates of chlorophyll than 'Summershade'. Grower ob-

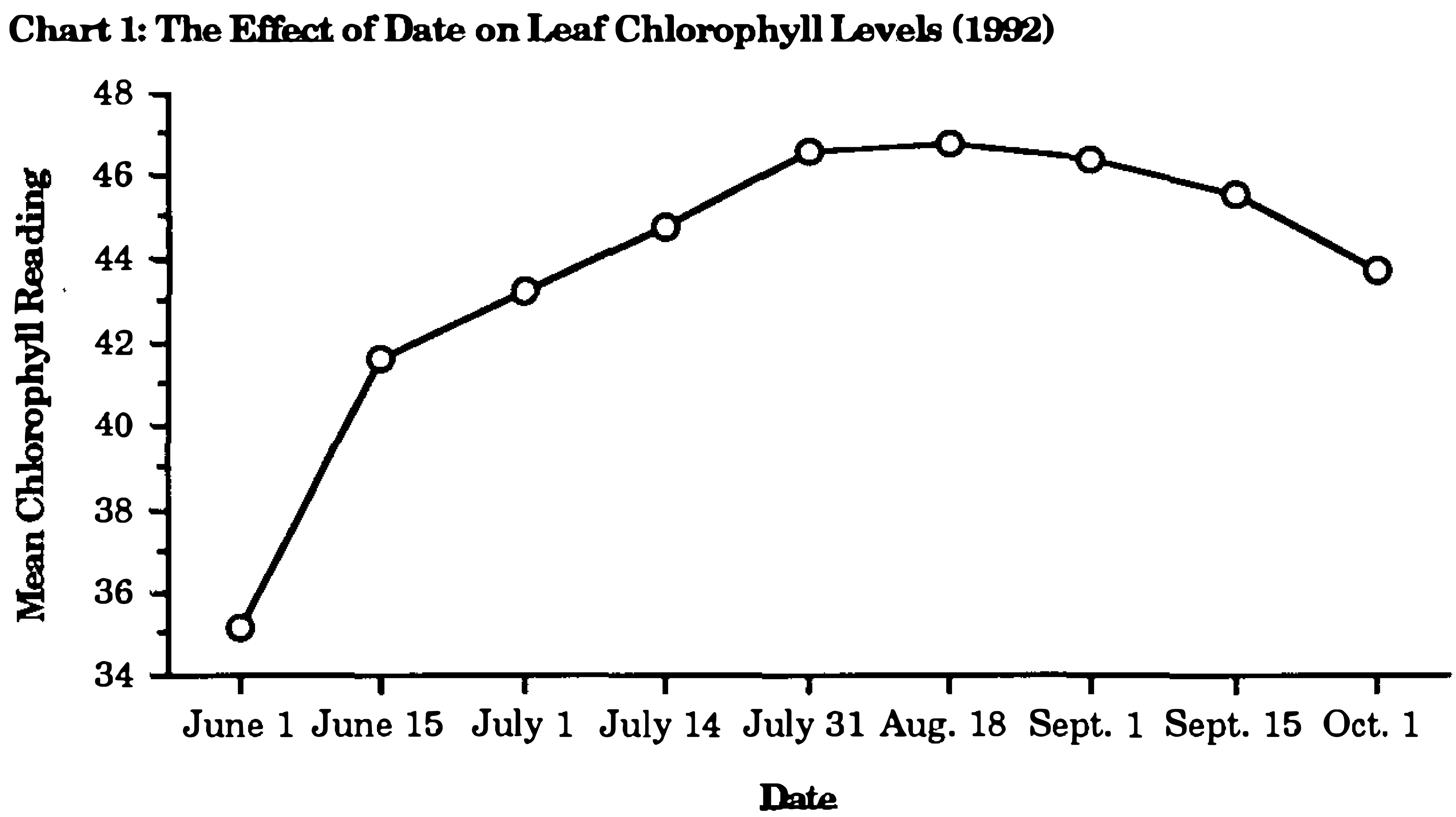

Figure 1. The effect of date on leaf chlorophyll levels (1992).

served growth rates for *F. americana* species indicated the greatest growth for 'Skyline' and the least in the 'Autumn Purple'. The highest indicated chlorophyll levels were found in 'Skyline' and the least in 'Rose Hill'.

Table 1. Shade tree chlorophyll ratings.

Variety	Annual mean[1]		Peak mean[2]	Peak date
Acer plataniodes 'Crimson King'	52.3	a	58.9	10/1
A. plataniodes 'Summeshade'	41.0	b	44.3	9/1
A. rubrum 'Autumn Flame'	40.8	b	45.5	8/18
A. rubrum 'Northwood'	40.2	b	43.4	7/31
A. rubrum 'Red Sunset'	45.9	a	50.0	9/15
Fraxinus americana 'Autumn Purple'	46.5	b	50.3	7/31
F. americana 'Rose Hill'	43.7	c	46.8	8/18
F. americana 'Skyline'	47.9	a	52.2	7/31
Tilia cordata 'Greenspire'	44.3		44.9	8/18
T. cordata 'Olympic'	43.8		46.9	10/1
Zelkova serrata 'Green Vase'	39.6	b	43.4	8/18
Z. serrata 'Village Green'	40.8	a	44.7	8/18

[1] Letters indicate significance within species at 95% probability.
[2] Significance not evaluated.

Dogwood cultivars were also evaluated for mean chlorophyll ratings. Significant differences in chlorophyll were indicated, with Celestial™ having the highest levels and Ruth Ellen®, the lowest levels (Table 2). Six of seven growers propagating these dogwood cultivars responded when asked to indicate the ease of propa-

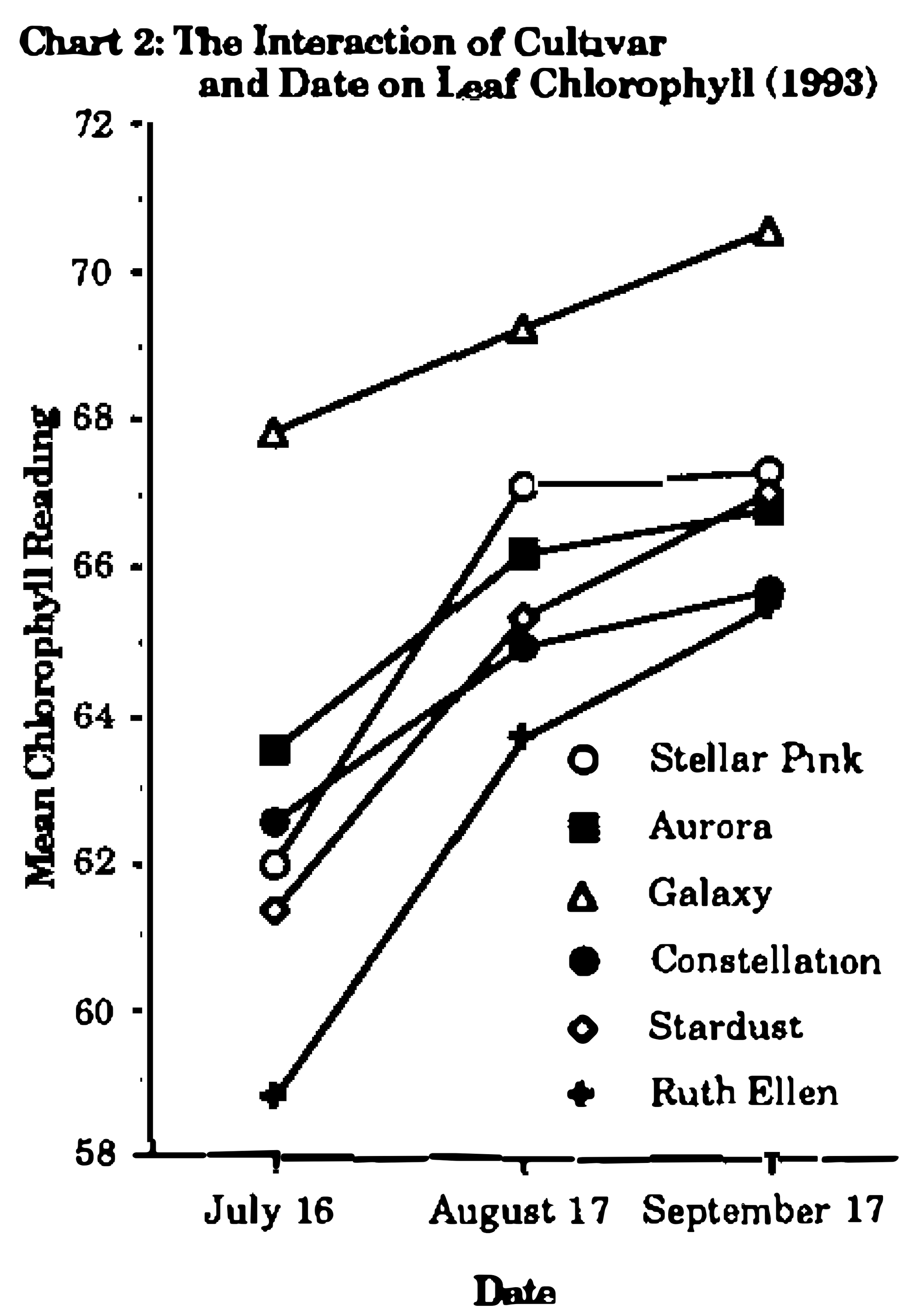

Figure 2. The interaction of cultivar and date on leaf chlorophyll (1992).

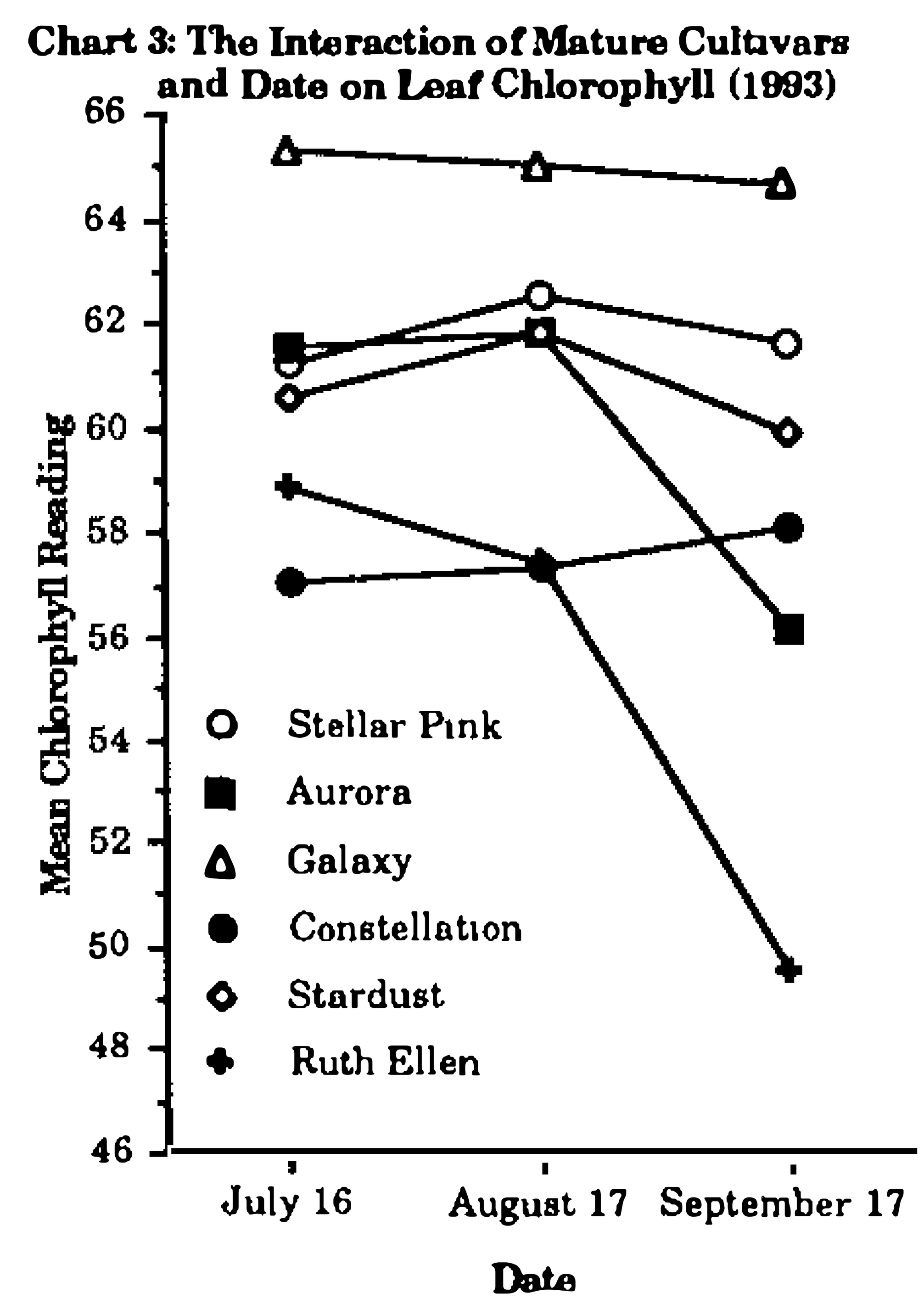

Figure 3. The interaction of mature cultivars and date on leaf chlorophyll (1992).

gation and the relative vigor of this plant material. This information is recorded in Table 3. With the exception of Stardust®, cultivars were rated as easy to propagate. Stardust® is more dwarfed in size as compared to the other cultivars, which may have an impact on propagation. A comparison of relative vigor indicated Aurora® and Ruth Ellen® as being the most vigorous cultivars. Only Stardust® was significantly poorer in vigor than the other cultivars, which is probably related to its genetic potential. Stellar Pink® was intermediate in vigor.

Table 2. Dogwood chlorophyll ratings.

Variety	Annual mean [1]	Peak mean [2]	Peak date
Cornus Stellar Pink ®	65.5 b	67.3	9/17
Cornus Aurora ®	65.5 b	66.7	9/17
Cornus Celestial ™	69.2 a	70.6	9/17
Cornus Constellation ®	64.4 bc	65.7	9/17
Cornus Stardust ®	64.6 bc	67.0	9/17
Cornus Ruth Ellen ®	62.6 c	65.5	9/17

[1] Letters indicate significance within species at 95% probability.
[2] Significance not evaluated.

Table 3. Dogwood grower evaluation.

Variety	Ease of propagation [1]	Vigor
Cornus Stellar Pink ®	6.3 a	7.7 ab
Cornus Aurora ®	8.7 a	8.2 a
Cornus Celestial ™	8.0 a	7.8 a
Cornus Constellation ®	8.5 a	8.0 a
Cornus Stardust ®	4.5 b	3.5 b
Cornus Ruth Ellen ®	7.8 a	8.2 a

[1] Evaluated on a 1 to 9 scale with 9 being the best cultivar.

As a validation of the chlorophyll levels recorded in the block of young dogwood, mature trees of the cultivars were also measured for chlorophyll levels (Table 4). Celestial™ again recorded the highest chlorophyll levels, while Ruth Ellen® had the lowest levels, as was the case with the younger material. Overall, the position of the relative chlorophyll levels were similar to those recorded on younger material. The actual recorded chlorophyll levels were somewhat lower than those recorded on younger material. For younger plants, the highest mean chlorophyll levels each occurred on the latest test date. On the mature material, the highest levels did not correspond to an individual test date.

Table 4. Mature dogwood chlorophyll ratings.

Variety	Annual mean [1]	Peak mean [2]	Peak date
Cornus Stellar Pink®	61.8 b	62.6	8/17
Cornus Aurora ®	59.9 bc	61.9	8/17
Cornus Celestial ™	65.0 a	65.4	7/16
Cornus Constellation®	57.6 cd	58.1	9/17
Cornus Stardust®	60.8 b	61.8	8/17
Cornus Ruth Ellen®	55.3 d	58.9	7/16

[1] Letters indicate significance within species at 95% probability.
[2] Significance not evaluated.

Data developed regarding the interaction between young dogwood cultivars and the date as they relate to leaf chlorophyll levels is shown in Fig. 2. Celestial™ had the highest chlorophyll levels consistently through the year, Ruth Ellen® consistently had the lowest, and other cultivars varied with the time of year. Observation of other nursery plant material indicates that, for many plants, early growth is an indicator of overall performance. Aurora®, which was rated highest in vigor by growers, was second highest in early season chlorophyll levels. Constellation® was rated just behind Aurora®, followed by Stellar Pink® and Stardust®. Each is rated in the same position for early season chlorophyll levels and for grower vigor ratings.

Chlorophyll levels in mature plant material had relationships that were similar to those found will less mature material (Fig. 3). Celestial™ again was found to have the highest levels of chlorophyll throughout the season, while the cultivar Ruth Ellen® was near the lowest all season. Although Constellation® recorded the lowest overall chlorophyll rating, it was the only mature tree cultivar to increase in chlorophyll level throughout the season.

DISCUSSION

The use of chlorophyll meters as an indicator of plant performance has occurred primarily with small grains. These rapidly growing annual crops are subject to nutritional deficiencies. Because of the perennial nature of woody plants, they are usually more tolerant of nutritional variations.

Information developed over three years has not resulted in a development of a reliable testing procedure where one would benefit from the use of a chlorophyll meter as a diagnostic tool in woody ornamental plant material. While some relationships appear to exist within species, there seems to be little consistent correlation between leaf chlorophyll levels and growth or ease of propagation. A factor that was not documented was that of plant canopy size. Since the total leaf area can compensate for individual leaf chlorophyll levels, a measurement would be useful to further clarify the information developed in this study. Although actual levels were lower, validation of chlorophyll levels was achieved through the measurement of chlorophyll in mature trees.

There is much work left to do. While leaf chlorophyll level may be involved in plant performance, information from other factors related to plant performance must be developed. Whether we look for ways to evaluate vigor, cold hardiness, nutrition, or other possibilities, databases must be developed. With additional performance factors, it may be possible to develop useful models that can serve as early indicators of plant performance. It is up to us, however, to identify which electronic devices are tools, and which are toys.

BRIAN MAYNARD: With *Acer platanoides* 'Crimson King' do you have to calibrate your meter for other pigments in the leaves?

JAMES JOHNSON: No you don't.

Question Box

Moderated by Ralph Shugert and Bruce Briggs

Question. For John Larson. What is the rooting percentage for the third generation of cuttings?

John Larson: It is 90% to 95%.

Question. For John Larson. What commercial plug mix are you using for rooting commercial cuttings on? What size/type of plug tray are you using?

John Larson: We are using Grace Sierra vegetable plug mix, and a 400-plug tray.

Question. Which variety of forsythia is most suitable for winter forcing of bloom? Can the white flowering form be forced?

David Schmidt: Most *Forsythia* × *intermedia* cultivars will do well.

Clayton Fuller: 'Spring Glory' or 'Lynwood' will do well for forcing. It takes about 10 days.

Bill Barnes: I have worked with *Abeliophyllum distichum*, often called white flowering forsythia, and it forces as well as forsythia.

Question. For Brian Maynard. Why can't shade plants grow in the sun? What physiological process limits these plants to grow in low light levels?

Brian Maynard: A lot has to do with how chlorophyll is found in the chloroplast and how the chloroplasts are arranged in the leaf, how thick the leaf is, and the capacity of the leaf to adapt. Leaves that grow in low light are thinner and have chloroplasts that are flatter to intercept more light. When grown in high light the chloroplasts become orientated in a vertical manner and the leaf lamina becomes thicker. One of the problems with intercepting too much light is that the photosynthetic process goes to fast, and the leaves start to oxidize. Therefore the answer to the question is how much the plant can adapt.

Question. If one buys an index to past proceedings but doesn't possess the volumes, is there a source one might call and get a certain article faxed or copy sent?

Charles Heuser: I do not have a complete set of the proceedings so I am not a source for all the information. There is one person who has a complete set, and that is Ralph Shugert, and in the past he has been willing to send copies.

Editor's Note: Tom Pinney, indicated that Ron Amos of his firm will send copies; Dick Zimmerman has a complete set and he has volunteered; Kris Bachtell noted that the Morton Arboretum will do it; and Chris Graham noted that the RGB has a set and would serve Canadian members. A question was raised regarding the availability of back Proceedings. It was noted that there are a few back issues available, mostly newer volumes, and interested individuals should contact John A. Wott, International Secretary/Treasurer for information.

Question. For Mary McClelland. What concentration of hydrogen peroxide would you recommend for surface decontamination of tissue- cultured explants?

Mary McClelland: I'm sorry to say that I can't confidently give you a recommended rate at this time. We are just starting our work with it. But gathering from the interest the topic generated, I was encouraged to document our trials and get back to you with practical advise. If any of you have other information on other sterilants, please contact me.

Steve McCulloch: We surveyed a number of products and published a paper in the Proceedings. We concluded that sodium hypochlorite was the best.

Deb McCown: We use quatinary ammonium compounds, such as Lysol, as surface sterilants.

Bill Barnes: Some of us have tried Physan but have found it to be species specific, some plants react negatively to it, and it is not labeled for such use.

Carmine Raguse: Benadine, and iodine compound; it is an excellent compound, is a close relative of iodine.

Question. For Bill Hendricks. I thought you suggested that compost on beds helps prevent disease, could you explain?

Bill Hendricks: The product I am using is composted municipal sludge (not sludge) plus bark. The bark brings in disease suppression. It is also a source of fertility and micro nutrients.

Ralph Shugert: Before you abandon a fungicide program in your seed beds, you need to do some R&D to check it out.

Question. For Phillip King. What is the maker of the air-jet fog head and where do you get them?

Phil King: They are made by Spraying Systems. I will be glad to provide any additional information members may want by phone.

Tom Kimmel: Bete Company is also a source of such nozzles.

Question. For those nurseries with a student intern program. How and where do you attract the best students?

Dan Studebaker: It really gets down to who you know. We work through the university system, 2-year program at Wooster, and contribute to scholarship programs.

Ted Meyers: We work about the same with Michigan State University, and the state nursery trade association and in conjunction with the winter meeting. The best way is to have the university and trade associations get together and work something out.

Ralph Shugert: We have not had an intern for 3 years. I am very particular about who we have and require that they come to the nursery for a 3-h visit. That personal interview is so important to assess their ability.

Question. For Kenneth O'Dell. Is there a source where one can purchase fern spores?

Dale Hendricks: The American Fern Society might be a source. They have a spore exchange.

Carl Totemeyer: I might add the New York Botanical Garden has a world authority on ferns and would have sources. John Mikkel would be a potential contact person.

Question. Has anyone used sprays of dilute methanol on the foliage of plants to increase plant growth?

Tom Kimmel: My research person who has a large research file on the subject is not here, but it is supposed to add oxygen to the leaves.

Question. Does root activity continue at night at the same rate as during the day?

Sid Waxman: The person who did the work was Koths and it is in the Proceedings.

Question. What would a typical propagation schedule and percent rooting be for *Sciadopytis verticillata?*

Sid Waxman: The first thing to do is to find a clone that works for you. Then the following should work: take cuttings in January/February, place cuttings into water to let the resin drain out, treat with Woods (1 : 5) or Hormodin #3, mist, 70F bottom heat, and a medium of 3 peat moss and 2 perlite (v/v). They should root in 5 to 6 months.

Clayton Fuller: We do essentially the same thing as Sid, except we do not remove the resin. Instead we double wound with a slit wound, not the normal wound, about 3/4 in.

Ralph Shugert: Could you also discuss the sexual germination of *Sciadopytis*?

Sid Waxman: We found that soaking in aerated water produced more uniform germination. The seeds also respond to photoperiod, long day inhibits and short day encourages.

Ralph Shugert: We found with *Pinus mugo* that soaking made a big difference in the germination of that plant. A good Canadian friend mentioned to me that all conifer seeds should be soaked before sowing.

Question. Has anyone found a way to propagate *Spiraea japonica* 'Shiboi' to get true tri- or at least bi-color flowers rather than a high percentage reverting to either all white or all pink flowers?

Steve McClouch: It is very easy to root. However, the key is careful selection of wood with the proper selection of pigmentation is the key.

Ron Amos: My observation is that if you if you select foliage with only the red it will not show both. Foliage on the lighter green side will be better and show both.

Question. What is the best method for propagation of *Daphne cneorum*?

Voice: There are probably as many ways to grow it as nurserymen growing it. We have found that summer is bad, they can not stand moisture on their leaves. We are doing it now (December), bottom heat of 21C, and lay off the water. You should get 50% to 60% rooting. With the Daphne burkwoodii types, summer cuttings work best.

Bruce Briggs: We have found that tough old plants work best and leave a heal on the cuttings.

Question. How do you get *Styrax japonicus* 'Pink Chimes' and weeping forms to go through one winter?

Bill Barnes: Ideally you should have no fertilizer after it is rooted. The best solution is to bring stock plants into the greenhouse in February/March, force cutting wood, root them when the photoperiod will keep them growing. We run into the same problem with *Hamamelis* and *Stewartia* cuttings.

Question. For Elwin Orton. Can *Cornus kousa* × *C. florida* hybrids be grown on their own roots? What understock should be used if grafted?

Elwin Orton: You can do it easily, if you are licensed. They do grow well from rooted cuttings.

Deb McCown: We are under contract to Rutgers University to micropropagate Dr. Orton's dogwood. We have five in culture. We can sell them only to a list of licensed growers.

Question. For Elwin Orton. Does the bract color on *Cornus kousa* 'Satomi' hold well in your experience?

Elwin Orton: I have never seen a good red form. We may be seeing the same thing that we see in *C. florida* where in cool seasons the heterozygote condition for red causes the development of a pink color. The same condition may exist in *C. kousa*.

Question. What rate of Basmid would you recommend for a soil sterilant before sowing the grass seed for the grass to feed deer? Also what post emergence herbicide would you recommend and at what rate per acre?

Ralph Shugert: I would recommend 330 lb/A and probably could cut back to 270 lb/A.

Question. What is the best tool for applying a top dress fertilizer to a container?

Ben Davis: A spoon.

Clayton Fuller: People do not like to bend over, so we build a drop tube device. It consists of a waste basket—of a size that will hold 20 pounds of Osmocote that is attached with a belt to the worker. We then purchased a funnel and attached a plastic tube which allows us to direct the flow of fertilizer.

Kees Govers: Plant Products Co. in Ontario carries two stainless steel applicators that strap to the chest with a capacity of 20 lb capacity. The mechanism consists of a nylon plunger on a spring-loaded shaft. Quantity is set by screwing the plunger further into the shaft. The hopper feeds into a chamber below, the plunger dispenses when pulled up or pushed down depending on the model. A 3/4-in. drop tube made of PVC drops the fertilizer into the container. Labor savings are 40% to 50% over spoon feeding. Material savings also occurs as the applicator is set for a certain container size and always drops the same amount.

The second part of the morning session convened 1:30 p.m. with Charles E. Tubesing serving as moderator.

MONDAY AFTERNOON AWARDS LUNCHEON

The Awards Luncheon was held in President Ford Room of the Amway Grand Plaza Hotel, Grand Rapids, Michigan.

EASTERN REGION RESEARCH GRANTPRESIDENT SMEAL

The 1993 grant was awarded to D. Cameron Smith. The title of his research grant was: "Automated Cutting Orientation Sensor Development."

FELLOW RECIPIENTSEASTERN REGIONCLAYTON FULLER

The Eastern Region named its fourth class of Fellows at its 43rd Annual Meeting. The new Fellows introduced by Clayton Fuller are:

Dr. Philip L. Carpenter

Dr. Richard A. Jaynes

Edward H. Losely

Dr. Elwin R. Orton, Jr.

Dr. Harold Pellett

AWARD OF MERITEASTERN REGION

Peter Orum made the following Award of Merit presentation.

When I was asked to present the Award of Merit 1993 here in Grand Rapids I felt honored, and much joy, because of whom I will present it to.

It is customary to present some background about the member who will receive the Award of Merit—and keep you all in suspense as long as possible. I shall attempt to do this.

The Award of Merit is the highest honor and recognition we can bestow upon a member. It is a way of saying "thank you, for all you have done for our Society." It is bestowed upon a member in recognition of what he or she has done for plant propagation and for our Society. Some have over the years done more work in plant propagation while others have done more in Society work. Even though our honoree today has been a successful propagator and grower through much of his life, it is especially his work with people in this Society we are thinking about today.

Our member who we a honoring today was born during the depression. That was a time in history for most people here today. For those that were in it, it was a very tough time. It was a time, my grandfather in Denmark said to me, that the farmers were rationed Hog-Cards which allowed them to sell hogs for $7 a piece for slaughter and export to England. It was a time when my father told me he would work on farms in Nova Scotia for board and one pack of tobacco a month—in the wintertime. And I am sure our honoree today could tell us stories of a tough, hard-working life on the nursery farm.

Our honoree and the nursery family made it through. The years after the war brought studies and graduation from Michigan State University, which makes it most appropriate to be here in Michigan not far from East Lansing.

Also back in history there was a time when every able young man was drafted into the Armed Forces for 2 years. Our honoree was no exception. Later, when he returned to nursery work, he managed to get to a few I.P.P.S. meetings. I do not know if he came as a guest for more than 1 year (I suspect he did) but sure am glad the secretary-treasurer did not chase him out! He did become a member way back when it was just the I.P.P.S (they could call it that because of Canada and great ambitions). The split up in regions did not start until a few years later, when the Western Region came into being.

Since then he has been to every conference—I think. I am not sure when I first met him, but it must have been in the late 1960s. I am fairly sure that he just came up to me and said, "Hello, I am (honoree of the day), it's good to meet you here." That is how he was/is, he always made people, including new people, feel welcome.

Our honoree spent years in local and state nursery association work and ended up as president of almost everything he became involved in, including civic association work. He must have spent a least 15 years on I.P.P.S. association work—from committees, to board, to vice president and program chairman, and to president. He later became one of our most capable and respected international delegates, helping to bring back lost Eastern Region influence to the International Board. He has worked for the I.P.P.S. in the most dedicated, capable, and unassuming ways. Through it all he and his brother ran a most successful nursery.

He is a man we can depend on. He always finds ways of doing things, of cutting through and getting the task done. He listens, he tries to understand, he involves people, and when he speaks people listen.

I do not know when our honoree got married, but I know that he is still married to the same wonderful lady.

As John Wilde many years ago became my mentor in plant propagation, so did our honoree of today become my mentor in association work.

And now, ladies and gentlemen, you may be well on your way to knowing who our honoree is.

No Eastern Region/I.P.P.S. member is more worthy to receive the 1993 Award of Merit than Chuck Tosovsky!!!

Propagation of Astilbe

David J. Beattie
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Astilbes are members of the Saxafragaceae family, native to North America and Asia, and are hardy, deciduous perennials. Most grow in dense clumps although some spread by underground rhizomes.

Astilbes can be propagated by seed, tissue culture, or division. Seed propagation is not recommended because cultivars do not come true from seed. Although *Astilbe chinensis* var. *pumila* plants are often propagated by seed, the most uniformly dwarf plants are produced from asexual divisions.

Astilbe seeds are small so when they are sown they should be lightly pressed into the germination medium. Seeds do not appear to require a stratification requirement, and germination temperatures should be maintained at about 65 to 70F.

Some astilbe cultivars are being tissue cultured, especially in England. I do not recommend this method because of the propensity of astilbe to mutate (sport)—particularly red cultivars.

Most astilbes are propagated by division of the crown. In commercial propagation it is important that division be done at least once—and sometimes twice—each year to maintain plants in a rapidly growing state. The best time to divide most astilbes is in the spring just before the leaves expand. After the first few leaves have fully expanded further division may result in aborted flower buds. Division can resume after flowering and continue until early August. Although astilbes can be divided after that date, some root zone (or greenhouse) heating should be provided to encourage root development. Late, out door division may result in poor root establishment so that plants will heave out of the bed or pot the following spring.

The crown is made up of many buds called eyes that are placed close to each other. The physical properties of the growing medium strongly influence the morphology of the crown. For example, the buds of plants grown in sandy soils tend to be widely spaced on the crown, whereas those grown on poorly drained or clay soils tend to be compressed and close together.

To divide astilbe, place a sharp knife between the eyes and cut downward through the entire crown structure. Commercial-sized divisions of the *A. arendsii* types contain 2 to 3 large eyes, but *A. simplicifolia* hybrids may contain as many as 5 to 10 eyes. *Astilbe chinensis* types are much more rhizomatous than the *A.* x *arendsii* types, so the underground stems are much elongated and may contain numerous buds. The rhizome should be cut apart, so that the division contains 2 to 3 buds. The 2- to 3-eye division is the most common size available in part because most of the astilbes are produced in Holland and must be washed free of soil in order to be pass USDA inspection and be imported into the U.S. Crowns containing more than three eyes are too difficult to wash free of soil. After division the propagules should be replanted to the same depth as they were in the original container.

VOICE: Is cutting propagation of *Chionanthus virginicus* possible?

DAVID BEATTIE: Yes, I am told, but you must take cuttings when they are very soft in May. The window is very narrow, as with *Syringa vulgaris*. Treat with 5000 ppm IBA in ethylene glycol. A rooting percentage of about 95% is possible.

The Propagator and the Computer: The Perfect Partnership

Mike Kolaczewski
Flora and Fauna Horticultural & Biological Consultants, 324 Silver Street, Elgin, Illinois 60123

INTRODUCTION

There are many tools that help you to accomplish your job of growing plants. There is another tool that can help you to sell your plants as well as run your business more efficiently. I am speaking of course of the computer. This is a tool that many people use every day, yet there are people out there who are still not taking advantage of these wonderful machines.

For many people, a computer is like a mystic relic, to be looked at and not touched. Yet if you were to sit down and take a few hours of your time, you would find out just how much you can accomplish on one of these desktop wonders. With the advent of home computers there has literally been an explosion of businesses that 10 years ago did not exist. The green industry should not be an exception to this new technology. If you have a small nursery or landscaping venture, you can perform many tasks with just one machine.

The obvious functions are bookkeeping, inventory, payroll, and several others that are touted as computer jobs. However, your computer can do much more than what many would term as simple tasks. Did you know that computers are also electronic publishing machines. They are capable of producing catalogs, graphic artwork, and other such items. What this presentation is intended to show you, is how you can produce many types of printed material at your own office.

This is a great revelation, you can control from start to finish, your entire catalog, newsletter, or whatever printed medium you use to reach your customers. Let us consider this, that in today's marketplace, there are many people either producing or selling the same items. You need to make the customers remember your company and your product.

THE CREATIVE EDGE

Just as every person has a particular style, so should your business. What you are and what you do should stand out from the crowd. If you are growing a plant nobody else has, or have a particular collection of plants to sell, then you need to let people know about them. Where and how you present your product or service can make the difference between being noticed and being one of the herd. First decide on how to market your company. Should you produce a catalog, or begin with a simple one page flyer. The impact you make on people will determine their response. This is where a logo or brand name can help flag people's attention.You condition people to recognize your particular sign as one that they can count on for that certain product.

You also of course, have to back up your claims with a reliable product. Remember that the following items go hand in hand: product, quality, and service. Once you can establish yourself in the marketplace, you then have to keep yourself there.You can make a simple logo from clip art. This is software that has images or drawings in a collection. You can incorporate this artwork into your letterhead, postcards, labels, business cards and envelopes.

With a drawing program you can design your own logo if you wish, and then you will have created a unique trademark for yourself.

FONTS—ELECTRONIC TYPE

It's not only what you say, and how you say it, it's how people read it that counts these days. Electronic typefaces are commonplace in today's computer world. There are literally thousands of type available. Their style and shapes have been developed to match particular types of publishing uses. You can control or influence the way people perceive your work by the fonts you use. For instance, Adobe Caslon is a serif font, that is the letters have brackets and bars to aid in reading them. What these "wings" do, is draw your eye to read across the groups of letters on the page. Since we tend to read words in blocks and not individual words, this can be useful.

Spacing of words, the size of the type, and how far apart the lines of print are, all determine how fast or slow we read. Try reading a contract or the fine print at the bottom of a TV screen, during a car or truck commercial. Compare that to the print used in a newspaper ad. Look further at the print used on candy wrappers and cereal boxes. You will soon discover how advertisers can and do influence your market decisions and how you perceive various products you purchase. When you decide what kind of font or fonts you will use, remember to keep the number you use to a selected few. Your font library can soon amount to several dozen different types of print. This of course can take up quite a bit of space in your computer's memory. What you do by using a few fonts is of course provide consistency to your work. This again brings us around to a recognized style, which people will associate with you and your product. For those of you who are interested in this presentation, and the accompanying poster, I would be happy to send you samples of my publishing or pertinent computer information.

Remember that it's how you say what you mean, that people will remember. In today's business environment that means being better not behind, and if not better then be different.

Differentiating Plant Clones in Culture and Maintaining "Virus Tested" Blueberry Clones

Michael V. DeGrandchamp
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INTRODUCTION

In 1986 the Michigan Department of Agriculture instituted the "Michigan Virus Tested Blueberry Clean Stock Program" for blueberries (*Vaccinium corymbosum*). DeGrandchamp Blueberry Farm Inc. entered into the virus tested program that same year. Part of the program required the maintenance of a foundation stock block for scion wood. It was decided at that time to maintain the stock block in vitro and produce scion wood as microshoots from tissue culture. The in vitro multiplication of 25 cultivars was contracted with an outside tissue culture laboratory. Unrooted microshoots are shipped to our nursery, rooted in our greenhouses, grown outside for 1 or 2 years and then sold to commercial growers.

DIFFERENTIATING PLANT CLONES

We soon discovered that all blueberry cultivar microshoots looked nearly identical until they were several months old. Cultivars were virtually impossible to tell apart. One of the greatest dangers associated with tissue culture propagation is the mixing or mislabeling of cultures (Hancock et al., in prep). After growing several cultivars for 18 months we discovered some cultivars were mixed with other cultivars. A complete investigation of our greenhouse propagation procedures revealed that the mixed cultivars originated from the tissue culture laboratory.

Dr. James Hancock, Department of Horticulture at Michigan State University, was contacted about the mixing problem. He had already conducted some research on identifying clones of blueberries by using starch gel electrophoresis. Cultivars vary greatly in their in vitro proliferation rates, and as a result, mislabeled, rapidly proliferating cultivars can replace properly labeled ones. Therefore, there was a need for biochemical markers that can be periodically employed to verify "trueness to type" (Hancock et al., in prep.). Because of the great deal of research already done on using isozymes to identify cultivars (referred to as finger printing) of a wide range of fruits (Torres, 1989), Dr. Hancock proceeded to finger print over 20 cultivars of blueberries from known "true-to-type" plants.

The procedure used in fingerprinting is the following. Dormant fruit buds, immature leafs, or in vitro microshoots of cultivars thought to be mixed were sent to Dr. Hancock's lab at Michigan State University. There Dr. Hancock uses the process of electrophoresis to identify cultivars by their isozyme patterns. An electrical current moves all the enzyme proteins that are in the sample through the starch gel. The proteins are separated by size—the different bands being different sizes of proteins (see Fig. 1). Thus, different cultivars can be distinguished because they have proteins of different sizes. It is possible to distinguish 20 of the major blueberry cultivars based on the combinations of banding patterns observed with only three enzymes. It should be possible to distinguish other cultivars by examining additional loci. (For example, although 'Northland' and 'Darrow' are identical at the three loci [Table 1], they have distinct patterns at a second locus at both MPH and 6PGDH.)

Table 1. Isozymes at three loci, as designated in Figure 1 for each of 20 blueberry cultivars.

Cultivar	PGI	MDH-2	6PGD2
Rubel	1	1	2
Earliblue	1	1	4
Blueray	1	3	2
Bluetta	1	3	5
Toro	1	1 *	2
Jersey	2	1	3
Patriot	2	2	2
Spartan	3	1 *	4
Bluecrop	3	1	2
Coville	3	3	2
Collins	3	2	5
Bluechip	3	2 *	1
Bluejay	3	1 *	3
Bluehaven	3 **	1	4
Berkeley	4	1	4
Northland	4	1	3
Nelson	4	1	2
Elliott	4	1 *	4
Darrow	4	1	3
Northcountry	5	3	1

* These cultivars run slightly faster at the MDH-2 locus than the others.

** The slowest allele in 'Bluehaven' is slower than the slowest allele in the other cultivars with PGI isozyme 3 (Hancock et al., in prep.).

Dr. Hancock can then determine if cultures are "true to type" or mixed, and often what cultivars are mixed. We were also able to visually confirm his findings by identifying cultivars of more mature plants that came from the identified mixed cultures.

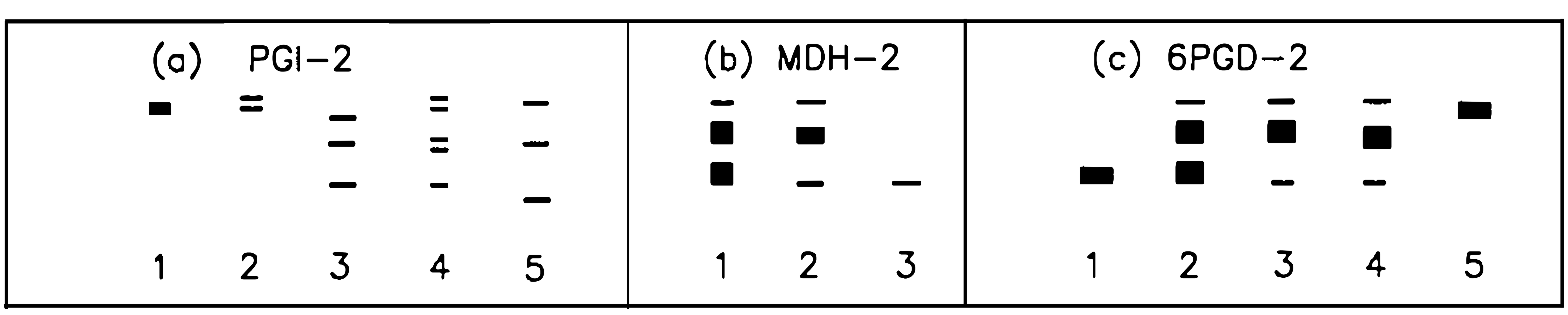

Figure 1. Observed isozymes among blueberry cultivars at 3 isozyme loci (a-c).

Our procedure now is to have Dr. Hancock confirm all cultivar cultures to be "true to type" before they are subcultured for multiplication. Also, when new cultivars are released, the stock plants are verified before they are put into tissue culture. An added benefit of this procedure is the cultures can be checked for possible mutations. During the first 6 months of growth in our greenhouses, any plants that appear to be "off type" are sent in for verification. By using electrophoresis we have eliminated mixed up cultivars coming from the lab, and coming out of our greenhouse to the commercial grower's fields.

The benefits are obvious in the commercial fruit business of true-to-type cultivars. What other uses does this procedure have outside of the fruit business? Isozymes fingerprinting has also been successfully used with *Taxus*, *Cornus*, and *Rhododendron* in Dr.Hancock's lab. Genotypes can be distinguished within these species. As propagators we can test a known stock plant from the source and verify that cultivars we are selling are true to type, thus eliminating much confusion in the industry.

MAINTAINING VIRUS-TESTED BLUEBERRY CLONES

The key to maintaining virus tested blueberry stock is the use of the enzyme linked immunosorbent assay (ELISA). Viruses that are tested for include:

- BBSSV (blueberry shoestring virus) which has infected 145,000 plants on 10,000 acres and has caused a loss of approximately 3 million dollars.
- BBLMV (blueberry leaf mottle virus) which causes stunted and very unproductive bushes that die after several years.
- TBRSV (tobacco ringspot virus) and TMRSV (tomato ringspot virus) which cause slow but steady decline and sometimes death.

One method of spreading these viruses is by using latent infected scion wood. Symptomless or latent infections are missed without the requisite indexing to assure freedom of infection from virus and virus-like entities (Ramsdale et al., 1987).

The decision was made to keep the foundation stock in tissue culture because of the ease of maintaining the requirements for certification versus maintaining the stock in the field. The requirements for the land selected for growing of foundation stock was: fumigation, freedom from *Agrobacterium tumefaciens* (crown gall), and isolation by 500 ft from any *Vaccinium* species. In addition the plantings cannot flower, and must be weed and insect free. All of these requirements can easily be met by maintaining the foundation stock in tissue culture.

ELISA testing is used on a 5% sampling of cuttings as soon as they have mature leaves (about 3 months after rooting). A second 5% sampling is taken the next year after they are fully leafed out (mid summer) in the container blocks. By sampling two times, our customers can be assured of the cleanest blueberry nursery stock available.

As propagators it is our job to produce the most disease free, healthy plants we can. By using ELISA testing we have made an important step in achieving this goal.

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BRUCE BRIGGS: Do you think that you can clean up virus problems by culturing plants?

MICHAEL DEGRANDCHAMP: I do not run a lab, but Dr. Hancock feels that you can not clean them up in culture.

Breeding Hardy Woody Landscape Plants

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The goal of the landscape plant improvement program at the University of Minnesota is to develop and/or identify superior woody landscape plants that are tolerant of the climatic conditions of Minnesota and other northern areas. We approach this goal through two main activities: evaluation and breeding. In the evaluation area we try to acquire as many plants as we can that we think may have any chance of surviving under our conditions. Unfortunately, in the past couple of years we have had to curtail this activity greatly due to dwindling support. We also do a lot of cold hardiness testing in the laboratory to acquire definitive data on actual hardiness levels of different cultivars throughout the winter season. Plant improvement activities include breeding programs involving hybridization between different species or between plants of the same species that possess different desired traits. We also grow out open pollinated progeny for selection of superior plants in cases where we expect to have considerable genetic diversity in the populations. In both of these methods we are involved with a number of different plant genera and species.

We've made quite a few introductions over the last 15 years from this research effort. The plants introduced from our program provide examples of the diverse group of plants that we work with and illustrate the approaches that we use. Our introductions include: northwood red maple, (*Acer rubrum* 'Northwood'), autumn splendor buckeye, (*Aesculus* 'Autumn Splendor'), Princess Kay plum, (*Prunus nigra* 'Princess Kay'), northern sun forsythia, (*Forsythia* 'Northern Sun'), cardinal dogwood, (*Cornus stolonifera* 'Cardinal'), and freedom honeysuckle, (*Lonicera* 'Freedom'). All of the preceding plants have been available for several years and are becoming well established in the nursery trade. In addition we have several plant selections that are recent introductions or will be introduced in the next few years.

Acer rubrum 'Autumn Spire' is a fairly recent red maple introduction. It was selected from seedlings produced from seed collected from the wild. The female parent of 'Autumn Spire' was growing near Grand Rapids, Minnesota. 'Autumn Spire' was introduced for its hardiness in northern areas, and for its outstanding red fall color and narrow, upright plant form.

The next two selections are trees that we've decided to introduce but we haven't chosen names for them at this time. Both of these were selected from plants growing in our collections in the arboretum and did not result from controlled pollinations. A male selection of *Phellodendron* was made from a few trees that we grew from seed of *P. sachalinense* obtained from the Morton Arboretum. This selection may be of hybrid origin. The tree is quite vigorous, and has a higher branching habit than Amur corktree which is more commonly found in the trade. This characteristic would enable the tree to be trimmed up more easily for visual clearance under the canopy. A male selection of Kentucky coffeetree, *Gymnocladus dioica,* was made because of its excellent narrow, more upright crown and seedlessness.

Viburnum 'Emerald Triumph' is the first introduction from our breeding efforts in the viburnum genus. It resulted from a cross between *V. burejaeticum* and *V.* × *rhytidophylloides* 'Allegheny'. 'Allegheny' is one of Don Egolf's introductions. It is a hybrid between *V. lantana* and *V. rhytidophyllum*. We look at 'Emerald Triumph' as a possible alternative to *V. lantana*. It is a more compact plant with darker, more glossy foliage. Its mature height and spread is about 8 ft. Fruit and flower qualities are similar to that of *V. lantana*. Fruits begin to color in early August in Minnesota, turning bright red and then black. Fall color develops quite late and frequently foliage is damaged by severe frosts before fall coloration fully develops. In extended fall seasons, an excellent bronze to dark red fall color develops.

When the honeysuckle witches'-broom aphid was first noticed in our area in 1981, we evaluated the various taxa of *Lonicera* in our collections at the Minnesota Landscape Arboretum for resistance and initiated a breeding program to develop resistant selections. Our goal has been development of resistant plants with pink to rosy red flower color and a fairly dense growth habit. We hoped to develop plants at least comparable to Zabel honeysuckle in plant quality but with resistance to the witches'-broom aphid. Through our breeding efforts, we have generated many hundreds of seedling that possess both rosy red flower color and resistance to the aphid. From those, we have selected 65 plants that have better plant form, flower quality, and late summer foliage quality. We have recently decided to introduce one of the earlier selections and have named it *L.* 'Honey Rose'. It has deep rosy red flower color, dark green foliage, and a compact plant habit with a mature height of 6 to 8 ft. Honey rose honeysuckle resulted from a cross between *L. tatarica* 'Zabelii' and *L. tatarica* 'Arnold's Red'.

'Northern Pearls' is a selection of *Exochorda serratifolia*. The mature plants are about 8 ft in height and 6 ft in width. It is hardy to Zone 4. 'Northern Pearls' is very showy for its large (2 in.) diameter white flowers which mask the foliage at time of bloom in mid May in Minnesota. Fall color is an attractive yellow.

The greatest effort in our breeding program has been devoted to development of cold hardy deciduous azaleas. Introductions to date include 'Pink Lights', 'Rosy Lights', 'Orchid Lights', 'Spicy Lights', 'Golden Lights', 'Northern Hi-Lights', and selection #43 for which we have not yet selected a name. The latest addition to the "Lights Series" of deciduous azaleas is 'Northern Hi-Lights'. Flower color is creamy white with a bright yellow upper petal. Plants grow to 4 ft in height and 4 to 5 ft in width. Foliage is quite resistant to mildew but not totally immune. Flower buds are hardy to -30F in mid winter. Foliage is a dark green and has a slight bronzy appearance as it first emerges in spring. Flowers open in late May in Minnesota. Selection #43 is a vigorous plant with red-orange flowers. Flower buds are hardy to -30F. in mid winter.

We are continuing our efforts with azaleas to obtain a more complete color range and to develop cultivars with better plant habits, foliage quality, and better resistance to mildew. We still need cultivars with pure yellow and red or near red flower color. We have many selections with pure yellow flowers and several with red-orange flower colors that are approaching true red. In recent years we have been using *Rhododendron viscosum* and Choptank River hybrids as parents. We have crossed them with many different Exbury cultivars. We now have many selections from second and, in some cases, third generation progenies. Many of these have excellent foliage qualities and nice clear flower colors representing quite a range of colors. We need to evaluate them further to determine their cold hardiness capabilities.

All of the introductions mentioned have been introduced through a royalty program. Funds from the royalties are used to support continuation of our breeding activities. Anyone interested in producing our introductions can contact me for details.

We are continuing efforts with most of the species represented by the introductions mentioned and are also involved to some extent with several other genera. Other efforts include work with shrub roses, *Philadelphus*, *Spiraea*, and intergeneric hybrids between *Sorbus* and other genera of the Pomoideae subfamily.

CENTER FOR DEVELOPMENT OF HARDY LANDSCAPE PLANTS

In addition to our breeding program at the University of Minnesota, I have been quite active in the Center for Development of Hardy Landscape Plants. There is tremendous potential for breeding of landscape plants as you can see by what we've been able to accomplish in Minnesota, by the efforts that Elwin Orton described earlier, by the activities at the U.S. National Arboretum, and others. However, in total there is a very limited amount of effort devoted to breeding of landscape plants. There is a definite need for more effort to develop and select landscape plants that are more tolerant to the biological and environmental stresses that we often expect them to tolerate. The Center for Development of Hardy Landscape Plants was established to help increase that effort.

The Center is a relatively new organization that was established in 1990 to develop landscape plants that are more stress tolerant. The Center is a cooperative effort organized as a non-profit corporation. Researchers located at nearly seventy different institutions across North America and in the Scandinavian and Baltic countries are cooperatively participating in the research efforts.

Through funds generated by contributions of supporting members, the Center has initiated some breeding programs. The initial effort, started in 1991, is breeding of small landscape trees of *Pyrus.* We have used the pear species collections growing at the USDA clonal repository in Corvallis, Oregon, to do most of the crossing. Interspecies crosses have been made between several different species that have the potential to contribute desirable characteristics. In general, the pears are fairly tolerant to heavy soils and thus survive in many landscape sites where other trees do not do well.

The only pear species that has received much landscape use in North America is the Callery pear, *P. calleryana*. They are hardy only to Zone 4b and thus are not reliable for use in Minnesota. The most cold hardy species is the Ussurian pear, *P. ussuriensis*, which unfortunately grows fairly large and has a larger fruit than is desired in many landscape sites. *Pyrus fauriei* is a large shrub or small tree that is also quite hardy (Zone 4a) and develops an excellent fall color and small black fruit. *Pyrus salicifolia* has attractive silvery foliage, while several of the species such as *P. nivalis* and *P. elaeagrifolia* have good potential for drought or heat tolerance. Another species with considerable merit, *P. betulifolia*, has small fruit and attractive foliage. The leaves are bright green on the upper surface and silvery green beneath, reminiscent of the quaking aspen.

We now have many hybrid populations of different combinations of these species. The first generation hybrids (F_1s) are being grown at the Washington State University Experiment Station in Puyallup, Washington. When they reach flowering age, we will produce F_2 populations and distribute them to sites in many different geographic regions for evaluation to select superior plants that are well adapted to the climatic conditions of the region in which they are selected. In this way we can efficiently breed and select plants for use in many different regions. We have started a second project to breed small maples and, as resources become available, we will expand this approach to breed many different groups of landscape plants. Through the Center we can develop excellent landscape plants that are adapted to many different regions of the world. However, for the Center to be able to continue and expand the activities started, and to be able to exist for the long term, we need a much broader base of support. We need widespread support from the nursery industry as well as the gardening public. Our sole source of continuing support is our supporting membership. Members receive our quarterly newsletter which describes activities underway and provides data from research results. To become a supporting member, contact me or other members or participants of the Center.

RALPH SHUGERT: Could you comment on the fragrance of the Northern Lights series of azaleas you have introduced.

HAROLD PELLET: 'Pink Lights', 'Rosy Lights', and 'Spicy Lights' are the best.

VOICE: Does 'Emerald Triumph' set seed.

HAROLD PELLET: It will set some seed by itself.

Adventitious Root Initiation—Future Research on the Site of Auxin Action

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INTRODUCTION

It has been shown many times under controlled conditions that auxins are the applied phytohormones which consistently enhance adventitious root production. Indeed, research has shown that division of the root initial cells is dependent upon either applied or endogenous auxin (Hartmann et al. 1990.) In a recent review, Jarvis (1986) summarized the evidence supporting the idea that auxins have a central role in the initiation and development of rooting. However, even though auxin involvement in adventitious root initiation is well established, knowledge of the mechanism of auxin action in adventitious root initiation remains unclear (Blakesley et al., 1990). It is important to understand the mechanism of auxin action for the propagator as well as the basic scientist. This paper deals with experiments performed in our laboratory on the regulation of adventitious root initiation in mung bean (*Vigna radiata* [L.]R. Wilcz).

MATERIALS AND METHODS

Plant Material and General Procedures. Mung bean seeds were surfaced sterilized in 10% Clorox (v/v) for 10 min and rinsed in tap water. After aeration for 24 h in tap water, they were sown 1 cm deep in plastic trays containing perlite. The growth room was maintained at 26±1C. A 16-h photoperiod was supplied at a quantum flux density of approximately 205 $\mu E/m^{-2}/s^{-1}$.

Uniform cuttings made from 9-day-old seedlings were placed in sterilized distilled water prior to use. Each cutting consisted of a 3-cm hypocotyl, the epicotyl, two primary leaves, and the apical meristem. Ten cuttings were placed in a 19 × 65 mm shell vial containing 1 ml of the treatment solution. After uptake of the various solutions (approx. 2 h), distilled water was added to the cotyledonary node and maintained at this level for the duration of each experiment.

DISCUSSION

Inhibition of Adventitious Root Formation by Transcriptional and Translational Inhibitors in Mung Bean. As mentioned above auxin appears to be the phytohormone that consistently stimulates rooting. In mung bean, the synthetic auxins IBA and NAA are more effective and promote adventitious root formation between a concentration range of 10^{-7} and 10^{-3} molar (Geneve and Heuser, 1982) (Fig. 1); 2,4-D is less active than the other auxins tested while IAA, the native auxin, is not as active as NAA and IBA possibly because IAA is metabolized (Hess, 1965) or converted to various conjugated forms (Norcini and Heuser, 1985).

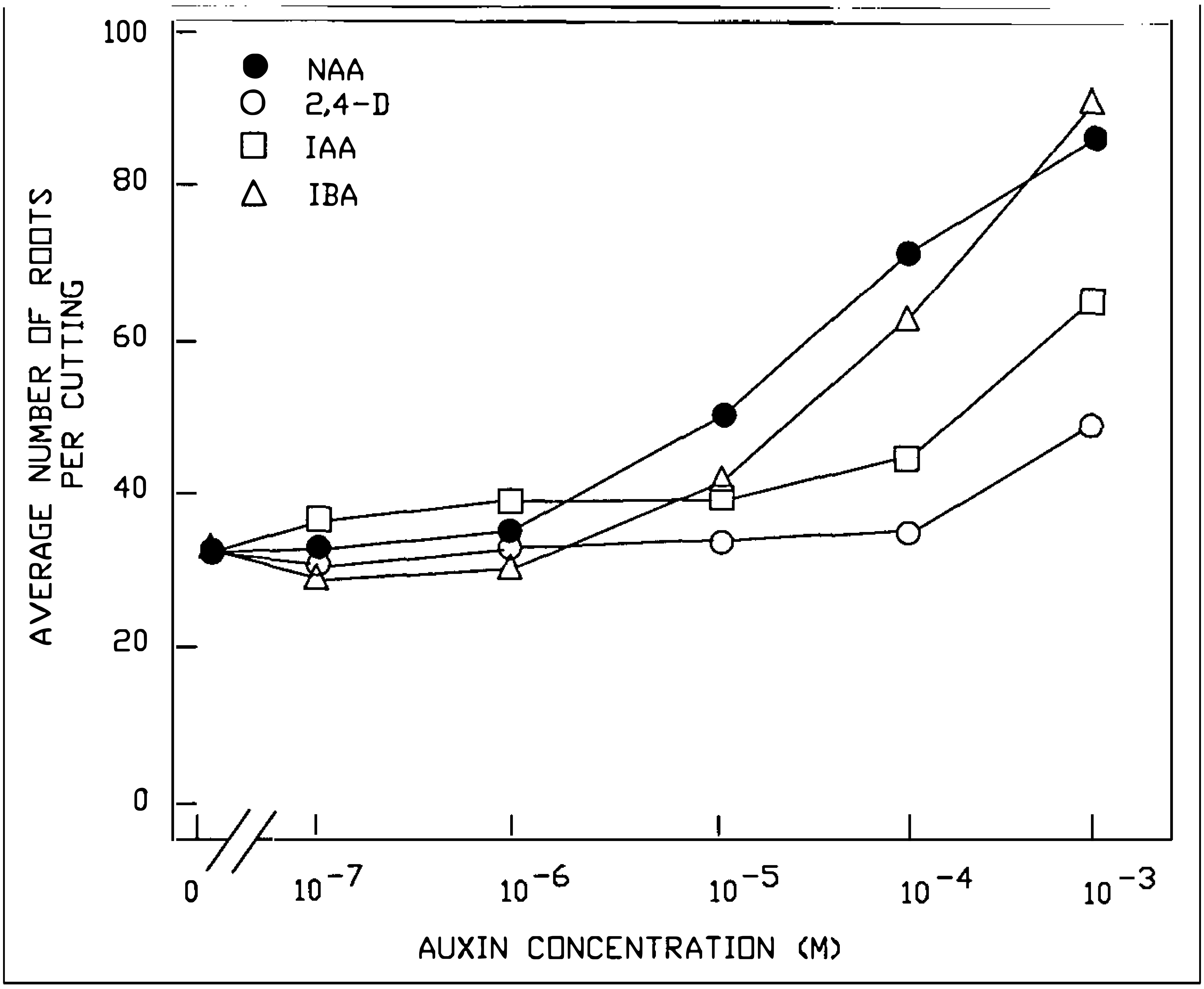

Figure 1. The relative effectiveness of IAA, IBA, NAA, and 2,4-D on adventitious root initiation in mung bean. (From Geneve and Heuser, 1982)

The process of root formation involves both cell division and enlargement, and therefore appears to be dependent on synthesis of nucleic acids and proteins. Because it is likely that the process of root formation is dependent upon the synthesis of nucleic acids and proteins, chemicals which interfere with or block nucleic acid (transcriptional) and/or protein (translational) synthesis should inhibit rooting. Indeed, in mung bean, the exogenous application of 6-methylpurine inhibits root formation presumably due to the production of defective mRNA or due to the inhibition of mRNA synthesis (Blazich and Heuser, 1981). At a concentration of 10^{-5} M or higher 6-methylpurine inhibited rooting with complete inhibition and no observable injury to the cuttings occurring at 6×10^{-5} to 10^{-4} (Fig. 2). Cycloheximide, a putative inhibitor of ribonucleic acid (RNA) synthesis, first inhibited rooting at 10^{-6}M which increased with concentration, the cuttings being killed at 10^{-4}M (Fig. 3).

In *Phaseolus vulgaris* (green bean)a study of early biochemical changes during root initiation showed that an increase in total RNAs and poly(A)+RNA synthesis were detected only 2 h after transfer of IBA-pretreated hypocotyls to fresh basal medium (Kantharaj et al., 1979).

In mung bean hypocotyls, the phloem parenchyma cells are the site of adventitious root initials. These "rooting-zone parenchyma" [R-ZP] were shown by Tripepi et al. (1983), who used ^{3}H-uridine and ^{3}H-thymidine as indicators of nucleic acid synthesis that nuclei in the R-ZP first became labeled with ^{3}H-uridine (2 h, nucleolus) and then with ^{3}H-thymidine (14 to 16 h). By 8 h, ^{3}H-uridine was found

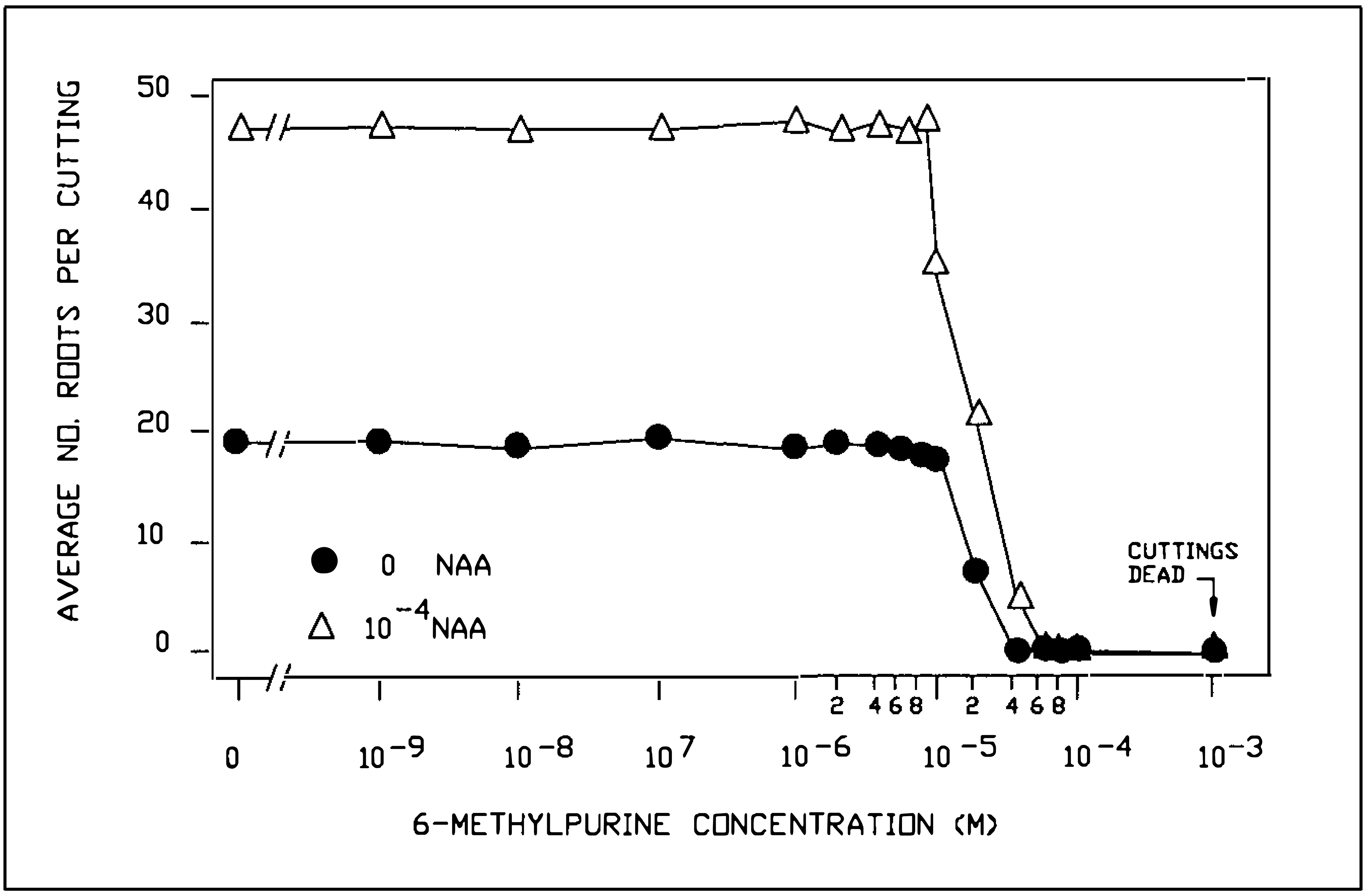

Figure 2. Effect of 6-methylpurine on adventitious root initiation in mung bean cuttings. Each point is the mean for 30 cuttings. (Redrawn from Blazich and Heuser, 1981).

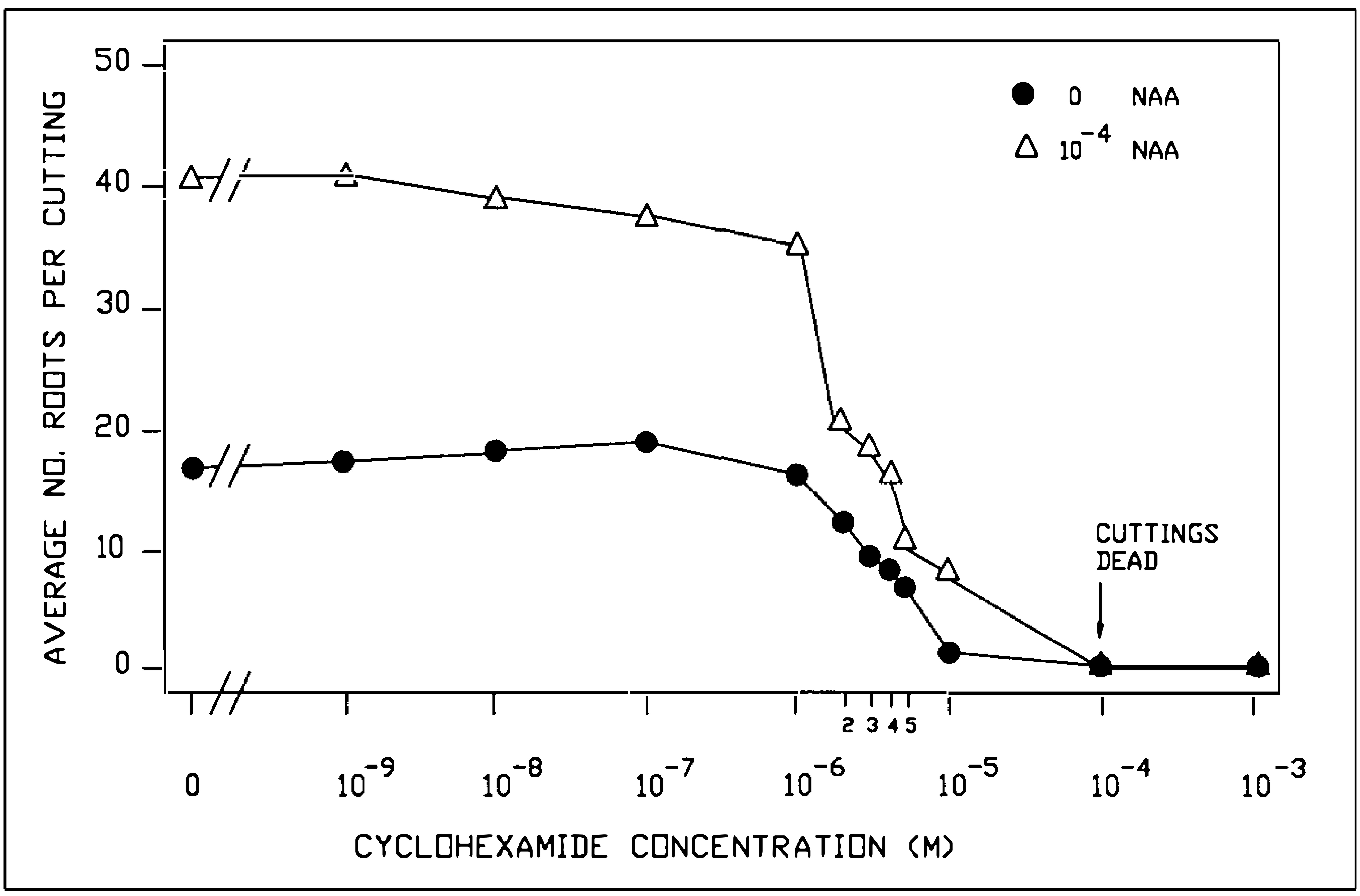

Figure 3. Effect of cycloheximide on adventitious root initiation in mung bean cuttings. Each point is the mean for 30 cuttings. (Redrawn from Blazich and Heuser, 1981).

in the cytoplasm and cell wall. ^{3}H-thymidine incorporation was in close agreement with the first cell divisions (23 to 26 h). It therefore appears that the effect of auxins on adventitious root initiation may be associated with early transcriptional and translational events during the initiation phase.

Future Studies in Root Initiation. The above examples are suggestive that auxin works through its effects at the transcriptional and translational levels. Gene expression in plants (Theologis, 1986; Guifolyle, 1986; Key, 1989) have been shown to be regulated by auxin. However, there are no research reports on the isolation of auxin-responsive genes from any adventitious rooting systems, although auxin-induced or auxin-repressed genes have been isolated and characterized for responses such as cell division, cell elongation, and fruit ripening.

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....tgaaactgctgtgttctctgt
      E  T  A  V  F  S  V
tggcccatctatacttgttctggga
 G  P  S  I  L  V  L  G
ggagcatatggagttggatcccttg
G  A  Y  G  V  G  S  L  V
ttattca...
  I  Q
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Figure 4. An example of a short nucleotide sequence and deduced amino acid sequences for cDNA clone.

Future molecular studies on the mechanism(s) of auxin action in root initiation will focus on the accumulation of specific mRNAs (messenger ribonucleic acids) in the early phases of rooting. To fully understand the rooting process, the isolation and characterization of specific genes which determine root initiation will be required. Such molecular studies will entail the construction of a cDNA library from auxin-induced adventitious rooting systems and the isolation of specific auxin-regulated cDNA clones by screening and subsequent sequence analysis. Such studies will lead to the construction of nucleotide sequences and deduced amino acid sequences. An example of part of such a sequence is shown in Fig. 4.

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Alternative Methods for Sterilization and Cutting Disinfestation

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THE PROPAGATOR'S ROLE AS PART OF THE GREEN INDUSTRY

In recent years, increasing evidence has been reported on the adverse effects of chlorine on our environment. Most of the controversy over chlorine pollution has been centered around two sources: (1) chlorinated hydrocarbons, which deplete the atmospheric ozone layer protecting us from damaging ultraviolet rays, and (2) the manufacturing processes using chlorine (e.g., plastic polyvinyl chlorides and paper bleaching) which produce a multitude of toxic chlorine compounds called organochlorines.

Health effects linked to the bioaccumulation of organochlorines in humans and wildlife include breast cancer and reproductive problems. Many of the compounds are carcinogens and mutagens. While working on a community education project on the dangers of chlorine pollution, we became concerned about what chlorinated products we might routinely use as part of our nursery operations.

At McHenry County Nursery, we have made every effort to use sustainable nursery practices in our field production including contour-tillage for soil and water conservation, and integrated pest management to reduce the need for chemical pest control. But what about other departments? What about the bleach used as part of the cutting and pot sanitation procedures? What are we using and where does it go? What are the environmental risks we are taking in some of our routine nursery practices? And if they are damaging, can we establish some cost-effective alternatives that are also environmentally responsible? As stewards of the land—propagators, producers and promoters of living plants—shouldn't we be concerned about the long-term effects of our practices on our environment?

DISINFECTANTS USED IN CUTTING PROPAGATION

The range of chemicals used in nursery production is quite broad, and includes fungicides, insecticides, herbicides, fumigants, nematicides, fertilizers, and disinfectants. A disinfectant is any chemical used to surface disinfest plant material, or to sterilize tools, work surfaces, or other materials. This paper reviews some of the common disinfectants used for material sterilization and plant surface disinfestation in the cutting propagation phase of nursery production. Many of these disinfectants are also used in micropropagation. Although cuttings are not always surface disinfested before sticking, it is a recommended practice because it reduces the need for chemical fungicide and bactericide treatment later (MacDonald, 1986).

A list of common disinfectants is shown in Table 1. Of these, bleach (sodium hypochlorite) has traditionally been the most effective, least expensive and most available. It is used to surface disinfest plant material and to sterilize materials and tools.

Table 1. Common disinfectants used in cutting propagation.

Disinfectant[1]	Chemical formula
bleach (sodium hypochlorite)	$NaClO$
bleach (calcium hypochlorite)	$Ca(ClO)_2$
isopropyl alcohol	$CH_3(CH\text{-}OH)CH_3$
Physan, Triathalon, Green-Shield	benzalkonium chlorides
hydrogen peroxide	$HOOH$
calcium peroxide	$Ca(OOH)_2$
mercuric chloride	$HgCl_2$
ethylene oxide	$(CH_2)_2O$

[1] Italicized disinfectants are oxidizing chemicals.

The most effective disinfectants are oxidizing chemicals (Table 1.). There are always by-products after oxidation. These by-products are what make their way into our soils, surface water, and ground water systems (Table 2.). They can combine with other organic compounds in the environment forming compounds that are often more harmful than the original formula.

Table 2. Common disinfectants and their by-products.

Disinfectant	Principle oxidation reaction by-products
bleach (sodium hypochlorite)	sodium, hypochlorite, and water
bleach (calcium hypochlorite)	calcium, hypochlorite, and water
isopropyl alcohol	isopropyl and other minor by-products
benzalkonium chlorides	chloride and other minor by-products
hydrogen peroxide	oxygen and water
calcium peroxide	oxygen and calcium hydroxide
mercuric chloride	mercuric chloride and other minor by-products
ethylene oxide	ethylene glycol and other minor by-products

Each of these disinfectants has advantages and disadvantages to the plant (effectiveness, toxicity); to production (availability, worker safety); to the budget (long- and short-term costs); and to the environment (consequences of use to plants, soil, and water) (Table 3.).

Table 3. Three common sterilants and their effects on the plant, the budget and the environment.

Sterilant	Plant	Budget	Environment
Isopropyl alcohol	At high concentrations dehydrates plant tissue, at lower concentrations is not strong enough to disinfest plants of micro-organisms or work surfaces of bacteria	Inexpensive	Toxic to skin and dangerous to breathe
Benzalkonium chlorides	Must use at commercially recommended rates for each formulation	Economical	Basically inert by-products if not used in excess of what is needed
Bleach, hypochlorite solutions	Can be toxic to plant tissue on contact, if concentration is more than 10%; for work surface sterilization usually 1 part bleach to 10 parts water is recommended.	Inexpensive	The chloride ion (OCl^-) by-products combine with organic compounds in soils and become toxic in all forms—taken up through roots in plants, ingested by animals; excess bleach that enters environment will also oxidize any living tissue it comes in contact with
Hydrogen peroxide	Must use higher concentrations than hypochlorites (30%)	More expensive than bleach; but has many more uses—kills fungus and bacteria used in soil, water, and on plants	Totally non-toxic byproducts of oxygen and water; if used in excess, evaporates before oxidation of other living tissue can occur

A NEED FOR CHANGE

Isopropyl alcohol is commonly used as a disinfectant for several propagation procedures (most commonly sterilization of work surfaces and tools) but is not a reliable bactericide.

Benzalkonium chlorides have been used in similar ways as both fungicides and bactericides for over 50 years, but have some phytotoxic effects on certain plants (Dirr and Heuser, 1987; Kyte, 1987; MacDonald, 1986; Pierik, 1987; Torres, 1989). Many commercial formulations are available. The naturally occurring chloride ion (Cl^-, part of what makes up sea water) is one of the oxidation by-products of benzalkonium chloride disinfectants. These by-products do not pose serious environmental hazards when used at recommended rates.

Bleachs (hypochlorite solutions) are inexpensive and effective. Research does indicate that in some uses, however, hypochlorite cannot be completely washed off of plant material. It leaves enough residue to interfere with plant metabolism (Abdul-Baki, 1974a, 1974b). It is also a very uniquely harmful disinfectant. The by-product of bleach oxidation is the hypochlorite ion (OCl^-). It is the hypochlorite ion (not the chloride ion) that is harmful when it makes its way into our natural water systems. The hypochlorite ion attaches to organic compounds in the soil and forms very stable chlorinated organic compounds. These compounds are then taken up through roots and ingested by humans, aquatic species, and animals. Neither the hypochlorite ion nor its organic compounds occur in nature—plants and animals, therefore, have no enzymes to metabolize or detoxify them. These chlorinated organic compounds bioaccumulate in body fat (Thornton, 1991). Recent studies in the Great Lakes region of the U.S. indicate that some health epidemics can be attributed in part to organochlorine compounds. Increases in human breast and prostate cancers as well as other health problems in birds, fish, and other aquatic wildlife have been connected to the high levels of organochlorines in tissue (DeCrosta, 1978; Hileman, 1993; Swanson, 1994; Thornton, 1991, 1992).

A promising disinfectant for propagation and other industries is hydrogen peroxide (H_2O_2). It can be used as a sterilant for both fungi and bacteria. It has absolutely no toxic by-products (it breaks down to water and oxygen) and it has no residual effects in water or soil. It can be used as a soil, water, and plant disinfectant and is even used as a seed coating to enhance germination. Hydrogen peroxide is also used in cleaning up water polluted with toxic chemicals (Environmental Services Company,Carus Chemical Co., Ottawa).

Hydrogen peroxide can be purchased in bulk at the 35% concentration rate. It can be used to control fungi and bacteria. A recommended concentration for surface disinfestation of plant material is 1 part H_2O_2 (35%) to 100 parts water (Environmental Services Company, 1993). It is twice as expensive as bleach, but is currently being considered as an effective alternative for industrial chlorine bleaching used in paper and other manufacturing processes. It may soon be more economical and more available (Kroesa, 1990).

THE FUTURE

The extensive use of elemental chlorine in other industries (e.g., pulp and paper manufacturing, manufacturing and use of organochlorine pesticides, water treatment, metallurgical processes, and plastics manufacturing) pose much greater risks to animals, humans and the environment than our slight uses in propagation. Yet, even something as common as everyday bleach has hidden dangers. We do have a responsibility to become informed about the chemicals we use. In doing so, we can promote safety and health in our work place and our environment.

The important thing is for all industries to start looking for alternatives. By reducing the amount of organochlorine-causing chemicals we use, we begin to reduce the amount found in the environment and reduce the potential health hazards related to them. Other industries have begun exploring alternative methods of purifying, disinfecting, and bleaching products. They include innovative processes of ozonation (to replace chlorination) of drinking water, and using hydrogen peroxide to bleach paper and clothing (Kroesa, 1990; Richardson 1993). From Canada to Switzerland to Sweden, other countries are taking more serious steps in phasing out the use of organochlorines (Hileman, 1993; Palter, 1989; Vallentyne, 1992).

A complete list of commercially available chemicals, and their chemical formulas, by-products, and toxicity to humans and the environment can be acquired by your cooperative extension agent through a computer toxicology network (EXTONET) and from an organization called NCAMP (National Coalition Against the Misuse of Pesticides) that publishes *Pesticide Reviews* .

Being informed makes sense. It can be a bonus for our business and our public relations, our production practices and our plants, our employees and our environment.

Acknowledgements
Thank you to Dr. Lou Marchi, Professor of Environmental Chemistry, Columbia College (Columbia, Missouri) for advice and consultation.

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