NY118
Clonal propagation from difficult cuttings of ornamental plants by new dynamic pulse propagation

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CONTENTS

FINAL REPORT

PROJECT TITLE: Clonal propagation from difficult cuttings of ornamental plants by a new dynamic pulse propagation technique.

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LOCATION: Institute for Horticultural Development Knoxfield.

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1. SUMMARY

a) INDUSTRY SUMMARY

Hydropropagation 'Dynamic Pulse' is the propagation of cuttings in a recycling solution. The cuttings are supported in channels by polypropylene beads. The recycling solution temperature can be heated for optimal rooting response.

The major advantages of the hydropropagtion method over conventional propagation, for faster and improved root quality are:

1. Precise hormone concentration pulsing / composition
2. Early introduction of nutrients
3. Protection from water stress.

The following crops were successfully propagated in hydropropagtion when the ambient air temperatures was greater than 17°C and the house covered by a 60% white shade cloth. ***Daphne odora*** (IBA 10 mg/litre exposed for 14 days gave a 98% strike in 4 weeks, no fogging or solution heating required.), ***Melaleuca gibbosa*** (IBA 2 mg/litre exposure time 7 days gave 87% strike in 4 weeks 23°C solution temperature, nil fog).

Early nutrient introduction to the recycling solution 0.25 strength hydroponic feed commenced at day 5, improved early root and shoot growth of ***Banksia rose 'alba'*** (Nil IBA, and 21°C solution heat).

The hydropropagation system with continuous flowing solution failed to form roots on the following crops: ***Banksia ericifolia, Grevillea 'Poorinda Peter'*** in both cases the base of the cuttings swelled only. ***Eucalyptus ficifolia*** and ***Grevillea Ivanhoe*** tended to brown of at the base of the cuttings when the recycling solution was continuously flowing. The use of intermittent flow 15 minutes on 15 minutes of did alleviate browning in ***Grevillea Ivanhoe*** but did not promote rooting.

Hormone toxicity due to type and concentration could be a problem (100% death's) eg. ***Swainsonia formosus*** (NAA at 10 mg/litre) and ***Banksia rose 'alba'*** (IBA 5 mg/litre). The toxicity symptoms were identified by leaf desiccation and discolouring. In general any hormone toxicity effects were reduced if the hydropropagtion was combined with fogging. The choice of rooting hormone type and optimal concentration need to be determined before hormone pulsing can be used successfully. Hormones may not be necessary for good hydropropagation results eg. ***Buaera sessiliflora*** (96% rooting in 4 weeks, solution temperature 23°C). In a heated environment good hydropropagation results can be achieved without solution heating for some crops eg. ***Swainsonia formosus***.

The temperature control system designed for the hydropropagation system performed well and could be used for general greenhouse environment management.

The hydropropagation system works excellently for some crops but the total failure to produce roots in other crops indicates that further research and development is needed before this method could be used universally for all crops.

b) TECHNICAL SUMMARY

Incorporating auxin at low concentration for short exposure time (2-14 days) can advance root initiation at optimal concentration and promote high quality root development. Hormone toxicity can be a problem with some cutting lines if the concentration and exposure time is not optimal. Mild over-dosing delays root development, while severe over-doses causes death of the cutting.

The addition of low strength nutrients (approximately 0.25 strength hydroponic nutrients)into the recycling solution early in the propagation period may improve early root and shoot development.

The combination of fogging and hydropropagation can be complementary for some cutting lines and assists in reducing the risk of hormone toxicity should over-dosing accidently occur.

Whilst the hydropropagtion systems works well for some cutting lines (eg ***Daphne odora, Melaleuca gibbosa and Swainsonia formosus***); there were equally as many cutting lines for which it did not promote rooting when the recycling solution was continuous (eg. ***Banksia ericifolia, Grevillea spp*** *and* ***Eucalyptus ficifolia***). These cuttings would swell or form callus but fail to root. Another common association with failure to root in the hydropropagtion continuous flow system was browning of the cutting base. These symptoms are synominous with insufficient aeration and the use of intermittent flowing solution can reduce the incidence of basal browning and indirectly suggests that aeration is inadequate in a continuous flow solution for rooting of some cutting types.

Using peat in the recycling solution was beneficial in promoting rooting eg ***Banksia ericifolia***. This could be due to a pH effect or caused by other factors.

Eucalyptus ficifolia adult wood cuttings developed callus (root-like structures with rudimentary disorganised xylem but no apical meristem) in the hydropropagation system. These non-root structures could support shoot growth when cuttings were either potted-on or maintained in solution when the aerial environment was fogged although growth was slow.

2. *RECOMMENDATION*

a) Extension / adoption by industry of research findings.

The general findings of the hydropropagtion research were presented at the NIAA Conference February 17th, 1993 and a paper was presented at the IPPS Conference, May 1993.

b) Direction for future research.

The hydropropagation technique totally inhibited rooting in some plants and characteristically the cuttings would brown-off at the base. These symptoms are typical of inadequate oxygen. The use of air stones in the reservoirs and expansion of the intermittent flow approach would contribute to investigating if aeration is a problem.

Using peat in the propagation medium was beneficial for rooting of ***Banksia ericifolia***. Therefore investigation of whether this is a pH effect or caused by other factors may prove useful.

Nutrient levels with the emphasis on specific ions on promotion of rooting should also be investigate.

The variable response to different auxin type warrants further investigation with the possibility of testing combinations of auxin.

The hydropropagation technique did not promote roots on adult cuttings of ***Eucalyptus ficifolia***. Hydropropagation did however stimulate the production of callus which had a root-like appearance but lacked organised meristems. If the hydropropagation system could be used like tissue culture ie. manipulating pH, auxin and nutrients then it may be possible to organise the callus into to real roots. Alternatively, ***Agrobacterium*** could be cultured in the recycling solution to act as transgenic agents between unstruck adult wood and roots of

Eucalypt seedling growing in the same system.

There is a need to investigate the benefits of fogging type (sonic crystal vs compression) in conjunction with hydropropagation on the rooting of cuttings.

In order to maintain complete control of the hydropropagation solution temperature, a cooling capacity needs to be incorporated into the system.

c) Financial / commercial benefits of the research findings.

It is too premature to estimate the financial / commercial benefit of the hydropropagation technique. The faster improved quality root system of some plants (eg. ***Daphne odora***) will be of commercial benefit immediately but as a universal plant propagation system, this approach to propagation requires further research, before it's full potential can be attained. Potentially the hydropropagation technique offers the ideal vehicle for propagating clonal cutting material suitable for export.

The production of ***Eucalyptus ficifolia*** is restricted largely to seedling material which gives no guarantee as to the ultimate plant growth and performance or flower colour. The hydropropagation system maybe the approach in order to generate normal root development from the callus. The economic value of achieving clonal vegetative propagation of ***Eucalyptus ficifolia*** (and ***Eucalyptus spp.***) on the local and export markets is estimated to be worth millions of dollars.

"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 with water. Temperature is often regulated so that the rooting medium is 5-10°C warmer than the aerial temperature. High light intensity can result in overheating of the cutting 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. Factor 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:

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

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

(iii) Show that hydropropagated cuttings established well in standard potting-mix.

(iv) Determine whether fogging could improve rooting.

MATERIALS AND METHODS

The hydropropagation modules consisted of galvanised powder coated channels 2.3 meters long, 100 mm wide by 40 mm deep, filled with black polypropylene beads, approximately 4mm by 3mm in size (fig.1). 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 42L plastic drums through 13mm 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 16-18°C) 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 35°C was circulated through the tubing and the flow was controlled by solenoid valves linked to Datataker® and I/Opack® control units (see Technical Report Part b, for details of the Temperature Control System used for the Hydropropagation). 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 21°C and 8 seconds misting at 8-10 minute intervals. The medium used was sterilized washed sand:perlite:sieved peat moss mixed in proportions of 1:1:1 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.

RESULTS

Sturt's Desert Pea (*Swainsonia 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 seconds) were both beneficial to rooting in the mist bed (Table 2b).

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. A typical hydropropagated cutting is shown in figure 4. The number of roots produced was also greater in the absence of fog.

Banksia rose 'alba'

Incorporating IBA into the recycling solution was toxic to *Banksia rose '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).

Cuttings from each treatment were grown on in a standard pinebark 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 minutes on/15 minutes off) did not improve the result. When cuttings were placed in a medium consisting of plastic beads/peat moss (approximately 5:1 by volume) 62% rooting was achieved in 6 weeks without recycling water. The percentage rooting increased to 82% when intermittent recycling was used in combination with the beads/peat medium (Table 5 and figure 3).

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 (fig. 2). 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 (2500 mg/litre for 5 seconds) did not significantly improve rooting under mist bed conditions.

Buaera sessiliflora

Buaera sessiliflora cuttings were easy to root in the hydropropagation system (96% rooted after 4 weeks) Table 7.

IBA was toxic to the cuttings even at 2 ppm resulting in leaf dicolouration (fig.5).

Fogging reduced the toxicity effect and advanced early root development.

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 per cent of cuttings died within 6 weeks (fig.5).

Under fog conditions 23 per cent of *G. rosmarinifolia* cuttings rooted within 6 weeks and this increased to 63 per cent 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 (fig. 6-7) This callus developed on approximately 50 per cent of two-leaf cuttings, and cuttings potted into a pinebark 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

Incorporating auxin at low concentration for short exposure time (2-14 days) can advance root initiation at optimal concentration and promote a high quality root development; for some plants e.g. *Daphne odora*. However auxin is not always necessary eg. *Buaera sessiliflora*, and in some cases can be toxic even at low concentrations (2 ppm), e.g. *Grevillea rosmarinifolia*. The importance of hormone type and toxicity was highlighted by *Swainsonia formosus*.

The early addition of low strength nutrients can be beneficial to advance early root and shoot development. Hydropropagated cuttings can be successfully grown on using standard pine based potting media, e.g. *Banksia rose 'alba'.*

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, e.g. *Banksia 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. *Grevillia 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.

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APPENDIX A

Hydropropagation results

Table 1a - Summary of Hydropropagation treatments, environment and test plants.

Plant	*Swainsonia formosus*	*Daphne odora*	*Banksia rose 'alba'*	*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	Nil	0.5	0.25	Nil	Nil	Nil
Start @ day	"	16	5 or 10	"	"	"
Renewal (days)	"	14	14	"	"	"
Recycling solution:						
Flow: Continuous	✓	✓	✓	✓	-	✓
Pulsed	-	-	-	-	✓	-
Temperature °C:						
Setpoint	21	-	-	22	23	-
Ambient	-	✓	✓	-	-	✓
Medium: Beads (only)	✓	✓	✓	✓	✓	✓
Beads:Peat	-	-	-	-	✓	-
Light (µEm^{-2}/s 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

Table 1b - Summary of Hydropropagation treatments, environment and test plants

Plant	Buaera sessiliflora	Grevillea Ivanhoe	Grevillea Poorinda Peter	Grevillea rosemarinifolia
Commenced	21 Dec	22 Dec	22 Dec	22 Dec
Duration	6	6	6	6
Hormone:	IBA	IBA	Nil	IBA
Auxin (potassium salt)				
	2 or 10	2 or 10	"	2 or 10
Concentration (ppm)	7	7	"	7
Exposure time (days)				
Nutrients:				
Strength	Nil	Nil	Nil	Nil
Start @ day	"	"	"	
Renewal (days)	"	"	"	"
				"
Recycling solution:				
Flow: Continuous	+	+	+	+
Pulsed	-	-	+	-
Temperature °C:				
Setpoint	-	-	23	-
Ambient	+	+	+	+
Medium: Beads (only)	+	+	+	+
Beads:Peat	-	-	–	-
Light (uEm^{-2}/s PAR)	940	940	940	940
Fog (75% RH)	+/-	+/-	+/-	+/-
Cutting: Length (cm)	13	12	12	11
Node Number	7	6	6	34
Number(per treatment)	45	45	45	51

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 %	Percentage 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
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 %	Percentage 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
0.01	0.37	29.3	11.0

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

Table 4a

Effect of nutrient timing during propagation on root and shoot developement of ***Banksia rose 'alba'***.

Nutrients started	Root		Shoot	
	number	length (max.) 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

Table 4b
Effect of nutrient timing on the hydropropagated cuttings shoot development of ***Banksia rose 'alba'*** when grown on in stanadard potting mix for 5 and 15 weeks.

Nutrients started	Shoot number		Shoot length (max.) cm.		Total shoot cm.	
	5 weeks	15 weeks	5 weeks	15 weeks	5 weeks	15 weeks
None	1.7	3.3	14	45	17	88
Day 5	2.7	4.0	18	47	25	108
Day 10	2.0	3.4	17	44	25	93
LSD 0.05	ns	ns	ns	ns	ns	ns

Potting mix:- Pine bark:sand:brown coal (16:6:2) by volume. Fertilizer rate (rate per 24 buckets) 220 gram 3-4 month Osmocote, 670 gram 8-9 month Osmocote, 670 gram dolomite, 110 gram Micromax and 115 gram coated iron. After 10 weeks 5 gram 3-4 month Osmocote was applied per 125 mm pot.

Table 4c
Effect of IBA quick dip on shoot development of ***Banksia rose 'alba'*** when grown on in standard potting mix.

Hormone	Shoot number		Shoot length (max.) cm.		Total shoot cm.	
	5 weeks	15 weeks	5 weeks	15 weeks	5 weeks	15 weeks
IBA zero	1.0	2.8	4	23	4	48
IBA dip (2500 ppm for 5 seconds.)	1.2	3.3	5	18	6	38
LSD 0.05	ns	ns	ns	ns	ns	ns

Table 5

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

Medium	Flow	Percentage strike		Percentage callused or swelling		Percentage death	
		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

Table 6a

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

Treatment	Percentage strike	Root		Dry weight (grams)	
		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	Percentage strike (4 weeks)	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

Note: ( ) Percentage of quality cuttings

Having >10 roots and the shortest root was >1.5 centimetres

Table 7

Effect of auxin concentration on the rooting of ***Buaera sessiliflora*** after 4 and 6 weeks using hydropropagation and fogged or nil fogged environments.

Environment	Hormone	Percentage strike		Percentage death	
		4 weeks	6 weeks	4 weeks	6 weeks
Nil-fog	Control (zero IBA)	51	91	2	9
	IBA 2 mg/litre	76	84	2	24
	IBA 10 mg/litre	18	28	56	84
Fog	Control (zero IBA)	96	96	0	2
	IBA 2 mg/litre	80	96	2	2
	IBA 10 mg/litre	73	78	22	22

Table 8

Effect of solution exposure time on the rooting of ***Grevillea 'Poorinda Peter'*** after 4 and 6 weeks hydropropagation.

Flow	Percentage strike		Percentage callused		Percentage death	
	4 weeks	6 weeks	4 weeks	6 weeks	4 weeks	6 weeks
Pulsed	0	0	84	84	7	16
Continuous	0	0	73	73	0	7

Table 9

Effect of auxin concentration on the rooting of ***Grevillea Ivanhoe*** after 4 and 6 weeks hydropropagation in a fogged or nil-fogged environment.

Environment	Hormone	Percentage strike		Percentage swelling		Percentage death	
		4 weeks	6 weeks	4 weeks	6 weeks	4 weeks	6 weeks
Nil-fog	Control (zero IBA)	0	0	2	13	2	9
	IBA 2 mg/litre	4	9	88	67	4	24
	IBA 10 mg/litre	0	0	38	7	50	84
Fog	Control (zero IBA)	0	0	0	18	4	7
	IBA 2 mg/litre	0	0	69	78	11	20
	IBA 10 mg/litre	0	0	48	51	38	73

Table 10

Effect of auxin concentration on the rooting of ***Grevillea rosmarinifolia*** after 4 and 6 weeks hydropropagation in a nil-fogged or fogged environment.

Environme nt	Hormone	Percentage strike		Percentage swelling		Percentage death	
		4 weeks	6 weeks	4 weeks	6weeks	4 weeks	6 weeks
Nil-fog	Control (zero IBA)	0	23	15	19	25	50
	IBA 2 mg/litre	50	40	0	0	38	58
	IBA 10 mg/litre	5	0	0	0	90	100
Fog	Control (zero IBA)	0	4	23	65	8	10
	IBA 2 mg/litre	21	63	40	10	13	13
	IBA 10 mg/litre	15	2	35	4	15	69

A TEMPERATURE CONTROL SYSTEM FOR HYDROPROPAGATION

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INTRODUCTION

Root zone temperature at the base of cuttings is considered a significant factor influencing root initiation. It is important to encourage root development ahead of shoot development and application of a uniform artificial heat source to the base of cuttings can assist the induction of root initiation. The conventional mist bed propagation technique provides this constant temperature for propagation purposes. Propagation systems are universally heated by methods known as bottom heat in which heating pipes or electric cables are embedded directly into the growing medium. A heating capacity of 150-200 watts per sq.meter of propagation bed or bench are considered adequate to supply optimum conditions of between 18-30°C depending on the plant to be propagated. Precise control of temperatures in growth media can also be a limiting factor in determining plant response to specific root-zone temperature.

The development of methods to control root zone temperature while servicing a number of experimental units has become a pre-requisite for research into root zone warming RZT. The development of soilless cultivation techniques, such as nutrient film technique NFT, or rockwool systems further enable the control a number of variables influencing the root zone environment eg. temperature. The aim of this work was to develop a controller useful for the management of root-zone temperature assisting further research into hydroponic propagation techniques and other potential applications.

MATERIAL AND METHODS

Hydroponic propagation method required that a heat exchange process be chosen for heating the solution. Direct heating methods such as electric elements are affected by corrosive salts and may affect solution characteristics.

A single heat source was used to distribute heated water to a number of stock solution tanks. A 2m coil of 15mm flexible PVC tubing was placed into each tank. Heated water pumped through the coils was used as a simple heat exchanger, to heat the stock solution. The heated water was driven via a pump and pressure relief valve to each solution tank from a single supply manifold. Solenoids valves placed at inlet to the exchangers, controlled the supply of heated water to each solution tank.

A feedback control loop to the Control Unit(computer hardware), provided the mechanism for switching solenoids on or off. If the solution was below the control set-point the solenoid was activated and heated solution flowed through the heat exchanger. Cooled water returned to the heat source via a single return manifold. Once the stock solution was above the control set-point the solenoid was deactivated.

The controller is designed around analogue input and digital output devices. These devices are programmable for up to sixteen and more I/O channels. This configuration gave the flexibility to control sixteen solenoid valves with independent temperature control. By connecting three stock solution tanks in a loop to one solenoid valve, a maximum of 48 propagation channels were operable.

The Control Unit was wall- mounted within the glasshouse and contained both input and output device. Control wires ran from the output controller to each of the heat supply solenoids and Type T Thermocouple wire provided input lines to the DataTaker 100. A communication line ran approximately 15 metres from the glasshouse to a laboratory where an 8086-PCbased computer managed the Control Unit operation.

1. Hardware.

1.1. Communications.

Communication between the control program and the I/O hardware devices is provided via a single RS232 communications port. The datataker DT100 interface provides for both direct and buffered input for networking purposes.

1.2. Data Acquisition.

All data acquisition and conversion functions are programmable directly through the DataTaker100 Logger which samples the temperature points for the system.

1.3. Digital Control.

The system switches solenoids to supply supplementary heating to each experimental unit. The solenoids are driven from a 24Volt AC. supply. Activation of the supply voltage to the solenoids is provided by 240 VAC Output Modules mounted within an Action Instruments I/O Pak Controller. This controller is programmable for both input and output which is used here.

2. Software.

The host control program was written in Turbo Prolog. TProlog was chosen because of the short development time required to provide programmable logic capabilities equal to the purpose.

Using Prolog meant it was possible for software to be developed in a short time. The control program was written with less than 300 lines of code. A complete listing of the control program is in the Appendix B.

The program maintains four lists of facts regarding the system performance.

1. A list of instructions to the I/O Pak.
2. A list of instructions to the DT100.
3. A list of system control set-points.
4. A real-time logic variable for each control device.

The instructions for control devices are selected from a range of firm ware instructions available from each device.

RESULTS

The temperature control system was able to maintain a uniform minimum root zone temperature for a range of glasshouse ambient conditions. Figure 1a shows a typical 36 hour profile. A uniform minimum hydropropagation solution temperature was maintained (20°C) even though the inside and outside air temperatures fell to 13°C and 4°C respectively.

The temperature control system could maintain multiple temperature treatments. Figure 1b shows two temperature treatments; setpoint 28°C (RZW Set1) and 20°C (RZW Set2). The deviation from the setpoint during Spring was approximately 1°C (Table 1 and Figure 2).

The capacity of the temperature control system to maintain uniform channel setpoint temperatures is shown in Figure 3. Forty eight channels were run at the setpoint (20°C) during Winter and the temperature data of six channels selected at random are presented.

Figure 1c shows that under peak energy load of Winter the storage heat temperature fell below it's setpoint of 35°C. The storage heater temperature dropped over night but recovered during the day when the glasshouse temperature exceeded the minimum channel solution temperature.

Good propagation results were achieved without root zone warming for some