ENVIRONMENTAL PREFERENCES OF *EUCALYPTUS GLOBULUS* STEM CUTTINGS IN ONE NURSERY

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ABSTRACT

The initial survival of *Eucalyptus globulus* Labill. ssp. *globulus* stem cuttings, under intermittent mist in a glasshouse, was increased by: shade on clear days, the amount depending on season; increasing the wettability of cuttings; periodic water stress of mother plants; and, in winter, by supplementary lighting of cuttings and mother plants. In cuttings from greenhouse-grown plants, survival and the rooting ability of survivors did not vary overall with season, but short-term environmental variation (over 1 week) was significant. Rooting was sensitive to fertiliser in the medium of both mother plants and cuttings, and to the level of shading of cuttings. In summer, outdoor environments were satisfactory for mother plants and favourable for cuttings.

Keywords: clone; propagation; rooting.

INTRODUCTION

Rooted clonal cuttings of tropical and sub-tropical eucalypts are planted on a large scale in Brazil (Zobel & Ikemori 1983), the Congo (Souvannavong 1992), and South Africa (Denison & Kietzka 1993). *Eucalyptus globulus* is the most widely planted species in Mediterranean climates but it is relatively difficult to propagate, both by stem cuttings (Borralho & Wilson 1994) and by micropropagation (Willyams *et al.* 1992).

Within a nursery, individual species, hybrids, and clones have their own environmental preferences. Many elements of the propagation system also vary with time, affecting the propagation characteristics of different harvests of cuttings within clones. This is particularly likely in the climates in which *E. globulus* grows.

Environmental factors typically interact strongly, so the appropriate conditions for propagating woody stem cuttings, and for growing the plants from which they are harvested, depend partly on the propagation system as a whole, including the climate, structures (i.e., glasshouses or shadehouses), management practices, and materials of the nursery. Nursery managers therefore require local predictive ability, which they acquire through their own (formal or informal) propagation trials.

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When some cuttings die before rooting is assessed, the number of cuttings rooted as a proportion of the original number becomes a product of the proportion which survived and the proportion of the survivors which rooted. These two components were generally poorly related (Borralho & Wilson 1994) and are therefore reported separately.

Many trials were conducted while techniques were being developed for propagating *E. globulus* stem cuttings in one nursery in Portugal. This paper describes those trials in which the initial survival and the rooting ability of surviving cuttings were affected by the nursery environments for mother plants and for cuttings, broadly defined to include potting and rooting media.

MATERIALS AND METHODS

Plant Material, Equipment, and General Conditions

The work was done in the development nursery of Celulose Beira Industrial (CELBI) S.A. near Óbidos in Portugal, about 10 km from the Atlantic coast at latitude 39.5°N. The annual temperature range of the coastal waters was 14°–17°C (Michelin Map 437), moderating the Mediterranean-type climate at all seasons. All trials were established with clonal stem cuttings of the Portugese land race of *E. globulus*. The clones were individual genotypes originating from first- or second-generation plus-trees.

Mother plants were grown from rooted cuttings:

(a) In pots, either in a greenhouse (GH) or unshaded outdoors (OUT). The pots were made of black plastic and were 23 cm deep with internal top and basal diameters of 26 cm and 20 cm. Net rooting volume was approximately 8 litres.

(b) In the greenhouse in Lannen paperpot trays, at a stocking of 150–250 plants/m^2.

(c) In the field, where the stumps of 2- to 4-year-old trees yielded coppice shoots 0.2–0.4 m long (COP).

The greenhouse was a single-span double-skin plastic arch of 25 × 80 m, with vents 1 m from the ground and very large doors at each end with cooling (extractor) fans above them. Temperatures were 5°–15°C at night and several degrees higher than the ambient temperature during the day (15°–38°C), and relative humidity was 70–90% (night) and 40–60% (day). The structure lowered light intensity, giving a diffuse light, and air movement at plant level during the day (when doors were generally open) was appreciable.

The potting medium was peat:styrofoam/perlite:sand, approximately 1:1:1 (v:v:v), containing N:P:K 15:10:12 slow-release fertiliser (SRF) (at 3 kg/m^3) of 6 months' duration. Potted plants were harvested for cuttings every 2–4 weeks when principal shoots were 15–30 cm long. Shoots less than 12–15 cm long were left on the plants to facilitate renewed growth, maintaining a globular crown on a low and open woody framework. New shoots arose either from the leafy axils of decapitated shoots or from formerly dormant buds on the framework. The plants were periodically treated with 3 kg SRF/m^3 and occasionally given a form pruning.

The rooting medium of the plants in paperpots was as for cuttings (*see below*). Shoots (all first-order laterals) were harvested if at least 10 cm long when mean maximum shoot length was 15–20 cm.

In all mother-plant types, one apical cutting was prepared per shoot. Cuttings from plants in containers were prepared with two maturing or newly mature leaf pairs (three-quarter size to full-size), trimmed to approximately one-third of the entire area, and the more distal (immature) leaf pair which was left entire. The shoot apex and immature leaves less than 1.5 cm long were removed. Coppice cuttings, which were fleshier, were prepared with the two more-mature leaf pairs only. Leaf area per cutting was in the range 20–40 cm^2. Cuttings were immersed for 30 seconds in benomyl fungicide solution (2–3 g/*l*), then set at 550 cuttings/m^2 in peat:perlite (usually 2:1 v:v) containing 3 kg SRF/m^3.

Cuttings were set either in an outdoor shadehouse or in a glasshouse and were kept well-wetted with intermittent mist, the regime varying with season and weather. The shadehouse was covered with 85% shadecloth at the sides and 25% above, making it permeable to the weather. The glasshouse was a single span of 12 × 50 m with vents at the sides and apex. Temperatures were 15°–20°C at night and 20°–32°C during the day. Relative humidity dropped to as little as 70–75% in the middle of clear days. Cuttings were provided with 85% shade when the weather was clear and were unshaded when overcast. Natural daylength was sometimes supplemented with high-pressure sodium lamps giving 6–8 h of 40–60 $\mu E/m^2.s$ at cutting/mother-plant level from dusk onwards.

The design and equipment of the greenhouse (for mother plants) and glasshouse (for cuttings) were Scandinavian. Danish DGT climate computers helped in managing the environments (and in gathering environmental data), but manual adjustments were also necessary.

Layouts

Each comparison of treatments (a trial) consisted of one or more replications in time (tests). In each test, cuttings were harvested from one to four clones, each clone represented by one uniform batch of mother plants. There were at least 20 cuttings per plot and at least three replications per test (at least 60 cuttings per treatment per test). Tests in which treatments were positions or environments were simple randomised designs with at least 4 × 20 cuttings per position or environment. Otherwise, replications were generally randomised complete blocks. When there was more than one clone in a test, blocks and clones were confounded. Tests were enumerated by digging up the cuttings when roots had emerged up to 10 cm from the base of the propagation containers, 35–50 days after setting.

Assessments and Data Analysis

Cuttings were "dead" if they had no surviving stem below the level of the medium or no remaining foliar area. The number of cuttings surviving as a percentage of the original number (survival (%)), the number rooted as a percentage of the survivors (rooted (%) of survivors), and (usually) the number of roots per rooted cutting were recorded per plot. Original percentages are cited but were angular-transformed before analysis of variance. Further hypothesis tests follow Snedecor & Cochran (1980). When many percentages were close to 0% or 100%, indicating marked departure from normality, analysis was by the χ^2 test of independence (with Yates' correction for continuity), after combining blocks. The results of different tests within a trial were also combined if consistent. Trials were identified 1A, 1B, ... etc., and the mother-plant type (GH, OUT, or COP) and the month of harvest of

each test (Jan, Feb, etc.) were noted. There were up to five tests per trial. For example, "OUT Jun Jul Sept" signifies that outdoor-grown plants were harvested for test cuttings on three occasions, in the months indicated.

Mother-plant Environment Treatments

Mother plants were:

1A Grown with or without supplementary light (SL) for at least a month before cuttings were set (GH Feb Mar Mar).

1B Either well-watered or watered only when plants were wilting. Cuttings were set after 2 weeks, when the drier plants had wilted and been watered twice (GH Apr).

1C Kept in full light or put under 25%, 50%, or 85% shade for 16 days before cuttings were harvested (OUT Jul).

1D Planted outdoors in January in fresh medium containing the usual "high N" SRF at 3 kg/m^3, "high K" (N:P:K 10:11:18) SRF at 3 kg/m^3, or the 1:1 mixture at 3 kg/m^3 or 6 kg/m^3 (OUT Jun Jul Sept). The analysis partitioned "treatments" and "tests".

1E Grown (OUT) and (GH). In samples of 12 plants per environment the length of all shoots (including laterals) was recorded in the size-classes 0, 2, 4, ... cm. Some of the outdoor plants were then moved into the greenhouse and some of those inside were moved outdoors (Jul). Cuttings were harvested after a further 7 days, during which the mean daily max./min. temperatures and relative humidity were 29°/16°C and 92%/45% (GH) and 25°/14°C and 80%/35% outdoors. There was also more light and air movement outdoors.

Propagation Environment Treatments

Position effects in the glasshouse

Cuttings were set as follows:

2A At six positions, three to either side of the extremity of an 85% shadescreen, giving a gradient from full light to 85% shade. Due to the angle of the sun, Positions 2 and 3 were shaded in the middle of clear days for approx. 1 and 3 h respectively (COP Jan).

2B As for 2A, except that there were 10 positions, five to either side of the shadescreen (COP Mar).

In Trials 2A and 2B there was no supplementary light, the shade boundaries ran approximately east-west, and (as usual) all cuttings were unshaded when the weather was overcast.

2C At eight positions (40 cuttings per position) in a line perpendicular to a single operating irrigation line, creating a gradient in the rate of deposition of mist (COP Jan).

2D At 24 positions (20 cuttings per position) along one irrigation line. There were six blocks either adjacent to sprinklers or midway between sprinklers, and four positions within a block from adjacent to the line to midway between the two operating lines (COP Jan).

Trials 2C and 2D were established at the same time with cuttings from the same origin. The mist regime was 20 s mist every 15 min during the day and every 60 min at night.

After the cuttings were set, the mean deposition of mist per 12-h period (mean of day and night rates) was estimated at each position.

Fertiliser in the rooting medium

3A Propagation trays were filled with moist peat:perlite (1:4), either with or without 2 kg SRF/m^3, and stored at 15°–25°C for 2 weeks before cuttings were set (COP Jan).

3B Trays were filled with newly mixed peat:perlite (1:1), either with or without 3 kg SRF/m^3, and placed under intermittent mist in the glasshouse in October. The pH and conductivity of the incoming irrigation water, and of the leachate from the trays with and without fertiliser, were measured 17 times over 82 days. After 3–4 months, in two tests, these "old" trays were arranged with freshly mixed "new" trays (also with or without SRF), and cuttings were set within 2 days (GH Jan Feb).

Supplementary light, bottom heat, and immersion in fungicide solution

Cuttings were set as follows:

4A SL in the glasshouse (GH Jan Mar Mar). In the first test there were two intermediate positions 3 and 6 m from the light source.

4B Bottom heat (BH) in the shadehouse (GH Apr Dec). In the April harvest, mean temperature at the base of the cutting was approximately 24° with BH and 18°C without BH.

4C Prior immersion for 30 s in benomyl fungicide solution at 2 g/*l* (GH Apr, OUT Jul).

Comparisons in the glasshouse and shadehouse

Cuttings were set:

5A In the two environments (various origins, five tests, from spring to summer).

5B In the shadehouse under 25% or 44% shade (OUT end Jul). This trial was conducted at the hottest and sunniest time of the year.

RESULTS

The main results are presented in Tables 1, 2, and 3. Those which speak for themselves from the Tables are then reviewed in the Discussion.

Mother Plant Environment

Over the three tests of Trial 1D (Table 1), fertiliser treatments were not significant for percentage survival ($F = 2.1$) or roots per rooted cutting ($F = 0.8$), but were weakly significant for rooted percentage of survivors ($F = 3.2^{+}$ 3, 42 df). Treatment mean rooting of survivors varied from 58% to 68%, the lowest value being "high N" at 3 kg/m^3. However, most of the variation was due to the severe loss of rooting ability in all treatments in the final September test. Crown size in this and in the preceding (July) test was within the accepted range: the mean length ±95% confidence limits of the longest shoots was 23.0 ±1.4 cm, and 27.8 ±2.2 cm, respectively. This difference was insufficient to have much affected rooting ability

TABLE 1–Number of cuttings surviving as a percentage of the original number (Survival(%)), the number rooted as a percentage of the survivors (Rooted(%)of survivors), and the number of roots per rooted cutting (Roots/rc) in control cuttings and cuttings harvested from mother plants treated in various ways. Treatments are described in the Methods section. Analysis was by ANOVA (F).

		Survival (%)		Rooted (%) of survivors	Roots/rc
1A	**Supplementary light to mother plants. Cuttings set in January and March.**				
		January	March		
	Control	52	72	65	3.1
	Supplementary light	71	66	73	3.2
	F	10.0++	ns	6.2++	ns
1B	**Mother plants subjected to 2 weeks of periodic wilt before harvest of cuttings.**				
	Control	56		40	1.7
	Wilt	79		40	1.6
	F	4.2#		ns	ns
1C	**Mother plants under various levels of shade outdoors. Cuttings harvested after 16 days.**				
	Control	72		33	1.6
	25% shade	90		51	1.7
	50% shade	96		39	1.5
	85% shade	80		39	1.2
	F	7.1*		1.6 ns	2.8#
1D	**Slow-release fertiliser in mother-plant medium. Cuttings set on three occasions, the last beyond the life of the fertiliser.**				
	Jun	96		89	3.5
	Jul	83		84	3.2
	Sept	82		16	1.7
	F	15.8**		174.3**	36.9**
1E	**Mother plants grown outdoors or indoors, or moved from one environment to the other 7 days before cuttings were harvested.**				
	Outdoors	87		90	4.0
	Indoors	87		92	3.5
	Outdoors to indoors	98		97	4.5
	Indoors to outdoors	92		92	4.1
	F	4.7++		1.6 ns	3.9+

Probability # <0.1
+ <0.05
++ <0.025
* <0.01
** <0.005
ns not significant

(data not shown, but see 1E below). However, cuttings production in the intervals before the two tests was 1.6 and 0.7 cuttings per plant per week, suggesting that the growth rate of mother plants had slowed by September, probably due to exhaustion of fertiliser in all treatments.

In 1E (Table 1), 7 days before outdoor and GH plants were harvested for cuttings, mean length of the longest shoots was 26.5 cm (s.d. 4.38) for outdoor and 18.2 cm (s.d. 3.28) for GH plants. The outdoor plants had slightly more shoots of any length per plant (17.2 compared with 15.2 shoots) but newly developing laterals in the length range 2–6 cm were

relatively numerous. There were 8.4 shoots over 12 cm long per outdoor plant and 7.3 per GH plant.

Propagation Environment

Position effects in the glasshouse

In the light-gradient trials, rooting was highest in winter (2A) at the two positions in the glasshouse which were shaded for approximately 1–3 h in the middle of clear days (Table 2). In spring (2B), rooting was higher at the five positions shaded for at least 5–6 h per clear day than at the others, shaded for 1 h or less ($LSD_{0.05}$, transformed data).

The unreplicated trial 2C suggested that mist deposition rates of less than about 6 mm per 12 h reduced both survival and the rooting of survivors.

TABLE 2–Percentage survival, rooted percentage of survivors, and roots per rooted cutting in cuttings set in the glasshouse under various shade levels (2A–B) and mist deposition rates (mm/12 h; 2C). Trial 2C was not analysed formally because if was not replicated. Treatments are described in the Methods section. Analysis was by ANOVA (F).

			Survival (%)	Rooted (%) of survivors	Roots/rc
2A	**Winter: Increasing shade**				
	Full light	1	99	48	2.2
		2	99	51	2.4
		3	96	60	2.3
		4	95	45	2.1
		5	87	46	1.8
	85% shade	6	91	36	1.5
	F		–	2.1 ns	4.5++
2B	**Spring: Increasing shade**				
	Full light	1	96	45	1.7
		2	97	39	1.5
		3	99	41	1.9
		4	96	47	2.4
		5	99	58	2.6
		6	97	59	2.4
		7	90	64	2.1
		8	96	65	2.4
		9	97	67	2.7
	85% shade	10	97	63	2.1
	F		–	5.1**	2.0#
2C	**Increasing dryness**				
	Mist (mm/12 h)	12.5	100	52	
		10.0	95	42	
		8.5	97	59	
		6.0	90	50	
		3.5	87	31	
		2.0	75	30	
		2.0	25	20	
		0.7	0	0	

Probability # <0.1
++ <0.025
** <0.005
ns not significant

TABLE 3–Percentage survival, rooted percentage of survivors, and roots per rooted cutting in cuttings treated in various ways. Treatments are described in the Methods section. Analysis was by ANOVA (F) or χ^2.

		Survival (%)	Rooted (%) of survivors	Roots/rc
3A	**Slow-release fertiliser (SRF) in the rooting medium of the cuttings.**			
	Without SRF	84	57	2.0
	With SRF	88	67	2.4
	F	ns	5.5#	48.8**
3B†	**Fresh or old rooting medium with or without SRF (two tests for rooted(%)survivors).**			
	Fresh with SRF	60	21 74	
	Fresh without SRF	46	9 57	
	Old with SRF	55	4 57	
	Old without SRF	48	0 58	
	F	3.7++	3.1#	
	χ^2		9.2**	
4A	**Supplementary light (SL) for cuttings in glasshouse.**			
		Winter Spring Spring		
	Control	32 58 86	67	2.9
	Intermed.	46		
	Intermed.	57		
	With SL	84 98 91	74	2.9
	F	47.2** 0.7 ns	8.5++	ns
	χ^2	71.1**		
4B	**Bottom heat for cuttings in outdoor shadehouse.**			
		Spring Winter	Spring Winter	
	Control	78 71	60 0	
	With bottom heat	77 44	80 11	
	F	ns 10.1+	4.0 ns –	
4C	**Immersion of cuttings for 30 s in fungicide.**			
	Control	76	60	
	With fungicide	89	63	
	F	5.5+	ns	
5A	**Cuttings set in the glasshouse or shadehouse; means of five tests from spring to summer.**			
	Glasshouse	71	54	2.1
	Shadehouse	92	55	2.5
	(see text for analysis)			
5B	**Shade level for cuttings in the outdoor shadehouse 25% or 44%.**			
	25% shade	95	30	
	44% shade	88	29	
	F		ns	
	χ^2	7.9**		

Probability # <0.1
+ <0.05
++ <0.025
** <0.005
ns not significant

† 3B, Test 1: rooting compared in treatments with fresh rooting medium only.

In a survey of the variation in mist deposition in the glasshouse (2D; not shown in Table 2), mean survival and rooting of survivors were 93% and 41% respectively. Block mean deposition of mist varied from 8.5 to 15 mm/12 h (F = 22.0** 5, 15 df), blocks adjacent

to sprinklers giving the extreme values. Deposition also increased slightly with distance from the irrigation line (due to the influence of the adjacent line), from 10.7 to 12.3 mm ($F = 3.0^{\#}$ 3, 15 df). Overall, position mean deposition varied from 6 to 15 mm (mean = 11.7 mm; s.d. 2.74), while survival and rooting began to decrease when deposition was less than approximately 6.0 mm (2C; Table 2). The normal deviate (11.7–6.0/2.74 = 2.08) is exceeded by 1.8% of observations (Quenouille1966) indicating that, neglecting possible variation between irrigation lines, an estimated 1–2% of the greenhouse area was prejudicially dry (on that occasion). Similarly, approximately 45% of the area received at least 12 mm, double the estimated minimum. In 2D, mist deposition was weakly positively related to percentage survival ($r^2 = 0.16$; $p = 0.05$) but not to rooted percentage of survivors ($r^2 = 0.01$), and there was no relationship between percentage survival and rooted percentage of survivors ($r^2 = 0.03$).

Fertiliser in the rooting medium; supplementary light, bottom heat, and immersion in fungicide solution; comparisons in the glasshouse and the shadehouse

In 3B (Table 3), the mean pH of the irrigation water was 8.2 ±0.2 (95% confidence limit), and 6.2 and 6.0 in the leachate from the trays with and without fertiliser. The pH of the leachates was consistently similar ($F = 3.0$ ns 1, 16 df), tending in both to decrease with time ($F = 10.5^{**}$ 16, 16 df) from approximately 5.5 initially to beyond 7.0 after 65 days, and reaching pH 8 by Day 82.

On the first day that trays were placed in the glasshouse, conductivity in the leachate from trays with and without fertiliser was 2.32 and 0.71 "mmhos/cm at 25°C", but dropped to representative values by Day 12. Beyond this, mean conductivity was 0.52 (with fertiliser), 0.43 (without fertiliser), and 0.64 (irrigation water; $F = 148.2^{**}$ 2, 28 df). Conductivity tended to increase with time (from 0.50 to 0.58; $F = 3.4^{**}$ 14, 28 df), at least in the leachates.

In 5A, survival was higher in the shadehouse than in the glasshouse in four of five tests ($p < 0.025$ in each), and similar in the fifth (86% and 85% ns) (Table 3). In each of the five tests rooting of survivors was within 3% in the two environments, but in three of the tests there were more roots per rooted cutting in the shadehouse ($p < 0.1$, 0.05, and 0.01).

At night, the ambient air temperature in the glasshouse was higher than in the outdoor shadehouse. During the day, temperatures in the two structures were similar when the outside temperature was in the range 20°–25°C, but at higher temperatures the glasshouse was cooler (up to 6°C cooler at the highest recorded outdoor shade temperature of 36°C). Daytime (wetted) leaf temperatures (measured with an infrared thermometer) were probably similar in the two environments, being similar to the air temperature at relative humidities higher than about 80%, as in the glasshouse, but up to about 6°C less in the shadehouse.

DISCUSSION

Treatments of potted mother plants, which increased the initial survival of cuttings harvested from them, included supplementary light (SL) to prolong daylength in winter (Trial 1A, Table 1) and subjecting plants to periodic water stress (1B). Both treatments may have reduced cuticular transpiration from cuttings since they visibly increased glaucousness, and stress may also have conditioned the stomata to close more readily prior to wilting (Clemens & Jones 1978). Glaucousness was a potentially adverse trait, reducing wettability

under intermittent mist, but was largely nullified if cuttings were briefly immersed in fungicide solution before setting (4C, Table 3). This treatment markedly increased wettability (and survival ability), and was accompanied by a conspicuous and virtually immediate colour change to a non-glaucous green.

Mother-plant treatments had relatively little effect on the rooting ability of surviving cuttings, except for slow-release fertiliser (SRF) in the medium of potted plants, the lack of which reduced cuttings production (i.e., growth rate) and led to a severe loss of rooting ability (1D, Table 1).

Short-term variation (over 1 week) in the mother-plant environment significantly affected the survival and rooting of cuttings harvested from them (1E, Table 1). However, over many tests spanning 2 years, the propagation characteristics of greenhouse-grown cuttings of one clone did not vary appreciably with season (data not shown). The cuttings production of mother plants was higher in the greenhouse, particularly in winter, and shade in summer (as would be created by the greenhouse structure) was advantageous with one clone (1C, Table 1).

In the glasshouse environment, heavy shade tended to moderate the temperature, but even with shade, day temperatures easily exceeded 30°C when ventilation was restricted. However, restricted ventilation also conserved relative humidity above 85–90% and appeared to be better for cuttings (but less comfortable for staff) than more ventilation, with more moderate temperatures but relative humidities as low as 70–75%. The rate of venting and air mixing within the glasshouse was extremely sensitive to outdoor air movement, and when priority was given to conserving humidity the vents required frequent manual adjustment.

SRF in the medium of cuttings increased rooting (3A, 3B, Table 3), in one trial approximately doubling total root number even when added to medium made with commercially pre-fertilised peat (data not shown). SRF had little effect on the pH and conductivity of the leachate from propagation trays and did not prolong the ability of the medium to buffer the high pH of the irrigation water. Thus, the fertiliser probably had direct effects on the cuttings, either being absorbed to nourish the whole cutting or having local effects on the callus at the base, from which roots normally emerged.

In winter, SL to extend daylength in the glasshouse markedly increased survival (4A, Table 3) while, in the absence of SL, shade throughout the day on clear days was prejudicial to both survival and rooting. The optimum appeared to be light shade during the mid-part of clear days (2A, Table 2). SL was given only in conjunction with the standard 85% shade regime so the SL effect in winter (if any) under optimum shade cannot be estimated. However, in spring, SL was still beneficial (4A) when up to 85% shade on clear days was appropriate (2B).

The optimum light regime is extremely difficult to specify, even locally. Cuttings from different origins probably have different preferences, the effects of light (for example, on the water economy of the cutting) depend on other environmental conditions in the propagation environment, and the light intercepted by cuttings is the result of interactions between ambient light including SL, the form of the cutting (including leaf area), and stocking.

In summer, survival in the outdoor shadehouse was higher than in the glasshouse (5A, Table 3). The shadehouse was much brighter than the glasshouse (light shade only was

advantageous even in midsummer; 5B) but heat did not accumulate, and night temperatures were lower. Mist deposition in the glasshouse varied between sprinklers to the extent that (on one occasion) a small proportion of the area was prejudicially dry (2C, Table 2; 2D), but this had a minimal effect on mean survival. The mist settings would have been more important if misting had been generally lighter, or if there had been evidence of a prejudicial excess. In southern pine cuttings in the United States, 75% of the variation in rooting was due to variation in mist fall (Greenwood *et al.* 1980).

The intermittent mist in the shadehouse was also relatively fine, and the often marked and turbulent air movement resulted in a more thorough wetting of cuttings, including (to some extent) the undersides of the leaves. This evidently protected the cuttings from the low ambient relative humidities of the shadehouse. The two main functions of fine mist or fog (namely, the wetting of cuttings and maintenance of high ambient relative humidity) should therefore be clearly separated in *E. globulus* propagation.

The outdoor shadehouse was favourable for cuttings in summer (5A, Table 3) but was not suitable in winter (minimum night temperatures 0°–5°C). Bottom heat could possibly extend its use to several of the warmer months of the year (4B, Table 3). In any one season the appropriate propagation environment could also change with time from setting, as was suggested for *E. grandis* Hill ex Maid. (Wilson 1994a). Newly set *E. globulus* cuttings were sometimes slightly wilty, but seemed to become more hardy after a day or two.

In practice, ease of propagation in *E. globulus* depends on efficient clonal selection, especially for rooting potential. Realising this potential in selected clones, as consistently as possible, also requires a good understanding of propagation traits and good management. Without this, it can be misleading to describe *E. globulus* clones as easy or difficult to root because variation within the clone can be high. Consequently, propagation trials at the management level, including those involving the environment, will have high impact in practice. They are also required to create a context for more fundamental studies (Wilson 1994b).

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