Production and Postharvest Treatment of Cut Stems of *Eucalyptus* L. Hér. Foliage

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Abstract. Optimum pruning height for cut foliage production was investigated for 3-year-old trees of *Eucalyptus globulus* Labill. Trees cut at a height of 1.0 m above ground level had most stems resprouting from the trunk, but a pruning height of 0.5 m produced the longest stems. Postharvest trials were conducted to assess the vase life of cut stems, and the effect of pulsing and simulated transportation on vase life. Holding solutions containing 1% or 2% sucrose and 8-HQC at 200 mg·L⁻¹ significantly increased vase life of *E. globulus* and *E. cinerea* F.Muell. ex Benth. over the control, but pulsing *E. cinerea* in 1%, 5%, or 10% sucrose plus 8-HQC for 2 hours at 24 °C or 24 hours at 3 °C had no effect. In simulated transport trials, pulsing overnight in 1% or 5% sucrose plus 8-HQC at 3 °C followed by 1 week dry storage at 3 °C had no effect on the vase life of cut stems of *E. sideroxylon* Cunn. ex Wools., *E. platypus* Hook., *E. spathulata* Hook., *E. cladocalyx* F.Muell. x *E. platypus*, or *E. spathulata* x *E. sargentii* Maiden, but a 5% sucrose pulse plus 8-HQC significantly increased the vase life of *E. spathulata* x *E. platypus*. A long pulse at low temperature (24 hours/3 °C) followed by 1 week dry storage was more effective than a short pulse at high temperature (2 hours/24 °C) for *E. albidia* Maiden & Blakely stems and no sucrose was more effective than 1% or 5%. Thus, a pruning height of 0.5 or 1.0 m was optimum for cut foliage production of *E. globulus*, and a 2% sucrose holding solution extended vase life. There was no advantage of sucrose pulsing to extend vase life, or to improve vase life following dry storage, except for the hybrid *E. spathulata* x *E. platypus*. Chemical name used: 8-hydroxyquinoline citrate (8-HQC).

Juvenile *Eucalyptus* foliage provides an important filler crop in floral decorations for world floriculture markets, but little research has been conducted on its production or postharvest handling. *Eucalyptus* foliage has been cultivated in the United States for some years (Nowak and Rudnicki, 1990), and Rumine and Bellandi (1989) investigated 11 species for adaptability to the Italian climate. They concluded that *E. cinerea*, *E. stuartiana* F.Muell. ex Miq., *E. parvifolia* Cabbage, *E. gunnii* J.D.Hook., and *E. maidenii* F.Muell. gave the best quality foliage. At present the

worldwide industry is based on relatively few species, with *E. gunnii* the most widely cultivated; to fulfill the requirement for a wider range of foliage types, we have commenced a selection and crossing program (Ellis et al., 1991). Correct pruning is necessary to produce juvenile stems from most *Eucalyptus* species. Some, such as *E. cinerea*, retain the juvenile form at maturity, but most, such as *E. gunnii* and *E. globulus*, change rapidly from the waxy, juvenile leaf to the glossy, adult form. Research is needed to find the most appropriate pruning height for eucalypts.

The efficiency with which postharvest storage and handling are carried out is very important (Halevy and Mayak, 1979, 1981). Sucrose concentrations that are too high can damage *Eucalyptus* foliage, causing browning of leaf margins (Jones and Sedgley, 1993). An important part of postharvest handling is correct storage and transportation conditions, because foliage must often travel to distant markets with the risk of quality loss. Work carried out by Forrest (1992) on *E. gunnii* showed that foliage could be stored wet or dry for up to 4 weeks at 5 °C without damage. Similar work with *E. crenulata* Blakely & Beuzev. and *E. gunnii* by Jones et al. (1993, 1994) found dry storage at 1 °C for up to 35 days did not affect

longevity. We conducted our study to establish the correct pruning height for *E. globulus* trees and to find the most appropriate postharvest solutions for a range of species and hybrids.

Materials and Methods

Plant material. All material was sourced from close to Adelaide, South Australia (lat. 34°58'S, long. 138°38'E). *Eucalyptus globulus* plants were located on a grower's property at Inman Valley. *Eucalyptus cinerea* and *E. albidia* stems were harvested from the Waite Agricultural Research Institute Arboretum. Stems of *E. sideroxylon*, *E. platypus*, *E. spathulata*, *E. cladocalyx* x *E. platypus*, *E. spathulata* x *E. platypus*, and *E. spathulata* x *E. sargentii* were collected from plantations at Murray Bridge. The hybrids were the result of a crossing program (Ellis et al., 1991).

Pruning of *Eucalyptus globulus*. Fifty 3-year-old trees that were similar in size and trunk diameter and had not been pruned were selected from a population direct-seeded into a sandy loam soil, pH 5.5, with no irrigation. The trees were pruned (coppiced) in Sept. 1994 to four heights above ground level, 0.1, 0.5, 1.0, and 1.5 m, with a control group (height 2 m) that was not pruned. There were 10 trees per group and all lateral stems were cut off flush with the trunk. The total number of new lateral stems was counted at 1, 2, 3, and 6 months. Harvested stem lengths were measured at 6 months.

Vase life. Stems of *E. globulus* and *E. cinerea*, 40–50 cm long, were placed into 750-ml bottles containing either 0, 1%, or 2% sucrose with 8-HQC at 200 mg·L⁻¹, pH 5. Bottles were placed in a growth cabinet maintained at 20 °C with a 12-h photoperiod, 70% relative humidity, and illuminated at 315 μmol·m⁻²·s⁻¹. The number of leaves on each stem was recorded initially and at regular intervals, and vase life was considered to be over when 50% of the leaves commenced wilting or browning.

Pulsing. Stems of *E. cinerea* were pulsed in 0, 1%, 5%, or 10% sucrose with 8-HQC for either 2 h at 24 °C, 24 h at 3 °C, or for 24 h at 20 °C. After pulsing, stems were placed in water with 8-HQC and tested for vase life as described above.

Pulsing and simulated transportation. Stems of *E. sideroxylon*, *E. spathulata*, *E. platypus*, *E. cladocalyx* x *E. platypus*, *E. spathulata* x *E. platypus*, and *E. spathulata* x *E. sargentii* were placed into pulsing solutions of 0, 1%, or 5% sucrose with 8-HQC. Pulsing was conducted for 18 h at 3 °C. *Eucalyptus albidia* stems were placed into pulsing solutions of 0, 1%, 5%, or 10% sucrose with 8-HQC for 2 h at 24 °C or for 24 h at 3 °C. After pulsing, stems were stored dry, wrapped in newsprint, and placed 40 per transport carton in a room at 3 °C for 1 week. Stems were then placed into water with 8-HQC. Growth cabinet conditions and measurements were the same as for the vase life experiments.

Statistical analysis. Data were tested for analysis of variance using Genstat 5.2.

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Dunnnett's test ($P = 0.95$), comparing treatment means to controls, is presented where appropriate. The statistical designs were: 1) Pruning experiment: 10 trees $\times$ 5 groups (control, 0.1, 0.5, 1.0, and 1.5 m pruning height) = 50 trees; trees were assigned treatments randomly within the population. 2) Vase life of *E. globulus* and *E. cinerea*: 24 stems of *E. globulus* $\times$ 3 treatments = 72 stems with two stems per bottle = 36 bottles divided into three blocks within a growth cabinet. For *E. cinerea* there were 36 stems divided into 3 treatments $\times$ 3 blocks $\times$ 4 replications with one stem per bottle. 3) Pulsing experiments: 3 pulsing solutions $\times$ 4 replications = 12 stems per genotype with two stems per bottle; bottles divided into two blocks within a growth cabinet. 4) *Eucalyptus albidus* pulsing experiment: stems were pulsed with 4 pulsing solutions $\times$ 2 time/temperature regimes $\times$ 4 replications = 32 stems with two stems per bottle. Bottles were divided into two blocks within a growth cabinet.

Results

Pruning of *Eucalyptus globulus*. At 6 months, the trees pruned to 1 m showed significantly more regrowth of new shoots than all other treatments except those pruned to 0.5 m (Table 1). The drop in total shoot count between 2 months and 6 months presumably was due to competition between the large number of regrowth shoots. After 6 months, the longest average stem length was produced by the trees pruned to 0.5 m or 0.1 m. There were no significant variations in stem thickness or leaf color or shape between the pruning regimes. All regrowth was juvenile in character. On 0.1-m pruned trees, the regrowth emerged from all areas of the remaining trunk, including the cut surface. On 0.5-, 1.0-, and 1.5-m pruned trees, the regrowth emerged from the upper half of the trunk.

Vase life. Sucrose solutions of 1% and 2% extended the vase life of *E. globulus* and *E. cinerea* by ≥ 2 days (Table 2). Stems of *E. globulus* had a vase life of 13 days and *E. cinerea* up to 19 days in 2% sucrose.

Pulsing. There was no significant effect of pulsing with sucrose for up to 24 h on the vase life of *E. cinerea* stems that were subsequently held in water. Vase life ranged from 12 to 15 days following pulsing.

Pulsing and simulated transport. Pulsing *Eucalyptus* stems of three species and hybrids for 18 h at 3 °C with sucrose solutions of 1% or 5% before dry storage for 1 week at 3 °C gave no advantage over the control pulse solution except for the *E. spathulata* $\times$ *E. platypus* hybrid (Table 3), where 5% sucrose for 18 h at 3 °C doubled vase life. All other species and hybrids had a vase life of 5–6 days.

Vase life of *E. albidus* stems was not improved over the control after pulsing with 1% to 10% sucrose at 3 °C or 24 °C before 1 week of dry storage at 3 °C (Table 4). Control stems lasted up to 18 days and treated stems up to 16 days. The longer cooler pulse was significantly better than the short warm pulse. The warm (24 °C) pulse with sucrose was deleteri-

Table 1. Effect of height after pruning on regrowth of *Eucalyptus globulus* stems.

Ht (m)	No. shoots				Length of stems ^z (cm)
	Time from pruning (months)				
	1	2	3	6	
0.1	6.3	52.3	45.4	31.7	64.9
0.5	5.4	69.3	60.7	48.6	68.9
1.0	3.3	89.4	63.3	59.3	40.3
1.5	0.8	52.4	32.8	31.1	26.8
Not pruned	0.4	5.9	7.1	16.8	49.6
SEM ^y	1.43	11.22	14.69	13.53	10.83
Significance	***	***	***	*	**

^zMeasured at 6 months.

^ySEM = standard error of mean (45 df) based on error mean square from analysis of variance.

*, **, ***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively; $n = 50$.

ous relative to the control, with vase life reaching only ≈ 3 days. This trend was evident after 4 days.

Discussion

Pruning *E. globulus* trees to 0.5 m or 1.0 m produced good yields of commercial length (>40 cm) stems. Regeneration of *E. globulus* following pruning is from epicormic buds on the trunk (Carr et al., 1984). Other foliage species of *Eucalyptus* that have a lignotuber, such as *E. pulverulenta* Sims and *E. albidus*, may need to be cut lower than 0.5 m to encourage juvenile regrowth from lignotuber buds; more research is needed on such species. Other commonly grown species, such as *E. cinerea* and *E. gunnii*, with no obvious lignotuber may need to be cut at ≥ 1.0 m to allow more surface area from which epicormic buds could develop.

Our results are in agreement with previous research showing that holding solutions containing up to 2% sucrose are beneficial, whereas a pulse of up to 10% sucrose is not (Forrest, 1992; Jones et al., 1993, 1994). In our study, *E. cinerea* had a vase life of 19 days when held in 2% sucrose, but only 13–15 days after pulsing with 5% sucrose and holding in water. Sucrose solutions greater than 5% were not beneficial to the stems due to browning and wilting of the leaves. We also confirm and extend previous results that highlight variability in species response. Jones et al. (1993, 1994) report that vase life of *E. crenulata* is improved by 0.25% sucrose, whereas *E. gunnii* responded to concentrations up to 2%. We found that stems of *E. cinerea* responded equally to 1% and 2% sucrose, while 2% was more effective for *E. globulus*. *Eucalyptus cinerea* also had a longer vase life than *E. globulus*, and *E. albidus* was the most tolerant of simulated dry transport. This difference existed despite the fact that all of the trees were grown in similar environments and stems were tested under controlled conditions.

To our knowledge, ours is the first study to investigate sucrose pulsing before dry storage of eucalypt stems, and is also the first to assess new hybrids. There was no advantage of a sucrose pulse before simulated dry transport on vase life, except for the hybrid *E. spathulata* $\times$ *E. platypus*. There was no obvious morphological reason why the hybrid stems showed such a dramatic effect of prestorage sucrose pulsing on vase life. Stems of *E. albidus*, which

Table 2. Effect of sucrose on the vase life of cut stems of *Eucalyptus globulus* and *E. cinerea*. All solutions contained 8-HQC at 200 mg·L⁻¹.

Sucrose (%)	Vase life ^{z,y} (days)	
	<i>E. globulus</i>	<i>E. cinerea</i>
0	6.5 b	14.9 b
1	9.7 b	16.8 a
2	12.7 a	18.8 a
SEM ^x	1.808	0.497
Significance	*	***

^zVase life was considered over when 50% of the leaves showed wilting or browning.

^yMean comparisons with control using Dunnnett's test at $P = 0.95$ (22 df) = 3.65 days. Within columns, values followed by a common letter are not significantly different.

*, **Significant at $P \leq 0.05$ or 0.001, respectively.

^xSEM = standard error of mean based on error mean square from analysis of variance.

Table 3. Effect of sucrose concentration in overnight (18 h, 3 °C) pulsing solutions before dry storage for 1 week at 3 °C on the vase life of cut stems of three *Eucalyptus* species and three hybrids. Stems were placed in water after dry storage. All solutions contained 8-HQC at 200 mg·L⁻¹.

Species	Sucrose (%)	Vase life ^{z,y} (days)
<i>E. sideroxylon</i>	0	6.9 b
	1	6.2 b
	5	6.4 b
<i>E. platypus</i>	0	6.4 b
	1	5.7 b
	5	6.1 b
<i>E. spathulata</i>	0	4.7 b
	1	6.3 b
	5	6.4 b
<i>E. cladocalyx</i> $\times$ <i>E. platypus</i>	0	5.6 b
	1	5.7 b
	5	4.6 b
<i>E. spathulata</i> $\times$ <i>E. platypus</i>	0	6.1 b
	1	5.2 b
	5	12.3 a
<i>E. spathulata</i> $\times$ <i>E. sargentii</i>	0	6.5 b
	1	6.4 b
	5	5.9 b
SEM ^x		1.16
Significance		**

^zVase life was considered over when 50% of the leaves showed wilting or browning.

^yMean comparisons with controls using Dunnnett's test at $P = 0.95$ (20 df) = 2.36 days. Within columns, values followed by a common letter are not significantly different.

**Significant at $P = 0.005$.

^xSEM = standard error of mean based on error mean square from analysis of variance.

Table 4. Effect of pulsing regime before dry storage for 1 week at 3 °C on the vase life of cut stems of *Eucalyptus albida*. Stems were placed in water after dry storage. All solutions contained 8-HQC at 200 mg·L⁻¹.

Treatment			
Sucrose (%)	Time (h)	Temp (°C)	Vase life ^{z,y} (days)
0	2	24	13.7 b
	24	3	18.1 a
1	2	24	2.6 c
	24	3	14.9 a
5	2	24	2.7 c
	24	3	16.2 a
10	2	24	2.3 c
	24	3	16.4 a
SEM ^x			1.48
Significance			***

^zVase life was considered over when 50% of the leaves showed wilting or browning.

^yMean comparisons with control using Dunnett's test at $P = 0.95$ (7 df) = 4.28 days. Within columns, values followed by a common letter are not significantly different.

***Significant at $P < 0.001$.

^xSEM = standard error of mean based on error mean square from analysis of variance.

were pulsed for 2 hours at 24 °C before storage, had a shorter vase life than those pulsed at 3 °C for 24 hours, an effect observed at all sucrose concentrations and in the control. Apparently, *Eucalyptus* foliage will not tolerate even moderately high temperatures for even a short period, unlike many cut flower stems that are routinely pulsed at temperatures between 20 °C and 27 °C to open flower buds (Halevy and Mayak, 1981).

Of particular significance is the variability in species response shown by this and previous studies, and the vase life superiority of the *E. spathulata* x *E. platypus* hybrid over both parental species following dry storage. The results suggest that introduction of vase life and storage longevity into a *Eucalyptus* selection program may lead to rapid improvements in cut stem quality.

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