Cold Storage of Selected Members of the Proteaceae and Australian Native Cut Flowers

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Additional index words. *Leucospermum* spp., *Protea* spp., *Leucadendron*, *Thryptomene calycina*, *Teloepa speciosissima*, *Chamelaucium uncinatum*, *Verticordia* spp., *Anigozanthos* spp., postharvest physiology, vase life

Abstract. Five members of the Proteaceae and 13 Australian native cut flower cultivars were stored for 35 days under standard conditions at 1C to assess their ability to withstand long-term storage and transport. *Protea cynaroides* L., *Leucadendron* ‘Silvan Red’, *Leucospermum* ‘Firewheel’, *Thryptomene calycina* (Lindl.) Stapf., *Teloepa speciosissima* R. Br., and *Verticordia grandiflora* Endl. retained a vase life of at least 7 days after 21 days of storage. *Leucospermum cordifolium* Salisb. ex Knight, *Protea neriifoli* R. Br., *Chamelaucium uncinatum* ‘Alba’, *C. uncinatum* ‘Purple Pride’, *Verticordia monadelpha* Turcz., *Verticordia plumosa* (Desf.) Druce, and *Verticordia nitens* (Lindl.) Schau. suffered a decline in vase life ranging from 31% to 100% after 14 to 21 days of storage. Species of *Verticordia* and *Chamelaucium* were particularly susceptible to fungal infection. *Anigozanthos pulcherrimus* Hook. and the *Anigozanthos* cultivars Ruby Delight, Bush Harmony, Bush Haze, and Gold Fever all showed a significant reduction in vase life after 14 days of storage compared with unstored controls.

Early research on the postharvest handling of cut flowers demonstrated the potential of dry storage in the rose, carnation, and chrysanthemum (Fischer, 1952; Hauge et al., 1947; Neff, 1939; Thornton, 1930). Recent studies have also concentrated on storage protocols for traditional flower crops (Goszczynska and Rudnicki, 1988; Hardenburg et al., 1986) The rapid expansion of the Australian cut flower industry has resulted in a marked increase in the export trade of Aus-

Received for publication 21 Mar. 1991. This work was partially- funded by a grant from the Rural Industry Research Development Corn. We thank Ausflora Pacific Pty. Ltd.; The Australian Protea Growers Assn., Australian Flower Exporters Ply. Ltd, and Growth Industries Ltd. for supplying the flowers used in this study. We are also greatly indebted to Janyce Truett for her skilled technical assistance and Peter Franz for assistance with statistical analysis. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

tralian native cut flowers, particularly *Chamelaucium uncinatum* (Geraldton waxflower), *Anigozanthos* cultivars (kangaroo paw), and members of the Proteaceae. In the few storage trials conducted using these crops, the vase life of *Teloepa speciosissima* (waratah) was reduced by 25% after 28 days of storage at 1C (Faragher, 1986), while vase life in *Anigozanthos rufus* and *Chamelaucium uncinatum* was significantly reduced by 14 days of storage at 1C (Joyce, 1988; Seaton and Joyce, 1989). *P. cynaroides* and *L. cordifolium* withstood 42 days of dry storage at 2C without reduction in vase life (Haasbroek et al., 1973; Ireland et al., 1967; Meynhardt, 1976). During a transient period of high air-freight costs, successful seafreight of cut *Protea* flowers from Cape Town, South Africa, to Rotterdam, Holland, was completed by several South African *Protea* growers in 1980 using refrigerated containers, but no data exist on storage and transport protocol (J. Wood, personal communication). Storage protocols and conditions differed widely between these trials, and in many cases the

criteria for determining the end of vase life were not cited. The aim of this study was to assess the storage capacity of a wide range of commercial Australian native cut flowers and members of the Proteaceae family using specific vase life criteria and under a standard storage protocol. Cultivars that were suited to long-ten dry storage were determined to be those that retained a vase life of at least 7 days after 21 days of storage.

Verticordia spp. were obtained from Western Australia and airfreighted to Knoxfield within 30 h of harvest. The *Chamelaucium* and *Anigozanthos* cultivars were harvested from commercial flower growers, cooled for 6 h, and transported dry for 6 to 12 h to the laboratory. All other flowers were harvested locally and transported in water, arriving at the laboratory within 3 h of harvest. Control, unstored flowers were sprayed with 1 g iprodione/liter (wetttable powder, 50% a.i.; commercial name: Rovral, Rhone Poulenc, Melbourne, Australia) and placed in water at 1C for 24 h, then removed to 20C for vase life assessment. Stored blooms were thoroughly sprayed with 1 g iprodione/liter, allowed to dry, and kept at 1C for 24 h while standing in distilled water. Preliminary trials indicated that a pre- and poststorage treatment in water lasting at least 24 h was most effective (data not shown).

Flowers were bunched and tightly wrapped in two layers of newsprint and placed in low-density polyethylene bags (~38 µm thick). These were then placed in fiberboard flower boxes (1030 x 370 x 160 mm) and stored in a room set at 1 ± 1C and 80% ± 5% relative humidity (RH). A nonstored control group was placed directly into the evaluation

Table 1. Criteria used for determining end of vase life.

Genus	Termination of vase life
Leucospermum	First sign of wilting styles
Protea	Wilting styles and/or first sign of leaf blackening
Leucadendron	Desiccation of leaf tips
Thryptomene	50% of flowers closed
Teloepa	Perianth wilting and/or blue color
Chamelaucium	First sign of flower closing and abscission
Verticordia	First sign of flower closing and abscission and/or fading
Anigozanthos	Wilting flowers and/or fading

Fig. 1. Fitted curves representing changes in vase life after dry storage at 1°C in members of the Proteaceae. 1) *L. cordifolium* (○); $Y = 10.66 - 0.129X - 0.00596X^2$; Adj. $R^2 = 60.4$. SE = 0.128X; 0.00353X². 2) Firewheel (□); $Y = 9.68 + 0.033X - 0.00756X^2$; Adj. $R^2 = 39.4$. SE = 0.137X; 0.00378X². 3) *P. cynaroides* (◇); $Y = 7.83 - 0.0883X$; Adj. $R^2 = 17.9$. SE = 0.0389X. 4) *P. nerifolia* (Δ); $Y = 6.58 - 0.374X + 0.00542X^2$; Adj. $R^2 = 76.4$. SE = 0.0508X; 0.004X². Where Y = vase life (days); X = storage time (days).

room. After storage, the flowers were unwrapped, the stems recut and rehydrated at 1°C in distilled water for 24 h, with flower heads covered with a polyethylene bag similar to that used in packing to increase relative humidity in the air surrounding the flower heads. Vase life was evaluated at 20°C and 55% to 65% RH under constant light (10 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) supplied by cool-white fluorescent lamps. Criteria used to specify the end of vase life for each species and cultivar were defined (Table 1).

Each treatment (storage time) consisted of 10 replicate stems, and each storage trial was repeated twice. Regression analysis was performed on the data. Those stems infected with fungal growth during storage were arbitrarily assigned a vase life of zero, and these values were included in the calculation of mean vase life.

Proteaceae. *Leucadendron* 'Silvan Red', *Leucospermum* 'Firewheel', and *Protea cynaroides* retained a vase life of at least 7 days after 21 days of storage (Figs. 1 and 2). The vase life of 'Silvan Red' had decreased by only 11% (25 days compared with 28 days in unstored controls) after 28 days of storage

Fig. 4. Fitted curves representing changes in vase life in *Verticordia* spp. after dry storage at 1°C. 1) *V. grandiflora* (○); $Y = 13.67 + 0.1049(X) - 0.01499(X^2)$; Adj. $R^2 = 92.9$. SE = 0.0587(X); 0.0016(X²). 2) *V. nitens* (□); $Y = 6.503 - 0.2012(X)$; Adj. $R^2 = 72.0$. SE = 0.0178(X). 3) *V. monadelpha* (◇). No regression equation. 4) *V. pulmosa* (Δ). No regression equation. Where Y = vase life (days); X = storage time (days).

Fig. 2. Fitted curve representing change in vase life in *Leucadendron* 'Silvan Red' after dry storage at 1°C. $Y = 27.72 + 0.156X - 0.00626X^2$; Adj. $R^2 = 25.2$. SE = 0.182X²; 0.00321X². Where Y = vase life (days); X = storage time (days).

(Fig. 2), and storage was therefore continued for an additional 21 days. 'Silvan Red' maintained a commercially acceptable vase life of 19 days even after 49 days of storage (Fig. 2).

Poststorage vase life of *Leucospermum cordifolium* declined rapidly after 14 days of storage, mainly due to fungal infection (data not shown). A more effective anti-fungal treatment than we used probably would dramatically improve poststorage vase life in this flower. Preliminary trials with *L. cordifolium* indicated that stems not infected with fungal rot during storage had a vase life of at least 7 days after 21 days of storage.

Cold storage-induced leaf blackening after 14 days of storage in *P. nerifolia* resulted in a short poststorage vase life. Storage-induced leaf blackening was not observed in *P. cynaroides*.

Australian native cut flowers. Generally, Australian native cut flower species stored in these trials did not withstand the rigors of dry storage as well as members of the Proteaceae family (Figs. 3, 4, and 5). However, vase life in *Thryptomene calycina* and *Telopea speciosissima* did not change significantly after 21 days of storage (11 and 7

Fig. 5. Fitted curves representing vase life in kangaroo paw cultivars after dry storage at 1°C. 1) 'Gold Fever' (○); $Y = 13.3 - 0.578X + 0.00659X^2$; Adj. $R^2 = 83.5$. SE = 0.0757X; 0.00208X². 2) *A. pulcherrimus* (□); $Y = 12.17 - 0.521X + 0.0059X^2$; Adj. $R^2 = 72.0$. SE = 0.0941X; 0.0826X². 3) 'Bush Harmony' (◇); $Y = 6.45 - 0.01X - 0.0042X^2$; Adj. $R^2 = 69.5$. SE = 0.0498X; 0.00138X². 4) 'Bush Haze' (Δ); $Y = 7.1 - 0.1726X$; Adj. $R^2 = 80.8$. SE = 0.012X. 5) 'Ruby Delight' (▽); $Y = 6.53 - 0.162X$; Adj. $R^2 = 73.6$. SE = 0.014X. Where Y = vase life (days); X = storage time (days).

Fig. 3. Fitted curves representing changes in vase life in selected Australian native cut flowers after dry storage at 1°C. 1) *T. speciosissima* (○); $Y = 8.273 + 0.1744X - 0.00566X^2$; Adj. $R^2 = 8.3$. SE = 0.0847X; 0.00234X². 2) *T. calycina* (□); $Y = 6.622 + 0.1341X - 0.00482X^2$; Adj. $R^2 = 19.0$. SE = 0.0552X; 0.00153X². 3) *C. uncinatum* 'Alba' (◇); $Y = 8.847 - 0.4657X + 0.00756X^2$; Adj. $R^2 = 81.7$. SE = 0.0489X; 0.00135X². 4) *C. uncinatum* 'Purple Pride' (Δ); $Y = 7.8 - 0.4582X + 0.0069X^2$; Adj. $R^2 = 83.8$. SE = 0.0478X; 0.00132X². Where Y = vase life (days); X = storage time (days).

days, respectively; Fig. 3).

Verticordia grandiflora maintained a vase life of 10 days after 21 days of storage (Fig. 4), after which vase life declined severely, whereas the vase life of all other species of *Verticordia* declined significantly after 14 days of storage. No regression analysis was performed on *V. monadelpha* and *V. plumosa* as no stems survived after 14 days of storage.

Significant floral abscission occurred in *T. calycina* after 28 days of storage ($\approx 15\%$ to 20% of flowers). As there was no further abscission during vase life assessment, these stems were rated in a similar manner as control stems. Observations during preliminary trials indicated that abscission became a major problem during storage only when flowers are harvested late in the season and in full flower.

The vase life of stored *T. speciosissima* was 8 days after 35 days of storage, similar to the vase life of unstored control stems (Fig. 3). Faragher (1986) reported that waratah vase life was reduced by 50% (from 6 to 3 days) if stems were stored at 4°C, or if flowers were stored unwrapped, indicating the importance of low temperature (1°C) and the need to maintain flower hydration during storage with adequate wrapping.

Quality in both *C. uncinatum* 'Alba' and 'Purple Pride' declined rapidly after 14 days of storage (Fig. 3). Stems of *C. uncinatum* were stored with a similar reduction in vase life by Seaton and Joyce (1989). *C. uncinatum* suffered from fungal attack (identified as *Botrytis cinerea* Pers.) in these trials, despite a prestorage spray with 1 g iprodione/liter, resulting in poor poststorage vase life. Fungal infection was also prevalent in all *Verticordia* spp. and kangaroo paw cultivars after 21 days of storage. When present, it effectively ended vase life immediately after storage. The *Verticordia* spp. were not treated with an antifungal agent before air transport from Western Australia to Victoria, and conditions during transit (high temperature, high

relative humidity) possibly were conducive to fungal attack. Subsequent spraying with 1 g iprodione/liter was not sufficient to prevent further fungal infection.

The evaluation of other anti-fungal agents and spraying/dipping techniques has established the anti-fungal potential of a mixture of 1 g iprodione/liter and 1 g mancozeb/liter (wetttable powder, 80% a.i.; commercial name: Mancozeb, suggested by D. Joyce; data not shown). An effective anti-fungal treatment that can be applied immediately after harvest to improve the storage performance of *C. uncinatum* and *Verticordia* spp. possibly will be developed.

Kangaroo paw cultivars with a long control vase life (*Anigozanthos pulcherrimus* and the cultivar Bush Fever) suffered a substantial reduction in vase life after 14 days of storage (Fig. 5), leaving all kangaroo paw cultivars with a vase life of <7 days after 14 days of storage. Seaton and Joyce (1989) reported a dramatic decrease in vase life when *Anigozanthos rufus* cut flowers were stored for 2 weeks at 0C. Vase life significantly increased in unstored kangaroo paws pulsed with sucrose solutions of up to 30% (Carter et al., 1989; Manning et al., 1989), and it is possible that pre- and poststorage treatment with a sucrose solution might extend vase life significantly.

The vase lives cited in this study represent a minimum value. Further improvements of this storage protocol, including more advanced packaging techniques and the use of solutions containing a germicide and sucrose in the precooling and rehydration phases, should improve the length of storage possible and the condition of flowers after storage.

Our results suggest that *Leucospermum* 'Firewheel', *Protea cynaroides*, *Leucadendron* 'Silvan Red', *Thryptomene calycina*, *Teloepa speciosissima*, and *Verticordia grandiflora* can be stored for at least 21 days and retain a commercially acceptable vase life of at least 7 days. Vase life of stored *Leucospermum cordifolium*, *Chamelaucium uncinatum* 'Alba' and 'Purple Pride', *Verticordia monadelphae*, *Verticordia plumosa*, *Verticordia nitens*, *Anigozanthos pulcherrimus*, and the *Anigozanthos* cultivars Ruby Delight, Bush Harmony, Bush Haze, and Gold Fever declined significantly compared with unstored controls. Australian native species were susceptible to fungal attack during storage. Effective anti-fungal treatments may extend the storage period and vase life of these species.

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