Postharvest Handling of Brodiaea Flowers

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Abstract. Vase life of individual flowers of cut brodiaea (*Triteleia laxa* Benth.) inflorescences ended 4 days after opening. Best vase life was achieved by harvesting inflorescences 1 to 2 days before anthesis of the first flower and holding them in a vase solution containing 2% sucrose and 200 ppm 8-hydroxyquinoline citrate (HQC). Such inflorescences had a display life of 12 days. Decreasing the pH of the vase solution or pulsing inflorescences with 10% sucrose for 16 hours did not increase their longevity. *T. laxa* flowers pretreated with 10% sucrose overnight could be stored for up to 2 weeks without significant reduction in vase life.

The commercial production of brodiaea flowers (specifically *Triteleia laxa* 'Queen Fabiola') recently has increased markedly, and there is now interest in using other species of the brodiaea complex as cut flowers. The commercial success of any new cut flower depends not only on its aesthetic qualities and ease of production, but also on its vase life after normal commercial handling. Optimal postharvest life of cut flowers is often strongly affected by the maturity at harvest, and may be improved by sucrose pretreatment and use of suitable vase solutions (Halevy and Mayak, 1979, 1981). The success with which cut flowers can be stored is variable, depending on the species (Hardenburg et al., 1986). We examined the optimal harvest stage for brodiaea flowers, and the effects of biocides, pH, and sucrose concentrations in the vase solution on their vase life. We also examined the possibility of long-term storage of harvested brodiaea flowers.

Plant materials and vase life evaluation. 'Queen Fabiola' brodiaea flowers were grown outdoors in Davis, Calif. Inflorescence maturity was defined on a scale of 0 to 4, depending on the number of open flowers in the inflorescence. One day before the first flower opened was defined as Stage 0, inflorescence with 1, 2, 3, or 4 open flowers was defined as Stage 1, 2, 3, or 4, respectively. Unless otherwise specified, inflorescences were harvested from the field when their first flower reached anthesis (Stage 1). The inflorescences were placed individually in sterile polyethylene vases containing ≈ 80 ml of vase solution. Their opening and vase life were evaluated in a controlled environment (21°C, 12 hr 15 μ mol·m⁻²·s⁻¹ cool-

white fluorescent light each day, 60% RH). The vase life was considered terminated when the number of senescent flowers exceeded the number of open flowers.

Harvest stage and sucrose. The postharvest life of cut flowers can be greatly affected by their maturity at harvest. Many flowers are normally harvested at the bud stage because buds are easier to handle and usually have a longer vase life than open flowers. Previous workers suggested that brodiaea inflorescences should be cut at stages 4 to 6 (De Hertogh, 1980; Kofranek, 1986). Our data show that brodiaea inflorescences harvested 1 to 2 days before anthesis of the largest flower bud lasted 4 days longer than those harvested at the stages previously recommended, regardless of the sucrose concentration used in the vase solutions (Table 1).

Brodiaea flowers opened steadily at a rate of one flower per day during the vase life of the inflorescence (Fig. 1), and the first flowers had senesced by day 4. The life of the individual flowers (horizontal distance between opening and senescence curves in Fig. 1) was ≈ 4 days throughout the vase life, and the life of the inflorescence (day when 50% of the open flowers were senescent) was 12 days.

To compare the effect of a continuous

Table 1. Effects of harvest stage and sucrose concentration in the vase solutions on vase life of *Triteleia laxa*. All vase solutions contained 200 ppm HQC.

Sucrose concn (%)	Vase life (days)	
	Stage 0 ^z	Stage 4 ^z
1	11.5	6.0
2	11.5	5.8
4	10.5	6.0
6	11.0	6.8
8	9.3	5.8
Linear regression	NS	NS
Planned comparison		
Stage 0 vs. Stage 4	**	

^zStage 0: no open flowers; stage 4: four open flowers.

NS, **Slope of the regression not significantly different from 0, or means significantly different at $P = 0.01$, respectively.

Table 2. Effects of sucrose treatments on the vase life of *Triteleia laxa*. Flowers were held continuously in various concentrations of sucrose, or pulsed in 10% sucrose for 16 hr at room temperature and then held in distilled water. All solutions contained 200 ppm HQC.

Sucrose concn (%)	Vase life ^z (days)	Flower buds opened ^y (%)
Continuous		
0	5.1	46
2	13.0	86
4	13.5	88
8	12.5	88
Pulsed		
10	7.0	59
Planned comparisons		
0% vs. (2%, 4%, and 8%)		**
0% vs. 10% pulse		NS

^zPartially open flower buds were not considered open flowers when determining the vase life of the inflorescences.

^yIncluding buds that were partly opened.

NS, **The planned comparisons were nonsignificant or significant at $P = 0.01$, respectively.

supply and pulsed application of sucrose on vase life, eight replicate inflorescences were placed in solutions containing 200 ppm 8-hydroxyquinoline citrate (HQC) and 0%, 2%, 4% or 8% sucrose, or were pulsed overnight at room temperature with 10% sucrose and

Fig. 1. Time course of the opening and senescence of *Triteleia laxa* flowers in an inflorescence placed in water.

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Fig. 2. Respiration rate of flowers of *Triteleia laxa* in relation to anthesis.

then placed in 200 ppm HQC solution without sucrose. An average of 1.6 ml of the pulsing solution was taken up by each inflorescence. As in the case of many other flowers (Halevy and Mayak, 1979), continuous development of small brodiaea flower buds to fully open flowers requires an external supply of carbohydrate. More than 50% of the buds on brodiaea inflorescences (harvested at Stage 0 or 1) placed in water failed to open, even if they were pretreated for 16 hr with 10% sucrose (Table 2). The percentage of open flower buds and the vase life of inflorescences placed in solutions without sucrose were less than those placed in solutions containing sucrose. The addition of sucrose to the vase solution greatly improved flower opening and, consequently, vase life. Sucrose at 1% was as effective as higher concentrations in improving the vase life of brodiaea (Table 1). Unlike for gladiolus (Mayak et al., 1973), pulsing with 10%

sucrose overnight had very little effect on the opening and vase life of brodiaea inflorescences (Table 2), possibly because gladiolus flowers have some leaves whose transpiration would tend to increase the carbohydrate accumulated during the pulsing period.

Rate of water uptake. Rates of water uptake were monitored continuously using a computer connected to the digital output of an electronic balance (Fisher Scientific Model 8301A). A beaker containing water (and covered with a sheet of Parafilm perforated in the center) was placed on the balance. An inflorescence was lightly held in a bench clamp so that its base dipped into the water but did not touch the beaker or the Parafilm. The decrease in weight of the beaker was taken as a measure of water uptake by the inflorescence. The contribution of different portions of the inflorescence to water uptake was determined by measuring water uptake after removal, first of the flower buds, then of the peduncles.

The typical steady rate of water uptake by a brodiaea inflorescence was 1.8 g H₂O/g fresh weight per day. By sequentially removing organs from an inflorescence, we determined that 60% of the water was taken up by the flower buds (fresh weight basis: 0.9 g·g⁻¹·day⁻¹), 16% by the peduncles (0.5 g·g⁻¹·day⁻¹), and 24% by the scape (0.4 g·g⁻¹·day⁻¹).

Effects of biocides. Inflorescences were placed in opening solutions containing 2% sucrose and a biocide. The biocidal solutions tested were 200 ppm HQC, 100 ppm Physan (n-alkyl dimethyl benzyl ammonium chloride-n-alkyl dimethylethylbenzyl ammonium chloride), or 50 ppm AgNO₃. In addition, the effect of 100 ppm Physan was tested for flowers whose base was first dipped for 10 sec in 1000 ppm AgNO₃. There were five replications per treatment.

None of the biocides tested had any significant effect on vase life when used in conjunction with 2% sucrose (Table 3). Of those biocides tested, HQC, the one used in many commercial preservatives, proved to be the best. Phytotoxicity was observed, however, on scapes placed in solutions containing either Physan or AgNO₃. Silver nitrate caused total blackening of the portion of the scape in the solution, and we found that Physan, recommended for this species by Kofranek (1986), led to rapid collapse of the immersed portion of the scape.

Effects of pH. Low pH in the vase solution, which has been reported to improve the vase life of cut roses (Durkin, 1979), had no significant effect on the vase life of brodiaea inflorescences. There were no significant differences in vase life of inflorescences that were harvested at Stage 2 or 3, then placed in vase solutions containing 2% sucrose and 200 ppm HQC whose pH was adjusted to 3, 4, 5, 6, or 7 with KOH or HCl (data not shown). The difference between cut roses and brodiaea may relate to the absence of leaves in brodiaea inflorescences. The water uptake of brodiaea inflorescences (12 ml·day⁻¹) is only one-fifth that of rose flowers (Carpenter and Rasmussen, 1973), and it is therefore probable that water supply to these flowers is seldom limiting.

Effects of storage. The flowering period for each species of brodiaea is short, and it would be useful if the inflorescences could be stored at low temperatures to extend the commercial marketing period (Hardenburg et al., 1986). To test how storage affects the life of brodiaea cut flowers, inflorescences harvested from the field were wrapped in perforated plastic bags. Some inflorescences were pretreated overnight with 10% sucrose as described above. They were then stored dry in the bags in darkness at 1°C for 2 or 4 weeks. After storage, the inflorescences were placed in solutions containing either 2% or 4% sucrose and 200 ppm HQC. Control inflorescences were placed in the same solutions immediately after harvest.

The vase life of inflorescences stored for 2 weeks and then placed in a 2% sucrose vase solution was the same as that at harvest, but fewer flower buds opened (Table 4). Increasing the sucrose concentration in the vase solution to 4% or pretreating the inflorescences with 10% sucrose before storage substantially improved bud opening of inflorescences stored for 2 weeks. Small flower buds (bud length ≤ 8 mm) aborted after prolonged storage, and increased sucrose concentration in the vase solution had no effect on extending the vase life of long-stored brodiaea inflorescences (Table 4). The slender scapes suggest that brodiaea inflorescences have a relatively small carbohydrate pool in relation to the high respiration rate of their flower buds (average 900 mg/kg fresh weight per hour) and the carbohydrate requirement for the developing buds. This situation may explain the advantageous results of high sucrose application to inflorescences that had been stored for 2 weeks.

Table 3. Effects of biocidal solutions on the vase life of *Triteleia laxa*.

Treatment	Vase life (days) ^a	Scape condition
2% sucrose + 200 ppm HQC	13.0	Remained green
2% sucrose + 100 ppm Physan	12.0	Immersed portion of scape turned brown and rotted
AgNO ₃ 1000 ppm dip, then 2% sucrose + 100 ppm Physan	9.4	Immersed portion of scape turned brown and rotted
2% sucrose + 50 ppm AgNO ₃	11.4	Immersed portion of scape turned black

^aMeans not significantly different when compared by Duncan's multiple range test at *P* = 0.05.

Table 4. Effects of dry storage and sucrose supplied after cold storage on vase life and opening of *Triteleia laxa*. All opening solutions contained 200 ppm HQC. Pulse treatments were applied before storage.

Storage (weeks)	Opening solution (% sucrose)	Vase life (days)	Flower buds opened (%)
0	2	13.0 a ^a	74 a
	4	12.7 a	76 a
2	2	12.8 a	48 b
	4	12.8 a	63 a
	10 pulse then 2	11.0 ab	68 a
4	2	9.2 bc	32 c
	4	8.8 bc	32 c
	10 pulse then 2	8.3 c	38 bc

^aMeans within columns with no letter in common are significantly different at *P* = 0.05, using Duncan's multiple range test.

Respiration rate of brodiaea flowers. Flower buds were harvested and placed in 25-ml glass vials ventilated ($2.4 \text{ liter}\cdot\text{hr}^{-1}$) with CO_2 -free air. The CO_2 content of the exit air stream was determined using an ADC infra-red gas analyzer type 225-2B-SS (Analytical Development, Hoddeson, England).

The respiration rate of young brodiaea flower buds was very high and decreased rapidly until they reached anthesis; that of open flower buds continued to decline, but at a slower rate, reaching a steady rate 3 days after anthesis (Fig. 2).

For maximum vase life, brodiaea inflorescences should be harvested 1 to 2 days before anthesis of the largest flower and pretreated with silver thiosulfate to prevent the action of external C_2H_4 encountered during marketing (Veen and van de Geijn, 1978; Han et al., 1990). They should be held in a

vase solution containing 2% sucrose and 200 ppm HQC. Brodiaea flowers may be stored up to 2 weeks without significant reduction in flower quality if pretreated with 10% sucrose overnight before storage.

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