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The dynamics of starch and sugar utilisation in cut peony (*Paeonia lactiflora* Pall.) stems during storage and vase life

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ABSTRACT

The carbohydrate dynamics of cut peony (*Paeonia lactiflora* Pall. 'Sarah Bernhardt') stems were examined during vase life of fresh-cut stems, while in storage at 0 °C and during their vase life after storage. During flower opening of fresh-cut stems, the rate of starch hydrolysis in the flower buds was more rapid than in those still attached to the plant, and once the flowers had opened, the total sugar concentrations of the flowers, leaves and stems were lower than in those still attached to the plant. Quantification of the sugar content of fresh-cut stems during flower opening and those still attached to the plant, suggests that an additional 3.2 g of sugars are translocated into attached stems during flower opening, which equates to nearly 42% of an open flower. However, reserves in fresh stems were still sufficient to provide a total vase life of 14 d, only 2 d less than stems still attached to the plant. During the first 4 weeks of cool-storage, starch reserves in the flower buds were almost completely hydrolysed, contributing to similar hexose concentrations but much higher sucrose concentrations than in fresh-cut stems. Flower opening was more rapid but the subsequent vase life was only 9 d, shorter than that for fresh-cut stems. Much of that difference could be attributed to the faster opening of buds (2 d cf. 5 d), which is likely to have been the result of the starch having already been hydrolysed during storage. Together, these results indicate that cut peony stems have sufficient carbohydrate reserves to drive flower opening and still have an acceptable vase life even after 8 weeks of storage.

1. Introduction

Flower crops used commercially in the cut flower industry have to survive harvest, packing and distribution, and still have acceptable quality for the consumer. Two important characteristics of cut flowers are the ability of flower buds to open after the stems have been harvested, and for open flowers to have a reasonable vase life. Cut flowers rely on stored carbohydrate reserves for flower opening and maintenance, as their carbohydrate supply from the rest of the plant ceases at harvest, and as cut flowers are often placed in low light conditions, there is little or no net carbon gain from photosynthesis (Halevy and Mayak, 1979). Dehydration and wilting, caused by either air embolisms in the stem xylem (at the time of cutting) or bacteria entering the stem from the vase water and blocking water uptake (Van Doorn, 1997), can also affect both the ability of flower buds to open and their vase life. For ethylene-sensitive species, such as rose and *Curcuma alismatifolia* Gagnep., ethylene-induced senescence, expressed as premature petal drop or leaf yellowing, can markedly decrease vase life (Ichimura et al., 2005; Bunya-atichart et al., 2004).

Herbaceous peonies are perennial plants that have been cultivated for many centuries and are valued for their highly attractive flowers. Modern cultivars used for commercial cut flower production are mainly derived from the species *Paeonia lactiflora* Pall. (Stern, 1946). Production of peonies has expanded in New Zealand over the last 20 years, primarily for export to Northern Hemisphere markets, as the domestic market is relatively small. To maximise returns, postharvest cool-storage is used to extend the service window, with flowers entering overseas markets when there is little or no competition. Peony stems are harvested before flower opening and typically have good postharvest performance, with a vase life of around 5–7 d, depending on the cultivar (Heuser and Evensen, 1986), the stage of maturity at which they are picked, the climate in which the plants had been growing (Gast et al., 2001) and the temperature at which they open.

The primary source of carbohydrate reserves for opening and maintenance of peony flowers on the plant is starch accumulated

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in the flower bud during development (Walton et al., 2007). However, the degree to which opening flowers rely on additional carbohydrates supplied by the parent plant is unclear. As no additional carbohydrates are available to cut stems after harvest, their absence may limit vase life and/or storage potential. We would like to be able to manipulate the carbon dynamics during production to maximise the postharvest performance of stored peony stems. Consequently, the aims of the current study were fourfold: (i) to compare the vase lives of freshly cut peony stems with those cool-stored for 8 weeks, (ii) to compare the carbohydrate dynamics of freshly cut stems during their vase life with those for stems attached to the plant (Walton et al., 2007), (iii) to describe the carbohydrate dynamics during cool-storage, and (iv) to compare the carbohydrate dynamics during flower opening of stored stems with those that were not stored.

2. Materials and methods

2.1. Plant source

On 13 November 2001, flowering stems were harvested from mature peony (*P. lactiflora* Pall. 'Sarah Bernhardt') plants growing at a commercial property near Clyde, Central Otago, New Zealand. Stems were selected following the industry standards for export grade flowers, i.e., buds were beginning to soften and outer petals had started to loosen and separate. Stems were then packed dry for overnight transport by refrigerated courier to Plant & Food Research Mt Albert, Auckland, New Zealand, for storage and postharvest evaluation.

2.2. Postharvest storage and evaluation

Stems that were to be stored were packed into export boxes (cardboard) containing polyliners, and placed into a coolstore at 0 °C. Polyliners were used to minimise water loss but were not sealed, allowing continued gas exchange. Stems were then stored for periods of up to 10 weeks by which time there were small but visible losses in quality (some tissue browning).

Vase life assessments were carried out on both freshly cut stems and those that had been cool-stored for 8 weeks. For vase life assessments, peony stems were re-cut to 50 cm and put into vases containing water. Vases were then placed into an evaluation room set to standard conditions (20 °C, 60% RH, 8 μmol s^{-1} m^{-2} and 12 h day/night cycle). For each vase life experiment, the course of flower opening was assessed on eight stems each day, for up to 14 d using the following rating scale:

(1) Tight bud, petal showing colour
(2) Loose bud, outer petals soft and loosening, firm inside
(3) Almost open flower, petal curved inwards
(4) Fully open flower, outer petals unfurled from inner petals
(5) Petals wilting, 50% of petals wilting, or petals starting to drop, end of flower life.

2.3. Carbohydrate analyses

Carbohydrate analysis was carried out on freshly cut stems and stems that had been stored for 8 weeks at 0, 1, 2, 3, 5, 7, and 10 d after placing them in the vase. Three replicates (each of two stems), were collected on each sampling date and each was separated into the buds/flowers, leaves and stem, weighed, a representative subsample retained, weighed and frozen in liquid nitrogen. In addition, stems were also sampled during storage, at 2, 4, 6, 8, and 10 weeks. At each date three replicates (each of two stems), were separated into buds/flowers, leaves and stems, weighed, sub-sampled and frozen as described above. Total weights of the stems were determined by summing the weights of the component parts. Samples were stored at −25 °C.

For analysis, frozen tissue was lyophilised, weighed and then ground to a fine powder. A sub-sample was extracted using 80% (v/v) ethanol and the filtrates analysed using gas-chromatography (Miller et al., 1998). Starch was estimated after the insoluble fraction was autoclaved, treated with amyloglucosidase to release glucose, and then quantified colorimetrically (Smith et al., 1992). All carbohydrate data are presented on a dry weight basis.

3. Results

3.1. Vase and storage life

On the fresh-cut (non-stored) peony stems, flower buds opened after, on average (with ±SEM), 4.9 ± 0.6 d and remained open for 9.1 ± 0.6 d (Fig. 1). In contrast, flower buds on stems that had been stored for 8 weeks opened more quickly (1.9 ± 0.4 d) and remained open for only 7.3 ± 0.3 d (Fig. 1). Consequently, the total vase life of fresh-cut flowers was 14.0 ± 0.4 d, whereas stems stored for 8 weeks only lasted for 9.1 ± 0.2 d. During the vase life studies, the fresh weights of the fresh-cut flower buds peaked at Day 5 (Fig. 2), when the flowers were fully open. There was little change in bud fresh weight during the 8 weeks of storage (mean 22.4 ± 0.43 g), but when placed in vases increased markedly (by 30%) in the 2 d it took the flowers to open (Fig. 2). After flower opening, flower fresh weights steadily declined in both fresh-cut and stored flowers.

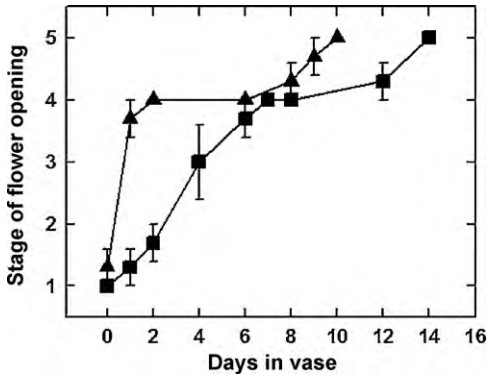

Fig. 1. Vase lives of fresh-cut peony stems (■) and after 8 weeks of storage at 0 °C (▲). Stages of flower opening: 1 = tight bud, Stage 2 = loose bud, Stage 3 = almost open, Stage 4 = fully open, and Stage 5 = petals wilting. Error bars represent ±SEM.

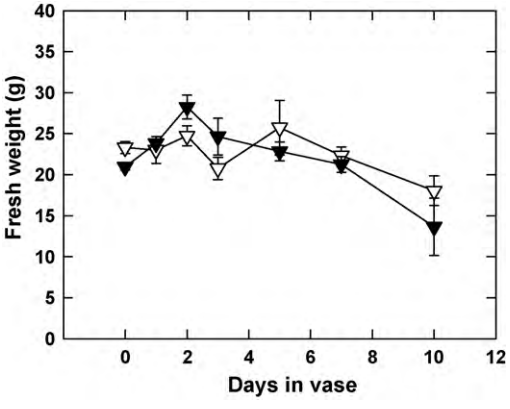

Fig. 2. Changes in fresh weights of fresh-cut (non-stored) (▽) and stored (▼) peony buds/flowers during vase life studies. Error bars represent ±SEM.