

Sandersonia aurantiaca: an evaluation of postharvest pulsing solutions to maximise cut flower quality

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Keywords gibberellic acid; postharvest; senescence; vase life

INTRODUCTION

Sandersonia aurantiaca (Hook.) is New Zealand's third largest export cut flower crop after orchids and *Zantedeschia*. Over 4 million stems are exported each year to Japan, Europe, and the United States, estimated to be worth NZ\$3.3 million in 2001 (Statistics NZ). The New Zealand sandersonia flower growers are well known for their excellent quality stems, although in recent years a number of different postharvest treatments have been heralded as best practice, including the use of FLOS sachets, which keep the stems hydrated during storage and transport, and various commercially available and home-made pulsing solutions. The scientific basis for these "best practices" is not always evident. Previous research in our laboratory has shown that sandersonia flowers are not sensitive to ethylene, therefore the use of silver-containing solutions is unnecessary (Eason & de Vré 1995). In addition, we have shown that vase life is extended when cut flowers are supplied with a carbohydrate source (sucrose or glucose, Eason & Webster (1995); Eason et al. (1997)).

Preservative solutions are often composed of a mixture of chemicals (e.g., carbohydrates, plant growth regulators, anti-ethylene compounds, biocides, acidifiers) which in combination may minimise the risk of physiological disorders that occur in cut flowers after harvest (e.g., leaf chlorosis, leaf blackening, premature flower abscission). Certain cut flowers may be classified according to their postharvest physiology (e.g., ethylene-sensitive), and the manufacturers of the preservative solutions can therefore develop treatments that will suit a particular class of cut flowers. There are, however, subtle differences between cut flower species, and the current research is necessary to optimise the postharvest care regime of sandersonia, an important New Zealand export crop. This study

Abstract The postharvest quality of sandersonia (*Sandersonia aurantiaca* (Hook.)) cut flowers is a function of the quality of individual flowers (fused tepals in the form of a lantern) and the quality of the leaves attached to the cut stem. The vase life of sandersonia cut flowers, therefore, is considered terminated when >50% of the flowers have senesced (faded and wilted) or the leaves have signs of chlorosis and/or necrosis. In the current study, 13 different postharvest pulsing solutions were analysed for their effectiveness in maintaining at-harvest quality for florets and leaves of sandersonia stems. The most effective pulsing solution for preventing leaf chlorosis was Chrysal-SVB (1 tablet in 2 litres of water). The pulsing solution that was most effective in maximising the overall postharvest quality of sandersonia stems contained Chrysal-AVB (3 ml litre⁻¹) and Chrysal-SVB (1 tablet per 2 litres). Pulsing with the mixture of Chrysal-AVB/SVB (18 h, 5°C) delayed the initiation of flower senescence and prevented leaf chlorosis. The stems pulsed with this solution had an average vase life 5 days longer than stems that were held in water. Further analysis of sandersonia flowers treated with gibberellic acid (GA₃), a component of certain preservative solutions, indicate that this plant growth regulator is effective in extending sandersonia vase life, by delaying the onset of tepal fading and wilting and delaying senescence-associated proteolysis.

identifies the commercial preservative solutions available in New Zealand that are beneficial in extending sandersonia vase life and concludes that gibberellins are an important component in any good preservative solution for sandersonia.

MATERIALS AND METHODS

Treatments with commercial postharvest pulsing solutions

Flowering stems were harvested from plants grown under cover at Russell and Joy England's property (Albany, Auckland). At harvest each stem (60 cm) had 2–3 flowers in colour with at least a further three buds visible on the stem. After harvest, the stems were treated with a range of commercial pulsing solutions in two consecutive trials: Chrysal-SVB (Pokon & Chrysal, Naarden, Holland) is a preservative solution based on plant hormones, typically used to prevent leaf yellowing; Chrysal-AVB (Pokon & Chrysal, Naarden, Holland) contains silver thiosulphate (STS) and is used to extend the vase life of ethylene-sensitive flowers; Rogard Gold (HortMax Limited, Masterton, New Zealand) contains complex carbohydrates, chelating agents and biocides; Florissant 500 (Florissant Sales G V, Vander Spong Laboratory, Holland) contains sucrose, acid preservative, and a bactericide. To prevent dehydration during storage and transport, the cut ends of flower stems may be held in FLOS sachets (Argent Group Limited, Auckland, New Zealand) which contain a hydrated gel. The use of FLOS for sandersonia stems was also evaluated.

In the first trial, stems were pulsed with one of nine different postharvest treatments solutions at the recommended concentration for 18 h at 5°C: Florissant 600 (10 ml litre⁻¹), Florissant 500 (1 tablet/2 litres), Chrysal-AVB (1 ml litre⁻¹), Rogard Gold (10 ml litre⁻¹), Chrysal-AVB (3 ml litre⁻¹) and Chrysal-SVB (1 tablet/2 litres), sucrose (5 g litre⁻¹) and bleach (0.21 g litre⁻¹ sodium hypochlorite), and water. A selection of stems that had been treated with water and Rogard Gold (10 ml litre⁻¹) were also packaged in FLOS sachets, all other stems were held dry. Each treatment was replicated on 10 stems.

In the second trial, stems were pulsed with more concentrated levels of Chrysal-AVB and/or Chrysal-SVB solutions for 12 h at 5°C; Chrysal-AVB (1 ml litre⁻¹), Chrysal-SVB (1 tablet/4 litres), Chrysal-SVB (1 tablet/2 litres), Chrysal-AVB (1 ml litre⁻¹) and Chrysal-SVB (1 tablet/4 litres), Chrysal-AVB

(1 ml litre⁻¹) and Chrysal-SVB (1 tablet/2 litres). Each treatment was replicated on 10 stems.

Following the overnight pulsing treatments, stems were packed in sleeves with and without FLOS sachets (as indicated above) and transported from Auckland to Crop & Food Research's Food Industry Science Centre (Palmerston North, New Zealand), arriving 2 days after harvest. The flower boxes were stored for a further 24 h at 5°C simulating the time taken to arrive at an international market, before vase life assessment.

Gibberellin treatment of sandersonia

Sandersonia flower stems (60 cm) were harvested from plants grown at Crop & Food Research (Batchelar Road, Palmerston North), when 3–4 flowers were open and orange. The cut stems were pulsed with gibberellic acid (GA₃) (0, 100 μM, 500 μM, 1 mM, 10 mM GA₃, pH 4.0 with citric acid) for 24 h at 7°C. Each treatment was replicated on 11 stems.

Preliminary trials indicated that solutions containing GA₃ at 10 μM or higher delayed the senescence of detached stage 5 and stage 7 flowers. Therefore, the most dilute effective GA₃ concentration (10 μM) was used in all subsequent trials. To determine the effect of GA₃ on the progression of flower senescence, individual detached stage 5 flowers (Eason & Webster 1995) were held in vials of 0 or 10 μM GA₃ and their colour and firmness measured daily. The treatments were replicated on a minimum of seven separate flowers. Flower colour was measured with a Chroma Meter (Minolta CR-200) on opposite sides of flowers at the point where the flower diameter is the greatest. Results are expressed as hue angle ($H^\circ = \tan^{-1} b/a$, Little 1975). Flower firmness was measured by compression using an Instron Universal Testing Machine (model 4301). A flat probe (25 × 5 mm) compressed the flower at its widest diameter by 20% of the original floral diameter. The crosshead speed was 50 mm min⁻¹. Resistance to compression was measured as maximum load (Newtons).

Protease activity in GA₃-treated flowers

Protease activity is a consistent marker of senescence in sandersonia tepals (Eason et al. 2002). Individual detached stage 5 flowers (Eason & Webster 1995) were held in solutions of GA₃ (0, 10 μM GA₃). At intervals after the initiation of GA₃ treatment (0, 1, 2, 3, 5, and 7 days), tepals were excised from the flowers by cutting below the nectarines with a sharp razor blade, and tissue from a minimum of five flowers was pooled to make one sample and frozen

in liquid nitrogen and stored at -80°C . Replicate tepal tissue samples were analysed for protease activity using azocasein as previously described (Eason et al. 2002).

Vase life analysis

After postharvest treatment, the stems were re-cut under water and placed in individual vases of MilliQ water (Barnstead/Thermolyn ULTROpure Reverse Osmosis System, series 682, Barnstead/Thermolyn Corporation, Dubuque, United States). The stems were held in a controlled environment room ($20 \pm 1^{\circ}\text{C}$, with a light level at bench height of $20\text{--}25 \mu\text{mol m}^{-2} \text{s}^{-1}$ provided by cool white fluorescent tubes and a 12-h photoperiod) and their quality was monitored daily. The end of vase life of each stem was defined as the time when greater than 50% of the flowers were visibly senescing (fading and wilting). The proportion of senesced flowers was calculated by dividing the number of visibly senesced flowers with the total number of flowers that reached full maturity. The proportion of aborted buds per stem was calculated by dividing the proportion of buds that did not reach maturity during the vase life trial with the total number of buds per stem. The number of stems with chlorotic leaves at the end of the trial (c. 15 days) was calculated as a percentage of the total stems in a treatment ($n = 10$).

Statistical analysis

Data were statistically analysed by analysis of variance (Minitab 13) and least significant differences (LSD, 5% level) were calculated.

RESULTS

Treatments with commercial postharvest pulsing solutions

Sandersonia stems that were treated with water alone (control stems) had an average vase life after transportation and storage (which constituted the initial 3 days after harvest) of 10 days (Table 1). There was no significant advantage in treating the stems with Florissant 600, Florissant 500, Rogard Gold, sugar/bleach solutions, or packaging the stems in FLOS sachets (Table 1). Indeed, two of the postharvest treatments used in the trial (Florissant 500, Rogard Gold) produced stems of significantly lower quality than the water control (Table 1). The home-made sugar/bleach pulse resulted in early browning of the mature leaves at the base of the cut stem and pulsing stems with Florissant 600 prevented normal bud development; the tepal tips of flowers (at the opening of the “lantern”) remained dark green even after they had reflexed and these

Table 1 Postharvest quality measurements of *Sandersonia aurantiaca*. Stems were pulsed for 18 h at 5°C with one of nine different treatment solutions. End of vase life is defined as the time (days) when $>50\%$ of the flowers that have reached maturity senesce. Treatments were replicated on 10 flowering stems.

Treatment	Concentration (per 4 litres)	Vase life (days)	Proportion of buds aborted*	Leaf chlorosis†
1	Water	–	0.17	80%
2	Florissant 600	40 ml	0.28	90%
3	Florissant 500	2 tablets	0.18	90%
4	Chrysal-AVB	4 ml	0.06	70%
5	Rogard Gold	40 ml	0.11	100%
6	Chrysal-AVB/SVB	12 ml AVB, 2 tablets SVB	0.12	0%
7	Sucrose/bleach	20 g sugar, 0.84 g sodium hyperchlorite	0.13	100%
8	Rogard/FLOS	40 ml	0.20	80%
9	Water/FLOS	–	0.16	40%
LSD ($P < 0.05$)		(0.8)	(0.07)	–

*Proportion of buds not fully mature at the end of vase life.

†Percentage of stems developing chlorosis at the end of vase life.

‡Tepal tips (at the opening of the “lantern”) remained dark green after they had reflexed.

§The treatment resulted in early leaf browning.

Table 2 Postharvest quality measurements of *Sandersonia aurantiaca*. Stems were pulsed for 12 h at 5°C with one of five different treatment solutions. End of vase life is defined as the time (days) when >50% of the flowers that have reached maturity senesce. Treatments were replicated on 10 flowering stems.

Treatment		Concentration (per 4 litres)	Vase life (days)	Proportion of buds aborted*	Leaf chlorosis†
1	Chrysal AVB	4 ml	12.6	0.08	50%
2	Chrysal SVB	1 tablet	13.2	0.05	40%
3	Chrysal SVB	2 tablets	13.8	0.04	0%
4	Chrysal AVB/SVB	4 ml AVB/1 tablet SVB	13.7	0.03	50%
5	Chrysal AVB/SVB	4 ml AVB/2 tablets SVB	13.8	0.02	10%
LSD ($P < 0.05$)			(1.1)	(NS)	–

*Proportion of buds not fully mature at the end of vase life.

†Percentage of stems developing chlorosis at the end of vase life.

Table 3 Ranking of the most to least effective postharvest pulsing solution for *Sandersonia aurantiaca*. Stems were pulsed at 5°C.

Ranking	Treatment (concentration in 4 litres)	Vase life range (days)	Vase life average (days)	Length of pulse (h)
1	Chrysal AVB (12 ml) and SVB (2 tablets)	12–17	15.1 ± 1.5*	18
2	Chrysal AVB (4 ml) and SVB (2 tablets)	13–15	13.8 ± 0.6	12
2	Chrysal SVB (2 tablets)	12–16	13.8 ± 1.3	12
3	Chrysal AVB (4 ml) and SVB (1 tablet)	11–16	13.7 ± 1.6	12
4	Chrysal SVB (1 tablet)	12–16	13.2 ± 1.2	12
5	Chrysal AVB (4 ml)	10–14	12.6 ± 1.6	12
5	Chrysal AVB (4 ml)	10–13	11.5 ± 1.2	18
6	Water	8–11	10.2 ± 1.1	12
Pulsing solutions not recommended for sandersonia because of postharvest abnormalities:				
7	Rogard Gold (40 ml)	8–11	9.5 ± 1.0	18
7	Florissant 500 (2 tablets)	7–11	8.6 ± 1.2	18
8	Sugar (4 tsp) and bleach (1 tsp)	8–10	9.7 ± 0.7	18
9	Florissant 600 (40 ml)	9–11	10.0 ± 0.7	18

*Standard deviation ($n = 10$).

stems had the highest proportion of aborted buds (Table 1). Pulsing the stems with Chrysal-AVB extended their vase life to an average of 12 days (Table 1). Treatment of stems with a mixture of Chrysal-AVB and Chrysal-SVB (Treatment 6, Table 1) further extended the vase life of the stems to an average of 15 days. The stems treated with the Chrysal mixture senesced more slowly, fading and wilting later than the control stems that were held in water, and the tepals of the treated stems did not become dark brown and brittle, but faded to a pale yellow colour. In addition, the proportion of stems that developed chlorosis after harvest was much

reduced following treatment with the Chrysal-AVB/SVB mixture compared to stems pulsed with any of the other solutions (Table 1).

The results of the first trial indicated that pulsing sandersonia stems with a mixture of Chrysal-AVB and Chrysal-SVB (Treatment 6, Table 1) gave the greatest extension of vase life compared to the water-treated controls. A mixture of Chrysal products is relatively expensive for the grower, particularly when the components were used at a double/triple dose over that recommended by the manufacturer. Therefore, we undertook a second trial to determine whether Chrysal-SVB alone is sufficient to extend

Table 4 Effect of gibberellic acid (GA₃) treatment on vase life of *Sandersonia aurantiaca*. Stems were pulsed for 24 h at 7°C with one of five different GA₃ solutions. End of vase life is defined as the time (days) when >50% of the flowers that have reached maturity senesce. Treatments were replicated on 11 flowering stems.

GA ₃ (mM)	Vase life (days)
0.0	12.8
0.1	14.9
0.5	14.8
1.0	15.8
10.0	15.1
LSD (<i>P</i> < 0.05)	(1.2)

the vase life of sandersonia stems and at what level it can be applied to the stems and be effective. We repeated the 1 ml per litre rate of Chrysal-AVB in the second trial as a control, and to enable comparisons with the first trial to be made.

In the second trial, sandersonia stems that were pulsed with the 1 ml litre⁻¹ rate of Chrysal-AVB had an average vase life of 13 days (Table 2), which is within the range of vase life measured for 10 replicate stems of this treatment in that trial (vase life range for Chrysal-AVB in first trial was 11–13 days). The vase life of sandersonia stems was greater with treatments of Chrysal-SVB (2 tablets/4 litres) and with both mixtures of Chrysal-AVB/SVB (Table 2). The leaves on the flowering stems that were treated with a double dose of Chrysal-SVB (2 tablets/4 litres, Treatments 3 and 5) did not become chlorotic during the vase life trial and were therefore of higher quality than the single dose treatment (Treatments 2 and 4).

Gibberellin treatment of sandersonia

The presence of GA₃ in pulsing solutions at concentrations ranging from 100 μM to 10 mM, extended the vase life of sandersonia stems (Table 4). Stems pulsed with 1 mM GA₃ had the greatest average vase life of 16 days, compared to 13 days for the water controls. Treatment of detached stage 5 flowers with GA₃ resulted in a greater content of pigment (measured as hue angle) and hence colour within the tepal tissue at Day 4 (LSD_{0.05} = 0.6, Fig. 1A) and Day 5 (LSD_{0.05} = 0.6, Fig. 1A). In addition, the tepal tissue of GA₃-treated flowers did not become dark brown, but rather remained a light pale yellow colour as the flowers senesced. GA₃-treated flower tepals were significantly firmer than the water-treated control flowers at Day 4 (LSD_{0.05} = 0.04, Fig. 1B), and remained firmer than the control

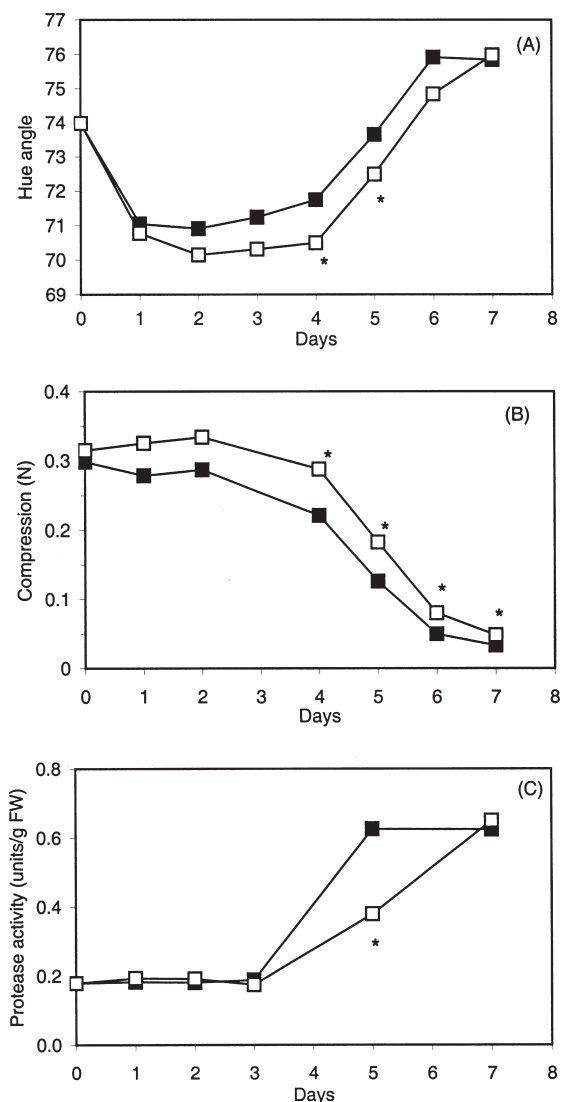


Fig. 1 Effect of gibberellic acid (GA₃) treatment on the: **A**, colour; **B**, firmness; and **C**, and tepal protease activity of detached *Sandersonia aurantiaca* flowers. Detached immature (stage 5) flowers were held in vials of water (■) or 10 mM GA₃ (□) at 20°C. Treatments were replicated on seven flowers. Numbers that are statistically significant (*P* < 0.05) are indicated with an asterisk. Hue angle degrees of freedom (d.f.) = 27, flower compression d.f. = 13, protease activity d.f. = 23. (FW, fresh weight.)

flowers until Day 7. The compression measure in Fig. 1B gives an indication of the onset of tepal wilting and shows that GA₃-treated flowers wilted later than the control flowers that were held in water. Protease activity is a consistent marker of senescence

in sandersonia tepals (Eason et al. 2002) and assays were used here to determine whether the physiological effects associated with GA₃ treatment were associated with biochemical changes. GA₃ treatment of stage 5 flowers delayed the rise in protease activity associated with the progression of tepal senescence, there was a significant reduction in protease activity at Day 5 for flowers held in GA₃ compared to the water controls (LSD_{0.05} = 0.12, Fig. 1C).

DISCUSSION

In the current trials, the best postharvest pulsing solution for maximising sandersonia vase life was an 18-h pulse of Chrysal-AVB/SVB (12 ml AVB, 2 tablets SVB/4 litres, Trial 1, Treatment 6) at 5°C, which gave a vase life of 15 days (Tables 1, 3). However, this is also the most expensive pulsing solution and sandersonia flower growers will need to carry out cost/benefit analyses to determine whether the Chrysal AVB/SVB mix is cost effective. To this end, the pulsing solutions have been ranked from the most (1) to least (6) effective, with four solutions considered not suitable for postharvest treatment of sandersonia stems, being worse or no better than water alone (Table 3).

We have previously shown that postharvest solutions which contain a source of carbohydrate (sucrose or glucose) have the ability to delay the senescence of sandersonia flowers and enable young buds to develop to maturity thereby extending the vase life of the stems (Eason & de Vré 1995; Eason et al. 1997). In the current study, bleach was added to the sucrose solutions as a precaution against bacterial growth in the commercial pack house. The bleach resulted in early browning of mature leaves, a feature not seen previously on stems treated with sucrose alone. Therefore, any positive effect of the sucrose may have been negated by the deleterious effect of the bleach in the home-made pulsing solutions.

Treatment with Chrysal-AVB alone increased the vase life of the stems compared to the controls (by 1 day), but did not prevent leaf chlorosis. Although the 1-day vase life extension is not significant in a commercial environment, it raises several scientific questions. Chrysal-AVB contains STS and is used to extend the vase life of ethylene-sensitive flowers. Earlier research in our laboratory has shown that the senescence of sandersonia flowers is not sensitive to ethylene (Eason & de Vré 1995); solutions of STS

did not extend vase life, treatment with propylene did not enhance flower senescence, and the flowers did not produce measurable ethylene during senescence. The full chemical composition of Chrysal-AVB is not known, but our previous research (Eason & de Vré 1995) suggests that a chemical other than STS is influencing the vase life of sandersonia stems in the current trial. Further work using the ethylene analogue 1-methylcyclopropene (1-MCP) may indicate whether low levels of ethylene play a role in controlling senescence in sandersonia.

GA₃ extended the vase life of sandersonia stems when it was present in pulsing solution at levels of 10 µM or greater. The plant growth regulator increased the pigmentation of detached sandersonia flowers compared to control flowers that were held in water, and delayed subsequent tepal fading and wilting. Gibberellins have been shown to enhance the postharvest quality of several cut flowers by preventing leaf chlorosis (Han 1997; Kappers et al. 1998; Ranwala & Miller 1998; Skutnik et al. 2001). Indeed, we have previously shown that treatment of *Santonia* 'Golden Lights', a hybrid of *Sandersonia aurantiaca* × *Littonia modesta* with GA₃ prevented postharvest leaf chlorosis (Eason et al. 2001). However, the effectiveness of the various gibberellin compounds in preventing leaf chlorosis varies. GA₄₊₇ has been shown to be effective but GA₃ not so, in preventing post-production leaf yellowing in Easter lily (Han 1997). On the other hand, GA₃ was effective in preventing leaf yellowing of excised Easter lily leaves (Franco & Han 1997). Whether GA₃ is the most effective gibberellin compound in delaying floral senescence or possibly leaf chlorosis in sandersonia requires further research.

Sabehat & Zieslin (1995) showed that GA₃ treatment increased the fresh and dry weight of detached rose petals. In earlier work they found that the postharvest decline in cell membrane fluidity resulting in ion leakage from petal cells and the decomposition of proteins associated with senescence were suppressed following GA₃ application (Sabehat & Zieslin 1994). Here we have shown that GA₃ treatment of sandersonia flowers delays the senescence associated increase in protease activity, which by implication will delay the breakdown of senescence associated proteins.

In conclusion, postharvest treatment with GA₃ extends the vase life of sandersonia cut flowers by enabling the tepals of immature flowers to reach a brighter orange colour, and by delaying the subsequent onset of tepal senescence (colour fading

and tissue wilting). The data presented here suggest that gibberellic acid is an essential component of any effective postharvest solution for treatment of sandersonia.

ACKNOWLEDGMENTS

I thank Russell and Joy England for the provision of plant material and for treating the stems before dispatching them for vase life analysis. This research was funded in part by New Zealand Foundation of Research Science and Technology through the Technology Expertise Access Program.

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