Croton (*Codiaeum variegatum* (L.) Blume 'Excellent'): An Evaluation of Foliage Performance after Shipment and of Vase Water Treatments to Maintain Vase Life

M.P. Hettiarachchi[1] and J. Balas[2]
[1]Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka
[2]Institute of Fruit Growing & Horticulture, University of Natural Resources & Applied Life Sciences, Peter Jordan street 82, A-1190, Vienna, Austria

Keywords: Floral preservatives, postharvest quality, vase life, 8-Hydroxyquinoline sulphate, chroma, hue angle

Abstract

In the current study *Codiaeum variegatum* (L.) Blume 'excellent' grown in Sri Lanka were used to apply postharvest treatments in Vienna, Austria. Stems with 5 or 6 leaves were treated with Standard Vase Solution (SVS), 8-HQS (biocide), Biovin (biological product), commercial preservatives (Chrysal, Flora, Flower fresh) and tap water (control). Foliage stems treated with 8-HQS produced the longest vase life (31.14 d) while the shortest vase life (18.90 d) occurred in Chrysal. There were no significant differences for vase life of foliage stems placed in Biovin, Flora, Flower fresh, tap water or 8-HQS (all around 30 days). Fresh weight of all treatments gradually declined over the vase period. For the investigated period, the differences in fresh weight of stems placed in tap water or floral preservatives were small and nonsignificant. Water transpiration and uptake continuously decreased in the vase period. However, higher transpiration was observed at senescence. Water uptake was positively correlated with vase life of croton. Low leaf tip osmotic potential and low Brix value at leaf base was correlated with lower vase life and general foliage appearance. Leaf colour components and chlorophyll fluorescence did not change significantly. Recutting of stems and refilling of the vases had a positive influence on leaf colour and fluorescence yield. Results indicated that physical quality traits (colour and foliage appearance) were slightly affected by floral preservatives. 8-HQS, Biovin and tap water and commercial preservatives (Flora, Flower fresh) most consistently had a positive influence on vase life, foliage colour and chlorophyll fluorescence yield.

INTRODUCTION

Croton (*Codiaeum variegatum* (L.) Blume) is an important crop in Sri Lanka. It is mainly exported to Europe as cut stems or rooted stems. The development of cut foliage cultivars for the Sri Lanka export market requires knowledge of the best cultural practices, harvest procedures, and postharvest technologies that will maximise foliage longevity and quality. Cut greens normally play a major role in floral arrangements; they are expected to be inexpensive and to last well in the vase (Reid and Kofranek, 1980). Loss of quality of leaves or stems may result in rejection at the market place.

The variety of colours and the ability to transport them in dry state put crotons in remarkable demand from other countries. However, it takes usually 4 - 5 days to deliver packed boxes from the harvesting point of Sri Lanka to the final destination in Europe. Growers do not normally provide special postharvest treatments for croton like cut greens in the farm gate. There are no published records documenting vase water treatments for croton. This study identifies the commercial preservative solutions available in Europe that are beneficial in extending croton vase life and concludes that commercial preservatives are an important component in maintaining foliage colour and chlorophyll yield for *C. variegatum* after long-distance shipment.

MATERIALS AND METHODS

Cut stems of *Codiaeum variegatum* (L.) Blume 'Excellent', grown in shade houses in Sri Lanka, were obtained from a commercial grower to conduct laboratory experiments in the Institute of Fruit Growing and Horticulture, Vienna, Austria. Upon arrival, boxed stems were held at 12 ºC until processed the same day for experiments. All stems were re-cut under water to maintain 20 cm in length prior to place in vase solutions.

Standard Vase Solution (SVS - $NaHCO_3$ 125mg/l, $CaCl_2.2H_2O$ 99mg/l, $CuSO_4.5H_2O$ 1.2mg/l proposed by van Meeteren et al. 2000), biocide (8-HQS - 200mg/l) and commercially available preservative solutions (Chrysal® (10g/l) - Pokon & Chrysal, Holland, Flower Fresh™ (9g/l) - Smithers-Oasis, Australia, Flora (1ml/l) - France, Biovin (1ml/l) - Austria) at recommended rates were assessed. Clean plastic vases that held 500ml of floral solution were used in experiments and held under office conditions where air temperature averaged 19/25 ºC minimum/maximum, and light level averaged 50 μmol^{-2} s^{-1} at bench level from fluorescent tubes. Air humidity was varied 55 to 65 % during the vase period and each vase had to be re-filled with the desired vase solution according to water consumption rate.

Parameters such as vase life, fresh weight, water uptake, transpiration, foliage colour and chlorophyll fluorescence during vase period and soluble solid concentration, osmotic potential and dry weight at termination were determined. Vase life was determined by yellowing or browning of the basal leaves, wilting or shedding of leaves, unusual spots or scars on leaves and the stem collapse.

Flower colour (*L*a*b**) was measured by chroma meter (Minolta, model CR-200b, Ahrensburg, Germany) during experimental period. Chroma ($C^*-(a^{*2}+b^{*2})^{1/2}$) and hue angle (hº - arctangent *b*/a**) values were calculated by using standard equations (McGuire, 1992). Chlorophyll fluorescence was measured with a portable chlorophyll fluorometer (MINI PAM, Walz, Effeltricht, Germany). F_v was calculated by an equation (The optimal quantum yield in photo system II is equal to $F_v/F_m = (F_m-F_o)/F_m$, where F_m and F_0 denote maximum and minimum fluorescence (Schreiber and Bilger, 1993) in dark adapted tissue, respectively). A Wescor Vapour Pressure Osmometer (Wescor, Inc., Utah, USA) was used to measure leaf and stem osmotic potential at the end of vase life. Soluble solid concentration of frozen samples was determined by a hand-type refractometer (Atago Co., Tokyo, Japan). Three replications were used for each treatment consisted of four foliage stems. The experimental design was a randomised complete block. Data were subjected to the general linear model procedure, and means separation was accomplished by Tukey HSD test. Correlation among variables was calculated by Pearson method (SPSS, USA, 1996).

RESULTS

Vase Life and Fresh Weight

Stems placed in 8-HQS had the longest vase life (31.14 d) but the shortest vase life occurred in Chrysal vases due to rapid death of stems. Stems showed no significant difference in vase life (Table 1) when placed in floral preservatives, tap water or 8-HQS. In contrast, stems in SVS showed significantly lower vase life (26.36 d) than commercial floral solutions (average in 30 d). The addition of floral preservatives to the vase solution had no effect on changes in fresh weight or dry weight and showed continuous decline in fresh weight remaining values below the initial weights over the vase period (data not shown). Dry weight values and moisture percentage of cut stems were affected by different vase solutions, but values were not significantly different from each other. Cut stems in Biovin vase solution showed the lowest dry weight while stems placed in Flower fresh gave the lowest moisture percentage in the treatments (data not shown). Vase life was significantly correlated (R=0.60) with the floral treatments at the 0.01 level.

Osmotic Potential and Soluble Solid Concentration (ºBrix)

Treatment effects were significant for leaf and stem osmotic potentials at

senescence. A lower leaf and stem osmotic potential was observed in tap water vases and Flora vases than other floral vases. Chrysal showed significantly lower osmotic potential only in leaf tips. In contrast, stems in SVS had significantly higher leaf and stem osmotic potentials. Croton that had been treated with Flora showed significantly ($P = 0.05$) greater ^{o}brix in tip and middle parts of leaves than SVS treated stems. There was no significant difference in stem ^{o}brix due to floral solutions. Of all floral vases, Chrysal showed the lowest stem ^{o}brix (4.85) compared to other treatments (Table 1). Vase solution was positively correlated with leaf base and stem brix values (R = 0.55, R = 0.45 respectively at $P = 0.01$).

Transpiration and Water Uptake

Transpiration rates were markedly increased at senescence that was distinguished from that of initial values (Table 2). However, it had no significant difference with vase treatments. In contrast, water uptake rates were gradually declined throughout the vase period except tap water and Flower fresh vases. Stems in Chrysal showed a significantly lower uptake rate (1.90 g/d.stem) than stems in control treatments (2.71 g/d.stem) at termination. Refilling of vases and recutting of stems influenced transpiration and water uptake processes.

Chlorophyll Fluorescence

Of all floral solutions, stems placed in SVS, Chrysal and Flora showed significantly higher F_o over the vase period 1 than 8-HQS (data not shown). There was no significant difference in F_0 for floral solutions on day 7, 14 and 21. However, stems in Flora gave lower F_o than that of SVS. In contrast, no significant difference was observed in F_m for floral vases throughout the vase period except on day 7. Stems in Flora vases produced lower F_m than other treatments. On day 1 and 7 posttreatment stems in tap water had the highest chlorophyll fluorescence yield. There were significant differences in yield for floral vases throughout the vase period until senescence (Table 3). Recutting and refilling were positively affected on fluorescence yield however they had no differences for floral treatments.

Foliage Colour

Treatment effects were significant for L^* on day 14 after treatment. Leaves of stems treated with SVS and Flower fresh were significantly lighter (higher L^*) than control vases. However, on day 1, 7, 21 and end of vase life *C. variegata* did not show significant differences for L^*. There were no significant differences in a^*, b^* (data not shown), chroma and hue values for treatments. Leaf colour intensity (chroma) showed a gradual decline in first phase of the vase period. Values were again increased after recutting the stems and refilling of vase solutions. However, the smallest chroma value was observed in stems placed on tap water vase on day 14 (Fig. 1). Higher values were shown in all vase solutions except tap water at the end of the vase life. Hue angle values were also affected by different vase water treatments, but those differences did not show significant differences. However, stems placed in SVS vases were positively influenced up to recutting and refilling processes. Then values were gradually declined, but hue value at senescence was higher than initial hue value (Fig. 2). Hue angle values of all treatments showed higher values at senescence except Chrysal and tap water.

DISCUSSION

This is apparently the first reported study of the postharvest quality of *C. variegatum* after long-distance shipment. We have assessed vase life, water uptake, soluble solid concentration, osmotic potential, foliage colour and chlorophyll fluorescence with placing stems in floral solutions to identify the most useful quality measures for future work on this species. The data reported here demonstrate that croton has an adequate vase life, even after long-distance shipment over several days; usually exceeding that of the cut flowers. Recutting of stems and refilling of vases during the vase period

positively influenced the vase life and other quality parameters. This effect relates to the removal of desiccated basal vascular tissues, which might considerably hinder the flow of water from stem to the leaves.

Preservative solutions are composed of a mixture of chemicals that enhance the postharvest quality and longevity of cut stems. The solutions may contain carbohydrates (sucrose, glucose), biocides, plant growth regulators (gibberellins, cytokinins), anti-ethylene compounds (silver thiosulphate), or chemicals known to reduce water tension and aid water uptake. 8-HQS was the most effective postharvest solution used in this study, extending vase life by 1 day for croton over commercially preservative solutions and tap water. However, addition of a biocide (8-HQS) and floral preservatives (Flora, Biovin and Flower fresh) did not show statistically significant differences in vase life of the stems. Stems had the significantly lowest vase life of 18.90 days when placed in Chrysal. Stems in SVS gave 26.36 days in vase life, which was significantly lower than 8-HQS, control and floral preservatives.

Water uptake of croton cut stems decreased slowly over the holding period, with small daily rises and falls. This pattern was observed for other species (Halevy and Mayak, 1981). Microbial growth has long been associated with increased stem resistance to water flow (Larsen and Frolich, 1969), but other factors, such as oxidative processes resulting from harvesting injury and pectinaceous occlusions derived from the breakdown of cell walls, have been implicated in stem plugging (Halevy and Mayak, 1981). The gradual decline in water uptake by *C. variegatum* may well be related to changes in cell physiology associated with senescence as van Meeteren (1978) reported for gerberas. Transpiration increased slowly over the vase period, with daily rises and falls, until senescence when it rose more rapidly. Stems placed in SVS, Chrysal Flora 8-HQS and Flower fresh showed higher transpiration rates at senescence than initial values.

In many cut flowers, the length of vase life is limited by a drastic decrease in water uptake, which is accompanied by a decrease in transpiration rate (van Doorn, 1999). The latter occurs due to closure of the stomata, which leads to a lower water potential in the flowering stem. However, the decrease in transpiration rate does not equal to the decrease in water uptake, and therefore, the water deficit increases with time. The factors involved in the decrease in water uptake can be categorized as physiological blockage that is inherent to the stem, the effects of microbial growth and the formation of emboli (air bubbles). Various flower species and cultivars respond differently and emboli affect vase life that leads to symptoms of water stress during vase period.

Foliage stems placed in tap water, Chrysal and Flora showed similar variations in leaf osmotic potential for different places such as leaf tip, middle part and the base. However, we observed a lower osmotic potential for both leaves and stems in tap water vases. These data indicate that long distance shipment does not cause serious water loss or stress to cut stems. Moreover it clearly demonstrates that clean tap water has an ability to maintain vase life, fresh weight and other quality parameters during the vase period. Tap water also contains mineral compounds such as Cl^-, NO_3^-, SO_4^{2-}, Ca^{2+}, Na^+, Cu^{2+} that provide nutrients to cut flowers. Those compounds in tap water influence the water balance of cut flowers during the first days after harvest (van Meeteren et al., 1999).

Colour components were not significantly affected by vase water treatments except leaf lightness (L^*). However, variation of values during vase period showed the importance of floral preservatives in tap water. Chlorophyll fluorescence was significantly influenced by vase solutions. Stems placed in tap water vases gave the highest yield values of all treatments. Van Kooten et al. (1991) reported that chlorophyll fluorescence is a fast and non-invasive technique to determine the physiological status of plant tissue. Potted *Codiaeum* plants showed decline of chlorophyll yield after transportation and exposure to the mild stress. However, no adverse effects of transport could be detected on visual inspection of plants and leaves did not change colour (van Kooten et al., 1991). This was further supported by results of our study. Vase water treatments had no significant difference in foliage colour components of a^*, b^*, chroma and hue angle.

CONCLUSIONS

Applying postharvest treatments for *Codiaeum* cut stems showed highest vase life in 8-HQS and had no significant differences for commercial preservatives and tap water. 8-HQS controlled microbial growth in the holding solution and helped to prolong vase life of cut stems. However, long-distance shipment affected the water relations of cut croton. Results showed that colour lightness was significantly affected by vase solutions, suggesting the use of a floral preservative in the holding solution. Foliage colour is an extremely interesting feature for consumers therefore market success is mainly dependent on the appearance of cut stems.

ACKNOWLEDGEMENTS

The authors thank Mr. M. Keerthiratne in Sri Lanka for providing croton cut stems, Institute of Fruit Growing & Horticulture for arranging laboratory facilities and Austrian Development Cooperation for granting a Ph.D. scholarship.

Literature Cited

Björkman, O. and Demmig, B. 1987. Photon yield of CO_2 evolution and chlorophyll fluorescence at 77K among vascular plants of diverse origins. Planta 170:9-504.

Eason, J.R. 2002. *Sandersonia aurantiaca*: an evaluation of postharvest pulsing solutions to maximise cut flower quality. Newzealand Journal of Crop and Horticultural Science, 30:273-279.

Halevy, A.H. and Mayak, S. 1981. Senescence and postharvest physiology of cut flowers. Part 2, Hort. Rev. 3:59-143.

Larsen, F.E. and Frolich, M. 1969: The influence of 8-hydroxyquinoline citrate, N-dimethylamino succinamic acid, and sucrose on respiration and water flow in 'Red Sim' carnations in relation to flower senescence. Proceedings of the American Society of Horticultural Science 87:458-463.

Reid, M.S. and Kofranek, A.M. 1980. Recommendations for standardized vase life evaluations. Acta Hort. 113:171-173.

Schreiber, U. and Bilger, W. 1993. Progress in chlorophyll fluorescence research: Major developments during the past years. Progress in Botany 54:151-73.

van Doorn, W.G. 1999. Vascular occlusion in cut flowers. I. General principles and recent advances and II. Some species of tropical provenance Acta Hort. 482:59-63 and 65-69.

van Kooten, O., Mensink, M., Otma, E. and van Doorn, W.G. 1991. Determination of the physiological state of potted plants and cut flowers by modulated chlorophyll fluorescence. Acta Hort. 298:83-91.

van Meeteren, U. 1978: Water relations and keeping quality of cut gerbera flowers. II. Water balance of aging flowers. Scientia Horticulturae 9:189-197.

van Meeteren, U., van Gelder, H. and van Ieperen, W. 2000. Reconsideration of the use of deionized water as vase water in postharvest experiments on cut flowers. Postharvest Biology and Technology 18, 169-181.

Tables

Table 1. Effects of vase solutions on vase life, osmotic potential and ºbrix of *Codiaeum variegatum* (L.) Blume 'Excellent'. Values are means of 12 stems.

Floral preservative	Osmotic potential (mmol/kg)				ºBrix value				Vase life (d)
	Leaf			Stem	Leaf			Stem	
	Tip	Middle	Base		Tip	Middle	Base		
SVS	-10.7 b	-10.5 b	-10.2 b	-10.1 b	6.7 a	6.4 a	6.0 ab	5.4 a	26.4 b
Chrysal	-12.3 a	-11.7 ab	-10.9 ab	-10.5 ab	6.9 ab	6.6 ab	5.2 a	4.9 a	18.9 a
Flora	-12.8 a	-12.5 a	-11.9 a	-10.9 ab	7.9 b	7.4 b	6.1 ab	5.80a	29.9 c
Flower fresh	-11.9 ab	-11.5 ab	-11.1 ab	-10.9 ab	7.4 ab	7.0 ab	6.7 b	6.0 a	30.2 c
Biovin	-12.0 ab	-11.6 ab	-10.9 ab	-10.2 b	7.2 ab	6.9 ab	6.2 b	5.5 a	30.3 c
Tap water	-12.9 a	-12.5 a	-11.9 a	-11.9 a	7.2 ab	6.4 a	6.1 ab	5.2 a	30.0 c
8-HQS	-11.7 ab	-11.3 ab	-10.8 ab	-10.8 ab	7.1 ab	6.4 a	6.3 ab	5.3 a	31.1 c

Means separation across columns; means followed by the same letter are not significantly different by Tukey SD test at $P = 0.05$

Table 2. Effects of vase solutions on transpiration and water uptake rates on day 1, 15 and end of vase life of *Codiaeum* cut stems. Each column shows means of three replicate stems ± SE.

Floral preservative	Transpiration (g/d.stem)			Water uptake (g/d.stem)		
	Day 1	Day 15	End of vase life	Day 1	Day 15	End of vase life
SVS	3.6 ± 0.2	2.7 ± 0.2	5.6 ± 0.6	2.5 ± 0.2	2.6 ± 0.2	2.0 ± 0.2
Chrysal	3.8 ± 0.6	2.3 ± 0.4	4.5 ± 0.3	2.7 ± 0.1	2.1 ± 0.2	1.9 ± 0.2
Flora	3.9 ± 0.4	2.7 ± 0.2	5.1 ± 0.9	2.9 ± 0.2	2.4 ± 0.1	2.4 ± 0.2
Flower fresh	3.7 ± 0.5	2.5 ± 0.3	3.9 ± 0.6	2.6 ± 0.3	2.1 ± 0.2	2.1 ± 0.2
Biovin	3.7 ± 0.4	2.8 ± 0.3	4.1 ± 0.5	2.8 ± 0.3	2.6 ± 0.2	2.5 ± 0.2
Tap water	3.9 ± 0.6	2.6 ± 0.2	3.8 ± 0.4	2.9 ± 0.3	2.5 ± 0.2	2.7 ± 0.1
8-HQS	3.7 ± 0.5	2.9 ± 0.2	5.8 ± 0.5	2.6 ± 0.3	2.8 ± 0.2	2.5 ± 0.1

Table 3. Effects of vase solutions on chlorophyll yield of croton stems in vase solutions. Each column shows means of three replicate stems. Means within column with different letters are significantly different at $P = 0.05$.

Floral preservative	Chlorophyll yield				
	Day 1	Day 7	Day 14	Day 21	End
SVS	0.76 a	0.75 a	0.77 a	0.74 a	0.67 a
Chrysal	0.76 a	0.76 ab	0.78 b	0.74 a	0.68 a
Flora	0.76 a	0.77 b	0.78 b	0.75 a	0.69 b
Flower fresh	0.76 a	0.76 ab	0.77 a	0.75 a	0.68 a
Biovin	0.77 a	0.77 b	0.78 b	0.76 b	0.69 b
Tap water	0.76 a	0.76 ab	0.78 b	0.75 a	0.67 a
8-HQS	0.76 a	0.76 ab	0.78 b	0.75 a	0.69 b

Figures

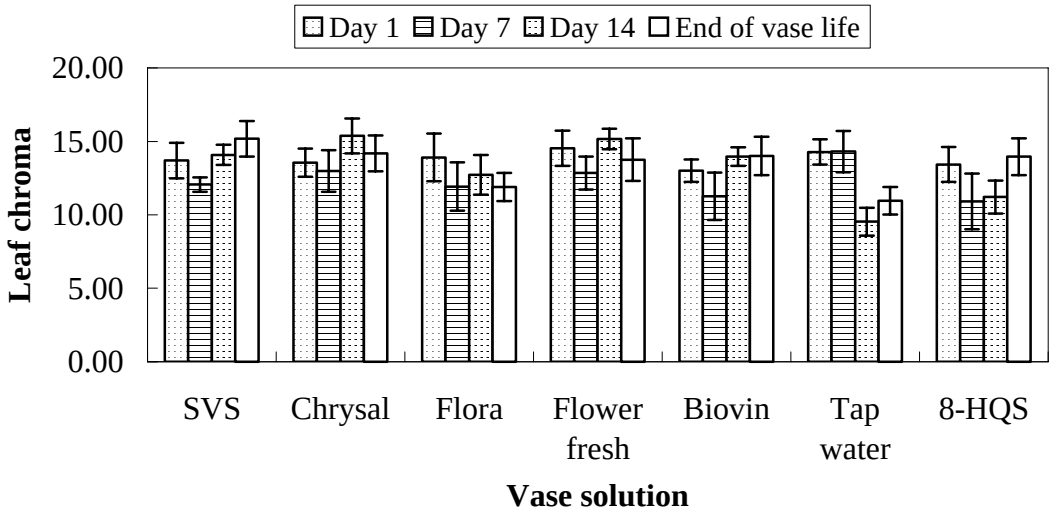

Fig. 1. Effect of vase solutions on chroma value of *Codiaeum* cut stems during vase period. Vertical bars indicate SD of 3 replicates.

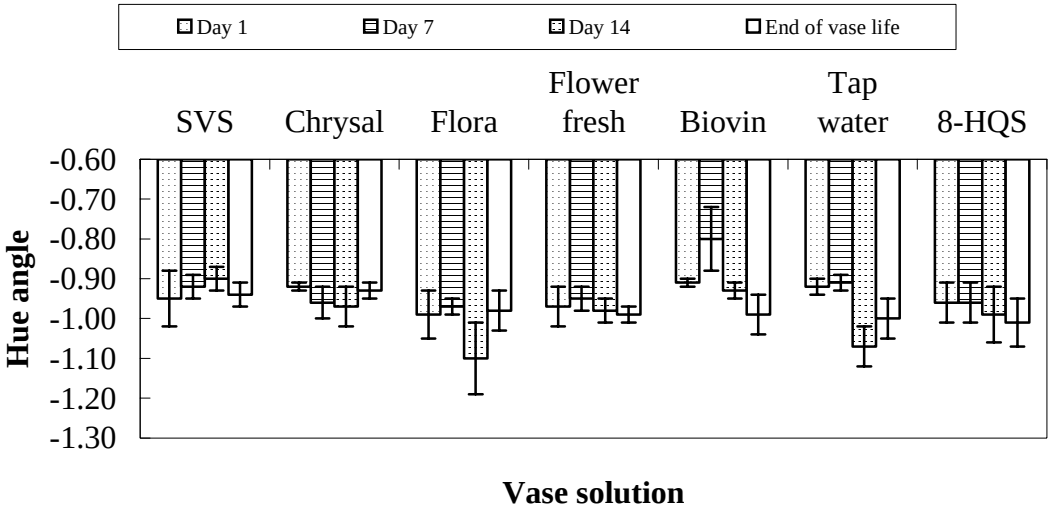

Fig. 2. Variation of ºhue of croton stems placed in vase solutions. Vertical bars indicate standard error (n = 3).