J. Natn.Sci.Foundation Sri Lanka 2007 35(3): 153-159

RESEARCH ARTICLE

# Plant selection, pre-harvest treatments and post-harvest management to prolong the vase-life of shoot cuttings of *Codiaeum variegatum* (croton)

**G.K.K.P. Kumara[1], R.K. Angunawela[2] and W.A.P. Weerakkody [2*]**

[1] *Tropiflora Ltd., Handessa.*

[2] *Depratment of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya.*

Revised: 23 March 2007 ; Accepted: 20 April 2007

**Abstract:** *Codiaeum variegatum* is easily grown under hot and humid field conditions and has a high export potential. However, wilting and senescence during post-harvest operations often reduces its vase-life. To improve this drawback, an investigation was conducted to preserve the export quality of *C. variegatum* vars. Mariana, Batik and Aucubeafolia. Eight separate experiments were conducted to maintain high quality standards during storage life of three varieties of C. *variegatum.* Cold treatment with or without hot water dip, leaf morphology, leaf maturity with cutting type, pre-harvest hormonal regulation, de-topping, post-harvest hormonal regulation, commodity treatments and combined treatments of the above were the test criteria.

The vase-life of three *Codiaeum* varieties were significantly different from each other. Similarly their response to individual treatments was also variable. Some of these individual treatments such as hormonal regulation were not compatible to be used as a combined treatment. Selection of mature or partially mature stem cuttings having a full length of purple and elongated leaves, de-topping 1-2 weeks before harvesting, spraying of 0.1mM of Kinetine 4 days before harvesting, application of 100 ppm of Gibberellic acid ($GA_3$) after harvesting, pre-cooling at 17°C and 79% humidity for one day (after harvesting) and application of commodity treatment of 2mg/L of $KMnO_4$ with 2.5% of sugar and citric acid were the ideal individual treatments for extending the vase-life of *Codiaeum* varieties.

Except post-harvest hormonal regulation, all the other plant selection criteria and post-harvest treatments that are mentioned above could be practiced in combination to increase the vase-life of all three varieties of *Codiaeum* without loosing the export standards significantly. The increased vase-life under combined treatment was18 days for var. Mariana, 20 days for var. Batick and 24 days for var. Aucubaefolia which was a 36.2% increase.

**Keywords:** Cold treatment, commodity treatments, de-topping, hormonal regulation, shoot morphology.

## INTRODUCTION

Floriculture has become a profitable sub-sector of agribusiness throughout the world in recent years. The climatic variation coupled with a diverse terrain enables Sri Lanka to develop a wide range of floriculture flora[1]. The export trade in floriculture began in early 1980s, By now it has grown substantially to become one of Sri Lanka's major foreign exchange generating ventures[2]. Export earnings from floriculture have increased from Rs. 191.1 Mn in 1990 to Rs. 624.7 Mn in 2000. Sri Lanka was the world's 32nd largest exporter of live plants with 0.1% share of the market[3]. Foliage ornamentals have a 90% share of the ornamental exports which is 5.2% of the annual agricultural export earnings of Sri Lanka[4]. Correspondingly, foliage ornamentals are grown in 472 ha which is 94% of the total land area under floriculture (500 ha)[5].

*Codiaeum* the magnificent, multi-coloured foliage plant is long since known in horticulture as Croton. It is a tropical shrub with highly ornamental, thick leathery glossy leaves in many shapes and sizes. Croton plant is said to be the world's most colourful and variable shrub[6]. Being herbaceous and perishable, foliage plants are susceptible to post-harvest conditions. Special care is necessary to ensure their market standards. Particularly, cut foliage undergoes stress after harvesting. Excessive moisture loss from the cut surface, while metabolic activities are continuing, leads to desiccation and loss of food reserves in tissues. Most of the popular croton varieties undergo considerable leaf drop upon placement in interior environments[7]. There are two main symptoms associated with defoliation of the cut shoots of croton, *viz.*,wilting of leaves and discolouration (yellowing).

*Corresponding author

Previous work on prolonging vase-life and qualitative improvements of cut foliage of croton variety, Mariana have given unsatisfactory results. Supplementary plant nutrition or commodity treatments (after harvesting) could not extend the vase-life beyond 14 days[8]. Review of literature on the efforts on prolongation of vase-life of other cut flowers and foliage reveal the possibility of using cold storage[9], post harvest commodity treatments[10,11] and hormonal regulations[12,13].

Therefore this investigation was carried out to determine the most suitable pre-harvest and post-harvest treatments to prolong the vase-life of the cut foliage of *Codiaeum variegatum* vars. Mariana, Batik and Aucubeafolia.

## METHODS AND MATERIALS

*Experimental conditions and designs*: The research was carried out at Green Farms (Pvt.) Ltd., Marawila (Low Country Intermediate Zone) from December 2004 to March 2005. Altogether eight experiments were conducted to investigate the possibility of increasing the vase-life of cut shoots of three selected varieties of *C. variegatum*, namely Mariana, Batik and Aucubeafollia. Experiments 2 & 3 were conducted as single factor Completely Randomized Designs (CRDs) while the remaining experiments were conducted as two-factor Factorial CRDs, having three replicates. Each replicate composed of 4 cuttings. In Factorial designs, treatments were arranged as factor 1 in each experiment (as described below), and factor 2 was the variety in all the experiments.

*Experimental procedures*: In the first experiment (Expt. 1), delaying of the senescence process by cold treatment (at 17°C) for 1 or 2 d with and without instant hot water dip (at 38°C) (for sealing latex flow and disinfection) was compared with room temperature (29°C) storage (factor 1) using eight treatment levels. Room temperature without hot water dip (T1), Room temperature with hot water dip (T2), Cold treatment without hot water dip (T3) and Cold treatment with hot water dip (T4) were given for 1 d. Another set of treatment combinations (range from T5 to T8 in the same order) were continued for 2 d. The relative humidity (RH) at cold room and normal storage (room temperature) were 79% and 52%, respectively†. Disease-free, healthy cuttings from open-field grown *C. variegatum* varieties were harvested to a length of over 50 cm (export standard†) during the period 7.00 - 9.00 a.m. Plants were irrigated abundantly in the previous day in order to maintain turgidity. Cuttings were immediately immersed in water (pH; 6.2 and EC; 0.1 mS/cm) to avoid air intake through the cut surface[13]. Before subjecting to the treatments an approximately 5 cm piece of stem was removed from the cut end at the pack house. The treated cuttings were re-cut to have the exact length of 52 cm and several leaves removed at least 10 cm from the base of the cutting, to match with buyer's specification for cut decorative shoots†.

The cuttings were packed in corrugated cardboard boxes (73 x 40 x 13 cm), at the rate of four cuttings per box, following the normal packing procedure†. These boxes were labelled and kept under illuminated cold room conditions for two days. Two days after packing, the boxes were opened, 2.5 cm of stem ends were again re-cut and dipped again in normal chlorinated water. Water in the containers was replaced at 5 d intervals. Data were collected on wilting rate and freshness of the leaves by visual quality ranking method at 2 d intervals (Table 1).

Experiment 2 (Expt. 2) was done to examine the effect of leaf colour and number of leaves on the vase-life of *C. variegatum* var. Mariana. The four treatments composed of purplish red and yellowish red leaves with full set of leaves and half set of leaves (left at the proximal end). Leaf removal was aimed at reduced maintenance need by the shoot cutting. Procedures followed in harvesting and immediate post harvest handling of cuttings were similar to Expt. 1. The best treatment of Expt. 1, cold treatment was practiced as a general practice for all successive treatments, beginning from Expt.2.

Experiment 3 (Expt. 3) was done to examine the effect of leaf colour, leaf shape and the stem maturity of *C. variegatum* var. Batik. Cuttings from two leaf colours (red and purple), three levels of leaf maturity (mature, partially mature and immature) and two types of leaf shapes (round and elongated) were combined to form 12 treatment levels.

Based on the knowledge on inhibition of senescence by Cytokinins and Gibberelins[13], the effect of pre-harvest application of plant growth regulators was tested. Three concentrations of Kinetine (0.1, 0.25 and 0.5 mM) and Gibberellic acid or $GA_3$ (0.05, 0.1 and 0.25 mM), two concentrations of salysilic acid (325 and 487 ppm) together with no hormone control were used to form 9 treatment levels in experiment 4 (Expt.4). Under each variety three adjoining replicates were identified within a field bed (1 $m^2$ in size, having 30 plants) for the hormonal treatment. Hormonal application was done in correct concentration at the rate of 1 litre per field bed (1 $m^2$) using a hand sprayer, wetting both sides of the lamina between 7.30 to 9.30 a.m. in order to minimize respiration. Tween 20 (polyoxyethylene 20) was added as a surfactant at the

† *unpublished data*, Green Farms (Pvt.) Ltd.

rate of 10–15 mL/10 L to each solution to improve the efficiency of absorption. Cuttings were taken either 4 or 8 d after hormonal application.

In experiment 05 (Expt. 5), effect of de-topping (removal of bud and several immature leaves at the field) on different degrees of maturity/branching habits (matured partially matured and immature) at 1 wk before harvesting (WBH) and 2 WBH was tested. In experiment 6 (Expt. 6), commodity treatments at post-harvest stage were tested using two acidifiers, citric acid and vinegar in combination with 2.5% and 7.5% of sugar (carbohydrate source) and 2 and 7 mg/L of $KMnO_4$ (biocide). Citric acid was the commonly used acidifier which facilitates solute uptake through the cut end[16] while vinegar was used as a cheap, easily available alternative for citric acid in the coconut growing areas. The range of concentrations of the carbohydrate source and the biocide were selected based on recommended levels for preservation of other ornamental species[11]. Cuttings were immersed in 10 cm deep treatment solutions (having pH of 3.5) just after making the cutting and kept for 1 d in the cold room.

In experiment 7 (Expt. 7), effect of post-harvest hormonal regulation on vase-life was investigated using a combination of Kinetine (at 25 and 50 ppm) with Gibberelic acid (at 50 and 100 ppm). The cuttings were immersed in each hormonal solution as in Expt. 6. The solution pH was adjusted to 3.5 using citric acid. In experiment 8 (Expt. 8), de-topping, pre-harvest hormone spraying and post-harvest (commodity) treatment were combined to form 6 treatment combinations and tested. The procedures followed were similar to individual treatments mentioned above. De-topping was done one wk before harvesting. For pre-harvest hormonal treatment, 0.1 mM Kinetine was applied four days before harvesting.

**Table 1:** Ranking method to assess the post harvest quality of cut foliage of *C. variegatum*

| Characteristics | Observations | Scale |
|---|---|---|
| Wilting of cutting | Best in freshness | 3 |
| | Slight wilting | 2 |
| | Moderate wilting | 1 |
| | Severe wilting | 0 |
| Freshness of leaves | Fresh appearance | 2 |
| | Slight pale colour | 1 |
| | Severe pale colour | 0 |

The post-harvest solution was prepared using 2 mg/L $KMnO_4$, 2.5% sugar, 100 ppm $GA_3$ based on the results of experiments 4, 5 and 6.

*Evaluation and analysis of data:* The self determined ranking method (Table 1) was used to assess the shelf-life and the appearance of the foliage (freshness and wilting of leaves). Ranking was done a day after opening the boxes and continued until the end of the experiment. The vase-life was computed using time (days) taken to transfer visual rankings from 3 to 2 with respect to wilting of cuttings and 2 to 1 with respect to freshness of leaves. (Table 1).

Analysis of Variance (ANOVA) procedure was followed by Duncan's New Multiple Range Test (DnMRT), using Statistical Analytical Systems[17] for testing treatment effects and separating treatment means, respectively.

## RESULTS

### Expt. 1: Temperature treatment

Cold treatment or removal of the field heat extended the export quality and vase-life of croton significantly (at p=0.05) (Figure. 1). Cold treatment for 1 day ($T_3$) gave better results than 2 days ($T_7$). When compared to room temperature control (T1), $T_3$ has increased the vase-life of *Codiaeum* vars. Mariana, Batik and Aucubaefolia by 6, 4 and 5 days, respectively. Instant hot water dip followed by room temperature storage ($T_2$ and $T_4$) or cold storage ($T_6$ and $T_8$) for 1-2 days were not significantly effective on quality and vase-life of crotons (Figure 1).

### Expt. 2: Leaf arrangement and colour

The cuttings of var. Mariana with full set of leaves in both leaf colour types, yellowish purple and yellowish red, had a longer vase-life when compared to cuttings with half set of leaves. Cuttings with yellowish purple colour were superior in keeping quality (vase-life) than those with yellowish red leaves (Figure 2).

### Expt. 3: Leaf shape and maturity

In var. Batik, cuttings with elongated leaf shape had longer vase-life than those with round shape. In addition, mature and partially mature cuttings lasted a longer period in storage when compared to immature cuttings. Partially mature cuttings with purple and elongated leaves had the longest vase-life (22 days), followed by fully mature cuttings of same type (for 20 days) (Figure 3).

### Expt. 4: Pre-harvest hormonal treatment

As shown in Table 2, pre-harvest application (spraying) of a 0.1-0.25 mM solution of kinetin 4 days before harvesting (DBH) has resulted in the highest mean vase-life of 11-13 days for var. Mariana. For var. Batik, pre-

harvest treatment of 0.25-0.5 mM of Kinetin and 0.25 mM of $GA_3$ was the best for extending the vase-life (upto 10–11 days) while 0.05 mM of $GA_3$ was best for var. Aucubaefolia (upto 22 days). Pre-harvest hormonal treatment with 4 DBH was always better than 8 DBH for the extension of vase-life for all tested hormones and for

**Table 2:** Effect of pre-harvest hormone application on the vase-life of *Codiaeum* varieties

| | | Mariana | | Batik | | Aucubaefolia | |
|---|---|---|---|---|---|---|---|
| Commodity | Concentration | 4 DBH | 8 DBH | 4 DBH | 8 DBH | 4 DBH | 8 DBH |
| Kinetin | 0.1 mM | 13.0$^{a}$ | 3.4$^{b}$ | 8.4$^{ab}$ | 7.4$^{b}$ | 10.0$^{c}$ | 9.0$^{c}$ |
| | 0.25 mM | 11.0$^{a}$ | 2.7$^{b}$ | 11.4$^{a}$ | 3.7$^{c}$ | 21.7$^{a}$ | 14.0$^{b}$ |
| | 0.5 mM | 4.4$^{c}$ | 3.4$^{b}$ | 10.7$^{a}$ | 7.0$^{b}$ | 15.0$^{b}$ | 9.4$^{c}$ |
| GA3 | 0.05 mM | 4.7$^{c}$ | 4.0$^{b}$ | 7.4$^{ab}$ | 7.0$^{b}$ | 14.0$^{b}$ | 14.7$^{b}$ |
| | 0.1 mM | 7.0$^{b}$ | 3.7$^{b}$ | 9.7$^{a}$ | 6.7$^{b}$ | 15.7$^{b}$ | 22.0$^{a}$ |
| | 0.25 mM | 6.0$^{bc}$ | 3.7$^{b}$ | 10.7$^{a}$ | 8.0$^{b}$ | 13.0$^{bc}$ | 20.0$^{a}$ |
| Salisilate | 325 ppm | 5.7$^{bc}$ | 4.0$^{b}$ | 9$^{a}$ | 7.7$^{b}$ | 11.4$^{bc}$ | 9.0$^{c}$ |
| | 487 ppm | 3.7$^{c}$ | 3.0$^{b}$ | 5.4$^{b}$ | 7.4$^{b}$ | 12.4$^{bc}$ | 13.7$^{b}$ |
| Control | 5.0$^{bc}$ 4.0$^{b}$ | 5.0$^{b}$ | 7.0$^{b}$ | 16.0$^{b}$ | 14.0$^{b}$ | | |
| LSD (at P=0.05) | 2.4 | 2.4 | 2.4 | 2.4 | 3.0 | 3.0 | |

DBH: Days before harvesting
Values within columns with the same letter(s) are not significantly different.

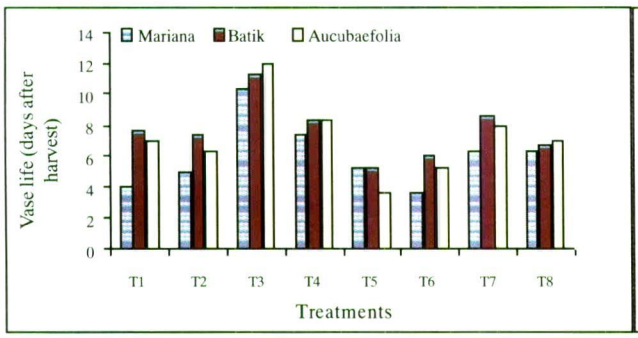


**Figure 1:** Effect of pre-temperature treatment on the vase-life of *Codiaeum* varieties [*LSD (p=0.05) = 2.4* for Mariana, 2.7 for Batik and 2.8 for Aucubaefolia]

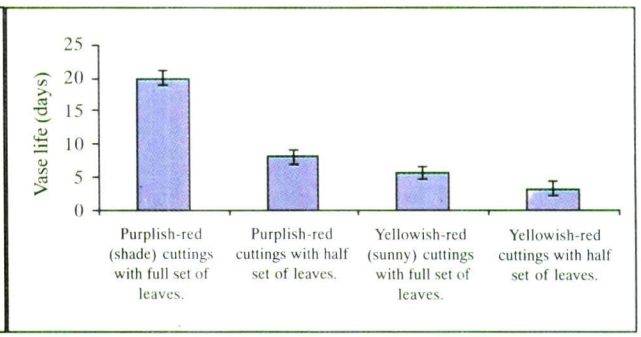


**Figure 2:** Effect of colour and arrangement of leaves on the vase-life of *C. variegatum var.* Mariana cut foliage

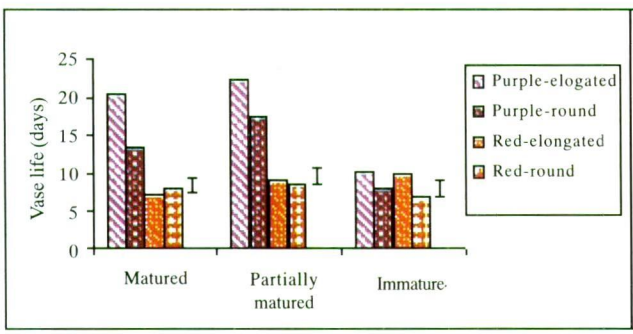


**Figure 3:** Effect of leaf morphology and shoot maturity on the vase-life of *C. variegatum* (var. Batik) cut foliage

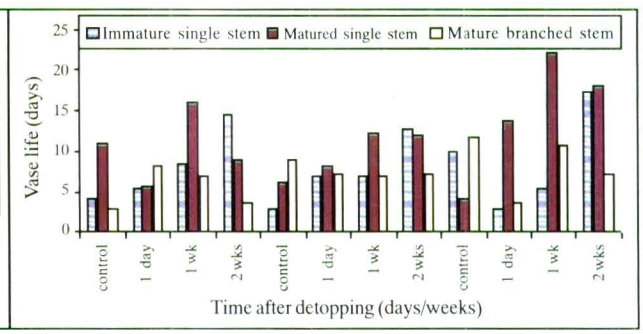


**Figure 4:** Effect of time of de-topping on the vase-life of cut foliage of *Codiaeum* varieties at different shoot maturities

all varieties. Hence, the effective period of exogenous hormones appeared to be upto 4 weeks.

### Expt. 5: De-topping of shoots

In the control (without de-topping), mature single stem cuttings had a higher vase-life than immature stem and mature, branched cuttings in var. Mariana. De-topping 1 week before harvesting (WBH) of mature single stem cuttings increased the vase-life up to 16 days while de-topping 2 WBH of immature stem cuttings also gave similar results for var. Mariana (Figure 4). Even though mature branched stems were the best for cuttings in var. Batik & var. Aucubaefolia de-topping reduced the vase-life as auxin: cytokinin ratio further decrease to undesirably low levels. These two varieties have also shown the longest vase-life when de-topped mature single stem cuttings 1 WBH (13–22 days) and immature stem cuttings 2 WBH (12–18 days). However, the influence of de-topping on vase-life was relatively low for var. Batik (12-13 days) and relatively high for var. Aucubaefolia (18-23 days).

### Expt. 6: Commodity treatment

Commodity treatment resulted in significant extension of vase-life of all three *Codiaeum* varieties emphasizing the necessity of a biocide, an acidifier and a food source[28] (Figure 5). Out of the three components present in the treatment, citric acid was more effective as an acidifying agent, compared to vinegar for *Codiaeum* varieties. In addition, citric acid may act as an antioxidant and prevent degenerative enzymatic reactions[10]. But there were no significant individual treatment effects of dosages of disinfectant ($KMnO_4$) and the food source (sugar) for all the varieties.

All three varieties performed best in response to $T_2$ (2 mg/L of $KMnO_4$ with 2.5% of sugar and citric acid) and was followed by $T_4$ (5mg/L of $KMnO_4$ with 2.5% of sugar and 0.1 N citric acid). However, $T_3$ (2 mg/L of $KMnO_4$ with 7.5% of sugar and citric acid) resulted the highest vase-life for var. Aucubaefolia (Figure 5).

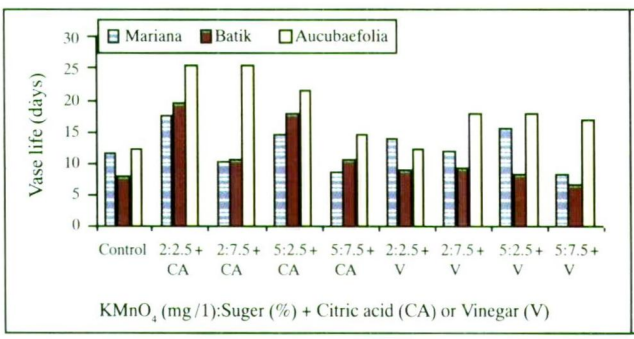


**Figure 5:** Post-harvest treatments on the vase-life of cut foliage of Codiaeum varieties (LSD (at p=0.05) = 3.1 for Mariana, 3.5 for Batik and 4.3 for Aucubaefolia)

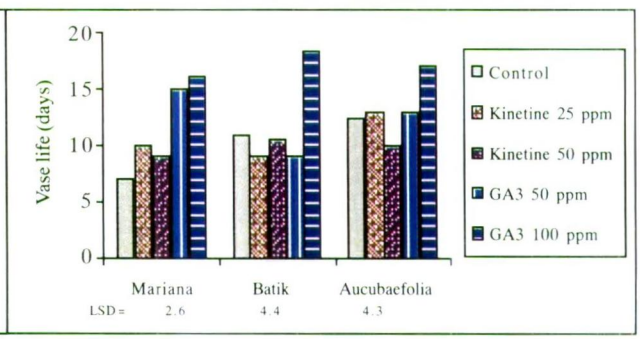


**Figure 6:** Effect of the post-harvest hormonal treatments on the vase-life of cut foliage of Codiaeum varieties

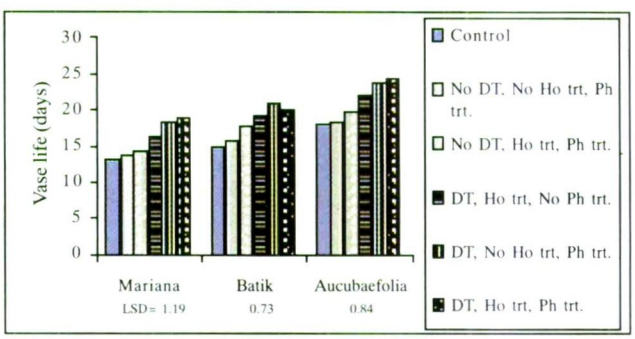


**Figure 7:** Effect of treatment combinations, de-topping (DT), pre-harvest hormone treatment (Ho trt) and post-harvest commodity treatment (Ph trt.) on the vase-life of cut foliage of *Codiaeum* varieties

**Expt. 7: Post-harvest hormonal treatment**

Even though highly effective as a pre-harvest treatment (Expt. 4), kinetin concentrations of 25-50 ppm were not significantly effective as a post-harvest treatment for extending the vase-life of *Codiaeum* (except for var. Mariana) as shown in Figure 6. Being a hardy shoot, it could lose access for exogenous substances along with the degenerative changes in the shoot tissues after detachment. Gibberelic acid at 100 ppm significantly increased the vase-life of vars. Mariana, Batik and Aucubaefolia upto 16, 18 and 17 days, respectively [while the control was 7, 11 and 14 days, respectively (Figure 6). However, the influence was lower than the effect of pre-harvest hormonal regulations (Expt. 4).

**Expt. 8: The combined effect**

Cold treatment of shoot cuttings with ideal morphological features and cutting types, followed by several optional combinations of de-topping, pre-harvest hormone spraying and application of commodity treatments at post-harvest stage lead to an overall increment in vase-life of all three varieties. According to Figure 7, mature single stem cuttings de-topped 1 WBH and subjected post-harvest treatments gave the highest vase-life (ranging within 18–24 days) for all three varieties. But pre-harvest hormone treatment was not significantly effective to extend vase-life in de-topped cuttings. Since pre-harvest kinetin treatment per-say was highly effective for prolonging vase-life (Expt. 4), it would be worthwhile to incorporate kinetin to the treatment combination with minor adjustments in the concentration or time of application.

## DISCUSSION

Reduction of the rate of respiration[18] and moisture loss[19] under low temperature and high humidity would have extended the vase-life of *Codiaeum* under cold treatment for 1 day. As recommended by Arora and Singh[20], removal of field heat must have contributed to the above result as the experimental site was located in a tropical environment, having a mean day temperature of 30°C. Meanwhile, 2 days appeared to be too long for the cold treatment. Furthermore, the negative impact on the vase-life of *Codiaeum* shoot tissues due to high temperature shock when dipped in hot water appeared to be more influential than its anticipated positive effect through the suppression of ethylene production[13].

The variability of the vase life of *Codiaeum* based on the type of shoots could be a result of many internal factors. Relatively short vase life of the shoots with half set of leaves could be due to extra energy requirement for wound healing on the stem. Further, the comparatively longer vase life by the yellowish purple shoots could have been an effect of some biochemical differences associated with the formation of pigments under partial shade. Since chlorophyll break down is a significant post-harvest deteriorative change in tissues[22], further analysis of chlorophyll compositions of leaves under different colours would comprehend the underlying mechanisms of variation of vase-life. As usual, reduced water loss through the epidermis due to formation of cuticle could be the reason for extended vase-life of partially matured shoots. At the same time, the degradation of shoot tissues (the senescence process) with over maturity[23] negatively influences the vase life. The results on the variation of vase-life under different leaf shapes is an indication of the genetic control (reflected through leaf morphology), when compared to environmental or ontogenic influences during post harvest period. Hence selection of shoots with the correct genentic entity (elongated leaves), grown under shade (for formation of yellowish purple colour) and harvesting with full set of leaves at partial maturity would collectively enhance the storage of *Codiaeum* shoot cuttings.

According to Bruinsma[24] high auxin: cytokinin ratio positively affects the senescence rate of shoots. Since auxin production is higher near the apical bud[25], lowering of the above ratio by de-topping may have resulted retarding the rate of senescence of stem cuttings in *Codiaeum* var. Mariana. This can also be due to partitioning of more dry matter and plant nutrients to the matured leaves after loosing the shoot-tip sink[26] which delays senescence[27]. Meanwhile, the variations in endogenous auxin/ cytokinin ratio among varieties and different maturity levels of shoots could be the reasons for differential responses to de-topping by the shoots of the other varieties and at different maturity levels.

The influence of the pre-harvest treatment with kinetin and $GA_3$ on the rate of senescence agrees with the work of Thiman[22] where cytokinins and gibberelins were found to reduce the rates of senescence and chlorophyll degradation. However, the responses of some *Codiaeum* vars. to post harvest application of the same plant growth regulators were either low or not significant. This could be due to a problem of entry or subsequent translocation of the hormones to sites of action[29]. Reports on insignificant influence of exogenous cytokinins on delaying senescence[30], though endogenous levels reduce in senescing tissues[31], support this result.

The commodity treatment was found highly effective on the extension of the vase life of *Codiaeum* varieties where the contribution of citric acid over vinegar was highlighted. Greater pH buffering capacity of citric acid, which enhances absorption[13], could be the main reason for this situation. In addition, citric acid may act as an antioxidant and prevent degenerative enzymatic reactions[10].

Based on the overall results, selection of mature or partially mature stem cuttings having stem full of purplish and elongated leaves, de-topping 1-2 weeks before harvesting, spraying of 0.1mM of Kinetin 4 days before harvesting, application of 100 ppm of $GA_3$ after harvesting, pre-cooling at 17°C and 79% humidity for one day (after harvesting) and application of commodity treatment of 2mg/L of $KMnO_4$ with 2.5% of sugar and citric acid (pH at 3.5) were the ideal individual treatments to extend the vase-life of tested *Codiaeum* varieties.

## References


1. Fernando P.V.A.M. (2000). Floriculture industry in Sri Lanka. *Business Lanka* **8**:2-9.
2. Dhanasekera D.M.U.B. (1998). Cut flower production in Sri Lanka. In: *Cut Flower Production in Asia* (1st ed.), FAO Publications, Rome.
3. Anoymous (2004). Export Development Board, 42, Navam Mawatha, Colombo-02.
4. Anoymous (2002). Export Development Board, 42, Navam Mawatha, Colombo-02.
5. Weerakkody W.A.P. (2004). Horticulture in Sri Lanka. *Chronica Horticulture* **44**:23-27.
6. Brown B.F. (1995). *Codiaeum Encyclopedia; Crotons of the World.* Valkaria Tropical Garden, Valkaria, Florida.
7. Henny R.J. (2001). Croton production guide. In: *CFREC - Foliage Plant Research Note.* pp. 1-5.
8. Wijesundara W.M.C.L. (2004). Effect of different combination of major nutrients, K, Mg and Ca on immature leaf senescence of croton. *B.Sc. Dissertation*, Faculty of Agriculture, University of Peradeniya, Peradeniya.
9. Hettiarachchi M.P. & Balas J. (2005). Storage performance of *Gloriosa superba* L. as a potential cut flower species in Europe. *Acta Horti culturae* (ISHS) **683**:455-462. http://www.actahort.org/books/683/683_59.htm
10. Jowkar M.M. & Salehi H. (2005). Effects of different preservative solutions on the vase-life of cut tuberose flowers at usual home conditions. *Acta Horti culturae* (ISHS) 669:411-418. http://www.actahort.org/books/669/669_54.htm.
11. Salunkhe D.K., Desai B.B. & Bhatt N.R. (1990). *Postharvest Biotechnology of Flowers and Ornamental Plants.* Naya Prokash, Culcutta pp10-15.
12. Sisler E.C., Kebenei Z., Winkelmann T. & Serek M. (2005). Efficacy of new inhibitors of ethylene perception in improvement of display life of ornamental crops. *Acta Horti culturae* (ISHS) **669**:315-320. http://www.actahort.org/books/669/669_41.htm.
13. Nooden L.D. & Leopold A.C. (1978). Photohormones and the endogenous regulation of senescence and abscission. In: *Plant Growth Substances; Principles and Applications.* pp. 166-172, Chapman and Hall, New York.
14. Hara A.H. (2006). *Hot water treatment to reduce pesticide usage,* Dept. of Entomology, University of Hawaii, CTAHR, 461 W Lanikaula st, Hilo, Hawaii. http://www.epa.gov/oppbppd1/PESP/regional_grants/1996/r9b-1996.htm
15. Nowak J. & Rudnicki R.M. (1990). Growing condition and longevity. In: *Postharvest Handling and Storage of Cut Flowers, Florist Greens and Potted Plants* (2nd ed.). (Ed. A.A. Duncan) pp. 36-51, 67-101, Timber Press, Skierniewice (Poland).
16. SAS. (1999). SAS Inc, New York.
17. Paull R.E. (1999). Effect of temperature and relative humidity on fresh commercial quality. *Post-harvest Biology and Technology* **15**:263-277.
18. Elgar J. (2002). Cooling requirement and temperature management. In: *HortFACT – Cut Flower and Foliage,* www.hortnet.co.nz/publications/hortfacts/ hfinall.htm-hf305004.
19. Arora J.S. & Singh K. (2002). Pre and post harvest management of cut flowers: management of cut flowers. *Indian Horticulture* **18**(2):20-27.
20. Uritani I. & Ashi T. (1980). Respiration and related metabolic activity in wounded and infected tissue. In: *Metabolism and Respiration; The Biochemistry of Plants* (Vol. 2). (Ed. D.D. Davis) pp.463-487, Academic press, New York.
21. Timann K.V. (1980). The senescence of leaves. In: *Senescence in Plants.* pp.98-107. CRC Press Inc., Boca Raton, Florida.
22. Kays S.J. & Paull R.E. (2004). *Post-harvest Biology.* p. 567 Exon press, Georgia.
23. Bruinsma J. (1983). Hormonal regulation of senescence, aging, fading and ripening. In: *Post-harvest Physiology and Crop Preservation.* (Ed. M. Lieberman) pp.141-144, Plenum Press, New York.
24. Arteca R.N. (1996). *Plant Growth Substances, Principles and Applications.* (3rd ed.) pp.166-173. Chapman and Hall, New York.
25. Hocking P.J. (1993). Seasonal dynamics of the accumulation, distribution and redistribution of dry matter and mineral nutrients in a weedy species of *Gladiolus* (*Gladiolus caryophyllaceus*). *Annals of Botany* **71**(6):495-509.
26. Gillespie I.M.M. & Deacon J.W. (1988). Effects of mineral nutrients on senescence of the cortex of wheat roots. *Soil Biology and Biochemistry* **20**(4):525-531.
27. Hardenburg J.K. (2002). Cut Flowers and florists greens. In: *Tropical Products Transport Handbook.* pp. 62-70. (www.ams.usda.gov/tmd/Tropacal).
28. Stoddart J.L. (1982).Growth regulators in plant senescence. *Proceedings of a Symposium of the British Plant Growth Regulator Group,* 20th April (Ed. M.B. Jackson) England. pp1-2.
29. Van Staden J. (1976). Season changes in the cytokinin content in *Ginko biloba* leaves. *Plant Physiology* **38**:1-5.
30. Van Staden J., Cook E.L. & Nooden L.D. (1988). Cytokinins and senescence. In: *Senescence and Aging in Plants,* (Eds. L.D. Nooden & L.D. Loepold), Academic Press, New York, pp. 281-328.