Morphophysiological Characteristics Associated with Vase Life of Cut Flowers of Anthurium

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Abstract. The vase life of 26 anthurium (Anthurium andraeanum Hort.) cultivars was evaluated in three separate trials. In the first trial, the influence of 12 morphophysiological characteristics of the cut flower on vase life was investigated. Of these, only spathe color and abaxial stomatal density were able to accurately predict vase life. A vase life prediction equation based on abaxial stomatal density, green/not green and white/not white was able to explain the cultivar variation in vase life in two separate trials conducted over two seasons. The equation was further validated using a different set of anthurium cultivars. Although vase life varied over seasons, the relative ranking of cultivars was similar as indicated by joint regression analysis. Changes in vase life over season were mediated through changes in stomatal density. Time to spadix necrosis was the only senescence indicator that occurred in all cultivars and was highly correlated to vase life determined by a complex criterion in all trials. Time to spadix necrosis is therefore suggested as a simplified criterion for vase life assessment. The possible mechanism for vase life deterioration and an approach to improving vase life in anthurium is discussed.

Anthurium andraeanum (Hort.) (Kamemoto and Kuehnle, 1996) is an important tropical ornamental crop, second only to orchids, based on global trade volume. It is grown for its showy cut flower, which comprises a spadix with over 300 spirally arranged minute flowers subtended by a brightly colored modified leaf, the spathe (Croat, 1988). The size, shape, texture, color, and patterns on the spathe determine the commercial value of the cut flower; whereas its vase life determines its marketability (Paull et al., 1985).

Halevy and Mayak (1979) defined vase life as the useful longevity of the floral product at the final consumer’s home. Commercially, a vase life of at least 3 weeks (Kamemoto and Kuehnle, 1996) is required to market anthurium cut flowers. Anthurium cut flowers are known for their relatively long vase life that ranges from 1 week to several months. An understanding of the morphophysiological characteristics associated with such a wide variation in vase life will allow breeders to develop varieties with long vase lives. There are no such studies in the literature.

Paull and Goo (1985) ascribed the symptoms of cut flower senescence in anthurium, that is, loss of spathe glossiness, spathe and spadix browning, and spathe wilting, to water stress. Another symptom, spathe blueing, is attributed to an increase in pH from 5.2 to 5.6 caused by an increase in ammonium ions resulting from the breakdown of proteins (Paull et al., 1985). There is no agreed set of criteria for determining vase life in anthurium, because what is deemed unsaleable by a wholesaler or retailer is different from what a consumer is prepared to discard (Paull, 1982). Shirakawa et al. (1964) used spathe wilting or spathe or spadix darkening as indications of vase life termination. Paull (1982), in addition, used loss of spathe glossiness and spathe blueing. Vase life is therefore determined by a complex criterion based on whichever of these symptoms appears first.

The objective of this study was to determine the morphophysiological basis for cultivar differences in vase life toward developing a prediction equation for vase life and to ascertain the validity of the prediction equation over seasons and a different set of cultivars. We also propose a simplified criterion for assessing vase life in anthurium.

Materials and Methods

Season and location. Vase life was investigated in three trials, Trial 1 (Mar. 2001; dry season), Trial 2 (Sept. 2001; wet season), and Trial 3 (Oct. 2001; wet season), at the laboratories of the University of the West Indies, St. Augustine, Trinidad. The cut flowers were harvested from a commercial farm, Kairi Blooms Ltd., in Arima, Trinidad. The average rainfall, temperature, and relative humidity for the months Mar., Sept., and Oct. 2001 in Arima were 34.3 mm, 25.7 °C, 77%; 202.5 mm, 26.5 °C, 84%; and 193.3 mm, 26.4 °C, 85%, respectively.

Cultivars and cultural practices. The 26 cultivars selected for the study were 3 to 4 years old and included various spathe shapes, textures, sizes, and colors. The cultivars were grown under shade houses (80% shade) on beds (23 m × 1.2 m) made of coconut husk and planted at a spacing of 0.45 m × 0.4 m. The beds were fertilized with either triple superphosphate (Chemos GmbH, Regenstauf, Germany) or 12N–11P–13K (Norsk Hydro Olje AB, NYBRO, Sweden) every month at a rate of 0.45 kg per bed. Urea (National Agro, Trinidad) and diammonium phosphate (Brenntag, Dominican Republic) were applied as necessary at a rate of 0.23 kg per bed. The plants were irrigated once daily for 15 min by overhead sprinkler irrigation. The pH of the beds was maintained at 5.6 by regular liming (Limestone; Trincarb, Trinidad).

Harvesting and transport of cut flowers. Overall, 26 anthurium cultivars were used in three experiments. Cut flowers with no scratches, no deformities, and straight peduncles were harvested at the three-fourths mature stage of the spadix (Kamemoto, 1962). The cut flowers were cut with a sharp, sterile knife, packed in boxes containing wet shredded paper, and transported to the university laboratory in an air-conditioned vehicle. Cut flowers were harvested from along the length of the bed for each cultivar to ensure a uniform representation of the variation within each cultivar. Experiments were set up on the day of harvesting.

Morphophysiological characterization. Seventeen cultivars were assessed for 12 morphophysiological characteristics using nine cut flowers per cultivar in Mar. 2001. Peduncle length was measured as the distance from the point of attachment of the peduncle to the spathae down to the cut end using a measuring tape. Peduncle diameter was measured using a pair of calipers (ENKAY Vernier Caliper 5-inch scale, Lo. 430-C ENKAY, Brooklyn, NY) at a distance of 15 cm from the spathe. Surface area of the spadix was obtained by tracing the spathe outline onto brown paper and measuring it with a ΔT Area Meter MK2 model (Delta-T Devices, Burwell Cambridge, UK) and multiplying the value obtained by two. Spatha color was recorded as described by Kamemoto et al. (1988). Spadix length was measured as the distance from the point of attachment of the inflorescence at the peduncle to the tip (Dai and Paull, 1990).

Spathe length, spathe size, and hydathode density were determined on three randomly selected spathes per cultivar. Four 1.5 × 0.5-cm pieces were cut from each...
spathe and placed in a clearing solution in a petri dish to remove pigments. The clearing solution was prepared by adding 15 g of NaOH pellets to 500 mL of water and 500 mL of 95% ethanol and was replaced routinely as it became pigmented or dried up. Cleared sections were mounted on slides, stained with toluidine blue, and warmed for 2 min on a slide warmer at 40 °C. Stomatal density and hydathode density were enumerated for each section based on four views on the lower and four views on the upper spathe surface at ×100 magnification using a light microscope (Euromex, Arnhem, Holland). From this, the mean number of stomata and hydathodes/mm on the abaxial and adaxial spathe surfaces of each cultivar was calculated. Stomatal size of each cultivar was measured under ×40 magnification using a calibrated eyepiece micrometer (Pyser-SGI Ltd., Kent, UK). The length and width of 10 randomly selected stomata each from the four views per section were measured and mean stomatal length and width calculated. The length and width of stoma plus guard cell were also measured. From these data, the area of each stoma was calculated using the following formula: area = πr1 × r2 where r1 is half the length and r2 is half the width, because the stomata were elliptical in shape.

Spathe thickness was recorded on three spathes per cultivar using three 1.5 × 0.5-cm segments along the midrib per spathe. The nine spathe segments per cultivar were mounted in wax, sectioned transversely using a microtome (20 μm thicknesses), and fixed on slides (Johansen, 1940; O’Brien and McCully, 1981). Slides were viewed under a light microscope at ×100 magnification and the mean thickness of each spathe was calculated from an average of five measurements per segment on each of the three spathe segments using a calibrated eyepiece micrometer as done previously.

To determine epicuticular wax, three whole spathes were first traced on brown paper and then placed in phenol–chloroform until all the wax had been removed (∼40 s). The wax was dried in a rotovac (Haake Buchler Instruments Inc., Saddel Brook, NJ) and weighed using an electronic balance (Acculab; AL-104, Mountville, PA) to 0.0001 g accuracy. The traced surface area of the spathes was measured using the “leaf area meter” and the average wax (mg·m⁻²) was calculated.

Only abaxial stomatal density and spathe color were measured in Trials 2 and 3 as described previously. Preliminary studies had shown that the other morphological characteristics were unaffected by seasonal differences.

Vase life determination. Cut flowers of the 17 cultivars used in the previous study were assessed for their vase life in sterile, 250-mL measuring cylinders in a laboratory setting (11 h white fluorescent light : 13 h dark; 24 °C; 75% relative humidity) (Trial 1). The cultivars were arranged in a completely randomized design with three to eight replications per cultivar and with three cut flowers per replicate. Cultivars ‘Pierrot’, ‘Mirjam’, and ‘Fla Range’ had five replications each; ‘Venus’ had four replications, ‘Spirit’ had seven replications, ‘Midori’ had eight replications, and the others had three replications each. Each cylinder contained 210 mL of sterile distilled water, which was maintained throughout the study period. Before placing the cut flowers into the cylinder, the outline of each spathe was traced on brown paper to determine the spathe area and the base of the peduncles were cut under water at an angle of 45° using a sterile scalpel.

The following variables were recorded daily: peduncle base browning, spadix browning/necrosis, spathe floppiness, spathe browning/necrosis, spathe discoloration, and loss of lustre/glossiness in the spathes. The experiment was continued for 70 d until all the cultivars began to show signs of spathe or spadix deterioration.

The vase life experiment was repeated using 16 of the 17 cultivars (except ‘Spirit’) used in Trial 1 under similar laboratory conditions (Trial 2). The experiment was arranged in a completely randomized design with three replications with three cut flowers per replicate. Vase life determination was done as before. The stomatal densities in the adaxial and abaxial surfaces were measured as previously described. Vase life was determined for an independent set of nine cultivars under similar conditions as before (Trial 3). The experimental design and data collection were the same as for Trial 2.

Data analysis. One-way analysis of variance was conducted (NCSS, 2001) to determine the significance of cultivar differences for the morphophysiological characteristics studied in Trial 1 and vase life as determined by the time taken to deterioration. The association between morphophysiological characteristics and vase life was assessed using Pearson’s product moment correlation (NCSS, 2001). Multiple regression analysis (NCSS, 2001) and forward and backward model selections were performed to identify a minimal subset of characteristics that best predicted vase life and time to spadix necrosis. For these purposes, spathe color was coded as follows: red/not red, orange/not orange, white/not white, and green/not green as described by Kamemoto et al. (1988). Boolean numbers 0 (absence of color) and 1 (presence of color) were used to describe categories.

Pearson’s product moment correlations (NCSS, 2001) were carried out in Trial 2 to determine the association between the morphophysiological characteristics measured. Comparison of regression lines (COLR program, Version 1, 1974; CARDI, 1974) between average vase life and vase life in Trial 1 or Trial 2 was performed to determine the stability of vase life over trials. The same was done for abaxial stomatal density, time to spadix, and spathe necrosis.

The regression equations developed in Trial 1 to predict vase life and time to spadix necrosis were validated in Trial 2 using the same set of 16 cultivars and in Trial 3 using a different set of nine cultivars.

Results

Cultivar differences in cut flower morphophysiology. There were significant cultivar differences (P < 0.05) for all characteristics except adaxial spathe hydathode density (Table 1). Cultivar differences for adaxial and abaxial stomatal density as well as abaxial hydathode density were particularly large as indicated by their large genotypic coefficient of variation (38% to 108%).

Abaxial stomatal density ranged from 1.8 per mm⁻² (‘Fla Range’) to 25.7 per mm⁻² (‘Evergreen’) with a mean of 6.2 per mm⁻². Adaxial stomata were generally very low in number or absent in the cultivars studied. Area of stomatal openings showed a twofold variation (209 μm² in ‘Midori’ to 442 μm² in ‘Success’; mean, 331 μm²).

The abaxial stomatal densities were on average 60-fold higher than abaxial hydathode densities and varied between 1.8 in ‘Fla Range’ to 25.7 per mm⁻² in ‘Evergreen’. Adaxial hydathode densities were very small with 53% of cultivars having no adaxial hydathodes. The large difference for hydathode density supports the uneven distribution noted in observations under the microscope.

Spathe epicuticular wax content showed a 3.5-fold variation among cultivars, from 50 mg·m⁻² in ‘Spirit’ to 170 mg·m⁻² in ‘Mirjam’.

The spathe size varied from 190 cm⁻² in cultivar ‘Fla Range’ to 804 cm⁻² in ‘Evergreen’; whereas spadix length varied from 53 mm in ‘Mirjam’ to 84 mm in ‘Cuba’ with a general mean of 69.5 mm. ‘Spirit’ and ‘Acorpolis’ had the narrowest spadix (8 mm), whereas ‘Terra’ and ‘Evergreen’ had the widest.

‘Evergreen’ had the widest peduncle diameter, whereas the cultivar ‘Acorpolis’ had the narrowest. ‘Acorpolis’ also had the shortest peduncle, whereas ‘Local Pink’ had the longest.

Cut flower senescence. There were highly significant (P < 0.001) differences in vase life among cultivars, varying from 14 to 49 d (Table 2). ‘Evergreen’, ‘Spirit’, and ‘Venus’ had short vase lives (14 to 15 d), whereas ‘Cuba’ and ‘Honduras’ had extremely long vase-lives (greater than 45 d).

Vase life was determined by the time to first evidence of cut flower deterioration. Some signs of deterioration such as peduncle base browning and spadix necrosis were common to all cultivars, whereas others (spathe floppiness, loss of lustre, and discoloration) were specific to only certain cultivars. Spathe necrosis was evident in all cultivars except ‘Cuba’.

Photo bleaching/lightening and blueing were the most common forms of spathe discoloration with blueing being evident in all red-spattered cultivars.

Peduncle base browning was the first sign of senescence and occurred between 8 and 15 d in the various cultivars with approximately half showing browning in 8 to 10 d.
This was usually followed by spadix necrosis in all cultivars, although some cultivars (e.g., ‘Spirit’, ‘Venus’, and ‘Evergreen’) showed spathe floppiness or loss of lustre a few days earlier. Spadix necrosis was often followed by spathe discoloration and necrosis. The time course for these senescence symptoms, however, varied with the cultivars.

Although there were significant differences \( P < 0.001 \) between cultivars for peduncle base browning, this did not correlate significantly with vase life. Spadix necrosis was the first symptom of deterioration on the showy part of the cut flower in all but three cultivars. Even in these three cultivars, the other signs of deterioration were earlier than spadix necrosis by only a few days and were not larger than the least significant difference \( (LSD_{0.05}) \) for vase life data. As a result, days to spadix necrosis were highly correlated \( (r = 0.98; \quad P < 0.001; \quad df = 16) \) to vase life determined by a combined criterion to measure vase life of anthurium. **Morphophysiological characteristics associated with vase life.** Correlations between vase life and morphophysiological parameters (Table 3) of cut flower investigated were not significant \( (P > 0.05) \). However, there was a strong, significant, and
positive correlation coefficient ($P \leq 0.01$) between abaxial stomatal density and abaxial hydathode density ($r = 0.73$) and between abaxial stomatal density and spathe surface area ($r = 0.74$) (Table 3). Cultivars with larger abaxial stomatal density also tended to have smaller spathe thicknesses ($r = -0.59$; $P < 0.05$) and shorter peduncle lengths ($r = -0.57$; $P < 0.05$). There was a significant positive correlation ($P \leq 0.05$) between spathe surface area and peduncle diameter ($r = 0.55$) and a significant ($P < 0.05$) negative correlation between spathe surface area and spathe thickness ($r = -0.56$).

Nevertheless, a stepwise multiple regression analysis on the dependence of vase life on morphophysiological characteristics showed that the smallest subset that best predicted vase life was given by the following equation:

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\text{Vase-life (days)} = 29.1 - 1.99(\text{abaxial stomatal density}) + 18.3(\text{green/not green}) + 18.5(\text{white/not white}).
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(R$^2 = 0.802$; $P < 0.001$; Fig. 1).

**Discussion**

The postharvest life of anthurium cut flowers is usually determined by the onset of one of a number of senescence symptoms: loss of spathe glossiness, bluing of spathe, spatix dehydration and necrosis, spathe wilting, browning of the peduncle base, or...
Peduncle base browning was the first senescence symptom to appear in anthurium cultivars, but it neither discriminated between the cultivars nor correlated with time to onset of spathe or spadix symptoms, and therefore was not considered a good measure of vase life. Spadix necrosis was usually the second symptom (14 to 49 d after initiation) to appear in anthurium cut flowers. This, apart from being discriminatory, correlated very well with vase life, the onset of spathe necrosis, and spadix discoloration, which, however, were either delayed in a cultivar-specific manner or did not occur at all. Importantly, the vase life of 82% of the cultivars was ended because of spadix necrosis.

The study demonstrated that time to spadix necrosis was the best measure of vase life in anthurium cut flowers for several reasons. It was the earliest occurring senescence symptom that is common to all anthurium cultivars and was highly correlated to all other important senescence symptoms. Furthermore, the study demonstrated that vase life determined by a more complex criterion correlated well with vase life determined by spadix necrosis and had a similar error estimate. It is recommended that vase life should therefore be based on the first sign of spadix necrosis.

Although vase life and time to spadix necrosis were found to be affected by the season, the relative ranking of cultivars was similar as indicated by the joint regression analysis. The study also showed that changes in vase life of cultivars over season were mediated through changes in stomatal density.

Of the 12 morphophysiological characteristics studied, only abaxial stomatal density and spathe color explained variation in vase life among the cultivars tested. The vase life prediction equation suggested that cultivars with a lower number of abaxial stomatal density and with green or white spathes were able to prolong their vase life. The prediction equation suggests that the relationship between stomatal density and vase life varied depending on whether the spathes had a color (red/orange) or not (white/greens). The prediction equation developed for vase life based on stomatal density, green/not green, and white/not white was robust and was able to predict vase life over trials (conducted in two different seasons) as well as in a different set of cultivars. The robustness of the equation suggests that it can be used in a wide range of situations for cultivars grown under standard management conditions.

The senescence rate of cut flowers is affected by many metabolic processes, the most studied being those related to carbohydrate metabolism, water relations, cell membrane properties, and ethylene production and sensitivity (Borochov and Woodson, 1989; Halevy and Mayak, 1979, 1981; Shvarts et al., 1997). Spathe color in anthurium is the result of carotenoids such as chlorophyll or colored flavonoids (anthocyanins) (Iwata

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**Table 4.** Abaxial stomatal density, time to spadix necrosis, spathe necrosis, and vase life of 16 *Anthurium andraeanum* (Hort.) cultivars evaluated in Trial 2.

| Cultivar   | Spathe abaxial stomatal number (mm⁻²) | Days to necrosis | Vase life (days) |
|------------|---------------------------------------|------------------|-----------------|
| Acropolis  | 14.6                                  | 16               | 16              |
| Cuba       | 2.6                                   | 41.4             | 41              |
| Evergreen  | 24.5                                  | 21.4             | 21              |
| Fantasia   | 16.2                                  | 14.2             | 14.2            |
| Flora      | 2.8                                   | 22               | 22              |
| Honduras   | 4.2                                   | 37.6             | 37.7            |
| Local Pink | 2.5                                   | 21               | 21              |
| Lydia      | 4.3                                   | 15.3             | 15              |
| Midori     | 6.2                                   | 48.7             | 48.7            |
| Mirjam     | 6.9                                   | 15               | 15              |
| Pierrot    | 6.5                                   | 34.3             | 34.3            |
| Success    | 5.6                                   | 19               | 19              |
| Tequila    | 11.2                                  | 21.5             | 21.5            |
| Terra      | 6.6                                   | 30               | 30              |
| Tropical   | 6.2                                   | 14.3             | 14              |
| Venus      | 5.6                                   | 20.3             | 18              |

| Significance (P ≤) | Mean | SEM | LSD (0.05) | Genotypic cv (%) |
|--------------------|------|-----|------------|-----------------|
| 0.001              | 7.4  | 0.954| 2.27       | 80.4            |
| 0.001              | 23.1 | 2.339| 5.56       | 44.5            |
| 0.001              | 30.3 | 4.45 | 10.6       | 39.0            |
| 0.001              | 22.8 | 2.26 | 5.37       | 45.6            |

**Fig. 2.** Comparison of actual vase life versus expected vase life based on the prediction equation (developed in Trial 1) for 16 *Anthurium andraeanum* (Hort.) cultivars evaluated in Trial 2. Triangles = red and pink spathe cultivars; squares = orange and coral spathe cultivars; diamond = green spathe cultivars; circle = white spathe cultivars.
Table 5. Abaxial stomatal density, time to spadix necrosis and actual vase life of nine Anthurium andraeanum (Hort.) cultivars evaluated in Trial 3.

| Cultivar        | Abaxial stomatal density (mm⁻²) | Time to spadix necrosis (days) | Vase life (days) |
|-----------------|---------------------------------|-------------------------------|-----------------|
| Champagne       | 11.1                            | 21.0                          | 21              |
| Cheers          | 4.7                             | 15.0                          | 15              |
| Gloria          | 5.0                             | 16.5                          | 16              |
| Ibara           | 18.6                            | 10.0                          | 10              |
| Kalapana        | 20.9                            | 10.0                          | 10              |
| Lunette         | 2.6                             | 19.0                          | 19              |
| Rosa            | 8.3                             | 14.0                          | 14              |
| Senator         | 12.7                            | 18.0                          | 18              |
| Sweety          | 4.7                             | 21.0                          | 21              |
| Significance (P ≤) | 0.001                          | 0.001                         | 0.001           |
| Mean            | 9.83                            | 16.05                         | 16              |
| SEM             | 0.76                            | 0.86                          | 0.86            |
| Least significant difference (₀.₀₁) | 2.39                          | 2.09                          | 2.09            |
| Genotypic coefficient of variation (%) | 66.2                          | 26.6                          | 26.7            |

The prediction equation, presented here, eliminates the need for vase life experiments in selection programs, which require replications (Kamemoto and Kuehnle, 1996) and are time-consuming, requiring up to 3 months. The prediction equation contains terms that are relatively easy to assess. If the stomatal density can be assessed without the clearing solution step, it can further accelerate selection as well as reduce the cost of breeding programs.

The role of abaxial stomatal density in the vase life prediction equation suggests that loss of water from the spathe may contribute to loss of vase life. Cultivars that had a higher stomatal number had a shorter vase life compared with those with lower densities. Furthermore, abaxial stomatal density explained 84% of the variation (based on the vase life regression equation) over trials (cultivar spathe color remained constant over trials). Dufour and Guerin (2003) demonstrated that young cut flowers had more abaxial stomata than mature ones with a corresponding decrease in vase life. Hence, the equation could be applied with the proviso that cut flowers used in vase life assessment be obtained from cultivars grown under similar conditions and harvested using the same harvesting standard.

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The prediction equation does not discriminate reds from pinks and oranges from et al., 1979, 1985) or copigmentation of both carotenoids and flavonoids (Kamemoto and Kuehnle, 1996) as seen in the cultivars ‘Honduras’ and ‘Terra’. The anthocyanin pigments are mainly pelargonidin 3-rutinoside and cyanidin 3-rutinoside and accumulate only in the hypodermal cells of both the upper and lower epidermis of anthurium spathe (Higaki et al., 1984; Watson and Shirakawa, 1967).

The inclusion of green/not green in the prediction equation for vase life may suggest a direct or indirect role for carbohydrates in the senescence process. The green-spathed cultivars performed better in vase life experiments than the reds (as also reported by Guo et al., 2003), oranges, and pinks. The red cultivar ‘Honduras’, which has a green copigmentation, also performed well in vase life experiments. Because the senescence symptoms in anthurium cut flowers are largely the result of water stress, it may well be that carbohydrate status is involved in the regulation of stomatal function. Paull et al. (1985) noted that the water-soluble carbohydrate balance of the anthurium cut flowers remained constant through senescence with only a little change in total sugar content, which led them to conclude that carbohydrate and sugar levels may not influence vase life in anthurium. Their study, however, did not include any green-spathed cultivars. In a subsequent study, Paull et al. (1992), found a strong relationship between preharvest temperature and vase life with higher temperatures resulting in lowered vase life, which suggested a role for carbohydrates. Cut flowers are usually known to last longer if harvested after a protracted period of photosynthesis (Sacalis, 1993).

Similarly, the variable, spathe white/non-white, was important in the prediction of anthurium vase life. The dominant pigments in white cultivars are flavones (Iwata et al., 1985), which have a strong and proven antioxidant capacity (Rice-Evans et al., 1997) and are excellent free radical scavengers. Furthermore, flavones are lipophilic (Gould et al., 2000) and may be involved in maintaining membrane integrity or they may have a role in protection from photo-inhibition (Dodd et al., 1998; Gould et al., 1995).

The red group showed typical blueing of spathe during senescence in this study. Paull et al. (1985) showed that pH increases from 5.2 to 5.6 as spathe blueing begins, which is consistent with the findings of Chaparro de Barrera and Arenas (1999). Paull et al. (1985) also demonstrated that the increase in pH detected in spathe, spadix, and peduncle tissues may be the result of a simultaneous increase in tissue ammonium ion concentration caused by the breakdown of α-amino acids.

Paull et al. (1985) also showed that anthocyanin concentration increases on senescence, which also corresponds to an increase in total phenols. The phenols may account for the browning of spathe seen particularly in the white-spathed cultivars in this study.

The role of abaxial stomatal density in the vase life prediction equation suggests that loss of water from the spathe may contribute to loss of vase life. Cultivars that had a higher stomatal number had a shorter vase life compared with those with lower densities. Furthermore, abaxial stomatal density explained 84% of the variation (based on the vase life regression equation) over trials (cultivar spathe color remained constant over trials). Dufour and Guerin (2003) demonstrated that young cut flowers had more abaxial stomata than mature ones with a corresponding decrease in vase life. Hence, the equation could be applied with the proviso that cut flowers used in vase life assessment be obtained from cultivars grown under similar conditions and harvested using the same harvesting standard.
corals. More importantly, the study shows a minimum acceptable vase life of 3 weeks (Kamemoto and Kuehnle, 1996) can be achieved in all the colors by selecting for lower abaxial stomatal density under standard conditions.

**Literature Cited**

Borochov, A. and W.R. Woodson. 1989. Physiology and biochemistry of flower petal senescence. Hort. Rev. (Amer. Soc. Hort. Sci.) 11:15–43.

CARDI. 1974. COLR programme, version 1. Caribbean Agricultural Research and Development Institute, St. Augustine, Trinidad.

Chaparro de Barrera, A. and G. Arenas. 1999. Cutting-time effect during harvest cycle on post harvest behaviour of three Gypsophila paniculata cv. Perfecta clones. Acta Hort. 148:71–76.

Croat, T.B. 1988. Ecology and life forms of Araceae. Aroideana 11:4–55.

Dai, J. and R.E. Paull. 1990. The role of leaf development on anthurium flower growth. J. Amer. Soc. Hort. Sci. 115:901–905.

Dodd, I.C., C. Critchley, G.S. Woodall, and G.R. Stewart. 1998. Photoinhibition in differently colored juvenile leaves of Syzygium species. J. Expt. Bot. 49:1437–1445.

Dufour, L. and V. Guerin. 2003. Growth, developmental features and flower production of Anthurium andraeanum L. in tropical regions. Scientia Hort. 98:25–35.

Gould, K.S., D.N. Kuhn, D.W. Lee, and S.F. Oberbauer. 1995. Why leaves are sometimes red. Nature 378:241–242.

Gould, K.S., K.R. Markham, R.H. Smith, and J.J. Goris. 2000. Functional role of anthocyanins in the leaves of Quintinia serrata A. Cunn. J. Exp. Bot. 51:1107–1115.

Guo, Z., L. Xiao, Y. Zou, Y. Hong, and R. Wang. 2003. Comparison of fresh-keeping age of different cultivars of Anthurium cut flowers. J. Hunan Agr. Univ. 29:485–487.

Halevy, A.H. and S. Mayak. 1979. Senescence and postharvest physiology of cut flowers Part 1. Hort. Rev. (Amer. Soc. Hort. Sci.) 1:204–236.

Halevy, A.H. and S. Mayak. 1981. Senescence and postharvest physiology of cut flowers Part 2. Hort. Rev. (Amer. Soc. Hort. Sci.) 3:59–143.

Higaki, T., H.P. Rasmusun, and W.J. Carpenter. 1984. A study of some morphological and anatomical aspects of Anthurium andraeanum Lind. University of Hawaii: HITAHR Res. Ser. 030:1–12.

Iwata, R.Y., C.S. Tang, and H. Kamemoto. 1979. Anthocyanins of Anthurium andraeanum Lind. J. Amer. Soc. Hort. Sci. 104:464–466.

Iwata, R.Y., C.S. Tang, and H. Kamemoto. 1985. Concentration of anthocyanins affecting spathe color in anthuriums. J. Amer. Soc. Hort. Sci. 110:383–385.

Johansen, D.A. 1940. Plant microtechnique. McGraw Hill Book Company Inc., London, UK.

Kamemoto, H. 1962. Some factors affecting the keeping quality of anthurium flowers. Hawaii Farm Sci. 11:2–12.

Kamemoto, H., R.Y. Iwata, and M. Marutani. 1988. Genetics of the major spathe colors in anthuriums. HITAHR Res. Ser. 030:1–12.

Kamemoto, H. and A.R. Kuehnle. 1996. Breeding Anthurium andraeanum Lind. Acta Hort. 49:125–134.

Kamemoto, H., R.Y. Iwata, and M. Marutani. 1979. Concentration of anthocyanins affecting spathe color in anthuriums. J. Amer. Soc. Hort. Sci. 104:464–466.

Kamemoto, H. and R. Kuehnle. 1996. Breeding Anthurium andraeanum Lind. Acta Hort. 49:125–134.

Kamemoto, H. and A.R. Kuehnle. 1996. Breeding Anthurium andraeanum. Proc. Amer. Soc. Hort. Sci. 85:642–646.

Kacperski, T., A. Borochov, and D. Weiss. 1997. Low temperature enhances petunia flower pigmentation and induces chalcone synthase gene expression. Acta Physiol. Plant. 99:87–72.

O’Brien, T.P. and M.E. McCully. 1981. The study of plant structure, principles and selected methods. Termarcaphr Pty. Ltd., Melbourne, Australia.

Paull, R.E. 1982. Anthurium (Anthurium andraeanum André) vase life evaluation criteria. Hort. Science 17:666–607.

Paull, R.E., N.J. Chen, and J. Deputy. 1985. Physiological changes associated with senescence of cut anthurium flowers. J. Amer. Soc. Hort. Sci. 110:156–162.

Paull, R.E. and T.T.C. Goo. 1985. Ethylene and water stress in the senescence of cut anthurium flowers. J. Amer. Soc. Hort. Sci. 110:84–88.

Paull, R.E., T. Higaki, and J.S. Imamura. 1992. Season and fertilizer affect the post-harvest flower life of anthurium. Scientia Hort. 49:125–134.

Rice-Evans, C.A., N.J. Miller, and G. Paganga. 1997. Antioxidant properties of phenolic compounds. Trends Plant Sci. 2:152–159.

Sacalis, J.N. 1993. Cut flowers: Prolonging freshness. Ball Publishing, Batavia, IL.

Salinger, J.P. 1975. Criteria for the evaluation of post-harvest senescence of cut flowers. Acta Hort. 41:207–216.

Shirakawa, T., R.D. Edolph, and D.P. Watson. 1985. N-6-Benzyladenine effects on chilling injury, respiration and keeping quality of Anthurium andraeanum. Proc. Amer. Soc. Hort. Sci. 85:642–646.

Shwarts, M., A. Borochov, and D. Weiss. 1997. Low temperature enhances petunia flower pigmentation and induces chalcone synthase gene expression. Acta Physiol. Plant. 99:87–72.

Watson, D.P. and T. Shirakawa. 1967. Gross morphology related to shelf-life of anthurium flowers. Hawaii Farm Sci. 16:1–3.