Vase Life of Imported *Anthurium* Flowers Evaluated in Japan in Relation to the Effects of Postimportation Benzyladenine Treatment

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Abstract. Effects of postimportation treatment of benzyladenine (BA) on vase life of imported anthurium flowers was examined after receiving the flowers in Japan and placing them either individually or together in vase solution. Cut anthuriums of two cultivars imported from Hawaii via air-freight were sprayed with 200 $\mu\text{g}\cdot\text{mL}^{-1}$ of BA upon arrival, and vase life of the flowers were evaluated by numerating days before observing apparent discoloration at the distal end of spadix. BA treatment significantly extended the vase life (by up to 22 d) in two cultivars in most cases during summer, but the effect was inconsistent in each cultivar when the test was done in winter. The effect of BA verified in summer was either nullified or significantly diminished by placing 10 flowers together in vase solution. In these tests, bacteria were isolated more frequently from the scape segments of bunched flowers than those of individual flowers. However, vase life was not affected when the vase solutions were inoculated with *Xanthomonas axonopodis* pv. *dieffenbachiae*. These results indicate that the postimportation BA treatment is mostly effective in extending the vase life of cut anthuriums during summer, but may not be reliable during winter in temperate regions. The preliminary evidence suggests that bacterial growth in vase solution be related to the loss of the effect of BA, but the pathogen of bacterial blight growing in the vase solution or invading the xylem of the scape is not responsible for the reduced longevity of imported anthuriums.

Anthurium is the major ornamental product in Hawaii. For its long-lasting flowers, the main focus of the local anthurium industry was to expand the market for the cut flowers in the mainland (Shehata, 1995) and Japan (Kogure, 1994). To ensure the best quality of the products in this scheme, the flowers need to endure tough conditions during air-freight and still have long vase life when displayed at the local retailer. Thus, treatments for extending the longevity of cut anthuriums are needed to maintain and improve their qualities after receiving the flowers from Hawaii.

Various methods of delaying senescence of cut flowers have been reported for a variety of plants, e.g., application of exogenous cytokinin (Nooden and Leopold, 1988; Van Staden et al., 1990) or CaCl_2 (Gerasopoulos and Chebli, 1999), treating cut flowers with ethylene inhibitors such as aminoethoxyvinyl-glucine and aminooxyacetic acid (Salisbury and Ross, 1992), or addition of sucrose in vase water (Huang and Chen, 2002; Ichimura and Hisamatsu, 1999). For anthuriums, a study done in Hawaii (Paul and Chantrachit, 2001) has shown that benzyladenine (BA) applied as a dip

or spray was effective in delaying senescence of cut flowers and increased the vase life by 1.4 to 3.2 fold (up to 51 d) in most cultivars. However, as for cut anthuriums shipped to the temperate regions, the effect of BA needs to be examined also at winter indoor temperatures and by using the flowers actually sent by air-freight to verify the results with those treated at the place where they are harvested. In an earlier study, cut anthuriums briefly dipped in a BA solution after 30-h shipping from Hawaii to Michigan showed only a marginal increase in vase life (Shirakawa et al., 1964), suggesting that postshipping BA treatment be ineffective or the effect of BA could be affected by the conditions involved in shipping.

The objectives of this study were to examine the responses of imported cut anthuriums to postimportation BA treatment during summer and winter in Japan to evaluate seasonal and climatological influences on the effect of BA on the vase life. Vase life was evaluated for individual flowers as well as those placed together in a vase, since the flowers are usually placed together in vase water when displayed at the retailer. The responses of the flowers to treatment with CaCl_2 were also examined in order to verify the precision of the results over time. Since CaCl_2 is expected to affect cut anthuriums differently from BA as judged by its effects on cut gerberas (Gerasopoulos and Chebli, 1999), it was used as the additional control to identify unexpected changes in

physiological conditions of cut anthuriums during shipment or in different seasons. The study also presents preliminary evidence suggesting that bacterial growth was related to the vase life of bunched anthuriums.

Materials and Methods

Anthurium flowers. Cut anthurium flowers of ‘Tropic Fire’ (red, tulip-type spathe) and ‘Red Leilani’ (red, heart-shaped spathe), with spathe in about 10 cm-diameter and 40-cm-long scape attached, were directly imported from Green Point Nurseries in Hilo, Hawaii by air-freight. The flowers were not treated with any chemicals at the nursery before shipping, and delivered to the laboratory in a double-layered cardboard box with moistened paper sheets filled inside the inner box to maintain humidity during shipment. The flowers were used for the tests within 5 to 7 d after being shipped out of the nursery, and stored above 15 °C in the laboratory until use.

Room condition. An enclosed room partition (150 × 120 cm, 90 cm in height) was constructed in the laboratory to provide a constant illumination and minimize fluctuation of temperature during evaluation of vase life of the flowers. The top and four sides of the room partition were enclosed with Styrofoam boards (9 or 18 mm thick), and each inner surface of which were pasted with a high light-reflecting white polyethylene film (Tyvek, DuPont, Maruwa Biochemicals Corp., Tokyo, Japan) to equalize the light condition inside the partition. Two 20-W fluorescent lamps were installed at the top of the room partition, and the area was illuminated for 14 h every day. When lighted up, the light intensity measured with a quantum sensor was 8.1 to 10.0 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPFD at the center of the partition unit and 6.7 to 10.0 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPFD at the corners. In each season, moderate cooling or heating was applied in the laboratory room in order to simulate average indoor environment in summer or winter. Temperature and relative humidity (RH) inside the room partition were monitored hourly using an automated thermo-recorder (RS-11, Espec Mic Corp., Aichi, Japan).

Summer tests. The first experiment was done in Summer 2001. Soon after removing the flowers from the shipping box, the proximal ends of the scapes were cut off in water to leave 30-cm portions of the scapes. Flowers showing any damages on their spathe and spadix were discarded. Then, a set of 10 flowers each of ‘Tropic Fire’ and ‘Red Leilani’ was sprayed with a solution of N^6 -benzyladenine (Kanto Kagaku, Tokyo, Japan) prepared with distilled water at 200 $\mu\text{g}\cdot\text{mL}^{-1}$ until water droplets run off from the spathe and spadix. Nontreated flowers were sprayed with distilled water. Another set of 10 flowers each of two cultivars was soaked in a 1.0% solution of CaCl_2 prepared with tap water for 1 h, and the flowers for the control to this treatment were soaked in tap water. After water droplets retained on the scape were wiped off, all flowers were placed individually in test tubes (17.5 × 1.2 cm) filled with 20 mL of vase solution containing 1.0% sucrose, 50 $\mu\text{g}\cdot\text{mL}^{-1}$ silver nitrate, 50 $\mu\text{g}\cdot\text{mL}^{-1}$ citric acid,

We thank the Gene Bank of Ministry of Agriculture, Fisheries, and Forestry for providing us with the strains of *X. campestris* pv. *dieffenbachiae* and the National Institute of Agrobiological Sciences for assisting us in using the Biolog MacroStation System.
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and 4 $\mu\text{g}\cdot\text{mL}^{-1}$ sodium hypochlorite. Then the openings of the tubes were sealed with parafilm to avoid excessive loss of vase solution by evaporation, and the tubes were installed in test tube racks randomly placed inside the room partition. Meantime, a separate set of 10 flowers each of two cultivars was treated with BA as described above, but these 10 flowers were placed together in 300-mL erlenmeyer flask filled with 200 mL of the same vase solution. Additional sets of 10 nontreated flowers were prepared similarly and placed together in the flask. The openings of the flasks for these flowers were not sealed. In all cases, vase solution was filled up approximately to the initial level when the remaining volume of the solution decreased to about one fourth of the original volume. Every 2 to 3 d, the flowers were observed visually for any visible discoloration in the spadix, and all flowers were repositioned randomly inside the room partition. Vase life of the flowers was evaluated by numerating days before >10% portions of the spadix were discolored in black or dark brown at its distal end.

At the end of the experiment (51 d after treatment), bacteria were recovered from the flowers to determine the extent of bacterial colonization inside the scapes. All flowers were removed from the vase solution, surface sterilized by soaking their scapes in 5% commercial bleach and wiping off with 70% ethanol, and the individual scapes were sectioned into 1-cm segments from the distal to proximal end using a disinfested blade on a disinfested cutting board. The sectioned scape segments then were sequentially stamped (proximal end down) on the surface of a plate of BGT medium (Saile et al., 1997). The plates were incubated for 3 to 5 d at 28 °C to detect colonies of bacteria growing at the respective positions on each plate.

The experiment was repeated in Summer 2002. In the second series of summer experiments, the effects of BA and CaCl_2 on vase life of the flowers were examined as described previously using the same two cultivars. For the test to examine the effect of bunching the

flowers, additional sets of BA-treated and nontreated flowers placed individually in the tubes were prepared without sealing the openings of the tubes to equalize the conditions between individual flowers and those put together in the vase solution. Both experiments were done with 10 replications for each treatment and cultivar.

The experiment to determine the extent of bacterial colonization inside the scapes also was repeated in Summer 2002 using cut flowers of 'Tropic Fire'. Additional sets of BA-treated and nontreated flowers placed individually in the tubes or together in the flask were prepared separately, since the flowers were to be sectioned before the end of the vase life to examine the extent of bacterial colonization inside the scapes during the earlier stages. Bacteria growing inside the scapes were detected 4 and 6 weeks after treatment as described previously. The experiment was done with 10 replications for each treatment in each time.

Winter tests. The effects of BA and CaCl_2 on vase life of the flowers were examined twice, once in Winter 2001–02 and once in Winter 2003, using the same two cultivars by the method described previously. The openings of the tubes were sealed with parafilm in these two experiments, each of which was done with 10 replications for each treatment and cultivar.

Inoculation of bacterial strains into the vase solution. A test was made to determine if *Xanthomonas campestris* pv. *dieffenbachiae* (McCulloch and Pirone 1939) Dye (*X. axonopodis* pv. *dieffenbachiae* [Vauterin et al., 1995]), the causal agent of bacterial blight of anthuriums, growing and spreading in the vase solution and subsequently invading the xylem of the scape was responsible for shortening the vase life of the flowers. Three strains of *X. campestris* pv. *dieffenbachiae*, MAFF301636 to 301638, were obtained from Gene Bank of Ministry of Agriculture, Fisheries and Forestry in Japan. These strains were grown individually on agar plates of peptone-dextrose medium (1.0% peptone, 0.5% glucose, and 1.7% agar in distilled water) for 2 d at 28 °C, and the

cells of each strain were suspended in distilled water. Cell density in each cell suspension (turbidity) was adjusted to about 10^9 colony forming units/mL using McFarland nephelometer (Lennette, 1985). The cell suspensions of three strains were mixed in equal volumes, and 20 μL each of the mixture was inoculated to 20 mL of vase solution or the same vase solution prepared without adding sucrose in test tubes. Inoculation of bacteria to vase solution was also made with three strains isolated from the vase solutions (strains UXC99 and UXC113) or the scape segment (UXC143E) of different flowers in the previous experiment. The colonies of these three strains grown on TZC (Norman and Alvarez, 1989) and YDC (Wilson et al., 1967) media were typical of those of *Xanthomonas* spp. These three strains of bacteria were inoculated to the vase solutions as described above, and the control tubes (nontreated) were not inoculated with any bacterial strains. The flowers of 'Tropic Fire' were prepared by cutting off their scapes to leave the 30-cm portions as described previously and wiping the scapes with 70% ethanol. The flowers then were placed individually in the tubes, and the openings of which were sealed with parafilm. The experiment was done in Summer 2002 with 10 replications for each treatment and vase solution, and vase life of the flowers was evaluated as described above.

Identification of unidentified bacterial strains. The three unidentified bacterial strains used in the inoculation test were identified to the genus level by the standard bacteriological tests (Schaad et al., 2001). The identities of the strains were further examined by Biolog MicroStation system (Biolog Inc., Hayward, CA) with the database of MicroLog3 (release 3.50) using the standard BUGM medium containing 5% sheep blood.

Statistical analysis. All experiments were conducted in complete randomized design. Data were analyzed by two-way analysis of variance (ANOVA) to examine the effects of the main treatment and subtreatment (cultivar, time, or type of vase solution), and their interactions. Means were separated by

Table 1. Weekly mean temperature and relative humidity (RH) during two summer and two winter experiments.²

Week	Summer 2001 ¹		Summer 2002 ²		Winter 2001–02 ³		Winter 2003 ⁴	
	Temp (°C)	RH (%)	Temp (°C)	RH (%)	Temp (°C)	RH (%)	Temp (°C)	RH (%)
1	27.2 ± 1.3	52.4 ± 13.1	27.5 ± 1.1	52.2 ± 10.7	17.8 ± 2.3	36.8 ± 5.2	17.9 ± 1.8	26.5 ± 4.4
2	27.3 ± 1.1	53.0 ± 9.3	27.7 ± 1.1	48.0 ± 6.6	18.4 ± 2.5	30.3 ± 7.8	16.2 ± 1.6	24.5 ± 5.7
3	26.6 ± 1.4	52.3 ± 9.0	28.6 ± 0.8	54.3 ± 8.3	16.0 ± 2.3	30.3 ± 4.6	16.6 ± 1.6	22.9 ± 2.9
4	26.3 ± 1.1	66.8 ± 9.6	28.9 ± 1.1	50.3 ± 10.1	15.0 ± 2.1	32.0 ± 3.3	18.4 ± 1.6	27.9 ± 7.2
5	26.9 ± 1.1	55.7 ± 9.3	27.8 ± 0.9	51.5 ± 10.5	13.2 ± 2.2	34.5 ± 4.5	17.7 ± 1.5	25.3 ± 4.4
6	26.9 ± 1.7	61.8 ± 10.6	27.3 ± 0.9	54.0 ± 9.2	16.1 ± 2.0	36.7 ± 7.0	17.7 ± 1.6	27.8 ± 5.0
7	26.5 ± 0.8	57.2 ± 8.5	28.1 ± 1.0	46.3 ± 7.1	---	---	17.9 ± 1.4	24.3 ± 5.7
8	25.9 ± 0.8	58.3 ± 4.8	27.0 ± 0.8	54.8 ± 9.9	---	---	17.6 ± 1.6	23.7 ± 6.0
9	---	---	25.9 ± 0.9	55.5 ± 7.5	---	---	18.0 ± 1.5	27.5 ± 5.7
10	---	---	25.8 ± 1.3	48.6 ± 7.6	---	---	20.4 ± 2.6	39.6 ± 7.9
11	---	---	24.9 ± 1.5	60.7 ± 10.0	---	---	---	---
12	---	---	25.2 ± 1.0	53.6 ± 7.1	---	---	---	---
Ave.	26.7	57.2	27.1	52.5	16.1	33.4	17.8	27.0

²Room temperature and relative humidity were recorded hourly, and the weekly mean values were calculated with the hourly data. The mean value is expressed with a range of one standard deviation.

¹Week 1 started on 17 July 2001.

²Week 1 started on 18 July 2002.

³Week 1 started on 6 Dec. 2001.

⁴Week 1 started on 17 Jan. 2003.

⁵Data were not recorded after the experiment was completed.

protected Fisher's least significant difference (LSD) test.

Results

Temperature and RH during the tests. The data recorded during the two summer and two winter tests revealed that temperature was maintained fairly constantly during each test period (Table 1). In average, the weekly mean temperatures during two summer periods were about 10 °C higher than those during two winter periods, and the weekly mean values for RH during two summers were about 20% to 30% higher than the values during two winter periods.

Effects of BA and CaCl₂ treatments in summer. BA treated to individual flowers significantly extended the vase life of the flowers of two anthurium cultivars in most cases except for 'Red Leilani' in the second summer. For 'Tropic Fire', BA treatment significantly extended the vase life consistently in two summer periods regardless of sealing of the test tubes: the vase life was extended by 11.5 d in Summer 2001 (Table 2) and by 14.7 or 22.2 d in Summer 2002 (Table 3). The vase life of 'Red Leilani' also was extended by 13.9 d in Summer 2001 (Table 2) and 16.8 d in the test examining the effect of bunching flowers in Summer 2002 (Table 3). The vase life of 'Red Leilani' also increased from 37.3 to 43.0 d in the other test done in Summer 2002, but the difference was not significant.

This effect of BA on cut anthuriums, however, was nullified or diminished by placing 10 flowers together in the vase solution. In the first test, bunching treatment on BA-treated flowers reduced the average vase life in two cultivars to 42.2 d, the value that was not significantly different from that for nontreated individual flowers (Table 2). In the second test in Summer 2002, the average vase life of BA-treated flowers in two cultivars were also reduced from 47.5 to 40.5 d by bunching the flowers (Table 3). Bunching treatment on nontreated flowers did not have any effects on the vase life in both cultivars in both tests. No significant effects by soaking in water or CaCl₂ solution were observed in any cases (Tables 2 and 3).

Effects of BA and CaCl₂ treatments in winter. Unlike the results obtained during two summer periods, the effect of BA treatment during winter on extension of the vase life was rather inconsistent in each year and cultivar (Table 4). In the first winter test, the significant effect of BA treatment was evident only in 'Tropic Fire', extending its vase life by 7.9 d as compared with that for the nontreated flowers (38.4 d). The vase life of 'Red Leilani' flowers ranged from 40.0 to 43.7 d for all treatments in this test. In contrast, the significant effect of BA treatment was only evident in 'Red Leilani' in the second winter test, extending its vase life by 29.7 d as compared with that for the nontreated flowers (25.3 d). In this test, the vase life of BA-treated or nontreated flowers of 'Tropic Fire' was as long as 66.0 or 67.4 d, and was longer by >15 d than that for the flowers soaked in water or CaCl₂ solution. In both tests, soaking in CaCl₂ solution

had no significant effects on the vase life in both cultivars.

Extent of bacterial invasion into the scape. In the test done in Summer 2001, the number

of scape segments from which bacteria were isolated was significantly greater in the flowers placed together in vase solution than the individual flowers regardless of BA treatment

Table 2. Effects of BA and CaCl₂ treatments and bunching the flowers on vase life of cut anthuriums in the first summer test.^z

Treatment	Vase life (d) ^y		
	Tropic Fire	Red Leilani	Avg
Nontreated/individual flowers	40.0	37.2	38.6 ab
Nontreated/in a bunch	32.0	38.3	35.2 a
Sprayed with BA/individual	51.5	51.1	51.3 c
Sprayed with BA/in a bunch	39.6	44.7	42.2 b
Soaked in water	39.6	43.8	41.7 b
Soaked in CaCl ₂ solution	38.9	38.6	38.8 ab

^zStarted in week 1, 2001.

^yThe values were means of 10 replications. Based on two-way (treatment by cultivar) ANOVA, the main treatment effect was significant ($P < 0.01$), but the effects of cultivar and the treatment by cultivar interaction were not significant. The values for the average indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Table 3. Effects of BA and CaCl₂ treatments and bunching the flowers on vase life of cut anthuriums in the second summer test.^z

Treatment	Vase life (d) ^y		
	Tropic Fire	Red Leilani	Avg
Nontreated	32.8 a ^y	37.3 ab	---
Sprayed with BA	55.0 c	43.0 b	---
Soaked in water	37.6 ab	41.2 ab	---
Soaked in CaCl ₂ solution	37.3 ab	38.5 ab	---
Nontreated			
Individual flowers	30.4	33.1	31.8 A ^x
10 flowers in a bunch	28.0	29.8	28.9 A
Sprayed with BA			
Individual flowers	45.1	49.9	47.5 C
10 flowers in a bunch	40.9	40.0	40.5 B

^zStarted in week 1, 2002.

^yThe values were means of 10 replications. Based on two-way (treatment by cultivar) ANOVA, the main treatment effect and the treatment by cultivar interaction were significant ($P < 0.05$). The means indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

^xBased on two-way (treatment by cultivar) ANOVA, the main treatment effect was significant ($P < 0.01$) but the effect by cultivar and the treatment by cultivar interaction were not significant. The means of the average indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Table 4. Effects of BA and CaCl₂ treatments on vase life of cut anthuriums in two winter tests.^z

Treatment	Vase life (d) ^y			
	Winter 2001–02		Winter 2003	
	Tropic Fire	Red Leilani	Tropic Fire	Red Leilani
Nontreated	38.4 ab	42.1 bcd	66.0 c	25.3 a
Sprayed with BA	46.3 d	43.7 cd	67.4 c	55.0 b
Soaked in water	35.7 a	41.2 bc	51.8 b	28.3 a
Soaked in CaCl ₂ solution	36.0 a	40.0 abc	48.1 b	27.1 a

^zStarted in week 1 in the respective years.

^yThe values were means of 10 replications. The effects of treatment and cultivar and their interaction were all significant ($P < 0.01$) for the first experiment, and the effects of treatment and cultivar were significant ($P < 0.05$) with no significant interaction for the second experiment. The means for each experiment indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Table 5. The extent of invasion by saprophytic bacteria into the scape of cut anthuriums of two cultivars when sprayed with BA and/or placed together in a base.^z

Treatment	No. of scape segments colonized by saprophytic bacteria ^y	
	Tropic Fire	Red Leilani
Nontreated/individual	4.9 a	13.2 b
Nontreated/in a bunch	19.3 c	29.8 d
Sprayed with BA/individual	2.3 a	13.8 bc
Sprayed with BA/in a bunch	17.7 bc	40.0 e

^zStarted in week 1, Summer 2001. Isolation of bacteria from the scape segments was made at the end of summer experiment (after 51 d of incubation) in 2001.

^yThe values were means of 10 replications. Based on two-way (treatment by cultivar) ANOVA, the effects of treatment and cultivar and their interaction were all significant ($P < 0.01$). The means indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

(Table 5). This significant trend was evident in both cultivars, but the overall frequency of recovering bacteria from scape segments was consistently greater for 'Red Leilani' than 'Tropic Fire'. The same tendency was observed in the second summer test when the extent of bacterial invasion into the scape of 'Tropic Fire' flowers was reexamined during the early stage of vase life. The number of scape segments containing bacteria was greater in the bunched flowers than the individual flowers regardless of BA treatment at both times of sectioning (Table 6); but the differences were significant only for nontreated flowers.

Identification of bacterial strains by Biolog system. Stains UXC99, UXC113, and UXC143E were identified as *X. campestris* pv. *poinsetticola* (probability = 98%), *X. campestris* pv. *poinsetticola* (probability = 99%), and *X. campestris* pv. *malvacearum* (probability = 100%), respectively.

Effects of bacteria inoculated to the vase solutions on the vase life. Vase life of 'Tropic Fire' flowers was not affected either by addition of sucrose in the vase solution or by inoculations of both mixtures of bacteria into the vase solution (Table 7).

Discussion

BA sprayed to individual cut anthuriums during summer significantly extended the vase life in two cultivars in most cases. The difference by BA treatment in 'Red Leilani' was insignificant in the second summer, but the trend still showed that BA also extended the vase life in this cultivar. Overall, it was confirmed that postimportation BA treatment was effective in delaying senescence of cut anthuriums during summer, despite the treatment was made on the flowers kept in the shipping carton for 5 to 7 d after being packed at the nursery. The previous study (Shirakawa, 1964) demonstrated that cut anthuriums dipped briefly into a solution containing 10 µg·mL⁻¹ of BA after 30-h shipping from Hawaii to Michigan showed only a marginal increase in vase life. In this study, exogenous BA at 200 µg·mL⁻¹ was applied as a spray. It was indicated that the effect by spraying BA was nearly equal to that by dipping, and the maximum increase in vase life was obtained at about 100 µg·mL⁻¹ or above (Paul and Chantrachit, 2001). Thus, it is essential to apply sufficient concentrations of BA to obtain the positive response in treated flowers.

The standard criteria for evaluating the vase life of cut anthuriums were based on visual spadix condition, spathe blueing, and the gloss of spathe (Paul, 1982). In this study, the vase life was evaluated on visual discoloration of

the spadix, since signs of senescence usually appear first on the spadix and also it was difficult to make visible evaluations on spathe blueing and the gloss of spathe consistently over a series of experiments done in different seasons. Nonetheless, our evaluation scheme on the spadix was comparable to the scheme used previously by Paul and Chantrachit (2001): flowers were discarded when they were rated 4 of the spadix senescence index from 1 (no senescence) to 5 (>50% of spadix showing senescence). In this study, BA treatment in summer extended the vase life by 11.5 to 22.2 d, or 1.3- to 1.7-fold, in two cultivars. This is comparable to 1.4- to 2.5-fold increase of vase life (by 13 to 24 d) in most cultivars previously recorded in Hawaii for the flowers held at 22 °C and 70% to 80% RH (Paul and Chantrachit, 2001). These results indicate that BA is effective in delaying senescence in the responsive cultivars whether it is applied before shipping or after unpacking the flowers.

This effect of BA, however, was inconsistent for each cultivar in each year when the same treatment was made during winter. The previous study showed that the effect of BA on extension of vase life depended upon season of harvest and cultivar (Paul and Chantrachit, 2001). Thus, the two studies done in different climatic zones point to the same conclusion. Even without treatment with BA, the vase life of cut anthuriums is affected by temperature in the room where the flowers are placed. It was shown that cut anthuriums held at 14 or 22 °C had a longer vase life than those held at 8 °C (Paul, 1987; Paul and Chantrachit, 2001). In this study, the vase life during winter was not considerably shorter overall than that during summer in both cultivars, indicating that the average temperatures during two winter tests (16.1 and 17.8 °C) were not sufficiently low to affect anthuriums. It was noteworthy, however, the vase life of BA-treated or nontreated flowers of 'Tropical Fire' in the second winter was 66.0 or 67.4 d, the longest longevity ever measured in all experiments, despite the average RH during the experiment was as low as

27%. However, even this is within the seasonal fluctuation of vase life (8 to 69 d) routinely observed in the past (Paul et al., 1992). These results suggest that the fluctuations by season of harvest and cultivar are probably responsible for the inconsistent effects of BA observed during winter.

Treatment with CaCl₂ did not affect the vase life in any cases. Calcium suppresses ethylene production when accumulated in plant tissues, and it was reported the vase life of cut gerberas extended by 3.3 to 5.9 d by injecting 1% CaCl₂ and up to 4.8 d by soaking into the solution (Gerasopoulos and Chebli, 1999). Apparently, such effects of CaCl₂ were not evident in anthuriums in both summer and winter, suggesting senescence of flowers is regulated by other mechanisms in anthuriums. It is noteworthy, however, that the vase life of 'Tropic Fire' flowers soaked in CaCl₂ solution or tap water in the second winter test was significantly shorter than nontreated flowers. The reason for which is not known; but soaking in cold water during winter may have caused undefined physiological changes in flowers of this cultivar.

The effect of BA on extension of vase life observed during summer was nullified or significantly reduced by placing the flowers together in the same vase solution, and bacteria were isolated more frequently from the scape segments of bunched flowers than those of individual flowers. The vase solution contained silver to improve water uptake by the flowers by protecting the cut stem ends (Paul and Chantrachit, 2001). Silver also exhibits oligodynamic action to inhibit microbial growth. Nonetheless, numerous numbers of bacteria were isolated from individual vase solutions or sectioned scape segments. Apparently, silver is not limiting the growth of bacteria in the vase solution and subsequently in the xylem of the scape.

One of the bacterial species that is likely to cause decline in water uptake by the flowers is *X. axonopodis* pv. *dieffenbachiae*, the causal agent of bacterial blight of anthuriums. When

Table 6. The extent of invasion by saprophytic bacteria into the scape of cut anthuriums ('Tropic Fire') when sprayed with BA and/or placed together in a base.^z

Treatment	No. of scape segments colonized by saprophytic bacteria ^y	
	After 4 weeks	After 6 weeks
Nontreated/individual	2.8 a	4.4 ab
Nontreated/in a bunch	5.7 b	8.9 c
Sprayed with BA/individual	3.9 ab	4.4 ab
Sprayed with BA/in a bunch	5.7 b	6.0 b

^zStarted in week 7, Summer 2002.

^yThe values were means of 10 replications. Based on two-way (treatment by time) ANOVA, the effects of treatment and time and their interaction were all significant ($P < 0.01$). The means indicated with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Table 7. Vase life of cut anthuriums ('Tropic Fire') placed in vase solutions inoculated with the bacterial blight pathogens or the related bacteria.^z

Treatment	Vase life (d) ^y	
	In vase solution with 1% sucrose	In vase solution without sucrose
Not inoculated	25.5	25.3
Inoculated with a mixture of 3 strains of <i>Xanthomonas</i> spp.	27.0	23.7
Inoculated with a mixture of 3 strains of <i>X. axonopodis</i> pv. <i>dieffenbachiae</i>	26.0	24.0

^zStarted in week 7, Summer 2002.

^yThe values were means of 10 replications. Based on two-way (treatment by addition of sucrose) ANOVA, both effects were not significant with no significant interaction between the effects.

this pathogen was inoculated to the cut end of the leaf petiole of anthurium plants, the bacterium grew and spread inside the xylem and caused wilting appearance in infected plants by clogging up the xylem (Fukui et al., 1998). The bacterium eventually establishes systemically and kills the plants. In this study, the vase life was not affected when a mixture of three strains of *X. axonopodis* pv. *dieffenbachiae*, or three strains of *Xanthomonas* spp., was inoculated to the vase solution. This indicates at least that the blight pathogen or the related bacteria (most likely pathovars of *X. campestris*) surviving in association with cut anthuriums and subsequently spreading into the xylem of the flowers were not responsible for the reduced vase life observed in bunched flowers. It is noteworthy that bunching the flowers reduced the vase life only in BA-treated flowers but not in nontreated flowers. The precise mechanism of this phenomenon and the involvement of bacteria in loss of the effect of BA deserve further investigations.

Addition of sucrose at 1% in the vase solution did not affect the vase life whether the solution was inoculated with the bacteria or not. It was reported that 4% sucrose in the vase solution significantly extended the vase life of cut *Eustoma* flowers (Huang and Chen, 2002). Addition of sucrose into the vase solution at 2.5% to 10% also significantly increased the vase life of cut snapdragons, and the concentration at 5% was most effective (Ichimura and Hisamatsu, 1999). However, addition of 2% sucrose into the vase solution neither affected the longevity nor the size of postharvest oriental lily (Han, 2003). These results may suggest that 1% sucrose in the vase solution was insufficient to induce measurable responses in long-lasting cut anthuriums. It may be also possible that the bacteria growing in the base solution could have consumed sucrose. The higher concentration of sucrose needs to be tested in relation to the growth of bacteria in the vase solution in order to evaluate its effect on the vase life of cut anthuriums.

This study identified bunching of the

flowers as an additional factor influencing the effect of BA and the vase life in addition to temperature, time of harvest, and cultivar. This factor may be significant since cut anthuriums are commonly placed together in vase water when displayed at the retailer as well as at home. Even at the nursery, cut anthuriums are usually sorted by cultivar in the same water basket after harvest. Moreover, conditions during air-freight can be the additional important factors. According to the representative of Japan Air Cargo, temperature in the cargo compartments of airplanes during flight varies from near 0 to 15 °C depending on the location in the compartment. Although the shipping carton containing cut anthuriums used in this study was double-layered, such low temperatures may have a great impact on anthuriums of cold-sensitive cultivars even when shipped during summer. All together, the results suggest that the vase life of cut anthuriums and the effect of BA can be affected considerably by the conditions in all stages involved in shipment.

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