Photoperiodic Flower Induction of Several *Kalanchoe* Species and Ornamental Characteristics of the Flowering Species

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Abstract. Our objectives in this study were to identify the flowering response of *Kalanchoe* spp. to photoperiodic treatments and characterize flowering and vegetative characteristics of flowering plants. Twenty vegetatively propagated *Kalanchoe* spp. were grown under one of four photoperiodic treatments: 1) short days (SD; 8-h photoperiod) for 16 weeks; 2) night interruption lighting (NI; 2000 to 0200 hr) for 16 weeks; 3) SD for 8 weeks then transferred to NI for 8 weeks; or 4) NI for 8 weeks then transferred to SD for 8 weeks. *Kalanchoe beauvardii*, *K. behariensis*, *K. fedtschenkoi*, *K. longiflora*, *K. marmorata*, *K. marnieriana*, *K. streptantha*, *K. tomentosa*, and *K. vigueridoidi* did not flower under any treatment. *Kalanchoe laetivirens* and *K. rosei* had minimal flowering when exposed to NI followed by SD, whereas *K. pumila* had minimal flowering when exposed to SD followed by NI. *Kalanchoe glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* flowered when exposed to SD for 8 or 16 weeks, and node number below the inflorescence and days to first open flower for these species increased when NI preceded SD. *Kalanchoe millotii* flowered under a 16-week SD treatment only. No plants flowered when grown under only NI. We classified *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* as obligate SD plants. Flower diameter, total flower number, total color index, shoot length, branch number, and leaf length and width varied among species. Based on these ornamental characteristics, we identified *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. uniflora*, and *K. velutina* as potential ornamental flowering potted plants.

The genus *Kalanchoe* includes 139 species indigenous to Madagascar, southern and eastern Africa, and, to a lesser extent, tropical Africa, the Arabian Peninsula, and southeastern Asia (Descoings, 2005; Gherig et al., 2001). One species, *K. blossfeldiana* von Poellnitz, is grown commercially as a flowering potted plant, whereas other species are grown as minor flowering or potted plants (Dole and Wilkins, 2005). *Kalanchoe* spp. are generally amenable to cultivation and propagate readily from stem and leaf cuttings or plantlets produced along leaf margins (Descoings, 2005). Additionally, *Kalanchoe* spp. can vary in flower color, size, number, and inflorescence structure as well as foliage size, shape, and color (C. Currey, personal observation).

Photoperiodic flower induction is a common mechanism for floral induction. Plants

that flower when exposed to SD or long-days (LD) are classified as SD plants (SDP) or LD plants, respectively (Thomas and Vince-Prue, 1997). Dual-daylength plants must be exposed to a specific sequence of photoperiods. For example, long-SD plants (LSDP) must be exposed to LD followed by SD (Thomas and Vince-Prue, 1997). *Kalanchoe* spp. studied have been categorized into two different photoperiodic response groups with respect to flowering: SDP and LSDP. *K. blossfeldiana* and *K. porphyrocalyx* (Baker) Baillon were classified as SDP (Schwabe, 1985; Zimmer, 1985). Zeevaart (1985) classified four *Kalanchoe* spp. as LSDP: *K. daigrimontiana* Hamet & H. Perrier, *K. laxiflora* Baker, *K. pinnata* (Lamarck) Persoon, and *K. prolifera* (Bowie ex Hooker). To produce floriculture crops commercially, requirements for flower induction need to be identified to program flowering (Roh and Lawson, 1998). This study was undertaken to evaluate the potential of additional *Kalanchoe* spp. as new flowering ornamental plants.

Our objectives in this study were to: 1) identify the response of *Kalanchoe* spp. to photoperiodic treatments and classify them into photoperiodic response groups; and 2) characterize flowering and vegetative characteristics of flowering species to select species

that have potential as new ornamental potted or garden plants.

Materials and Methods

Propagation and propagule culture. Stock plants of 20 *Kalanchoe* spp. (Table 1) were started from rooted and unrooted cuttings obtained from two firms. Vegetative stock plants were maintained in a greenhouse with 22 ± 1 °C and 18 ± 1 °C day and night air temperature set points, respectively, under ambient irradiance conditions (St. Paul, MN, 45° N) supplemented with $75 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ photosynthetic photon flux from high-pressure sodium lamps when ambient irradiance was less than $200 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ from 0700 to 0100 hr (18-h photoperiod). Plants were irrigated as necessary with tap water and fertilized once weekly with tap water supplemented with water-soluble fertilizer (Excel 15N-2.2P-12.5K Cal-Mag; The Scotts Co., Marysville, OH) to provide the following at each irrigation (in $\text{mg}\cdot\text{L}^{-1}$): 200 nitrogen, 29 phosphorous, 167 potassium, 67 calcium, 27 magnesium, 1.0 iron, 0.5 manganese and zinc, 0.3 copper and boron, and 0.1 molybdenum. The pH and alkalinity of the tap water was 7.7 and $55 \text{ mg}\cdot\text{L}^{-1}$, respectively.

On 8 Oct. 2008, cuttings of each species were harvested and the lowest set of leaves was removed from the cutting and cuttings were dipped in talc powder containing 1000 ppm indole-3-butyric acid (Hormodin 1; OHP Inc., Mainland, PA) to promote rooting. Cuttings were then placed in soilless high-porosity growing medium (SB500; SunGro Horticulture, Bellevue, WA) in 128-, 72-, or 50-cell plug trays with individual cell volumes of 25, 59, or 111 mL, respectively (Table 1), to accommodate species of different sizes. Air temperature and irradiance were as described previously with a media temperature set point of 21 °C maintained with bottom-heat mats placed beneath the trays. Cuttings were hand-misted daily and irrigated with water only as needed. After 1 week, cuttings were irrigated with tap water as needed and fertilized once weekly as previously described.

After rooting (4 weeks), cuttings were transplanted into 10.2-cm plastic pots (538-mL volume) filled with a high-porosity growing medium (SB500; SunGro Horticulture). Pots were then placed in the same environment in which they were rooted without bottom heat or daily misting. Plants were irrigated with tap water as needed and fertilized once weekly as previously described.

Photoperiodic treatments. Four photoperiodic treatments were selected to elicit flowering responses previously reported for *Kalanchoe* spp. (Schwabe, 1985; Zeevaart, 1985; Zimmer, 1985). Two weeks after transplant, plants were pinched to two nodes and placed under one of the following photoperiod treatments: 1) SD for 16 weeks (achieved by pulling an opaque cloth over the plants at 1600 hr and retracting it at 0800 hr); 2) NI for 16 weeks (natural daylength with $2 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ incandescent lamps from 2000 to 0200 hr; natural daylength varied from 9 h 24 min to 11 h 17 min); 3) SD

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for 8 weeks then transferred to NI for 8 weeks (SD-NI); or 4) NI for 8 weeks then transferred to SD for 8 weeks (NI-SD).

The plants were grown in a glass-glazed greenhouse with an exhaust fan and evaporative-pad cooling and radiant hot-water heating controlled by an environmental computer (Maximizer Precision 10; Priva Computers Inc., Vineland Station, Ontario, Canada). The greenhouse day and night air temperature set points were $22 \pm 1^\circ\text{C}$ and $18 \pm 1^\circ\text{C}$, respectively. Irradiance and air temperature at canopy height were measured with a quantum sensor (Model QSO-SUN; Apogee Instruments Inc., Logan, UT) and thermocouples (Type E Wire chromega/constantan; Omega Engineering Inc., Stamford, CT), respectively, and connected to a data logger (CR10X; Campbell Scientific Inc., Logan, UT), which recorded averages every 10 min. Environmental data are reported in Table 2. Plants were irrigated with tap water as needed and fertilized once weekly as previously described.

Data collection. Data were collected on the date of first flower opening, node number below the terminal inflorescence, terminal inflorescence flower number, axillary inflorescence number, axillary inflorescence flower number, flower diameter of the first open flower, leaf length and width of a fully expanded leaf, and shoot height from the base

of the shoot to the tip of the terminal inflorescence of the first flowering shoot when the first flower was fully opened. Days to first open flower were calculated by subtracting the date of placement of plants into initial treatments from the date of first flower opening. Total flower number was calculated by adding the terminal and axillary inflorescence flower numbers. Total color index was calculated by first calculating the area of the first open flower and then multiplying the individual flower area by total flower number. Data collection on plants that did not flower occurred 16 weeks after plants were placed in treatments. After 16 weeks, those plants with visible buds were allowed to remain in the lighting/photoperiod treatments until first flower opening (exceeding 16 weeks). Percent population flowering was calculated by dividing the number of flowering plants in a treatment by the total number of plants in a treatment at the end of the experiment.

Experimental design and statistical analysis. The experiment was designed in a randomized complete block design in a factorial arrangement and replicated in time three times (1 week apart) with five samples (plants) per treatment per species per replication. Main factors were species (20 levels) and photoperiod (four levels). Analyses of variance and mean separation by Tukey's honestly significant differ-

ence ($P \leq 0.05$) were performed on all data using SPSS 16.0 (SPSS Inc., Chicago, IL). Analysis of percentage data were performed on the arcsine of the square root of percentages (Little and Hills, 1978). Only plants in a treatment with a percentage population flowering significantly greater than zero were analyzed for node number below the inflorescence and days to flower. Only plants flowering under SD were analyzed for ornamental characteristics. There were no differences in environmental, flower induction, and ornamental data between replications so data were pooled.

Results

Flower induction and development. Species and photoperiod interacted to affect percent flowering plants. *K. beauvardii*, *K. behariensis*, *K. fedtschenkoi*, *K. longiflora*, *K. marmorata*, *K. marnieriana*, *K. streptantha*, *K. tomentosa*, and *K. vigueridoidi* did not flower under any treatment (Table 3). Although not significantly different from non-flowering (0%) populations, 9% of *K. pumila* flowered under SD followed by NI, whereas 2% and 25% of *K. laetivirens* and *K. rosei*, respectively, flowered under NI followed by SD. No flowering occurred when *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* were grown under continuous NI. One hundred percent of *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* flowered under continuous SD, SD followed by NI, and NI followed by SD, whereas 61% of *K. millotii* flowered under SD (Table 3).

Node number was affected by species and photoperiod differently. For instance, under SD followed by NI, *K. manginii* and *K. velutina* had seven nodes below the terminal inflorescence, whereas under NI followed by SD node number below the inflorescence was 12 and eight nodes, respectively (Table 4). There were four nodes below the terminal inflorescence of *K. millotii* under SD (Table 4). Node number below the terminal inflorescence of *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* increased when grown under NI preceded by SD compared with plants grown under SD or SD followed by NI and (Table 4).

Species and photoperiod interacted to affect days to first open flower. The days to first open flower of *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* under SD or SD followed by NI were fewer when compared with plants grown under NI followed by SD (Table 5). For example, days to first open flower for *K. laciniata* and *K. velutina* grown under SD were 90 and 91 d, respectively, and increased to 143 and 133 d, respectively, when grown under NI followed by SD (Table 4); *K. millotii* flowered in 107 d when grown under SD (Table 5).

Ornamental characteristics. Among species that flowered, species varied in flower

Table 1. Species used in this study with indigenous distribution, source of original material, and tray size used for propagation identified.

Species	Indigenous distribution ²	Source	Tray size (cell no.)
<i>K. beauvardii</i> Hamet	Madagascar	GW ³	128
<i>K. behariensis</i> Drake	Madagascar	AP	72
<i>K. fedtschenkoi</i> Hamet & H. Perrier	Madagascar	AP	128
<i>K. glaucescens</i> Britten 'Freeling's Sensation'	Central and east Africa, Sudan, Ethiopia, Somalia, Arabian Peninsula	GW	128
<i>K. laciniata</i> (Linné) De Chandolle	Morocco; east, south, and southwest Africa; Arabian Peninsula	GW	72
<i>K. laetivirens</i> Descoings	Madagascar	GW	50
<i>K. longiflora</i> Schlechter ex J. M. Wood	Madagascar, Toliara	AP	128
<i>K. manginii</i> Hamet & H. Perrier	Madagascar	AP	128
<i>K. marmorata</i> Baker	Central and east Africa	AP	128
<i>K. marnieriana</i> H. Jacobsen	Madagascar	AP	128
<i>K. millotii</i> Hamet & H. Perrier	Madagascar	GW	72
<i>K. nyikae</i> Engler	Kenya, Tanzania	AP	50
<i>K. pumila</i> Baker	Madagascar	AP	128
<i>K. rosei</i> Baker	Madagascar	GW	128
<i>K. rotundifolia</i> (Haworth) Haworth	Central and east to south and southwest Africa; Socotra	GW	128
<i>K. streptantha</i> Baker	Madagascar	GW	72
<i>K. tomentosa</i> Baker	Madagascar	AP	128
<i>K. uniflora</i> (Stapf) Hamet	Madagascar	AP	128
<i>K. velutina</i> Welwitsch ex Britten	Angola, Zimbabwe	GW	50
<i>K. vigueri</i> Hamet & H. Perrier	Madagascar	AP	128

²From Descoings, 2005.

³Plant sources were Altman Plants (AP; Vista, CA) or Glasshouse Works (GW; Stewart, OH).

Table 2. Mean day and night air temperature and daily light integral (DLI) for short-day (SD) night interruption (NI), SD followed by NI (SD-NI), and NI followed by SD (NI-SD) photoperiodic treatments.

Treatment	Air temp [mean $\pm$ SD ($^\circ\text{C}$)]		DLI (mol-m ⁻² ·d ⁻¹)
	Day	Night	
SD	23.1 $\pm$ 2.9	19.4 $\pm$ 2.3	4.3
NI	22.6 $\pm$ 2.8	18.9 $\pm$ 1.4	4.8
SD-NI	22.8 $\pm$ 2.7	18.1 $\pm$ 1.6	4.5
NI-SD	22.7 $\pm$ 2.9	18.3 $\pm$ 1.8	4.4

Table 3. The percent population flowering of 20 *Kalanchoe* spp. grown under short-day (SD) for 16 weeks (achieved by pulling an opaque cloth over the plants from 1600 to 0800 HR; 8-h photoperiod), night interruption (NI; 2 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ incandescent light from 2000 to 0200 HR) for 16 weeks, SD for 8 weeks then transferred to NI for 8 weeks (SD-NI), or NI for 8 weeks then transferred to SD for 8 wks (NI-SD)^z.

Species	Percentage population flowering (%)			
	SD	NI	SD-NI	NI-SD
<i>K. beauvardii</i>	0 ^y a ^x A ^w	0 aA	0 aA	0 aA
<i>K. behariensis</i>	0 aA	0 aA	0 aA	0 aA
<i>K. fedtschenkoii</i>	0 aA	0 aA	0 aA	0 aA
<i>K. glaucescens</i>	100 bC	0 aA	100 bD	100 bD
<i>K. laciniata</i>	100 bC	0 aA	100 aD	100 bD
<i>K. laetivirens</i>	0 aA	0 aA	0 aA	2 aAB
<i>K. longiflora</i>	0 aA	0 aA	0 aA	0 aA
<i>K. manginii</i>	100 bC	0 aA	100 bD	100 bD
<i>K. marmorata</i>	0 aA	0 aA	0 aA	0 aA
<i>K. marnieriana</i>	0 aA	0 aA	0 aA	0 aA
<i>K. millotii</i>	61 bB	0 aA	47 abC	47 abC
<i>K. nyikae</i>	100 bC	0 aA	100 bD	100 bD
<i>K. pumila</i>	0 aA	0 aA	9 aB	0 aA
<i>K. rosei</i>	0 aA	0 aA	0 aA	25 aBC
<i>K. rotundifolia</i>	100 bC	0 aA	100 bD	100 bD
<i>K. streptantha</i>	0 aA	0 aA	0 aA	0 aA
<i>K. tomentosa</i>	0 aA	0 aA	0 aA	0 aA
<i>K. uniflora</i>	100 bC	0 aA	100 bD	100 bD
<i>K. velutina</i>	100 bC	0 aA	100 bD	100 bD
<i>K. vigueridii</i>	0 aA	0 aA	0 aA	0 aA
Species	*** ^v			
Photoperiod	***			
Species $\times$ photoperiod	***			

^zAnalysis of percentage data were performed on the arcsine of the square root of percentages (back-transformed data are presented).

^yNumerals represent treatment mean.

^xLower case letters indicate mean separations across photoperiods, within a species, by Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

^wUpper case letters indicate mean separations across species, within a photoperiod, by Tukey's HSD test at $P \leq 0.05$.

^v***Significant at $P \leq 0.001$.

Table 4. Node number below the terminal inflorescence of *K. glaucescens*, *K. laciniata*, *K. laetivirens*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. pumila*, *K. rosei*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* grown under short-day (SD) for 16 weeks (achieved by pulling an opaque cloth over the plants from 1600 to 0800 HR; 8-h photoperiod), night interruption (NI; 2 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ incandescent light from 2000 to 0200 HR) for 16 weeks, SD for 8 weeks then transferred to NI for 8 weeks (SD-NI), or NI for 8 weeks then transferred to SD for 8 weeks (NI-SD).^z

Species	Nodes below the terminal inflorescence (no.)			
	SD	NI	SD-NI	NI-SD
<i>K. glaucescens</i>	6 ^y a ^x BC ^w	(17) ^y	6 aA	14 bDE
<i>K. laciniata</i>	8 aD	(8)	8 aB	13 bCD
<i>K. manginii</i>	6 aB	(13)	7 aA	12 bC
<i>K. millotii</i>	4 A	(6)	(6)	(6)
<i>K. nyikae</i>	7 aC	(6)	8 aB	10 bB
<i>K. rotundifolia</i>	6 aB	(17)	6 aA	16 bF
<i>K. uniflora</i>	6 aB	(15)	6 aA	12 bC
<i>K. velutina</i>	6 aB	(4)	7 aA	8 bA
Species	*** ^u			
Photoperiod	***			
Species $\times$ photoperiod	***			

^zOnly flowering plants were analyzed.

^yNumerals represent treatment mean.

^xLower case letters indicate mean separations across photoperiods, within a species, by Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

^wUpper case letters indicate mean separations across species, within a photoperiod, by Tukey's HSD test at $P \leq 0.05$.

^uNumerals in parentheses represent node number at the end of experiment on plants that did not flower.

^v***Significant at $P \leq 0.001$.

diameter, total flower number, and total color grown under SD. Flower diameter ranged from 8 mm to 28 mm for *K. millotii* and *K. laciniata*, respectively (Table 6). Flower number ranged from 29 flowers to 143 flowers for *K. uniflora* and *K. laetivirens*, respectively (Table 6). The total color index of flowering

species varied from 31 cm² to 364 cm² for *K. glaucescens* and *K. laciniata*, respectively (Table 6).

Vegetative characteristics also varied among species flowering under SD. Shoot length ranged from 12.6 cm to 33.9 cm for *K. uniflora* and *K. nyikae*, respectively (Table 7).

The number of branches varied from 0.0 branches for *K. glaucescens*, *K. millotii*, *K. nyikae*, and *K. rotundifolia* to 0.8 branches for *K. laciniata* (Table 7). Leaf length and width ranged from 4.8 cm and 1.9 cm, respectively, for *K. uniflora* to 14.7 cm and 13.1 cm, respectively, for *K. laciniata* (Table 7).

Discussion

Identifying flower induction requirements of *Kalanchoe* spp. with potential as new ornamental crops is a necessary step in commercialization (Wilkins and Erwin, 1998). In this study, 100% flowering was achieved for eight species, minimal flowering in two species, and no flowering in nine species. *Kalanchoe glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* all flowered when exposed to SD for 8 weeks or longer but did not flower when grown under NI only (Table 3). There was no difference in the number of nodes below the terminal inflorescence (Table 4) or days to first open flower (Table 5) for *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* grown under SD versus SD followed by NI, suggesting plants were induced at the same point in time. However, when NI preceded SD, there was an increase in node number below the terminal inflorescence (Table 4) and days to first open flower (Table 5) on *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* suggesting NI delayed flower induction. *K. millotii* flowered under SD but not NI. Taken together, we conclude that these species can be classified as obligate SDP based on the duration of exposure to different photoperiodic treatments used in this experiment.

The classification of these *Kalanchoe* spp. as SDP agrees with work on other *Kalanchoe* spp., which were classified as SDP (Schwabe, 1985; Zimmer, 1985). However, our classification of *K. velutina* as flowering in response to SD (19.4 °C average night temperature) contradicts results of Sharma (1973) in which flowering of *K. velutina* was induced by a 15.5 °C night temperature, demonstrating plants could be vernalized. It is not uncommon for species to have multiple flowering pathways, as observed in *Arabidopsis thaliana* (L.) Heynh. (Simpson and Dean, 2002).

Heat delay is a common physiological disorder associated with inhibition of photoperiodic flower induction of *K. blossfeldiana*, occurring when night temperatures during SD skotoperiods exceed 27 °C (Pertuit, 1977). The low percentages of *K. laetivirens* and *K. rosei* flowering under the NI followed by SD treatment may be the result of supra-optimal temperatures during NI (18.3 °C). *K. daigremontiana*, a LSDP, flowered under SD at 23 °C when the preceding LD air temperature was 11 to 15 °C but not 19 °C (Zeevaert, 1985). This may indicate a need for cooler temperatures during the LD phase to increase the percentages of *K. laetivirens* and *K. rosei* plants flowering.

Table 5. Days to first open flower of flowering *Kalanchoe glaucescens*, *K. laciniata*, *K. laetivirens*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. pumila*, *K. rosei*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* grown under short-day (SD) for 16 weeks (achieved by pulling an opaque cloth over the plants from 1600 to 0800 HR; 8-h photoperiod), night interruption (NI; 2 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ incandescent light from 2000 to 0200 HR) for 16 weeks, SD for 8 weeks then transferred to NI for 8 weeks (SD-NI), or NI for 8 weeks then transferred to SD for 8 weeks (NI-SD).^z

Species	Days to first open flower (no.)			
	SD	NI	SD-NI	NI-SD
<i>K. glaucescens</i>	74 ^y a ^x B ^w	— ^v	72 aA	116 bA
<i>K. laciniata</i>	94 aE	—	90 aBC	143 bC
<i>K. manginii</i>	87 aC	—	86 aB	132 bC
<i>K. millotii</i>	107 F	—	—	—
<i>K. nyikae</i>	88 aCD	—	88 aBC	134 bB
<i>K. rotundifolia</i>	67 aA	—	67 aA	115 bA
<i>K. uniflora</i>	92 aDE	—	90 aBC	133 bB
<i>K. velutina</i>	91 aCDE	—	90 aC	133 bB
Species	***u			
Photoperiod	***			
Species $\times$ photoperiod	***			

^zOnly flowering plants were analyzed.

^yNumerals represent treatment mean.

^xLower case letters indicate mean separations across photoperiods, within a species, by Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

^wUpper case letters indicate mean separations across species, within a photoperiod, by Tukey's HSD test at $P \leq 0.05$.

^vIndicates plants did not flower.

***Significant at $P \leq 0.001$.

Table 6. Flowering characteristics including flower diameter, total flower number, total color index, flower color and notes of flowering *Kalanchoe glaucescens*, *K. laciniata*, *K. laetivirens*, *K. manginii*, *K. nyikae*, *K. pumila*, *K. rosei*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* grown under short-day for 16 weeks (achieved by pulling an opaque cloth over the plants from 1600 to 0800 HR; 8-h photoperiod).

Species	Flower diam (mm)	Total flower number (no.)	Total color index (cm ²)	Flower color	Notes
<i>K. glaucescens</i>	8 ^z a ^y	58 bc	31 a	Orange	
<i>K. laciniata</i>	28 f	59 bc	364 c	Yellow	
<i>K. manginii</i>	14 c	43 ab	69 a	Red	Pendant flowers
<i>K. millotii</i>	8 a	104 e	58 a	White	Inflated calyces obscure corollas
<i>K. nyikae</i>	23 e	79 cde	353 c	Pink	
<i>K. rotundifolia</i>	11 b	75 cd	75 a	Orange	Pendant flowers
<i>K. uniflora</i>	16 d	29 a	58 a	Salmon	
<i>K. velutina</i>	16 d	100 de	209 b	Orange	
Species	***x	***	***		

^zNumerals represent treatment mean.

^yWithin-column means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

***Significant at $P \leq 0.001$.

Table 7. Vegetative characteristics including shoot height, branch number, leaf length, leaf width, leaf shape of flowering *K. glaucescens*, *K. laciniata*, *K. laetivirens*, *K. manginii*, *K. nyikae*, *K. pumila*, *K. rosei*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* grown under short-day for 16 weeks (achieved by pulling an opaque cloth over the plants from 1600 to 0800 HR; 8-h photoperiod).

Species	Shoot ht (cm)	Branch number (no.)	Leaf length (cm)	Leaf width (cm)	Leaf shape ^z	Notes
<i>K. glaucescens</i>	13.3 ^y a ^x	0.0 a	5.2 a	2.5 ab	Ovate	White margin on leaf
<i>K. laciniata</i>	27.3 c	0.8 b	14.7 c	13.1 e	Dissected	
<i>K. manginii</i>	20.6 b	0.2 ab	5.5 a	3.3 abc	Ovate	
<i>K. millotii</i>	16.9 ab	0.0 a	7.1 a	4.3 bcd	Ovate	Pubescent
<i>K. nyikae</i>	33.9 d	0.0 a	10.9 b	6.1 d	Sub-orbicular	Purple-green leaves
<i>K. rotundifolia</i>	21.5 b	0.0 a	6.2 a	3.3 abc	Oblong	
<i>K. uniflora</i>	12.6 a	0.1 ab	4.8 a	1.9 a	Elliptical	
<i>K. velutina</i>	30.2 d	0.3 b	7.1 a	5.1 cd	Sub-orbicular	Pubescent
Species	***w	***	***	***		

^zFrom Descoings, 2005.

^yNumerals represent treatment mean.

^xWithin-column means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

***Significant at $P \leq 0.001$.

The lack of complete flowering on *K. beauverdii*, *K. behariensis*, *K. fedtschenkoi*, *K. longiflora*, *K. marmorata*, *K. marnieriana*, *K. streptantha*, *K. tomentosa*, and *K. vigeridoid*

may be the result of a suboptimal duration of inductive photoperiods, lack of inductive photoperiods or temperatures, or low irradiance. Although none of these species were

grown from seed, Zeevaart (1985) reported *K. pinnata* and *K. daigremontiana* flowered after 37 leaf pairs and 10 to 15 leaf pairs were present, respectively, suggesting an extended developmental period before flower induction. Regardless of the reason for lack of flowering for these species, the fact that these species do not flower in a 16-week timeframe effectively excludes their commercial potential; commercial potted crops are required to have a relatively short production period under standard greenhouse conditions.

Flower colors observed in this study (Table 6) were consistent with the range in flower color observed in *K. blossfeldiana* cultivars (Descoings, 2005; Leonard and Nell, 2000). Total flower number of any species in this study did not exceed those previously reported for *K. blossfeldiana* (Schwabe, 1985). *K. manginii* and *K. uniflora* flowers had an attractive pendant habit that differs from the inflorescence of *K. blossfeldiana*, whereas *K. millotii* were less attractive because the white corollas were obscured by inflated green calyces. *K. laciniata* and *K. nyikae* produced the most striking display of flowers, mainly as a result of flower size and total color (C. Currey, personal observation).

Shoot length varied widely among the flowering species (Table 7), from short species such as *K. glaucescens* and *K. uniflora* to the taller ones including *K. nyikae* and *K. velutina*. Therefore, greater height control will likely be required for species with increased finishing heights. Additionally, if grown under non-inductive NI conditions, internode number below the terminal inflorescence will increase, although internode length of *K. laciniata*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. uniflora*, and *K. velutina* was shorter under NI than SD; photoperiod did not affect internode length of *K. glaucescens* and *K. rotundifolia* (data not shown).

In general, the number of branches on flowering plants was low and did not add to the "fullness" of the crop. As a result, increasing branching chemically with plant growth regulators such as ethephon [(2-chloroethyl) phosphonic acid] or benzyladenine [*N*-(phenylmethyl)-1*H*-purin-6-amine] or mechanically with pinching may be necessary to produce plants with branching similar to the free-branching modern *K. blossfeldiana* cultivars. Variation in leaf dimensions, shape, color, and/or texture has the potential to increase the variety of vegetative characteristics of commercially produced flowering *Kalanchoe*. In addition, foliage of some species may warrant their use as ornamental foliage plants. The shape and size of *K. laciniata* and *K. nyikae* foliage, coloration of *K. glaucescens* and *K. nyikae* foliage, and leaf surface of *K. velutina* foliage are all unique and attractive (C. Currey, personal observation).

Conclusions

Based on the flower induction and development data, we classify *K. glaucescens*, *K. laciniata*, *K. manginii*, *K. millotii*, *K. nyikae*, *K. rotundifolia*, *K. uniflora*, and *K. velutina* as

obligate SD plants. We were unable to classify *K. laetivirens*, *K. pumila*, and *K. rosei* as a result of minimal flowering. The requirements for flowering of *K. beauverdii*, *K. behariensis*, *K. fedtschenkoi*, *K. longiflora*, *K. marmorata*, *K. marnieriana*, *K. streptantha*, *K. tomentosa*, and *K. vigueridoi* are not understood. We identified six species *K. glaucescens* 'Freeling's Sensation', *K. laciniata*, *K. manginii*, *K. nyikae*, *K. uniflora*, and *K. velutina* with flowering and/or vegetative characteristics that have ornamental potential as flowering potted plants.

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