Floral Development and Flower Longevity in *Rhipsalidopsis* and *Schlumbergera* (Cactaceae)

Deirdre Scott¹, Thomas H. Boyle², and Susan S. Han³

Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003

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Abstract. Eight Easter cactus (*Rhipsalidopsis* Britt. & Rose) cultivars and five Holiday cactus (*Schlumbergera* Lem.) cultivars were used to study postanthesis floral development and individual flower longevity. Floral aging was characterized by desiccation of the perianth and ovary, and was generally followed by abscission of the entire flower from the phylloclade. Petal turgor was maximal during early development when petal color was most intense. Petal color became less intense in the later stages of development. Flower longevity ranged from 7 to 12 days and from 4 to 6 days for the *Rhipsalidopsis* and *Schlumbergera*, respectively. This study demonstrates that significant genetic variation occurs within *Rhipsalidopsis* and *Schlumbergera* for flower longevity.

Easter cactus [*Rhipsalidopsis* spp. and interspecific hybrids (Liberty Hyde Bailey Hortorium, 1976)] and Holiday cactus [*Schlumbergera* spp. and interspecific hybrids (Hunt, 1981; Liberty Hyde Bailey Hortorium, 1976; Poole et al., 1981)] are popular, flowering, potted plants in North America and northern Europe. There have been few postproduction studies of these two crops. Poole (1973) reported that *S. truncata* (Haw.) Moran 'Christmas Cheer' plants continued flowering for 4 to 6 weeks after anthesis of the first flower. According to Patch (1977), the longevity of individual flowers is 6 to 9 days for *S. truncata*. However, the environmental conditions maintained during evaluation of flowering were not specified in either Poole's (1973) or Patch's (1977) work. In addition, the criteria for evaluating flower longevity have not been defined for *Schlumbergera* (Patch, 1977; Poole, 1973) or *Rhipsalidopsis*.

Identification of *Rhipsalidopsis* and *Schlumbergera* cultivars with superior flower longevity would be useful for commercial growers and breeders. Information on morphological changes during floral development would aid in defining flower longevity. The objectives of this investigation were to 1) study the morphology of *Rhipsalidopsis* and *Schlumbergera* flowers from anthesis through senescence and 2) determine flower longevity for several *Rhipsalidopsis* and *Schlumbergera* cultivars.

Materials and Methods

Plant material and cultural procedures. Eight *Rhipsalidopsis* and five *Schlumbergera* cultivars were propagated and grown in glasshouses at the Univ. of Massachusetts (UMass), Amherst (lat. 42°22.5' N). Cultivars were chosen randomly from the collection of *Rhipsalidopsis* and *Schlumbergera* clonal germplasm maintained at UMass. Two of the *Schlumbergera* cultivars (88-50 and 88-68) were developed at UMass and were late-flowering selections from an F₁ population of *S. truncata* 'Rocket' × *S. ×buckleyi* (T. Moore) Tjaden 'Buckleyi' (Hunt, 1981); all other cultivars used in this study were commercial clones of unknown parentage.

Phylloclades were propagated in mid-Feb. 1991, using one or two phylloclades per 35-cm³ cell. Plants were transplanted into 220-cm³ plastic pots (7.6 cm in diameter) in mid-June. A commercial soilless mix (Fafard Mix no. 2; Conrad Fafard, Springfield, Mass.) was used as the propagation and growing medium. Plants were fertilized weekly with 20N-4.3P-16.6K (12% NO₃-N, 8% NH₄-N) at 200 mg N/liter. Fertilization began after phylloclades were rooted and continued until the start of growth chamber experiments. Photoperiod and temperature were regulated to manipulate flowering (Boyle, 1990, 1991; Boyle and Jacques, 1990). Immature apical phylloclades were removed 1 week after the start of inductive treatments to promote uniform bud development.

Stages of floral development. Plants with several mature flower buds (≈1 or 2 days before anthesis) were transferred from the glasshouse to a controlled-environment chamber (model 1-35LVL; Percival Manufacturing Co., Boone, Iowa). Chamber conditions were 20 ± 1°C, 75% ± 5% relative humidity (RH), and a 12-h photoperiod (0600 to 1800 hr) provided by cool-white fluorescent lamps [52 ± 8 μmol·s⁻¹·m⁻² photosynthetic photon flux

(PPF)]. A thermistor (LI-1000-16; LI-COR, Lincoln, Neb.) and a quantum sensor (LI-190SA; LI-COR) recorded air temperatures and PPF, respectively. A hygrometer (model 22-7059; Bacharach Instrument Co., Pittsburgh) measured RH. Plants were irrigated with tap water (≤0.12 dS·m⁻¹ electrical conductivity) when the media surface was dry.

Perianth turgor was evaluated subjectively as fully turgid (no wilting), slightly flaccid (onset of visible wilting), or moderately to severely flaccid. Petal color was characterized qualitatively with the *Royal Horticultural Society* (RHS) *Colour Chart* (RHS, 1966). Fully expanded petals were compared with the RHS *Colour Chart* to determine the color chip(s) closest to the predominant petal color. Kelly and Judd's (1976) color names dictionary was used for naming petal colors. Petal orientation was defined as the angle between a line parallel to the floral tube and a line from the base to the tip of the perianth segment (0° petal orientation—perianth parallel to the floral tube). One petal orientation measurement was obtained per flower. Petal orientation of zygomorphic *Schlumbergera* flowers was measured on the uppermost apical perianth segment at the distal end of the floral tube. Perianth segments within individual *Rhipsalidopsis* flowers did not differ in petal orientation due to the actinomorphic floral symmetry; therefore, petal orientation was measured on random perianth segments within each flower. Stigmatic lobe orientation was defined as the angle between a line parallel to the style and a line from the base to the tips of the stigmatic lobes. For each cultivar, data were collected on 10 flowers on four or more individual plants. Pots were randomized within the chamber and spaced ≈12 cm apart. *Rhipsalidopsis* flowers exhibited nyctinasty (diurnal opening), and all data were collected during the middle of the photoperiod regime (1100 to 1300 hr), when petal orientation for *Rhipsalidopsis* flowers was maximum.

Results and Discussion

Developmental stages. Four developmental stages from anthesis to senescence were defined for *Rhipsalidopsis* and *Schlumbergera* flowers: early, middle, late, and senescent (Table 1). For *Rhipsalidopsis* cultivars, perianth turgor was maximal during the early and middle stages. It began to decline during the late stage and was minimal in the senescent stage (Table 1). Petal orientation increased from ≈10° at anthesis to a maximum of ≈90° in the middle stage and then decreased to 0° at senescence (Fig. 1). *Rhipsalidopsis* petal color was most intense in the early stage and faded progressively during the middle and late stages (Table 2). Stigmatic lobe orientation increased from ≈0° to 30° at anthesis to a maximum of ≈90° in the middle, late, and senescent stages (Table 1, Fig. 1). Morphological changes occurred in the stigmatic lobes during flower development: lobes were erect during the early and middle stages but became reflexed during the late and senescent stages (Fig. 1). Stigmatic lobes of *Echinocereus fasciculatus*

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¹Graduate Student.

²Associate Professor; to whom reprint requests should be addressed.

³Assistant Professor.

(Englem.) L. var. *boyce-thompsonii* (Orcutt) L. Benson exhibited similar morphological changes during floral development (Grant and Grant, 1979).

Perianth turgor was maximal in *Schlumbergera* cultivars during the early and middle stages, and it declined progressively from the late to the senescent stage (Table 1). Petal orientation increased from $\approx 10^\circ$ at anthesis to $>45^\circ$ in the middle and late stages,

then decreased to 0° at senescence (Table 1, Fig. 2). Petal color was maximal during the early stage and began to fade during the middle stage, except for '88-68' flowers, which changed to a deeper shade of magenta during development (Table 2). The stigmatic lobes of *Schlumbergera* flowers were appressed during the early stage, and lobe orientation did not exceed 15° in the middle, late, or senescent stages.

Table 1. Stages of *Rhipsalidopsis* and *Schlumbergera* flower development.

Stage	Duration (days) ^a	Description ^b
<i>Rhipsalidopsis</i>		
Early	1.9 $\pm$ 0.1	Perianth fully turgid; petal orientation $\approx 10^\circ$; maximal intensity of petal color; stigmatic lobe orientation 0° to 30° ; stigmatic lobes erect.
Middle	5.6 $\pm$ 0.3	Perianth fully turgid; petal orientation $\approx 20^\circ$ to 90° ; petal color begins to fade; stigmatic lobe orientation $\approx 20^\circ$ to 90° ; stigmatic lobes erect.
Late	2.1 $\pm$ 0.5	Perianth slightly flaccid; petal orientation $\approx 30^\circ$ to 60° ; progressive petal fading; stigmatic lobe orientation $\approx 45^\circ$ to 90° ; stigmatic lobes slightly reflexed.
Senescent	1.6 $\pm$ 0.3	Perianth moderately to severely flaccid; petal orientation 0° ; petal color at minimal intensity; stigmatic lobe orientation $\approx 90^\circ$; stigmatic lobes moderately reflexed.
<i>Schlumbergera</i>		
Early	1.0 $\pm$ 0.0	Perianth fully turgid; petal orientation $\approx 10^\circ$; maximal intensity of petal color; stigmatic lobes appressed.
Middle	2.4 $\pm$ 0.2	Perianth fully turgid; petal orientation $\approx 45^\circ$ to $\geq 90^\circ$; petal color begins to fade; stigmatic lobe orientation $\leq 15^\circ$.
Late	1.8 $\pm$ 0.4	Perianth slightly flaccid; petal orientation $\approx 45^\circ$ to 90° ; progressive petal fading; stigmatic lobe orientation $\leq 15^\circ$.
Senescent	1.0 $\pm$ 0.0	Perianth moderately to severely flaccid; petal orientation $\approx 0^\circ$; petal color at minimal intensity; stigmatic lobe orientation $\leq 15^\circ$.

^aMean of eight *Rhipsalidopsis* cultivars $\pm$ SE, or five *Schlumbergera* cultivars $\pm$ SE.

^bDescriptions indicate the beginning of each stage.

Fig. 1. Floral development stages in *Rhipsalidopsis* 'Crimson Giant' from anthesis to senescence. (A) Early stage, with flowers showing erect stylar lobes (arrow). (B) Middle stage. (C) Late stage. (D) Senescent stage, with flowers showing flaccid petal tips (left arrow) and reflexed stylar lobes (right arrow). (left) Intact flowers and (right) longitudinal sections are shown in each photograph.

Flower longevity. For *Rhipsalidopsis* and *Schlumbergera*, flower longevity was defined as the number of days from the onset of the early stage (anthesis) until the start of the senescent stage. Flower longevity data demonstrated variance heterogeneity and were transformed [$\log_{10}(x + 1)$] before analysis of variance (SAS Institute, 1985). Flower longevity ranged from 6.7 to 12.2 days for the *Rhipsalidopsis* cultivars and from 4.3 to 6.2 days for *Schlumbergera* (Table 2).

The normal pattern of floral aging, exhibited by all of the *Rhipsalidopsis* and *Schlumbergera* cultivars, except for 'Mira', was senescence and desiccation of the perianth and ovary, followed by abscission of the entire flower from the phylloclade. A similar pattern of floral aging was reported for *Opuntia compressa* (Salis.) McBride [*O. humifusa* (Raf.) Raf.] (Grant and Connell, 1979) and appears to be characteristic of many Cactaceae species (Went, 1982). For 'Mira', however, flowers senesced but did not abscise, and ovaries eventually differentiated into fruit that contained many viable seeds (data not presented). 'Mira' flowers likely were not cross-pollinated in the growth chamber due to spatial separation between cultivars (≈ 12 cm minimum distance) and pollen vector exclusion (insects). Furthermore, isolated *Rhipsalidopsis* and *Schlumbergera* plants normally fail to set fruit due to the presence of self-incompatibility (Ganders, 1976; Taylor, 1976). Thus, our results suggest that 'Mira' is self-compatible or apomictic. It should be noted that flower longevity for 'Mira' was significantly less than for other *Rhipsalidopsis* cultivars (Table 2). The nature of the relationship between seed set and floral longevity in *Rhipsalidopsis* needs to be determined.

For potted plants with numerous flowers, flower longevity partially defines the duration that plants remain attractive; therefore, it is a major component of plant quality. Cultivars with superior flower longevity are expected to lead to greater consumer satisfaction and repeat purchasing (Langton, 1991). Our results indicate that, within both genera, there were significant differences in flower longevity between cultivars (Table 2). Thus, selection of *Rhipsalidopsis* and *Schlumbergera* cultivars with increased flower longevity is feasible. Genotypic differences in flower longevity have been reported in several other floricultural crops, including *Dianthus caryophyllus* (Wu et al., 1991), *Gerbera hybrida* (De Jong and Garretsen, 1985; Harding et al., 1981), *Pelargonium x domesticum* (Deneke et al., 1990; Evensen and Olson, 1992), and *Tulipa* (Van Eijk and Eikelboom, 1976). The physiological or genetic basis for diversity within *Rhipsalidopsis* and *Schlumbergera* for flower longevity needs to be determined.

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Table 2. Petal color and flower longevity for *Rhipsalidopsis* and *Schlumbergera* cultivars.

Cultivar	Predominant petal color ^y	Floral development stage ^z				Flower longevity (days) ^x
		E	M	L	S	
<i>Rhipsalidopsis</i>						
Andre	Vivid red	44A ^w	44A	44B	44B	9.6 b ^v
Crimson Giant	Strong red	34A	34B	34BC	34C	10.8 ab
Evita	Deep purplish pink	74A	74B	74BC	74C	11.1 ab
Thor-Anne	Vivid red	45A	45A	45CD	45CD	11.3 a
Mira	Deep purplish pink	74A	74B	74BC	74C	6.7 c
Purple Pride	Deep purplish pink	74B	74B	74BC	74C	10.6 ab
Red Pride	Strong red	34A	34B	34B	34BC	12.2 a
Rood	Vivid red	44A	44B	44BC	44BC	12.1 a
<i>Schlumbergera</i>						
Christmas Fantasy	Moderate reddish orange	37A	37B	37B	37C	6.2 a
Dark Marie	Vivid red	46B	46B	46C	46CD	4.3 b
Linda	Vivid red	53C	53C	53CD	53CD	4.6 b
88-50	Deep purplish pink	74A	74B	74BC	74C	5.1 ab
88-68	Deep purplish red	74B	74B	74AB	74A	5.7 a

^zE = early, M = middle, L = late, and S = senescent.

^yColor names from Kelly and Judd (1976) color standards.

^xDays from anthesis to commencement of senescence (mean of 10 observations).

^wRoyal Horticultural Society (RHS) Colour Chart numbers that are closest to the predominant petal color at each developmental stage. The RHS Colour Chart is composed of 202 sheets containing four chips per sheet (808 color chips total). Each sheet is designated by a number, and each of the four color chips on a sheet is specified by a letter (A, B, C, or D). For each sheet, the color is progressively lightened from the A to the D chip. Color chart numbers with two letters describe petal colors that are intermediate between two adjacent color chips.

^yMean separation of cultivars within *Rhipsalidopsis* or *Schlumbergera* by Tukey's Studentized range test, $P \leq 0.05$.

Fig. 2. Floral development stages in *Schlumbergera* 'Dark Marie' from anthesis to senescence. (A) Early stage, with flower at right showing $\approx 10^\circ$ petal orientation for the uppermost apical perianth segment (arrow); (B) middle stage, with flower at right showing an $\approx 45^\circ$ petal orientation for the uppermost apical perianth segment (arrow); (C) late stage, with flower showing flaccid petal tips (arrows); (D) senescent stage, with flower at right showing 0° petal orientation for the uppermost apical perianth segment (arrow). Each photograph shows the (left) ventral and (right) lateral surfaces of intact flowers.

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