Ethephon Foliar Sprays Prevent Premature Flowering of Tissue Culture-propagated *Streptocarpus* Hybrids

Christopher J. Currey^{1,3} and Nicholas J. Flax²

ADDITIONAL INDEX WORDS. ethylene, floriculture, flower abortion, gesneriad, pinching, potted plant

SUMMARY. Our objective was to quantify foliar ethephon application effects on flowering and growth of several streptocarpus (*Streptocarpus* × *hybridus*) cultivars. ‘Ladyslippers Blue Halo’, ‘Ladyslippers Deep Blue Vein’, and ‘Ladyslippers Red Rose’ streptocarpus were planted in 6-inch containers filled with a soilless substrate. Foliar spray applications of solutions containing 0, 125, 250, 500, or 1000 mg·L⁻¹ ethephon were applied either 2 weeks after planting (one application) or 2 and 4 weeks after planting (two applications). After 13 weeks, the total number of inflorescences was recorded and the growth index (GI) and time to flower were calculated. The efficacy of ethephon sprays depended on the concentration, number of applications, and cultivar. A single application of 250 to 1000 mg·L⁻¹ ethephon delayed flowering of ‘Ladyslipper Deep Blue Vein’ by 9 to 27 days, whereas one application of 1000 mg·L⁻¹ applied to ‘Ladyslipper Red Rose’ delayed flowering by 9 days. Similarly, two applications of any ethephon concentration delayed flowering of ‘Ladyslipper Deep Blue Vein’ by up to 37 days, while flowering of ‘Ladyslipper Red Rose’ was delayed by 17 days when 1000 mg·L⁻¹ was applied. The GI of ‘Ladyslipper Deep Blue’ and ‘Ladyslipper Red Rose’ was unaffected by ethephon and, while the GI of ‘Ladyslipper Blue Halo’ was smaller than untreated plants when one or two applications of 500 or 1000 mg·L⁻¹ ethephon was applied; these smaller plants were still of marketable size and quality. We conclude that ethephon may be used to delay flowering and reduce the number of inflorescences formed before finishing with minimal impact on finished plant size.

The genus *Streptocarpus* contains ≈130 species (Hilliard and Burt, 1971; Möller and Cronk, 2001). Hybrid streptocarpus, commonly called streptocarpus or cape primrose, are the most widely cultivated plants in the genus (Moore, 1957). Streptocarpus are flowering potted plants that grow and flower freely in interior or shaded outdoor areas. Leaf cuttings are commonly used by hobbyist growers or collectors (Ebert and Ebert, 1984), but commercial streptocarpus propagation requires a technique that produces more plants in a shorter time period. Modern streptocarpus cultivars are traditionally produced using F₁ hybrid seed (Dole and Wilkins,

2005). Additionally, streptocarpus do not require an environmental stimulus such as daylength (photoperiod) or cool temperatures (vernalization) for flower induction and development. The new ‘Ladyslippers’ streptocarpus series are propagated using tissue culture (Uhl, 2012). While these plants produce showy finished flowering plants, they regularly flower prematurely (i.e., while still in the liner tray) during greenhouse production, requiring hand labor to remove inflorescences.

Ethephon is a plant growth regulator (PGR) that is commonly applied as a foliar spray (Whipker et al., 2011b). When absorbed by plant tissue, the change in tissue pH causes ethylene gas to be generated within plant cells (Barrett, 2001). As a PGR, ethephon has several effects when applied to containerized ornamental

crops (Barrett, 2001; Whipker et al., 2011b). Ethephon may act as a plant growth retardant and minimize stem elongation by reorienting microfibril orientation in cell walls; this causes cells to expand laterally and minimize elongation, which restricts stem height or length. Additionally, ethephon may be employed to increase branching in crops by increasing the ratio of ethylene : auxin, which diminishes apical dominance and releases axillary buds, resulting in enhanced lateral branch development. However, one of the most common uses of ethephon is to delay flowering for vegetatively propagated ornamental flowering crops (Dole and Wilkins, 2005). Flowering delay of vegetatively propagated material is generally desirable to extend the vegetative phase of production (i.e., growth of leaves) to increase the size or “bulk up” a containerized crop and reduce the disease pressure posed by senesced flowers.

We have found no published information on effective concentrations of ethephon for foliar spray applications on streptocarpus to inhibit or delay flowering. The objective of our experiment was to quantify the impact of foliar ethephon applications on the growth and flowering of tissue culture-propagated ‘Ladyslipper’ streptocarpus.

Materials and methods

On 25 Sept. 2013, ‘Ladyslippers Blue Halo’, ‘Ladyslippers Deep Blue Vein’, and ‘Ladyslippers Red Rose’ streptocarpus rooted liners in 96-cell trays were received from a commercial supplier. The following day, liners were planted in 6-inch-diameter plastic containers [87.26 inch³ volume (Landmark Plastic Corp., Akron, OH)] filled with a soilless substrate (Sunshine Mix #1; Sun Gro Horticulture, Agawam, MA). Plants were grown in a glass-glazed greenhouse with fog cooling, radiant hot-water heating, and retractable shade curtains controlled by an environmental computer (Argus Control Systems,

Department of Horticulture, Iowa State University, 127 Horticulture Hall, Ames, IA 50011

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¹Assistant professor

²Former undergraduate research assistant

³Corresponding author. E-mail: ccurrey@iastate.edu.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.0929	ft ²	m ²	10.7639
0.4075	gal/100 ft ²	L·m ⁻²	2.4542
16.3871	inch ³	cm ³	0.0610
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Surrey, BC, Canada). The day and night greenhouse air temperature set points were 23 and 19 °C, respectively. A 16-h photoperiod (0600 to 2200 HR) consisting of natural daylengths with day-extension lighting was provided. High-pressure sodium lamps delivered a supplemental photosynthetic photon flux of $191 \pm 27 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at plant height [as measured with a quantum sensor (LI-190 SB; LI-COR Biosciences, Lincoln, NE)] to maintain a target daily light integral of $\approx 12 \text{ mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$. Plants were irrigated as needed with water supplemented with a blend of water-soluble fertilizers [50 and 100 $\text{mg}\cdot\text{L}^{-1}$ nitrogen provided from 21N–2.2P–16.6K and 15N–2.2P–12.5K, respectively (Everris NA Inc., Marysville, OH)] to provide the following (in milligrams per liter): 150 nitrogen, 8.6 phosphorous, 92.2 potassium, 33.3 calcium, 13.3 magnesium, 0.75 iron, 0.4 manganese and zinc, 0.2 copper and boron, and 0.5 molybdenum. Pour-Thru leachate extractions (Whipker et al., 2011a) were performed to monitor substrate pH and electrical conductivity to ensure values were within the ranges acceptable for streptocarpus production (Cavins et al., 2000).

Ethephon treatments commenced 2 weeks after planting. Foliar applications of solutions containing 0 (control), 125, 250, 500, or 1000 $\text{mg}\cdot\text{L}^{-1}$ ethephon (Collate; Fine Americas, Walnut Creek, CA) were applied at a rate of 0.5 gal/100 ft² to 10 plants of each cultivar, either 2 weeks (single application), or 2 and 4 weeks after planting (two applications).

The time to flower from planting was calculated as the number of days from transplanting until the first flower on a plant opened, and the total number of inflorescences each plant produced was recorded throughout the study. The recommended production time for ‘Ladyslippers’ streptocarpus is 12 to 14 weeks (Uhl, 2012); therefore, we collected final data 13 weeks after planting. Plant height from the surface of the substrate to the tallest growing point and the widths at the widest point and 90° from the widest point were recorded. These measurements were used to calculate the GI ($\text{GI} = \{\text{plant height} + [(\text{diameter } 1 + \text{diameter } 2)/2]\}/2$), an integrated measurement of plant size (Jeong et al., 2009; Krug et al., 2010).

The experiment was conducted in a completely randomized design

with 10 replications (individual plants) for each treatment. Regression analyses across ethephon concentrations within application and pairwise comparisons between all treatments using Tukey’s honestly significant difference test at $P \leq 0.05$ were performed using SPSS (version 21.0; IBM Corp., Armonk, NY).

Results and discussion

Ethephon concentration and application number interacted to affect time to flower, number of

inflorescences, and GI of cultivars differently (Tables 1–3). Ethephon delayed flowering for all three streptocarpus cultivars, but the effectiveness varied among cultivars with concentration and number of applications (Table 1). A single application of 500 or 1000 $\text{mg}\cdot\text{L}^{-1}$ ethephon delayed flowering of ‘Ladyslipper Blue Halo’ by 18 or 26 d, respectively, compared with untreated control plants, while 250 to 1000 $\text{mg}\cdot\text{L}^{-1}$ ethephon applied twice delayed flowering by 20 to 39 d ($R^2 = 0.70$).

Table 1. Time to flower of ‘Ladyslipper Blue Halo’, ‘Ladyslipper Deep Blue’, and ‘Ladyslipper Red Rose’ streptocarpus treated with foliar sprays of water (control) or solutions containing 125, 250, 500, or 1000 $\text{mg}\cdot\text{L}^{-1}$ (ppm) ethephon applied 2 weeks after transplanting (one application) or 2 and 4 weeks after transplanting (two applications).

Applications (no.)	Ethephon concn ($\text{mg}\cdot\text{L}^{-1}$)	Time to flower (d)		
		‘Ladyslipper Blue Halo’	‘Ladyslipper Deep Blue Vein’	‘Ladyslipper Red Rose’
Control	0	31 e ^z	29 f	34 bc
1	125	36 de	39 ef	29 c
	250	42 cde	41 de	34 bc
	500	49 bcd	50 cd	39 abc
	1000	57 b	56 bc	44 abc
	Significance (R^2)	Q*** (0.57)	Q*** (0.59)	Q** (0.16)
2	125	38 de	42 de	37 abc
	250	51 bc	50 cd	41 abc
	500	57 ab	63 ab	49 ab
	1000	70 a	68 a	51 a
	Significance (R^2)	Q*** (0.70)	Q*** (0.82)	Q*** (0.24)

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

Significance quadratic (Q) regression across ethephon concentrations within number of application.

**, ***Significant at $P \leq 0.01$ or 0.001, respectively.

Table 2. Number of inflorescences 13 weeks after transplanting ‘Ladyslipper Blue Halo’, ‘Ladyslipper Deep Blue’, and ‘Ladyslipper Red Rose’ streptocarpus treated with foliar sprays of water (control) or solutions containing 125, 250, 500, or 1000 $\text{mg}\cdot\text{L}^{-1}$ (ppm) ethephon applied 2 weeks after transplanting (one application) or 2 and 4 weeks after transplanting (two applications).

Applications (no.)	Ethephon concn ($\text{mg}\cdot\text{L}^{-1}$)	Inflorescences (no.)		
		‘Ladyslipper Blue Halo’	‘Ladyslipper Deep Blue Vein’	‘Ladyslipper Red Rose’
Control	0	29 a ^z	14 ab	20 abc
1	125	21 b	15 a	25 a
	250	22 ab	14 ab	22 a
	500	16 bc	13 ab	19 abc
	1,000	8 de	11 ab	18 abc
	Significance (R^2)	Q*** (0.60)	L* (0.09)	NS
2	125	19 bc	15 a	19 abc
	250	15 bcd	11 abc	21 ab
	500	12 cd	9 bc	11 c
	1,000	4 e	5 c	12 bc
	Significance (R^2)	Q*** (0.69)	Q*** (0.41)	Q** (0.18)

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

Significance of linear (L) or quadratic (Q) regression across ethephon concentrations within number of application.

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 3. Growth index (GI) 13 weeks after planting of ‘Ladyslipper Blue Halo’ streptocarpus treated with foliar sprays of water (control) or solutions containing 125, 250, 500, or 1000 mg·L⁻¹ (ppm) ethephon applied 2 weeks after transplanting (one application) or 2 and 4 weeks after transplanting (two applications).

Applications (no.)	Ethephon concn (mg·L ⁻¹)	GI ^a
		‘Ladyslipper Blue Halo’
Control	0	19.8 a ^y
1	125	17.5 abc
	250	19.0 ab
	500	17.3 bc
	1,000	16.9 bc
	Significance (<i>R</i> ²)	Q*** (0.23)
2	125	19.4 ab
	250	18.2 ab
	500	17.3 bc
	1,000	15.5 c
	Significance (<i>R</i> ²)	Q*** (0.49)

^a[Plant height + [(diameter 1 + diameter 2)/2]]/2.

^yWithin-column means followed by different letters are significantly different by Tukey’s honestly significant difference test at *P* ≤ 0.05.

Significance of linear (L) or quadratic (Q) regression across ethephon concentrations within number of application.

***Significant at *P* ≤ 0.001.

Similarly, 250 to 1000 mg·L⁻¹ ethephon applied once delayed flowering of ‘Ladyslipper Deep Blue Vein’ by 11 to 27 d, while all concentrations of ethephon applied twice delayed flowering by up to 39 d, compared with untreated plants. Flowering of ‘Ladyslipper Red Rose’ was delayed by 17 d, compared with control plants, when 1000 mg·L⁻¹ ethephon was applied twice. In addition to a diminished delay in time to flower for ‘Ladyslipper Red Rose’ in response to ethephon application when compared with the cultivars, the *R*² values were also lower (0.16 and 0.24) for regression analyses than the other cultivars (0.57 to 0.82).

Ethephon is used to delay flowering for other containerized flowering plants, including herbaceous perennials (Glady et al., 2007; Hayashi et al., 2001) and annuals (Starman and Williams, 2000; Starman et al., 2004). However, the degree of activity of ethephon depends on the species being treated, the number of applications, and concentration of ethephon solutions. For example, eight different species of containerized herbaceous perennials were treated one, two, or three times with foliar sprays containing 500 or 1000 mg·L⁻¹ ethephon (Hayashi et al., 2001). Applying three foliar sprays of 1000 mg·L⁻¹ ethephon delayed flowering of common yarrow (*Achillea millefolium* ‘Weser River Sandstone’), purple coneflower (*Echinacea purpurea* ‘Bravado’), bee balm

(*Monarda didyma* ‘Blue Stocking’), and false dragonhead (*Physostegia virginiana* ‘Summer Snow’) by 2 d (common yarrow) to 9 d (false dragonhead). Alternatively, ethephon had no effect on time to flower of threadleaf coreopsis (*Coreopsis verticillata* ‘Moonbeam’), shasta daisy (*Leucanthemum ×superbum* ‘Thomas Killen’), spike gayfeather (*Liatri spicata* ‘Kobold’), and garden phlox (*Phlox paniculata* ‘Mt. Fuji’). Glady et al. (2007) also reported that the efficacy of ethephon sprays applied to stock plants of herbaceous perennials varied among the species treated. Bi-weekly applications of foliar sprays of 600 mg·L⁻¹ ethephon or weekly sprays of 400 mg·L⁻¹ ethephon diminished flowering for threadleaf coreopsis and long-leaf speedwell (*Veronica longifolia* ‘Sunny Border Blue’), whereas flowering of carnation (*Dianthus caryophyllus* ‘Cinnamon Red Hots’) was unaffected by ethephon.

Ethephon affected the number of inflorescences for all three cultivars of streptocarpus in this experiment (Table 2). Compared with untreated control plants, 125 to 1000 mg·L⁻¹ ethephon applied once or twice resulted in 24% to 87% (7 to 25 inflorescences) fewer inflorescences of ‘Ladyslipper Blue Halo’, whereas two applications of 1000 mg·L⁻¹ ethephon to ‘Ladyslipper Deep Blue Vein’ caused 39% (nine inflorescences) fewer inflorescences to form. While there was a significant quadratic relationship between the concentration of ethephon

when two applications were made to ‘Ladyslipper Red Rose’, the *R*² was low (0.18) and there were no significant differences in the number of inflorescences of ethephon-treated plants compared with untreated plants.

Starman et al. (2004) applied foliar sprays containing 500 or 1000 mg·L⁻¹ ethephon to 27 different vegetative annuals. Ethephon application resulted in fewer flowers for 16 of the 27 species treated, though the magnitude of effect varied across species as well as among cultivars within a species. For example, although flower number of ‘Colorburst Red’ calibrachoa (*Calibrachoa ×hybrida*) was unaffected by ethephon, foliar sprays containing 1000 mg·L⁻¹ ethephon applied to ‘Liricashower Rose’ calibrachoa resulted in 47 fewer flowers per plant compared with untreated plants. In another study, Starman and Williams (2000) reported that spraying 500 or 1000 mg·L⁻¹ ethephon solutions on common fanflower (*Scaevola aemula* ‘New Wonder’) delayed flowering by 8 or 11 d, respectively, compared with control plants. Plant width was also suppressed by up to 77% compared with control plants when ethephon was applied.

The GI of each streptocarpus cultivar was affected differently by ethephon applications (Table 3). Increasing the concentration of ethephon up to 1000 mg·L⁻¹ suppressed the GI of ‘Ladyslipper Blue Halo’ by 15% for a single application (*R*² = 0.23) and 22% for multiple applications (*R*² = 0.49). Alternatively, ethephon did not affect the GI of ‘Ladyslipper Deep Blue Vein’ or ‘Ladyslipper Red Rose’ (data not shown). Though the GI was less for ‘Ladyslipper Blue Halo’ plants treated with ethephon, even the plants most affected by ethephon were still marketable. We believe that streptocarpus flowers are not significant sinks during production, since we observed little difference in GI regardless of flower number. Therefore, using ethephon to prolong the period of vegetative growth may be more useful to improve crop sanitation than for re-allocating carbohydrates to vegetative growth instead of flower production.

We observed no phytotoxic effects of ethephon applications, aside from flower bud abortion. However, in a few instances, we observed two or three leaves growing on the terminal

end of a peduncle of the inflorescence or phyllady. This was not widely observed across all ethephon treatments, including ethephon concentration and number of applications, or cultivars (data not shown). This phenomenon only occurred on plants treated with ethephon.

While the use of ethephon on flowering annual and perennial bedding plants has been reported, we found no reports of the effect of ethephon on the growth and flowering of streptocarpus. However, Callesen and Adriansen (1983) and Miller (2005) studied the impact of ethephon foliar sprays on growth and flowering of sylvan seemannia (*Seemannia sylvatica*) and achimenes or hot water plant (*Achimenes* hybrids), which are other plants in the family Gesneriaceae. Callesen and Adriansen (1983) quantified the response of sylvan seemannia to foliar applications of solutions containing 0, 1000, 2000, 4000, 8000, or 16,000 mg·L⁻¹ ethephon. Plants treated with 1000 mg·L⁻¹ ethephon flowered 4 to 6 weeks later than untreated plants, while plants treated with 16,000 mg·L⁻¹ ethephon flowered 14 weeks later. Additionally, height of sylvan seemannia was increasingly shorter than untreated plants as ethephon concentration increased. Miller (2005) applied solutions containing 0, 250, 500, or 1000 mg·L⁻¹ ethephon one, two, or three times to achimenes 'A09', 'A16', and 'A23'. The percentage of plants flowering at the end of the experiment ranged from 93% to 51%. Untreated plants flowered 7 weeks after treatments were initiated, while flowering of achimenes treated with 500 or 1000 mg·L⁻¹ ethephon three times was delayed up to 11 weeks compared with untreated plants.

We estimated the PGR cost for a foliar application of solution containing 1000 mg·L⁻¹ ethephon applied at 0.5 gal/100 ft² using PGRCALC (Krug and Whipker, 2010). Using the average price for the cost of a commercial ethephon product it would cost \$10.23 per spray application per 1000 ft² of bench space. Based on these calculations, we believe that the PGR and

application labor costs associated with applying ethephon to prevent premature flowering are minimal when compared with the potential labor costs to manually remove flowers for ≈4–5 weeks while plants are growing to a marketable size.

Conclusions

Ethephon applications delay streptocarpus flowering while having a minimal impact on the quality of finished, marketable plants. Based on our research, applying foliar sprays containing 1000 mg·L⁻¹ ethephon aid delaying flowering of 'Ladyslipper' streptocarpus cultivars and, therefore, minimize the use of hand labor for removing flower stalks before plants have reached a marketable size. Greenhouse producers will want to perform trials to evaluate the effectiveness of ethephon sprays with streptocarpus cultivars they use under their specific greenhouse environment and culture.

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