Research Reports

Paclobutrazol and Flurprimidol Control Stem Elongation of Potted Star of Bethlehem

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ADDITIONAL INDEX WORDS. substrate drenches, *Ornithogalum thyrsoides*, *Ornithogalum dubium*, willingness to pay

SUMMARY. Plant growth regulators (PGRs) are effective tools for controlling potted plant growth. In this article, the effects of flurprimidol, paclobutrazol, and ethephon media drenches on stem elongation of star of bethlehem (*Ornithogalum thyrsoides* and *Ornithogalum dubium*) were investigated. At the lowest paclobutrazol (0.5 mg/pot) and flurprimidol rates (0.05 mg/pot) tested, plant height was reduced 20% to 35% compared with controls in all tested cultivars. Ethephon applied as a media drench when plants reached visible bud (VB) stage had no effect on plant height or flowering. A consumer preference survey of 'Fire Star' star of bethlehem (*O. dubium*) plant height showed that about 60% of participants preferred PGR-regulated plants. With every level of preference increase for shorter plants (on a scale of 1 to 5), participants were willing to pay \$0.48 more for the shorter plant.

Star of bethlehem (*Ornithogalum* sp.) was first introduced to floriculture as a cut flower, but over the last 20 years has been gaining popularity as a potted plant. The expansion from a cut flower to the potted plant sector, which is supported by new breeding efforts, can help satisfy the market demand for novelty plants. In the U.S. market, potted geophytes used as winter-blooming house plants are especially in demand (Daly and Henry, 2009). More information on improved production protocols can support the further commercialization of potted star of bethlehem.

Unlike cut flowers, excessive stem growth is not desired for potted plants. A compact product with a plant plus pot:pot ratio of ≈ 1.6 is the theoretical optimum display (Sachs, 1976). Aside from breeding and controlling environmental factors to regulate stem elongation, PGRs are a common way of manipulating plant growth to achieve the desired shape and size. A major group of PGRs are the anti-gibberellin (GA) growth retardants, which act by inhibiting GA biosynthesis at various points in the GA biosynthesis pathway (Rademacher,

2000). The anti-GA PGRs are widely used in the flower bulb industry as sprays or substrate drenches (Currey et al., 2012; De Hertogh, 1996; Miller, 2014). Flurprimidol and paclobutrazol are two commonly used anti-GA retardants. Flurprimidol applied at 15 and 30 mg·L⁻¹ resulted in significantly higher chlorophyll content and shorter flower stems in star of bethlehem [*Ornithogalum saundersiae* (Salachna and Zawadzka, 2013)]. While not acting via inhibition of GA biosynthesis, ethephon is also used as a growth retardant in floriculture. Ethephon releases ethylene on application. It can inhibit stem elongation as drench application in daffodil and hyacinth and a range of bedding plants (Miller, 2014; Miller et al., 2012; Moe, 1980). To the best of our knowledge, no publications exist concerning the use of growth retardants in star of bethlehem production.

Anti-GA PGRs can regulate plant height and improve plant uniformity and can contribute to more accurate scheduling of flowering dates, meeting market requirements for plant height, and reduction of shipping costs. Although there are general guidelines suggesting the best ratio for potted plant (Sachs, 1976), commercially acceptable potted plant height is largely a matter of personal preference and varies by plant species. For a commercial grower, the acceptable height is that specified by the customer, either an individual or, in the case of larger growers, the wholesale buyer of the product. Consumers' preferences and willingness to pay (WTP) for different horticulture products and product attributes have been studied to assist making consumer preference-based market decision (James et al., 2009; Jowkar et al., 2007; Kelley et al., 2000). The objectives of this research were to evaluate the effect of flurprimidol, paclobutrazol, and ethephon as media drenches on stem elongation of star of bethlehem, and consumer preference for potted star of bethlehem plant height.

We thank Yodfat Revivim Horticulture Ltd. and the Fred C. Gloeckner Company for bulb donations.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
28,350	oz	mg	3.5274×10^{-5}
1	ppm	mg·L ⁻¹	1
$(^{\circ}\text{F} - 32) \div 1.8$	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$(^{\circ}\text{C} \times 1.8) + 32$

Materials and Methods

GENERAL PROCEDURE. In year 1, three star of bethlehem cultivars were used: Fire Star and Yellow Star (*O. dubium*) and White Star (*O. thyrsoides*). Bulbs (3–4 cm circumference) arrived from Israel on 17 Sept. 2012 and were kept at 27 °C in darkness until use. Before giving treatments, bulbs were selected for uniformity. Bulbs were held at 16 °C for 3 weeks immediately before planting as this treatment is generally thought to be beneficial for flowering (Yodfat Revivim Horticulture, Kibbutz Revivim, Israel). There were eight replicates (pots) for each treatment and cultivar. Three bulbs were planted per 5-inch round plastic azalea pot with a soilless peat-based substrate (LM-111; Lambert Peat Moss, Riviere-Ouelle, QC, Canada). All plants were grown at a constant air temperature set point of 17 °C in a glass greenhouse. Plants were irrigated as needed with tap water and were fertilized with 150 mg·L⁻¹ nitrogen from 21N–2.2P–16.6K water-soluble fertilizer (Jack's Professional 21-5-20; J.R. Peter's, Allentown, PA) every 10 d, with 674 mg·L⁻¹ magnesium sulfate. In year 2, general procedures were the same except as follows. Four cultivars were used: Fire Star, Yellow Star, and Orange Star 511 (*O. dubium*) and White Star. Bulbs arrived from Israel on 9 Aug. 2013. There were six replicates (pots) for each treatment and cultivar.

PGR DRENCH EXPERIMENT. In year 1, bulbs were planted on 25 Oct. 2012. Treatments were control (water); 1, 2, or 4 mg/pot paclobutrazol (Piccolo; Fine Americas, Walnut Creek, CA); and 0.1, 0.25, or 0.5 mg/pot flurprimidol (Topflor; SePRO Corp., Carmel, IN) each given in a 90-mL volume. Drench date varied according to cultivar growth, thus Yellow Star, Fire Star, and White Star were drenched on 20 Dec. 2012, 10 and 24 Jan. 2013, respectively. Growth and flowering data were observed and recorded. In year 2, bulbs were planted on 25 Oct. 2013. Three PGRs, paclobutrazol, flurprimidol (as above), and ethephon (Collate; Fine Americas) were applied as media drenches when plants were near VB stage. Treatments were control (water); 0.5, 1, or 1.5 mg/pot paclobutrazol; 0.05,

0.1, or 0.15 mg/pot flurprimidol; and 50, 100, or 250 mg·L⁻¹ (4.5, 9, or 22.5 mg/pot) ethephon each given in a 90-mL volume. The date of treatment varied according to cultivar growth, thus 'Yellow Star' and 'Fire Star' were drenched on 26 Nov. and 19 Dec. 2013, respectively. 'White Star' and 'Orange Easter 511' were drenched on 16 Jan. 2014. Growth and flowering data were observed and recorded.

Data collected from each pot included the date plants reached VB stage (defined as the time when one or more plants in the pot appeared to have a bud that reached 1.5 cm high and 0.5 cm wide) and the date of first flowering (when the first one or two florets were open). On the day of first flowering, leaf length, number of leaves, inflorescence height (stem length that has florets attached), scape height (leafless stem length below the lowest attached floret to the soil surface), and plant height (the sum of inflorescence and scape heights) were recorded. Data were analyzed using analysis of variance and regression analysis using JMP (version 10; SAS Institute, Cary, NC).

EVALUATION OF CONSUMER PREFERENCE AND WTP. 'Fire Star' plants with two different heights were selected from the PGR drench experiment and used to conduct a survey of consumer preference for height of potted star of bethlehem. The tall plants were from the control treatment without any PGR applied. The short plants were about 30% shorter than control plants (which averaged 19.6 cm) and were selected from paclobutrazol or flurprimidol treatments. Participant recruiting was done by sending e-mails to the mailing list maintained by the Laboratory for Experimental Economics and Decision Research (LEEDR) at Cornell University. Participants included Cornell University faculty, staff, and graduate students and a small number of Ithaca residents. Each participant was compensated \$10 for their time.

The survey experiment was conducted on 17 Feb. 2014 at the LEEDR laboratory. Three pairs of tall and short plants were placed in the laboratory. Participants were asked to read and sign a consent form before answering a two-sided (one-page) survey questionnaire. While answering the questionnaire, participants

were shown (by projector) an image of two potted plants with different heights and the three pairs of actual plants displayed in the laboratory. Participants were divided into two groups. The first group of participants was told that the two plant heights were a result of growing in different greenhouse environments. The second group was told the short plants had been treated with chemicals to reduce growth. The survey questionnaire included Likert scale questions addressing participants' attitudes toward the importance of potted flower attributes and their sociodemographics. The sociodemographic questions included age, gender, education, income, and frequency of buying potted plants. Data were analyzed with least-squares method of linear regression analysis using JMP (as above).

Results

PGR DRENCH EXPERIMENT. In year 1, paclobutrazol and flurprimidol drenches reduced scape height and leaf growth across the three cultivars trialed. Plants appeared more sturdy and compact when treated with PGRs, especially in 'Fire Star' and 'Yellow Star'. A linear increase in days from planting to flowering was observed in all three cultivars as paclobutrazol concentration increased. At the highest application rate (4 mg/pot), flowering of 'Fire Star', 'White Star', and 'Yellow Star' was delayed by 10, 12, and 8 d, respectively, compared with the control treatment (Table 1). A flowering delay was observed in 'Fire Star' as flurprimidol concentration increased. Plants treated with the highest flurprimidol concentration (0.5 mg/pot) flowered 5 d later compared with control plants. No delay of flowering in 'White Star' and 'Yellow Star' was observed from flurprimidol application (Table 2). Compared with the untreated controls, paclobutrazol and flurprimidol drenches reduced plant height in all three cultivars by reducing scape height and inflorescence height, except for 'White Star' where inflorescence height was unaffected by either material. All three cultivars showed highly significant linear relationships between PGR application rate and plant height. The plant height was reduced by 32%, 40%, and 43% at the lowest paclobutrazol rate tested [1 mg/pot (Table 1)] and was reduced

Table 1. Effect of paclobutrazol drenches on plant characteristics for three star of bethlehem cultivars in year 1.

Paclobutrazol rate (mg/pot) ^z	Leaf length (cm) ^y	Leaves (no.)	Time from planting to VB ^x (d)	Time from planting to first flower (d)	Time from treatment to first flower (d)	Time from VB to first flower (d)	Plant ht (cm)	Scape ht (cm)	Inflorescence ht (cm)
‘Yellow Star’									
0	13.9	7	63	120	64	57	20.9	14.5	6.4
1	12.5	7	62	122	66	60	11.9	6.2	5.6
2	12.1	6	63	126	70	64	10.3	5.0	5.3
4	12.0	6	62	128	72	65	8.7	3.5	5.2
Significance ^w	L*Q ^{NS}	L ^{NS} Q ^{NS}	L ^{NS} Q ^{NS}	L*Q ^{NS}	L*Q ^{NS}	L**Q ^{NS}	L***Q***	L***Q***	L***Q*
‘Fire Star’									
0	14.0	8	71	135	58	65	18.5	11.9	6.6
1	13.1	6	73	138	61	65	12.5	6.9	5.6
2	13.3	7	69	139	62	69	11.7	6.1	5.5
4	12.8	6	74	145	68	71	8.4	3.2	5.2
Significance	L*Q ^{NS}	L*Q ^{NS}	L ^{NS} Q ^{NS}	L***Q ^{NS}	L***Q ^{NS}	L*Q ^{NS}	L***Q**	L***Q**	L***Q ^{NS}
‘White Star’									
0	22.4	9	94	147	56	53	26.7	19.7	7.1
1	19.8	9	99	151	60	53	16.0	8.9	7.1
2	17.2	9	98	153	62	55	12.2	5.5	6.7
4	16.9	9	94	159	68	65	10.7	4.1	6.5
Significance	L***Q**	NS	NS	L***Q ^{NS}	L***Q ^{NS}	L**Q ^{NS}	L***Q***	L***Q***	L ^{NS} Q ^{NS}

^z1 mg = 3.5274 × 10⁻⁵ oz.^yLeaf length, number of leaves, plant height, scape height, and inflorescence height data were collected when first one or two florets flowered; 1 cm = 0.3937 inch.^xVB = visible bud.^wSignificance of linear (L) or quadratic (Q) regression: NS, *, **, *** denote nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2. Effect of flurprimidol drenches on plant characteristics for three star of bethlehem cultivars in year 1.

Flurprimidol rate (mg/pot) ^z	Leaf length (cm) ^y	Leaves (no.)	Time from planting to VB ^x (d)	Time from planting to first flower (d)	Time from treatment to first flower (d)	Time from VB to first flower (d)	Plant ht (cm)	Scape ht (cm)	Inflorescence ht (cm)
‘Yellow Star’									
0	13.9	7	63	120	64	57	20.9	14.5	6.4
0.1	12.2	7	61	117	61	56	11.7	5.6	6.1
0.25	11.9	7	62	119	63	57	9.1	4.1	5.0
0.5	11.0	7	62	125	69	63	7.7	2.9	4.8
Significance ^w	L***Q ^{NS}	NS	NS	NS	NS	NS	L***Q***	L***Q***	L***Q ^{NS}
‘Fire Star’									
0	14.0	8	71	135	58	65	18.5	11.9	6.6
0.1	13.5	6	71	138	61	67	14.1	8.3	5.9
0.25	12.7	7	73	139	62	66	10.7	5.2	5.5
0.5	12.4	6	73	140	63	67	9.7	4.3	5.4
Significance	L***Q ^{NS}	NS	NS	L***Q ^{NS}	L***Q ^{NS}	NS	L***Q***	L***Q***	L***Q*
‘White Star’									
0	22.4	9	94	147	56	53	26.7	19.7	7.1
0.1	19.1	9	91	147	56	54	19.8	13.3	6.5
0.25	18.1	8	93	147	56	55	16.7	9.5	7.2
0.5	16.3	8	95	149	58	54	13.8	6.5	7.3
Significance	L***Q*	NS	NS	NS	NS	NS	L***Q***	L***Q***	NS

^z1 mg = 3.5274 × 10⁻⁵ oz.^yLeaf length, number of leaves, plant height, scape height, and inflorescence height data were collected when first one or two florets flowered; 1 cm = 0.3937 inch.^xVB = visible bud.^wSignificance of linear (L) or quadratic (Q) regression: NS, *, **, *** denote nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

by 24%, 26%, and 44% at the lowest flurprimidol rate tested (0.1 mg/pot) in ‘Fire Star’, ‘White Star’, and ‘Yellow Star’, respectively (Table 2). Leaf length decreased linearly as paclobutrazol and flurprimidol concentration

increased. There was visible foliar phytotoxicity on leaf tips at the highest paclobutrazol dose (4 mg/pot) and the two highest flurprimidol doses (0.25 and 0.5 mg/pot) on ‘Yellow Star’. The number of leaves

was unaffected by paclobutrazol or flurprimidol treatment in any cultivar.

In year 2, the experimental rates of paclobutrazol and flurprimidol were reduced based on first year results. Days from planting to flowering

Table 3. Effect of paclobutrazol drenches on plant characteristics of four star of bethlehem cultivars in year 2.

Paclobutrazol rate (mg/pot) ^z	Leaf length (cm) ^y	Leaves (no)	Time from planting to VB ^x (d)	Time from planting to first flower (d)	Time from treatment to first flower (d)	Time from VB to first flower (d)	Plant ht (cm)	Scape ht (cm)	Inflorescence ht (cm)
‘Yellow Star’									
0	16.4	4	50	108	52	57	22.2	16.5	5.7
0.5	15.0	4	55	116	60	61	15.6	10.1	5.5
1	15.5	5	48	114	58	66	13.7	7.6	6.1
1.5	13.8	5	51	119	63	68	12.3	7.0	5.3
Significance ^w	L*Q ^{NS}	L*Q ^{NS}	NS	L***Q ^{NS}	L***Q ^{NS}	L***Q ^{NS}	L***Q***	L***Q***	NS
‘Fire Star’									
0	14.6	7	68	126	47	58	19.6	14.0	5.6
0.5	14.3	7	68	128	49	60	13.8	8.6	5.2
1	13.6	7	68	131	52	63	10.7	5.5	5.2
1.5	13.3	6	66	131	52	65	9.5	4.4	5.1
Significance	L*Q ^{NS}	NS	NS	L*Q ^{NS}	L*Q ^{NS}	L**Q ^{NS}	L***Q**	L***Q**	NS
‘White Star’									
0	24.4	8	97	152	45	55	25.7	17.9	7.8
0.5	22.3	8	97	153	46	56	17.6	9.9	7.7
1	20.5	8	98	160	53	62	13.7	5.3	8.4
1.5	21.0	8	100	159	52	59	12.8	4.8	8.0
Significance	L***Q ^{NS}	NS	NS	L*Q ^{NS}	L*Q ^{NS}	NS	L***Q**	L***Q**	NS
‘Orange Star 511’									
0	19.7	6.3	92	165	58	73	16.1	8.8	7.3
0.5	18.8	6.3	92	178	71	86	10.5	4	6.5
1	18.5	6.8	92	181	74	90	8.6	2.3	6.3
1.5	18.3	5.8	100	184	77	91	9.6	3.4	6.2
Significance	NS	NS	NS	L***Q ^{NS}	L***Q ^{NS}	L***Q ^{NS}	L***Q***	L***Q***	L*Q ^{NS}

^zPaclobutrazol was applied on 17 Nov. and 19 Dec. 2013 for ‘Yellow Star’ and ‘Fire Star’, respectively; and on 16 Jan. 2013 for ‘White Star’ and ‘Orange Star 511’; 1 mg = 3.5274 × 10⁻⁵ oz.

^yLeaf length, number of leaves, plant height, scape height, and inflorescence height data were collected when first one or two florets flowered; 1 cm = 0.3937 inch.

^xVB = visible bud.

^wSignificance of linear (L) or quadratic (Q) regression: ns, *, **, *** denote nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

in response to different PGR and rate combinations varied across cultivars. The effect of PGR rate on plant growth was similar to the first year's trials. Paclobutrazol delayed flowering in all cultivars. At the highest paclobutrazol rate (1.5 mg/pot), plants flowered 5, 7, 11, or 19 d later compared with control in ‘Fire Star’, ‘White Star’, ‘Yellow Star’, and ‘Orange Star 511’, respectively (Table 3). No flowering delay was observed when flurprimidol was applied, except for ‘Orange Star 511’. At the highest flurprimidol rate (0.15 mg/pot), ‘Orange Star 511’ flowering was delayed by 2 weeks compared with control (Table 4). All cultivars showed a highly significant linear relationship between paclobutrazol rate and plant height. Plant height was reduced by 30%, 32%, 30%, and 35% at the lowest paclobutrazol rate (0.5 mg/pot) tested in ‘Fire Star’, ‘White Star’, ‘Yellow Star’, and ‘Orange Star 511’, respectively (Table 3). Plant height was reduced by 33% at the lowest flurprimidol rate (0.05 mg/pot)

tested in ‘Fire Star’, ‘Orange Star 511’, ‘Yellow Star’, and by 21% in ‘White Star’. Decreased plant height was mainly attributed to decreased scape height. Inflorescence height generally was unaffected by PGR application (Table 4). Increasing rate of paclobutrazol and flurprimidol reduced leaf length in ‘Fire Star’ and ‘White Star’ in a linear manner (Tables 3 and 4). Leaf tip burn (possible foliar phytotoxicity) was observed with all three concentrations of flurprimidol in ‘Yellow Star’ and the highest concentration of paclobutrazol in ‘Orange Star 511’. However, tip burn was not as severe as in year 1, likely due to the lower rates of material used.

At the rates tested, ethephon drenches had no effect on any measured parameter (data not shown).

EVALUATION OF CONSUMER PREFERENCE AND WTP. A total of 70 people participated in the survey. Participants ranged in age from 18 to 74 years, and the mean age was in the range of 30 to 39 years. Most

participants had received a 4-year college degree and most (63%) were female. Questions addressing participants’ attitudes toward importance of potted flower attributes showed that the most important attribute was plant height, followed by flower color (Table 5). The result of the preference question showed that participants were more interested in the short plants, regardless of whether they were provided with information that shorter plants were treated with chemicals. When asked which height of potted plant they are more likely to purchase, about 60% of respondents chose the short plant. The two groups, with or without mentioning chemical application, showed the same trend of preference (Fig. 1).

A multiple regression model was developed with response variable set as the amount of money a consumer was willing to pay for a short plant provided that the tall plant market price was \$5.00. The multiple linear regression model, which was significant at $P \leq 0.001$, is shown below.

Table 4. Effect of flurprimidol drenches on plant characteristics of four star of bethlehem cultivars in year 2.

Flurprimidol rate (mg/pot) ^z	Leaf length (cm) ^y	Leaves (no.)	Time from planting to VB ^x (d)	Time from planting to first flower (d)	Time from treatment to first flower (d)	Time from VB to first flower (d)	Plant ht (cm)	Scape ht (cm)	Inflorescence ht (cm)
‘Yellow Star’									
0	16.4	4	50	108	52	57	22.2	16.5	5.7
0.05	14.1	4	52	111	55	59	14.8	8.8	6.0
0.1	14.4	4	50	112	56	61	12.2	6.6	5.6
0.15	14.5	4	50	110	54	60	11.6	6.0	5.6
Significance ^w	NS	NS	NS	NS	NS	NS	L***Q***	L***Q***	NS
‘Fire Star’									
0	14.6	7	68	126	47	58	19.6	14.0	5.6
0.05	14.3	6	68	125	46	57	13.2	7.0	6.2
0.1	13.1	6	70	129	50	59	10.7	5.7	5.0
0.15	13.7	8	68	129	50	60	9.9	5.0	4.9
Significance	L*Q ^{NS}	L ^{NS} Q*	NS	NS	NS	NS	L***Q**	L***Q***	NS
‘White Star’									
0	24.4	8	97	152	45	55	25.7	17.9	7.8
0.05	22.2	9	101	151	44	50	20.3	13.6	6.8
0.1	21.6	7	102	154	47	52	19.5	12.5	7.0
0.15	21.2	7	96	149	42	54	18.1	9.6	8.6
Significance	L*Q ^{NS}	NS	NS	NS	NS	NS	L***Q ^{NS}	L***Q ^{NS}	L ^{NS} Q**
‘Orange Star 511’									
0	19.7	6	92	165	58	73	16.1	8.8	7.3
0.05	19.2	6	93	166	59	77	10.8	4.5	6.3
0.1	18.1	6	95	176	69	81	10.2	3.7	6.5
0.15	20.0	7	93	179	72	86	9.3	3.0	6.3
Significance	NS	NS	NS	L***Q ^{NS}	L***Q ^{NS}	L***Q ^{NS}	L***Q*	L***Q*	NS

^zFlurprimidol was applied on 17 Nov. and 19 Dec. 2013 for ‘Yellow Star’ and ‘Fire Star’, respectively; and on 16 Jan. 2013 for ‘White Star’ and ‘Orange Star 511’; 1 mg = 3.5274×10^{-5} oz.

^yLeaf length, number of leaves, plant height, scape height, and inflorescence height data were collected when first one or two florets flowered; 1 cm = 0.3937 inch.

^xVB = visible bud.

^wSignificance of linear (L) or quadratic (Q) regression: ns, *, **, *** denote nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

$$\begin{aligned} \text{WTP} = & 2.24 - 0.62[\text{group}] \\ & + 0.48[\text{preference}] \\ & + 0.25[\text{shop frequency}] \\ & + 0.13[\text{education}] \end{aligned}$$

where [group] is a dummy variable of whether the participant was told there was chemical applied, with values of 1 = no chemical, 0 = chemical; [preference] is the level of preference for short plants from the participant form, with values of 1 = strongly prefer tall, 2 = moderately prefer tall, 3 = neutral, 4 = moderately prefer short, 5 = strongly prefer short; [shopping frequency] is how often a participant shopped for potted flowers, with values of 1 = never, 2 = less than once a month, 3 = 1–3 times a month, 4 = 4–5 times a month, 5 = more than 5 times a month; [education] is the highest level of education a participant completed, where 1 = less than high school, 2 = high school (GED), 3 = some college, 4 = 2-year college degree, 5 = 4-year college degree, 6 = master’s degree, and 7 = doctoral degree.

The model estimates consumer’s WTP for the PGR-treated plant with four variables: 1) whether given the information of chemical applied, 2) preference for short plants, 3) shopping frequency, and 4) education level. The multiple regression model suggested that when people were more interested in the product, they were willing to pay more. With every level of increase toward preferring short plants, the participants were willing to pay \$0.48 more for the shorter plants. We also found that higher education level and shopping frequency increased the WTP for PGR-treated plants. When consumers were told short plants were treated with chemicals, their WTP increased by \$0.62.

Application of plant retardant would increase the direct cost per plant. To estimate the increased cost, we estimated the chemical and labor costs per pot for a single application. Typical 2014 market prices for paclobutrazol and flurprimidol were \$37 and \$118.50 per liter, with active ingredient concentrations of 0.4 and

0.38 g·L⁻¹, respectively. The lowest effective rates we tested were 0.5 mg/pot paclobutrazol and 0.05 mg/pot flurprimidol. At these doses, the chemical cost of paclobutrazol and flurprimidol was about \$0.005 and \$0.002 per pot, respectively. It took about half an hour to make the PGR solution and apply to plants. New York minimum wage rate was \$8 per hour. Therefore, application labor cost was about \$0.08 per pot (substantially more than the actual cost of the chemical). Based upon the results of this survey, we conclude that application of plant growth regulator is a worthy investment for star of bethlehem potted plant production. Consumer showed more interest in the PGR-treated short plants compared with controls. With higher levels of preference for short plants, consumers were willing to pay more for the product based on the regression model.

Discussion

Flurprimidol, paclobutrazol, and ethephon application is a common

Table 5. Summary statistics for sociodemographic questions (gender, age, education, income, plant shopping habits, and attitudes on floral enjoyment) and Likert scale questions related to consumer attitude of attributes important to them when purchasing a potted plant (n = 70).

Variable	Description of variables	Mean	SD
Gender	Gender of participant? 1 = female 0 = male	±0.63	—
Age	Age of participant? 1 = under 18 years 2 = 18–24 years 3 = 25–29 years 4 = 30–34 years 5 = 35–39 years 6 = 40–44 years 7 = 45–49 years 8 = 50–54 years 9 = 55–59 years 10 = 60–64 years 11 = 65–69 years 12 = 70–74 years	4.79	2.78
Education	Highest level of education completed? 1 = less than high school 2 = high school (GED) 3 = some college 4 = 2-year college degree 5 = 4-year college degree 6 = Master's degree 7 = Doctoral degree	5.09	1.14
Income	Annual income range? 1 = below \$20,000 2 = \$20,000–\$29,999 3 = \$30,000–\$39,999 4 = \$40,000–\$49,999 5 = \$50,000–\$59,999 6 = \$60,000–\$69,999 7 = \$70,000–\$79,999 8 = \$80,000–\$89,999 9 = \$90,000 or more	4.13	2.47
Shopping	How often do you shop for potted flowers? 1 = never 2 = less than once a mo. 3 = three times a mo. 4 = four to five times a mo. 5 = more than five times a mo.	1.85	0.53
Enjoyment	Do you enjoy taking care of flowers? 1 = yes, very much 2 = yes, a little 3 = no, not really 4 = no, hate it	1.9	0.79
Likert scale attributes. Importance of the following attributes for potted flowers?			
	1 = not at all 2 = only a little 3 = a moderate amount 4 = a great deal		
Plant height		3.96	0.77
Flower color		3.17	0.89
Flower shape		3.04	0.81
Leaf length		2.16	0.83
Leaf color		2.48	0.92
Leaf shape		2.26	0.81

technique for plant height control in flower bulb forcing (Krug et al., 2005; Miller, 2003). This work shows that paclobutrazol and flurprimidol are effective for reducing stem elongation in star of bethlehem. At the lowest paclobutrazol rate (0.5 mg/pot) and flurprimidol rate (0.05 mg/pot) tested, plant height was reduced by 30% to 35%. However, 'White Star' plant height was only reduced by 21% at the lowest flurprimidol rate. Inflorescence height was reduced in

'Fire Star' and 'Yellow Star' in the first year but not in the second year. The results suggested that with a lower dose of PGR, plant height can be regulated without decreasing the size of the flower clusters.

Star of bethlehem generally suffers from a "tip burn" phenomenon that can be seen in a wide range of forcing environments, locations, and cultural horticulture production regimes (W.B. Miller, personal observation). With high rates of PGRs in year

1, PGR-linked phytotoxicity was widespread. In year 2, with lower PGR rates, it was substantially less. The effective rate of paclobutrazol (0.5 mg/pot) had little to no phytotoxicity and the effective rate of flurprimidol (0.05 mg/pot) had some (not quantified). Additional future work on the "tip burn" disorder, and relationship with PGR use, would be justified as this crop gains popularity.

At similar doses, flurprimidol is more powerful than paclobutrazol

Fig. 1. Response to the question regarding preference for potted star of bethlehem (n = 70).

and less flower delay was observed with flurprimidol. However, flurprimidol had a slightly higher risk of tip burn problems than paclobutrazol. Although there was a difference in chemical cost between flurprimidol and paclobutrazol for an effective dose (\$0.005 vs. \$0.002 for paclobutrazol and flurprimidol, respectively), the labor cost to apply the chemicals would always be substantially greater on a per-pot basis, so there is no economic rationale for choosing one product over the other.

When applied as a media drench, both paclobutrazol and flurprimidol effectively reduced scape height and leaf length in all star of bethlehem cultivars tested. Drench application at VB stage is early enough for effective treatment. With proper application of paclobutrazol and flurprimidol, plant quality and uniformity were improved and can meet the aesthetic ratio (Sachs, 1976). For the three star of bethlehem cultivars, 0.5 mg/pot paclobutrazol and 0.05 mg/pot flurprimidol will be a suitable application rate for potted plant production. For 'White Star', the dose might be increased, depending on preference and market size requirements. Growers would be advised to conduct small trials with 0.25 to 0.5 mg/pot paclobutrazol and 0.025 to 0.05 mg/pot flurprimidol before large-scale application. Media drenches of 0.5 mg/pot paclobutrazol or 0.05 mg/pot flurprimidol are likely to be the maximum dose needed for many star of bethlehem cultivars.

The three concentrations of ethephon applied as drenches showed no effect on star of bethlehem

flowering. Possible explanations of the result included application rate, species specificity, timing of application, and application method. Star of bethlehem responds to preplant ethylene exposure with increased plant height (Luria et al., 2002). It's possible that at VB stage, plants are not sensitive to ethylene. Also, by drench application, the ethephon solution was not in direct contact with leaves or stems, perhaps reducing effects on stem growth.

The consumer study suggests customers preferred shorter plants, and that they would be willing to pay more for shorter plants. This should be considered as a preliminary study, and wide ranging conclusions should not be drawn from it. However, it does seem clear that the cost of PGR use can be more than made up by a higher potential selling price: survey participants indicated they were willing to pay more for a shorter plant. If wholesale plant buyers were made aware of this result, perhaps growers could sell plants to them for a higher price with the knowledge customers would still be willing to buy a somewhat more expensive plant. Regardless, this seems to be an area where additional work could be done to help develop a more complete picture of this area.

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