Paclobutrazol Pre-plant Bulb Dips Effectively Control Height of 'Nellie White' Easter Lily

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SUMMARY. The influence of pre-plant bulb dips in paclobutrazol solutions on final plant height, days to flower, and flower bud number were evaluated for easter lily (*Lilium longiflorum*). 'Nellie White' easter lily bulbs were placed in solutions of paclobutrazol containing 0, 30, 60, or 120 mg·L⁻¹ for 15 min preceding planting. Days to flower and flower bud number were unaffected by paclobutrazol. Plant height at flowering for bulbs dipped in paclobutrazol solutions was 15% to 26% shorter compared with untreated bulbs. Additionally, dipping bulbs in 120 mg·L⁻¹ paclobutrazol resulted in plants that met target height specifications for commercially grown easter lily. Based on these results, dipping easter lily bulbs in paclobutrazol solutions can be an effective strategy for reducing stem elongation without negatively impacting days to flower or flower bud number for commercially grown easter lily.

Easter lily is an important flowering potted crop in the United States, with a wholesale value over \$26 million for the 15 largest-producing states (U.S. Department of Agriculture, 2007). Plant height can reach up to 1 m and must be controlled to produce plants 48 to 56 cm tall for aesthetic value and amenability for packing and shipping (Miller, 1992, 1993).

Height control of easter lily may be achieved environmentally, culturally, or chemically (Blom et al., 1995, 2004; Erwin et al., 1989; McAvoy, 2001). Stem elongation may be reduced environmentally by manipulating the difference between the day and night air temperatures—also known as DIF (Erwin et al., 1989). Increasing light intensity and reducing exposure to far-red-enriched light at the end of the day (twilight) are additional environmental techniques for reducing easter lily stem

elongation (Blom et al., 1995). Reduction of easter lily stem elongation may be achieved culturally with overhead irrigation using cold water from shoot emergence to flowering (Blom et al., 2004). While these environmental and cultural techniques may be used during easter lily production, they may be difficult to employ in greenhouses with multiple crops or limited infrastructure. Alternatively, chemical plant growth retardant (PGR) applications may be used to produce compact potted easter lilies (McAvoy, 2001).

Several PGRs have been reported to produce shorter easter lilies, including ancymidol, ethephon, paclobutrazol, and uniconazole (Bailey and Miller, 1989; Gianfagna and Wulster, 1986; Jiao et al., 1986; Larson et al., 1987; Lewis and Lewis, 1980, 1981, 1982; Sanderson et al., 1975; Wilfret, 1987, 1990; Wilfret and Reiser, 1996). While PGRs are commonly applied as sprays or media drenches, bulb crops may be submerged in PGR solutions before planting (bulb dip). Bulb dips can reduce labor costs and avoid reduced efficacy associated with

drench applications to substrate components, including bark (Barrett, 2001; Miller, 1993).

Bulb dips have been reported to be an effective method of applying PGRs to control height of numerous bulb crops, including hyacinth (*Hyacinthus*), paperwhites (*Narcissus*), and tulips (*Tulipa*) (Krug et al., 2005a, 2005b, 2006). Easter lily height also has been successfully suppressed in response to bulb dips, yet only solutions containing ancymidol or uniconazole have been used (Larson et al., 1987; Lewis and Lewis, 1980, 1981, 1982; Wilfret, 1990). Paclobutrazol has effectively reduced easter lily stem elongation when applied as a drench or spray (Gianfagna and Wulster, 1986; Jiao et al., 1986; Wilfret, 1987; Wilfret and Reiser, 1996). Dipping oriental lily (*Lilium auratum* × *Lilium speciosum*) and LA-hybrid lily (*L. longiflorum* × asiatic *Lilium* spp.) bulbs in paclobutrazol solutions has successfully controlled plant height (Francescangeli et al., 2007; Ranwala et al., 2002, 2005); however, we have found no reports of dipping easter lily bulbs in paclobutrazol solutions.

Our objectives in this study were to determine if dipping 'Nellie White' easter lily bulbs in paclobutrazol solutions would suppress final plant height and produce a commercially acceptable plant while not adversely impacting days to flower and flower bud number.

Materials and methods

On 27 Oct. 2008, 200 25- to 30-cm-circumference 'Nellie White' easter lily bulbs were delivered from the Easter Lily Research Foundation (Harbor, OR) to Purdue University in West Lafayette, IN (lat. 40°N), in pressboard cases filled with peatmoss. The cases were immediately placed in a walk-in environmental cooler set at 5 °C for a 6-week vernalization treatment. On 9 Dec. 2008, cases were removed from the cooler and the peat

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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
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
0.001	ppm	mL·L ⁻¹	1000
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

was gently removed as 40 uniform bulbs were selected. Ten bulbs were placed in each of 4 L of solution containing 30, 60, or 120 mg·L⁻¹ paclobutrazol (Bonzi; Syngenta Crop Protection, Greensboro, NC) or 4 L of reverse-osmosis water (control) for 15 min to promote uptake of solution and were then allowed to drain for 1 h. All bulbs were planted directly into 15-cm-diameter standard round plastic containers (1.6 L volume) filled with a commercial soilless medium composed of Canadian sphagnum peat, horticultural perlite, and vermiculite (ProMix-BX; Premier Horticulture, Quakertown, PA). Plants were irrigated as necessary with acidified water supplemented with 15N-2.2P-12.5K water-soluble fertilizer (Excel Cal-Mag; Scotts, Marysville, OH) to provide the following (in mg·L⁻¹) at each irrigation: 200 nitrogen, 29 phosphorous, 167 potassium, 67 calcium, 1.0 iron, 1.0 copper, 0.5 manganese, 0.5 zinc, 0.2 boron, and 0.1 molybdenum. Irrigation water was supplemented with 93% sulfuric acid (Ulrich Chemical, Indianapolis) at 0.08 mL·L⁻¹ to reduce alkalinity to 100 mg·L⁻¹ and pH to a range of 5.7 to 6.0.

The plants were grown in a glass-glazed greenhouse with exhaust fan and evaporative-pad cooling, radiant hot-water heating, and retractable shade curtains controlled by an environmental computer (Maximizer Precision 10; Priva Computers, Vineland Station, ON, Canada). The greenhouse temperature set point was 18 ± 1 °C with a 16-h photoperiod (0600–2200 HR) consisting of natural day-lengths with day-extension lighting (≈2 μmol·m⁻²·s⁻¹ at canopy level) from 1700 to 2000 HR with incandescent lamps. High-pressure sodium lamps delivered a supplemental photosynthetic photon flux (PPF) of 100 μmol·m⁻²·s⁻¹ at plant height [as measured with a light quantum sensor (LI-COR Biosciences, Lincoln, NE)] when the ambient greenhouse daily light integral was <10 mol·m⁻²·d⁻¹. Environmental data are reported in Table 1.

Plant height was recorded at emergence and weekly thereafter, and treatment averages were plotted (Fig. 1) on graphical tracking software (Heins et al., 1987). At visible anthesis (flowering), the number of flower buds and final plant height

were recorded. Days to flower were calculated for each plant. There were 10 replicates (bulbs) per treatment. A completely randomized design was used. Data were analyzed with the SAS (version 9.1; SAS Institute, Cary, NC) mixed model procedure (PROC MIXED), and pairwise comparisons between treatments were performed using Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

Results and discussion

Plant height was shorter for all paclobutrazol-treated bulbs compared with control plants (Table 2). Height at flowering was suppressed by 15% to 26% compared with control plants as paclobutrazol concentration increased from 30 to 120 mg·L⁻¹ (Table 2). Soaking bulbs in a 120 mg·L⁻¹ paclobutrazol solution resulted in plants that were 54.6 cm tall at flowering (Table 2), which met the target height range of 48 to 56 cm for potted, flowering easter lily (Miller, 1992). Neither days to flower nor flower bud number were affected by paclobutrazol applications (Table 2). Our results on the impact of paclobutrazol on height, days to flower, and flower bud number are in agreement with previous work using paclobutrazol sprays or drenches with easter lily, or paclobutrazol bulb dips with hybrid lilies (Francescangeli et al., 2007; Gianfagna and Wulster, 1986; Jiao

et al., 1986; Ranwala et al., 2002; Wilfret, 1987; Wilfret and Reiser, 1996).

Although paclobutrazol has been applied to easter lily, it has been applied as foliar sprays and media drenches (Gianfagna and Wulster, 1986; Jiao et al., 1986; Wilfret, 1987; Wilfret and Reiser, 1996). Gianfagna and Wulster (1986) demonstrated that paclobutrazol drench applications affected 'Ace' and 'Nellie White' easter lily differently. Paclobutrazol had no effect on final height or number of flowers per plant of 'Nellie White', yet the number of days to anthesis was reduced by 3.9 and 6.0 when 1.0 or 2.5 mg/pot was applied (Gianfagna and Wulster, 1986). The number of flowers per plant and number of days

Table 1. Mean greenhouse air temperature and daily light integral (DLI) during each month for 'Nellie White' easter lilies grown from bulbs left untreated (control) or soaked in paclobutrazol solutions preceding planting.

Month	Temp [mean ± SD (°C)] ^a	DLI (mol·m ⁻² ·d ⁻¹)
December	16.9 ± 1.2	8.4
January	17.1 ± 0.9	9.2
February	18.2 ± 1.0	10.0
March	18.8 ± 1.0	14.3
April	18.8 ± 0.6	18.9

^a(1.8 × °C) + 32 = °F

Fig. 1. Graphical tracking chart displaying the minimum and maximum target heights (solid lines) and weekly average heights of 'Nellie White' easter lily from untreated (control) bulbs or bulbs soaked in paclobutrazol solutions containing 30, 60, or 120 mg·L⁻¹ (ppm) for 15 min preceding planting (1 cm = 0.3937 inch).

Table 2. The effects of soaking ‘Nellie White’ easter lily bulbs left untreated (control) or soaked in paclobutrazol solutions containing 30, 60, or 120 mg·L⁻¹ for 15 min preceding planting on final plant height, days to flower, and flower bud number.

Plant growth retardant	Concn (mg·L ⁻¹) ^a	Final plant ht (cm) ^a	Time to flower (d)	Flower buds (no.)
Control	—	73.5 a ^y	111 a	5.5 a
Paclobutrazol	30	62.3 b	108 a	5.3 a
Paclobutrazol	60	57.1 bc	109 a	5.4 a
Paclobutrazol	120	54.6 c	112 a	4.5 a
Significance ^x		*		NS

^a1 mg·L⁻¹ = 1 ppm, 1 cm = 0.3937 inch.

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

^xNS, *, **, *** indicates not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Fig. 2. Flowering ‘Nellie White’ easter lily from bulbs left untreated (control) or soaked in paclobutrazol solutions containing 120, 60, or 30 mg·L⁻¹ (ppm) for 15 min preceding planting.

to anthesis of ‘Ace’ were unaffected by paclobutrazol, although treated plants were 29% to 44% shorter than untreated plants as drench concentration increased from 5.0 to 20.0 mg/pot (Gianfagna and Wulster, 1986). Jiao et al. (1986) reported that applying 2.0 to 6.0 mg/pot paclobutrazol suppressed ‘Nellie White’ plant height by 19% to 42% compared with untreated plants, but did not affect days to flower or flower number. Applying 2.0 or 4.0 mg/pot paclobutrazol drenches reduced stem elongation of ‘Ace’ and ‘Nellie White’ by 25% or 39% and 16% or 25%, respectively, while spraying 2.0 or 4.0 mg/pot reduced stem elongation of ‘Ace’ and ‘Nellie White’ by 13% or 23% and 7% or 12%, respectively, though neither days to flower or number of flowers of both cultivars was affected by paclobutrazol applications (Wilfret, 1987). Applying media drenches supplying 2.0, 3.0, or 4.0 mg/pot paclobutrazol to ‘Nellie White’ produced plants 19%, 27%, or 36% shorter compared with untreated plants, but had no effect on days to flower or flower

number (Wilfret and Reiser, 1996). Applying an additional 1.0 or 2.0 mg/pot paclobutrazol at floral bud emergence or floral bud stretch to pots already treated with 2.0 mg/pot further reduced plant height (Wilfret and Reiser, 1996). When taken together with our work, it appears that paclobutrazol can effectively control easter lily height without adversely impacting days to flower or flower number, regardless of application method.

Our results are similar to those using paclobutrazol bulb dips for oriental and LA-hybrid lilies (Francescangeli et al., 2007; Ranwala et al., 2002). Ranwala et al. (2002) demonstrated that dipping bulbs in 50 to 300 ppm paclobutrazol solutions was effective in suppressing height for 14 oriental hybrid and LA-hybrid lilies, although the concentration required for height suppression varied with cultivar. Flowering was delayed up to 4 d for ‘Casa Blanca’ dipped in 200 or 300 mg·L⁻¹, yet most cultivars were unaffected by paclobutrazol; flower number of any cultivar was unaffected

by paclobutrazol (Ranwala et al., 2002). Final height of ‘Ercolano’ and ‘Royal Prospect’ LA-hybrid lily was 29% to 45% and 45% to 59% shorter, respectively, compared with untreated plants as paclobutrazol concentration increased from 50 to 150 ppm. Days to flower of ‘Ercolano’ was unaffected by treatment, and while soaking ‘Royal Prospect’ bulbs in 150 ppm paclobutrazol did significantly delay days to first open flower by one day compared with untreated plants, this does not have much commercial significance (Francescangeli et al., 2007). The number of flower buds of ‘Ercolano’ and ‘Royal Prospect’ were unaffected by any treatment (Francescangeli et al., 2007). These results, combined with our findings, indicate that paclobutrazol bulb dips are an effective method of controlling height of oriental, LA-hybrid, and easter lilies.

Conclusions

Paclobutrazol is effective in reducing stem elongation of ‘Nellie White’ easter lily when applied as a bulb dip. Additionally, bulbs dipped in 120 mg·L⁻¹ paclobutrazol for 15 min flowered within the commercially acceptable specified range of heights without affecting the days to flower or flower bud number (Fig. 2). Applying paclobutrazol to easter lily bulbs using a bulb dip can reduce labor and chemical costs when compared with spraying plants or drenching media. Producers may want to conduct on-site trials, as Larson et al. (1987) has demonstrated that duration of the dip, concentration of a.i., and cultivar can affect height, days to flower, and flower number.

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