Comparison of Flurprimidol to Ethephon, Paclobutrazol, and Uniconazole for Hyacinth Height Control

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ADDITIONAL INDEX WORDS. Bonzi, Florel, plant growth retardants, Sumagic, Topflor

SUMMARY. Preplant bulb soaks of flurprimidol, paclobutrazol, and uniconazole; foliar sprays of ethephon and flurprimidol; and substrate drenches of flurprimidol were compared for height control of 'Anna Marie' hyacinths (*Hyacinthus orientalis*). Preplant bulb soak concentrations of flurprimidol and paclobutrazol were from 25 to 400 mg·L⁻¹, and uniconazole from 5 to 80 mg·L⁻¹. Height control was evaluated at anthesis and 11 days later under postharvest conditions. Ethephon (250 to 2000 mg·L⁻¹) and flurprimidol (5 to 80 mg·L⁻¹) foliar sprays were ineffective. Flurprimidol (0.25 to 4 mg/pot) drenches had no effect during forcing, but controlled postharvest height at concentrations ≥0.25 mg/pot a.i. with at least 4% shorter plants than the untreated control. Preplant bulb soaks resulted in height control with flurprimidol ≥25 mg·L⁻¹, paclobutrazol ≥100 mg·L⁻¹, and uniconazole ≥40 mg·L⁻¹; having at least 9%, 6%, and 19%, respectively, shorter plants than the untreated control. Based on our results, flurprimidol preplant bulb soaks have a greater efficacy than either uniconazole or paclobutrazol. Preplant PGR soaks are a cost-effective method of controlling plant height of hyacinths because of the limited amount of chemical required to treat a large quantity of bulbs.

The vivid colors and intense fragrance of hyacinths make them an excellent potted crop (Nowak and Rudnicki, 1993). However, excessive stem growth can be a concern. DeHertogh (1996) suggested that an optimal hyacinth plant, including the pot (3.5 inches), was 8 to 12 inches tall. A potential postharvest problem of hyacinth is "stem topple," the downward curvature of the flower scape due to postharvest elongation and the heavy inflorescence. To limit growth, strengthen the flower stalk, and prevent "stem topple," foliar applications of ethephon are recommended at concentrations between 500 and 2000 mg·L⁻¹. Limited research has been conducted using other plant growth retardants (PGRs) such as paclobutrazol (Bonzi; Syngenta, Greensboro, N.C.) or uniconazole (Sumagic; Valent USA, Marysville,

Ohio). Drenches and preplant bulb soaks of paclobutrazol and uniconazole have been studied, but no recommended concentrations are available (Miller, 2002). Flurprimidol (Topflor; SePRO Corp., Carmel, Ind.) is currently available in Europe (Topflor) as a 1.5% concentrate; however, there are no recommended concentrations for hyacinth. A U.S. formulation will become available at a 0.38% concentration. This study was conducted to determine the efficacy of preplant bulb soaks of flurprimidol, paclobutrazol, and uniconazole; foliar sprays of ethephon and flurprimidol; and substrate drenches of flurprimidol on hyacinth plant growth.

Materials and methods

Un-cooled hyacinth 'Anna Marie' bulbs were planted in standard 4-inch-

diameter round plastic pots with a volume of 575 mL on 25 Oct. 2002. The root substrate was Berger BM 6 (Berger Peat Moss, St. Modeste, Que., Canada), which contained 75% to 80% Canadian sphagnum peat and 20% to 25% perlite. From potting to 4 Jan. 2003, bulbs were held at 41 °F. On 4 Jan. 2003 temperature was lowered to 34 °F. Greenhouse forcing began on 27 Jan. 2003 with day/night set points of 68/65° F. Plants were forced under natural daylength. The experiment was a completely randomized design with six single plant replications of the 31 treatments.

PLANT GROWTH REGULATOR TREATMENTS. On 25 Oct. 2002, 15 of the 31 treatments were applied as a preplant bulb soak for 10 min: flurprimidol (0.38%) at 25, 50, 100, 200, or 400 mg·L⁻¹; paclobutrazol at 25, 50, 100, 200, or 400 mg·L⁻¹; and uniconazole at 5, 10, 20, 40, or 80 mg·L⁻¹. Foliar sprays and substrate drenches were applied on 4 Feb. 2003 when shoots were 3 to 4 inches tall, before any pink color was visible on the inflorescences. Foliar sprays based on an application volume of 0.5 gal/100 ft² consisted of ethephon at 250, 500, 1000, 1500, or 2000 mg·L⁻¹; and flurprimidol at 5, 10, 20, 40, or 80 mg·L⁻¹. Flurprimidol substrate drenches, 2 fl oz/pot, consisted of 0.25, 0.5, 1, 2, or 4 mg/pot a.i., or an untreated control. Anthesis date (one floret completely open), and total plant height at anthesis (measured from the pot rim to the uppermost part of the inflorescence) were recorded.

POSTHARVEST. Four plants, randomly selected from each treatment, were placed in a growth chamber at 20 °C after anthesis. Fluorescent cool white bulbs provided light at 24 to 75 μmol·m⁻²·s⁻¹. Plant height was recorded 11 d after anthesis.

DATA ANALYSIS. Data were tested by analysis of variance (ANOVA) using general linear model (SAS Institute, Cary, N.C.) and means separation by least significant differences (LSD) at *P*

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Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned. Thanks to Berger for the root substrates, Scotts for the fertilizer, Dillen Products for the pots, and SePRO for grant support.

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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
4,074.5851	gal/100 ft ²	L·ha ⁻¹	0.0002
2.5400	inch(es)	cm	0.3937
28,350	oz	mg	3.5274 × 10 ⁻⁵
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

≤ 0.05 . Forcing and postharvest plant height values were regressed using PROC REG procedure to determine the best-fit, linear or quadratic, model. Terms of the model were evaluated for significance based on a comparison of F values at $\alpha = 0.05$. PROC NLIN in SAS, as modified by Cox (1992), was used to calculate linear-plateau functions (model IV) relating forcing and postharvest plant height to flurprimidol preplant soak concentrations. The quadratic and the linear-plateau models were compared to determine the best fit based on r^2 values.

Results and discussion

The response of 'Anna Marie' hyacinth plants to flurprimidol preplant soaks during forcing was best fit to a linear-plateau model in which the

shortest plants, 8.0 cm tall, resulted from treatment with flurprimidol at concentrations ≥ 134.4 mg·L⁻¹ (Fig. 1A). No further increases in height control occurred at higher concentrations. Plants treated with 134.4 mg·L⁻¹ were 44% shorter than the untreated control. Flurprimidol soaks delayed anthesis by 4, 8, 10, 13 d at concentrations of 50, 100, 200, and 400 mg·L⁻¹, respectively, compared with the untreated control, $P \leq 0.05$ (data not shown). Response to flurprimidol soaks during the postharvest evaluation also was best fit to a linear-plateau model in which the shortest plants, 15.1 cm tall, resulted from treatment with flurprimidol ≥ 102.8 mg·L⁻¹ (Fig. 1A). No further increases in height control occurred at higher concentrations. Heights of plants treated with 102.8 mg·L⁻¹

were on average 43% shorter than the untreated control. Flurprimidol soaks ≥ 50 mg·L⁻¹ provided excessive control of growth. Commercially acceptable plants were produced with 25 mg·L⁻¹ flurprimidol, and additional trials to confirm optimal concentrations and cultivar response should focus on that concentration range.

Paclobutrazol preplant soak of 400 mg·L⁻¹ controlled plant height in greenhouse forcing, with no delay of anthesis (data not shown), resulting in plants 23% shorter than the untreated control (Fig. 1B). During the postharvest evaluation, control occurred at 100, 200, and 400 mg·L⁻¹, resulting in 17%, 28%, and 28% shorter plants, respectively, as compared to the untreated control (Fig. 1B). The high concentration of paclobutrazol

Fig. 1. Effects of (A) flurprimidol preplant bulb soaks, (B) paclobutrazol preplant bulb soaks, (C) uniconazole preplant bulb soaks, and (D) flurprimidol substrate drenches on pot hyacinth 'Anna Marie' height, measured at anthesis (Greenhouse) and 11 d after anthesis (Postharvest). Flurprimidol drenches had no effect on height at anthesis (1 cm = 0.3937 inch; 1 mg = 3.5274×10^{-5} oz).

required to provide height control may limit its suitability as a commercially viable alternative. Growers will need to evaluate how paclobutrazol compares economically with the other PGRs.

Preplant bulb soaks $\geq 40 \text{ mg}\cdot\text{L}^{-1}$ of uniconazole controlled height during greenhouse forcing, resulting in plants 19% shorter than the untreated control (Fig. 1C). Anthesis was delayed 7 d with $80 \text{ mg}\cdot\text{L}^{-1}$ uniconazole preplant soaks, which would be considered excessive by a commercial grower (data not shown). In the postharvest evaluation, the relationship between height and uniconazole concentrations of 10, 20, 40, and $80 \text{ mg}\cdot\text{L}^{-1}$ was linear, resulting in 4%, 7%, 15%, and 30% shorter plants, respectively, than the untreated control (Fig. 1C).

At the concentrations tested ($\leq 2000 \text{ mg}\cdot\text{L}^{-1}$), ethephon did not control height during forcing or during postharvest evaluation. Anthesis was significantly ($P \leq 0.05$) delayed at concentrations of 1500 and $2000 \text{ mg}\cdot\text{L}^{-1}$, by 1.8 and 1.6 d, respectively, as compared to the untreated control (data not shown). The lack of response contradicts the commercial recommendations of applying ethephon prior to coloration of the florets, corresponding to 8 d after commencement of greenhouse forcing. It is unclear why ethephon had no effect on height. The chemical apparently penetrated the plant tissue, as flowering was delayed at the highest concentrations.

Flurprimidol foliar sprays did not control height at any concentration tested ($\leq 80 \text{ mg}\cdot\text{L}^{-1}$). Sprays of $80 \text{ mg}\cdot\text{L}^{-1}$ flurprimidol resulted in a slight delay of anthesis by 1.8 d ($P \leq 0.05$),

compared to the untreated control (data not shown). Earlier applications may provide control of plant height, but control is still likely to be minimal because a limited amount of leaf area is present during the initial 8 d of forcing. Higher concentrations of flurprimidol foliar sprays should be tested for their effectiveness.

Flurprimidol substrate drenches had no effect on height during greenhouse forcing, but did limit postharvest elongation. Plants treated with 0.25, 0.5, 1, 2, 4 mg/pot a.i. resulted in 4%, 8%, 14%, 23%, and 22% shorter plants during the postharvest evaluation, respectively, than the untreated control (Fig. 1D). The lack of growth control during greenhouse forcing may be due to applying the drenches 8 d after forcing began. The root system was well developed when greenhouse forcing began; therefore, applying drenches within 24 to 48 h of moving the plants into the greenhouse should be studied. No anthesis delay occurred with flurprimidol drenches (data not shown).

Conclusions

Higher concentrations and application timing of flurprimidol foliar sprays should be explored to determine if sprays are a suitable method to control hyacinth plant height. Flurprimidol substrate drenches did not result in control during greenhouse forcing, but did limit elongation during the postharvest evaluation. This suggests additional work should be done to determine optimal application timing. The responses of 'Anna Marie' hyacinth

to preplant soaks of flurprimidol at $25 \text{ mg}\cdot\text{L}^{-1}$ and paclobutrazol at $100 \text{ mg}\cdot\text{L}^{-1}$ were comparable; producing 9% and 6%, respectively, shorter plants than the untreated control, but resulting in flower delay of 1 to 2 d. Preplant soaks of flurprimidol at $25 \text{ mg}\cdot\text{L}^{-1}$ and paclobutrazol at $100 \text{ mg}\cdot\text{L}^{-1}$ should be considered for use in commercial greenhouse production. Based on observations, plants treated with $\geq 40 \text{ mg}\cdot\text{L}^{-1}$ uniconazole were too short and no control occurred with $\leq 20 \text{ mg}\cdot\text{L}^{-1}$. Concentrations between 20 and $40 \text{ mg}\cdot\text{L}^{-1}$ should be explored. Based on our results, flurprimidol preplant bulb soaks have a greater efficacy than either uniconazole or paclobutrazol. Preplant PGR soaks are also a cost-effective method of controlling plant height of hyacinths because of the limited amount of chemical required to treat a large quantity of bulbs.

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