Narcissus Response to Plant Growth Regulators

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SUMMARY. Three experiments were conducted to determine the effectiveness of plant growth regulators (PGRs) on 'Tete a Tete', 'Dutch Master', and 'Sweetness' narcissus (*Narcissus pseudonarcissus*). Ethephon foliar sprays (500 to 2500 mg·L⁻¹) and substrate drenches of flurprimidol and paclobutrazol (0.25 to 4 mg/pot a.i.) did not control height during greenhouse forcing of 'Tete a Tete' at any concentration trialed. Stem stretch was controlled during postharvest evaluation with ethephon foliar sprays ≥ 1000 mg·L⁻¹, flurprimidol substrate drenches ≥ 0.5 mg/pot a.i., and paclobutrazol substrate drenches of 4 mg/pot a.i. A second experiment investigated preplant bulb soaks of flurprimidol (10 to 40 mg·L⁻¹) applied to 'Dutch Master' and 'Tete a Tete' narcissus bulbs. Flurprimidol preplant bulb soaks controlled postharvest stretch on 'Tete a Tete' and 'Dutch Master' at concentrations ≥ 15 and ≥ 10 mg·L⁻¹, respectively. A third experiment was conducted with paclobutrazol (75 to 375 mg·L⁻¹) on 'Tete a Tete' and 'Dutch Master' and three concentrations of flurprimidol on 'Sweetness' to determine optimal soak recommendations. Paclobutrazol preplant bulb soaks ≥ 75 mg·L⁻¹ controlled postharvest stretch of 'Tete a Tete' and 'Dutch Master', while 37.5 mg·L⁻¹ of flurprimidol controlled postharvest stretch of 'Sweetness'. Based on the results of these experiments, growers can now select a PGR to help control excessive plant growth.

When narcissus are grown in pots, a common problem encountered by growers is excessive plant height (Briggs, 1975; Moe, 1980). Typically, taller cultivars are grown in 6-inch-diameter pots and shorter cultivars are grown in 4-inch-diameter pots. Optimal height for plants grown in 6-inch pots at the "pencil" stage should be 10 to 12 inches tall; however, cultivars grown in 4-inch pots at the same stage should be shorter (De Hertogh, 1996). Plant growth regulators can be used to produce plants at the appropriate height. Ethephon is commonly used as a foliar spray at concentrations of 1000 to 2000 mg·L⁻¹ when the leaves and floral stalks are 3 to 4 inches tall (De Hertogh, 1996; Kamp and De Hertogh, 1986). Paclobutrazol (Bonzi; Syngenta, Greensboro, N.C.) label

recommendations include drench applications of 1.2 to 2.4 mg/pot a.i. 1 to 5 d after removal from the cooler, or a 1-h preplant soak at a concentration of 80 mg·L⁻¹; however, it has been reported that paclobutrazol is only marginally effective in controlling height (Adriansen, 1985). Bulb crops are listed on the uniconazole (Sumagic; Valent USA, Marysville, Ohio) label; however, for narcissus no specific recommendations are given, and it has been reported to have limited effectiveness (W.B. Miller, personal communication). Flurprimidol (Topflor; SePRO Corp., Carmel, Ind.) has been available in Europe for more than 20 years as a 1.47% concentration and is being introduced into the U.S. market as a 0.38% concentration.

These experiments were conducted to determine the efficacy of flurprimidol (0.38%) applied as a substrate drench compared to paclobutrazol substrate drenches and ethephon foliar sprays on 'Tete a Tete' narcissus. The optimum concentration for flurprimidol preplant bulb soaks on 'Tete a Tete', 'Dutch Master', and 'Sweetness' narcissus were investigated as well as optimum concentrations of paclobutrazol on 'Tete a Tete' and 'Dutch Master' as preplant bulb soaks.

Methods and materials

EXPT. 1. On 25 Oct. 2002, non-cooled narcissus 'Tete a Tete' bulbs were planted, two bulbs per pot, in 4-inch-diameter round plastic pots with a volume of 575 mL. 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. For 10 weeks the cooler temperature set point was 41 °F. On 4 Jan. 2003 the cooler temperature set point was reduced to 34 °F until 8 Feb. 2003. The bulbs were removed from the cooler at sunset and allowed to acclimate overnight. Greenhouse forcing began on 8 Feb. 2003 with day/night set points of 68/64 °F. Plants were forced under natural day lengths.

On 9 Feb. 2003, substrate drenches were applied at 2 fl oz solution per pot: flurprimidol (0.38%) at 0.25, 0.5, 1, 2, or 4 mg/pot a.i.; and paclobutrazol (Piccolo; Fine Americas, Walnut Creek, Calif.) at 0.25, 0.5, 1, 2, or 4 mg/pot a.i. Foliar sprays of ethephon at 500, 1000, 1500, 2000, or 2500 mg·L⁻¹ were also applied at 0.5 gal/100 ft² on 9 Feb., when the shoots were 3 to 4 inches tall. Untreated controls were also included. The experiment was a completely randomized design with six single-pot replications for each of the 16 treatments.

EXPT. 2. On 24 Oct. 2003, dry, noncooled 'Tete a Tete' and 'Dutch Master' were soaked for 10 min in

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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
0.4075	gal/100 ft ²	L·m ⁻²	2.4542
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

flurprimidol (0.38%) at 10, 15, 20, 25, 30, 35, or 40 mg·L⁻¹. Tap water was used to mix the soak solution at a temperature of 64 °F. Untreated controls were also included. The ‘Tete a Tete’ bulbs were allowed to air dry and were planted, two bulbs per pot, in 4-inch-diameter round plastic pots with a volume of 575 mL on the day of treatment. Narcissus ‘Dutch Master’ bulbs were also allowed to air dry and were planted, two bulbs per pot, in 6-inch-diameter round plastic pots with a volume of 1.9 L. The root substrate was Berger BM 6. The experiment was a completely randomized design with six single-pot replications for each of the eight treatments. For 10 weeks the cooler temperature set point was 41 °F. On 5 Jan. 2004 the cooler temperature set point was reduced to 34 °F until 5 Feb. 2004. The pots were removed from the cooler and allowed to acclimate overnight. Greenhouse forcing began on 5 Feb. 2004 with day/night set points of 68/64 °F. Plants were forced under natural day lengths.

EXPT. 3. On 28 Oct. 2004, dry, noncooled ‘Tete a Tete’ and ‘Dutch Master’ bulbs were soaked in paclobutrazol (Bonzi) for 2 min at 75, 150, 225, 300, or 375 mg·L⁻¹. Tap water was used to mix the soak solution at a temperature of 70 °F. Noncooled ‘Sweetness’ bulbs were soaked in flurprimidol for 2 min at 25, 37.5, or 50 mg·L⁻¹. Untreated controls were also included. The ‘Tete a Tete’, ‘Dutch Master’, and ‘Sweetness’ bulbs were allowed to air dry and were planted as described in Expt. 2. The experiment was a completely randomized design with eight single-pot replications of

10 treatments. From potting to 4 Jan. 2005, bulbs were held at 41 °F. On 4 Jan. 2005 the cooler temperature set point was reduced to 34 °F until 14 Feb. 2005. Greenhouse forcing began on 14 Feb. with day/night set points of 68/65 °F. Plants were forced under natural day lengths.

GREENHOUSE DATA COLLECTION. Anthesis date (one inflorescence per pot fully opened) and plant height at anthesis (measured from the soil line to the uppermost part of the inflorescence) were recorded.

POSTHARVEST EVALUATION. Four randomly selected plants from each treatment and each experiment were placed in a postharvest room at 68 °F after anthesis. Light was provided by fluorescent bulbs at 24 to 75 μmol·m⁻²·s⁻¹. Plant height was recorded 8 d (Expt. 1) and 10 d (Expt. 2 and Expt. 3) after anthesis.

DATA ANALYSIS. Data were tested by analysis of variance (ANOVA) using general linear model (SAS Institute, Cary, N.C.) and means were separated by least significant differences (LSD) at $P \leq 0.05$. Plant heights at the end of forcing were regressed using PROC REG to determine the best-fit, linear or quadratic models. Terms of the model were evaluated for significance based on 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 postharvest plant height to ethephon, flurprimidol, and paclobutrazol concentrations. The quadratic and the linear-plateau models were compared to determine the best fit based on r^2 values.

Results and discussion

EXPT. 1. Plant height of ‘Tete a Tete’ narcissus during greenhouse forcing was not controlled with ethephon foliar sprays at any concentration used (Fig. 1A). At the end of the postharvest evaluation, the response of ‘Tete a Tete’ narcissus plants to ethephon foliar sprays was best fit to a linear-plateau model in which the smallest plants (25.7 cm tall) occurred with sprays of 1518.4 mg·L⁻¹ (Fig. 1A). No further increases in height control occurred at higher concentrations. Plants treated with 1518.4 mg·L⁻¹ ethephon were 19% shorter than the untreated control. Ethephon foliar sprays did not result in delay of anthesis at any concentration trialed (data not shown). Ethephon foliar sprays of 1518.4 mg·L⁻¹ are within the 1000 to 2000 mg·L⁻¹ range recommended by De Hertogh (1996) to maintain a marketable plant height.

Flurprimidol substrate drenches did not significantly ($P \leq 0.05$) control plant height at any concentration trialed during greenhouse forcing (Fig. 1B). At the end of the postharvest evaluation, the response of ‘Tete a Tete’ narcissus plants to flurprimidol substrate drenches was best fit to a linear-plateau model in which the smallest plants (27.6 cm tall) resulted from drenches of 0.69 mg/pot a.i. (Fig. 1B). No further increases in height control occurred at higher concentrations. Plants treated with 0.69 mg/pot a.i. flurprimidol were 15% shorter than the untreated control. Flurprimidol substrate drenches did not delay anthesis at any concentration trialed (data

Fig. 1. Effects of ethephon foliar sprays (A), flurprimidol substrate drenches (B) and paclobutrazol substrate drenches (C) on pot narcissus ‘Tete a Tete’ height measured at anthesis (Greenhouse) and 8 d after anthesis (Postharvest) (Expt. 1) (1 cm = 0.3937 inch, 1 mg = 3.5274×10^{-5} oz).

Fig. 2. Effects of flurprimidol preplant bulb soaks on narcissus cultivars 'Tete a Tete' (A, above left) and 'Dutch Master' (B, above right) plant height measured at anthesis (Greenhouse) and 10 d after anthesis (Postharvest) (Expt. 2) (1 cm = 0.3937 inch).

not shown). Based on these results, flurprimidol at concentration of 0.69 mg/pot a.i. can be used as a substrate drench by growers who want to control postharvest stem stretch of 'Tete a Tete' narcissus grown in 4-inch pots.

Paclobutrazol substrate drenches did not control plant height at any concentration trialed during greenhouse forcing (Fig. 1C). Postharvest stem stretch of 'Tete a Tete' narcissus plants was controlled by paclobutrazol substrate drenches at a concentration of 2 mg/pot a.i. This resulted in plants 26.1 cm tall, which were 19% shorter than the untreated control (Fig. 1C). No concentration of paclobutrazol substrate drenches delayed anthesis (data not shown). Paclobutrazol substrate drenches of 2 mg/pot a.i. were within the 1.2 to 2.4 mg/pot a.i. listed on the paclobutrazol label.

EXPT. 2. Flurprimidol preplant bulb soaks significantly ($P \leq 0.05$) controlled 'Tete a Tete' and 'Dutch Master' plant height during greenhouse forcing at concentrations ≥ 25 mg·L⁻¹, which resulted in plants $\geq 19\%$ and $\geq 14\%$ shorter than the untreated control, respectively (Fig. 2A–B). No delay of anthesis occurred with any concentration of flurprimidol trialed for either cultivar (data not shown). Stem stretch of 'Tete a Tete' and 'Dutch Master' was controlled during the postharvest evaluation with flurprimidol preplant bulb soaks ≥ 25 mg·L⁻¹ and ≥ 20 mg·L⁻¹, respectively. These concentrations resulted in 'Tete a Tete' plants that were $\geq 15\%$ shorter and 'Dutch Master' plants $\geq 18\%$ shorter than the untreated control (Fig. 2A–B). Flurprimidol preplant bulb soaks can be used to control postharvest stem

stretch of 'Tete a Tete' and 'Dutch Master' at concentrations of 25 and 20 mg·L⁻¹, respectively.

EXPT. 3. Paclobutrazol preplant bulb soaks significantly ($P \leq 0.05$) controlled 'Tete a Tete' narcissus plant height during greenhouse forcing at concentrations ≥ 150 mg·L⁻¹, resulting in plants at least 20% shorter than the untreated control (Fig. 3A). At concentrations ≥ 150 mg·L⁻¹, anthesis was delayed by 0.5 d ($P \leq 0.05$), which would not be considered excessive by commercial standards. Based on linear plateau analysis, the use of ≥ 202.8 mg·L⁻¹ of paclobutrazol resulted in 'Tete a Tete' plants that were 18.6 cm tall at the end of the postharvest evaluation (Fig. 3A). These plants were 47% shorter than the untreated control. No further increases in control occurred at higher concentrations. Although

Fig. 3. Effects of preplant bulb soaks on narcissus cultivars using paclobutrazol on 'Tete a Tete' (A, above left) and 'Dutch Master' (B, above center), and flurprimidol on 'Sweetness' (C, above right) plant height measured at anthesis (Greenhouse) and 10 d after anthesis (Postharvest) (Expt. 3) (1 cm = 0.3937 inch).

the greatest control was provided by a concentration of 202.8 mg·L⁻¹, this would be considered excessive by commercial standards. A concentration of 75 mg·L⁻¹ would be considered commercially acceptable, which resulted in plants 17% shorter than the untreated control.

Paclobutrazol preplant bulb soaks controlled 'Dutch Master' narcissus plant height during greenhouse forcing at concentrations ≥ 75 mg·L⁻¹, resulting in plants at least 11% shorter than the untreated control (Fig. 3B). All concentrations with the exception of 150 mg·L⁻¹ delayed anthesis by 1 to 1.5 d, ($P \leq 0.05$), which would not be considered excessive by commercial standards. At the end of the postharvest evaluation, plants treated with concentrations ≥ 213.2 mg·L⁻¹ were 30.0 cm tall (33% shorter than the untreated control) (Fig. 3B). No further increases in control occurred at higher concentrations. The control provided by 213.2 mg·L⁻¹ would be considered excessive by commercial standards. Based on regression analysis, a concentration of 100 mg·L⁻¹ resulted in plants 37.9 cm tall (16% shorter than the untreated control) and would be considered commercially acceptable.

The paclobutrazol (Bonzi) label recommended an 80 mg·L⁻¹ bulb soak for 1 h; however, our recommendation of 100 mg·L⁻¹ required only a 2-min soak time. It is unclear why a lower rate was recommended with the longer soak time. Varying soak time for 2 to 40 min with flurprimidol was reported to have no effect on the plant height of hyacinth (*Hyacinthus orientalis*) (Krug, 2004). The shorter soak time would be beneficial in saving labor costs during the soak process.

Flurprimidol preplant bulb soaks controlled 'Sweetness' narcissus plant height during greenhouse forcing at concentrations ≥ 37.5 mg·L⁻¹, resulting in plants at least 15% shorter than untreated controls (Fig. 3C). No delay of anthesis was caused by any concen-

tration trialed (data not shown). At the end of the postharvest evaluation, plants treated with a concentration ≥ 25 mg·L⁻¹ were significantly shorter than the untreated control ($P \leq 0.05$); however, a concentration of 37.5 mg·L⁻¹ resulted in plants that were commercially acceptable (17% shorter than the untreated control).

Conclusions

'Tete a Tete' plant height was not controlled by ethephon foliar sprays, flurprimidol substrate drenches, or paclobutrazol substrate drenches during greenhouse forcing. Only preplant bulb soaks of flurprimidol and paclobutrazol were effective in providing shorter 'Tete a Tete' and 'Dutch Master' plants in the greenhouse. However, height control is often not a concern for commercial producers during greenhouse forcing, as the plants are shipped to consumers before stem elongation occurs (De Hertogh, 1996).

Control of postharvest stem stretch is of a greater concern to prevent unsightly stem elongation during marketing and to improve postharvest quality for consumers. Ideally, plants treated with PGRs should be at least 15% to 20% shorter than the untreated control at postharvest evaluation (T. Harger, personal communication). To provide postharvest control with 'Tete a Tete', a preplant soak of flurprimidol (25 mg·L⁻¹) or paclobutrazol (75 mg·L⁻¹) can be used. Substrate drenches of flurprimidol (0.69 mg/pot a.i.) or paclobutrazol (2 mg/pot a.i.) provided adequate control, as well as a foliar spray of ethephon (1518.4 mg·L⁻¹). Preplant bulb soaks of flurprimidol (20 mg·L⁻¹) or paclobutrazol (100 mg·L⁻¹) can be used to obtain 'Dutch Master' plants that are 15% to 20% shorter than the untreated control at postharvest evaluation. Flurprimidol preplant bulb soaks (37.5 mg·L⁻¹) can also be used to obtain commercially acceptable 'Sweetness' plants.

The responses of 'Tete a Tete', 'Dutch Master', and 'Sweetness' vary for flurprimidol as a preplant bulb soak. 'Tete a Tete' and 'Dutch Master' responses also vary for preplant bulb soaks of paclobutrazol. Cultivar response variation to PGRs has also been reported with sunflower (*Helianthus annuus*) (Whipker and McCall, 2000), hyacinth, and tulip (*Tulipa* spp.) cultivars (Krug, 2004). Therefore, growers should conduct on-site trials to determine the optimal concentrations for other narcissus cultivars.

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