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Potted Sunflower Growth and Flowering Responses to Foliar Applications of Daminozide, Paclobutrazol, and Uniconazole

Brian E. Whipker^{1,2} and
Shravan Dasoju²

ADDITIONAL INDEX WORDS. *Helianthus annuus*, growth retardant

SUMMARY. Plant growth retardant (PGR) foliar sprays (in mg·L⁻¹) of daminozide at concentrations from 1,000 to 16,000; paclobutrazol from 5 to 80; and uniconazole from 2 to 32 were applied to 'Pacino' potted sunflowers (*Helianthus annuus* L.) to compare their effectiveness at chemical height control. Plants were grown in 650-mL or 1.2-L pots. When the first inflorescence started to shed pollen, number of days from seeding until anthesis, total plant height measured from the pot rim to the top of the inflorescence, inflorescence diameter, and plant diameter were recorded. There was no significant difference in plant height between 'Pacino' plants grown in 650-mL or 1.2-L pots. Total plant height, plant diameter, inflorescence diameter, and days until flowering were significant for the PGR treatment main effect. Marketable-sized plants grown in the 1.2-L pots were produced with uniconazole concentrations from 16 to 32 mg·L⁻¹ or with daminozide concentrations

¹Department of Horticulture, Iowa State University, Ames, IA 50011-1100.

²Current address: Department of Horticultural Science, Box 7609, North Carolina State University, Raleigh, NC 27695-7609.

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from 4,000 to 8,000 mg·L⁻¹. Paclobutrazol foliar sprays up to 80 mg·L⁻¹ had little effect, and higher foliar spray concentrations or substrate drench treatments may be needed to effectively control height.

Annual sunflower is native to North America, and cultivars grown for seed or oil are tall with a prominent inflorescence. Potted sunflower plants can become disproportionately large relative to their container size when grown in a greenhouse, making them less attractive to consumers. Plant growth retardants (PGRs) are commonly applied to containerized crops when plants are likely to become disproportionately large relative to the container (Barrett et al., 1994; Tayama et al., 1992). Foliar sprays (66 and 132 mg·L⁻¹) of ancymidol (α -cyclopropyl- α -(4-methoxyphenyl)-5-pyrimidinemethanol) decreased plant height, node number, fresh and dry weights, and leaf area of four sunflower cultivars grown in pots under greenhouse conditions (Starman et al., 1989). Wample and Culver (1983) applied paclobutrazol [(+)-(R*,R*)- β [(4-chlorophenyl]

methyl)- α -(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol] drenches of 100 mL of solution containing 11.6, 58, and 116 mg·L⁻¹ of active ingredient to sunflowers and found that water use decreased as paclobutrazol concentration increased. This was attributed to a reduction in leaf expansion and internodal elongation, which resulted in reduced plant height measured at the end of the 8- to 14-d experimental period. In both of the above studies, field grown sunflower cultivars were grown in pots under greenhouse conditions. The only available recommendation for height control of potted sunflowers suggests applying foliar sprays of an unspecified concentration of daminozide 3 weeks after sowing (Benary Seed Co., 1996). This study was conducted to compare the effectiveness of daminozide, paclobutrazol, and uniconazole [(E)-1-(p-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)] as a chemical height control for 'Pacino' potted sunflowers grown in 650-mL and 1.2-L containers.

Materials and methods

EXPERIMENT 1. 'Pacino' potted sun-

flower seeds were sown into cell packs (8×4×5.5-cm cells) (2×1×1.4 inch) on 25 Jan. 1996. On 15 Feb. the seedlings were transplanted into 650-mL (11-cm-diameter) (4.5-inch) or 1.2-L (15-cm-diameter) (6-inch) round plastic pots. The root medium contained 2 soil : 5 sphagnum peat : 3 perlite (by volume) and was amended with ground dolomitic limestone to pH 5.1. Plants were fertilized at each watering (mg·L⁻¹) with 155N-21P-127K. Greenhouse day/night set points were 24/18 °C (75/65 °F). The plants were grown under natural daylength. Fifteen PGR foliar spray treatments (in mg·L⁻¹) were applied 18 d after potting by using a volume of 204 mL·m⁻²: daminozide at 1,000, 2,000, 4,000, 8,000, or 16,000; paclobutrazol at 5, 10, 20, 40, or 80; uniconazole at 2, 4, 8, 16, or 32; and an untreated control. A completely randomized design of 10 single-plant replications of the 32 treatment combinations (2 pot sizes × 16 PGR treatments including the control) was used. When the first inflorescence started to shed pollen, the number of days from seeding until anthesis, total plant height measured from the pot rim to the top of the inflorescence, inflorescence di-

Table 1. Effectiveness of foliar applications of daminozide, paclobutrazol, and uniconazole on plant height, plant diameter, inflorescence diameter, days from sowing until anthesis, and costs of the plant growth retardant (PGR) treatments for 'Pacino' potted sunflowers.

PGR treatment	Concn (mg·L ⁻¹)	Plant ht (cm) ^a	Plant diam (cm) ^a	Inflorescence diam (cm) ^a	Days to anthesis ^a	PGR cost per 100 pots (\$) ^b
Untreated control	---	48.8	39.8	14.0	75.8	---
Paclobutrazol	5	49.5	40.3	14.0	76.7	0.07
	10	48.2	39.7	14.1	75.7	0.13
	20	47.3	39.3	13.9	75.7	0.26
	40	46.0	38.6	13.7	75.7	0.56
	80	45.4	37.4	13.8	77.2	1.05
Significance		L***	L***	NS	Q**	
Uniconazole	2	47.7	39.6	14.0	75.7	0.16
	4	47.5	39.2	13.7	76.2	0.32
	8	46.3	38.0	13.7	76.2	0.64
	16	46.4	37.7	13.8	76.7	1.28
	32	40.7	35.4	13.0	78.9	2.56
Significance		L***Q**	L***	L***	L***Q*	
Daminozide	1000	42.4	38.4	13.3	77.0	0.09
	2000	44.6	39.4	13.8	76.3	0.18
	4000	40.6	38.5	13.4	77.1	0.36
	8000	38.7	38.6	13.2	77.4	0.71
	16000	38.0	38.8	12.7	78.9	1.43
Significance		L***	NS	L**Q**	L**Q*	

^aLSD ($\alpha \leq 0.05$) was 0.5 cm and 1.4 d, respectively, for plant height, plant diameter, inflorescence diameter and days to anthesis for the PGR treatments. Mean for both pot sizes and $n = 20$.

^bCost (rounded) as of 1 Jan. 1997 based on the use of foliar applications of PGRs on 1.2-L pots spaced pot to pot at 42 pots/m². Corresponding to the cost of \$102/qr for paclobutrazol, \$78/qr for uniconazole, and \$71/lb for daminozide.

^{NS,***,**}Nonsignificant or significant by single-degree-of-freedom test for each treatment grouping at $P \leq 0.05$, 0.01, or 0.001, respectively; L = linear, Q = quadratic.

ameter (measured at the widest dimension and turned 90°, and averaged), and plant diameter (measured at the widest dimension and turned 90°, and averaged) were recorded. Data were tested by analysis of variance by general linear model procedures (SAS Institute, Cary, N.C.). Means were separated by least significant difference (LSD) at $P \leq 0.05$.

EXPERIMENT 2. The same procedures used in Expt. 1 were repeated except as noted. 'Pacino' potted sunflower seeds were sown into cell packs on 18 Dec. 1996 and seedlings were transplanted into 1.2-L (15-cm-diameter) round plastic pots on 5 Jan. 1997. The PGR foliar spray treatments of daminozide and uniconazole were applied 15 d after potting at the same concentration as Expt. 1. The paclobutrazol treatments were not applied. A completely randomized design of 8 single-plant replications of the 11 treatment combinations (1 pot size $\times$ 11 PGR treatments including the control) was used.

Results and discussion

Results of the foliar PGR applications were similar for both experiments and only Expt. 1 results are reported. Pot size $\times$ PGR treatment interaction was not significant. Total plant height, plant diameter, inflorescence diameter, and days until anthesis were significant for the PGR main effect.

TOTAL HEIGHT. 'Pacino' potted sunflowers were not responsive to paclobutrazol concentrations ≤ 20 mg·L⁻¹ or uniconazole concentrations ≤ 4 mg·L⁻¹ compared to the untreated control (Table 1). Plants treated with 40 and 80 mg·L⁻¹ of paclobutrazol were 6% shorter than the untreated control. Plants were 5% shorter than the untreated control with uniconazole at 8 and 16 mg·L⁻¹, and 17% shorter at 32 mg·L⁻¹. Daminozide at all concentrations resulted in shorter plants by $\geq 17\%$ with concentrations $\geq 4,000$ mg·L⁻¹, with effectiveness increasing as the concentration increased. Plants treated with the highest concentrations of all three PGRs exhibited crinkled upper leaves, indicating excessive concentrations. In addition, plants treated with 16,000 mg·L⁻¹

daminozide developed inflorescence oriented upwards (at a 45° angle to the stem) instead of parallel to the stem.

PLANT DIAMETER. Plant diameter was not affected by daminozide (Table 1). Paclobutrazol at 80 mg·L⁻¹ produced plants 6% smaller in diameter, and uniconazole concentrations ≥ 8 mg·L⁻¹ resulted in plants 4% smaller in diameter compared to the control.

INFLORESCENCE DIAMETER. Uniconazole application at 32 mg·L⁻¹ and daminozide at 4,000 to 16,000 mg·L⁻¹ resulted in an inflorescence diameter $\geq 5\%$ smaller when compared to the untreated control (Table 1). When the inflorescence started to shed pollen was used as the timing to measure inflorescence diameter. After this point, the inflorescence was observed to increase in size for all PGR treatments except for uniconazole at 32 mg·L⁻¹ and daminozide at 16,000 mg·L⁻¹. Although inflorescence diameter was statistically significant at first pollen, the differences noted for all concentrations except uniconazole at 32 mg·L⁻¹ and daminozide at 16,000 mg·L⁻¹ would not be a detrimental reduction to commercial growers. Inflorescence diameter was not affected by paclobutrazol.

DAYS TO ANTHESIS. The number of days from seeding to anthesis were significant for the PGR main effect. A statistically significant delay in flowering occurred only with the highest concentration of paclobutrazol (80 mg·L⁻¹) and uniconazole (32 mg·L⁻¹) and with daminozide concentrations $\geq 8,000$ mg·L⁻¹ (Table 1). Flowering was 2 to 3 d later than the untreated control. Although the delay was statistically significant, it would not be a detrimental delay to commercial growers. The 2- to 3-d delay of flowering is shorter than the 10- to 18-d delay reported when three foliar applications of daminozide at 1,500 mg·L⁻¹ were used in Germany (Benary Seed Co., personal communication).

Conclusions

Sachs et al. (1976) recommended that optimal plant height should be 1.5 to 2 times the container height. In this study, marketable-sized plants grown in the 1.2-L pots were produced with uniconazole concentrations

from 16 to 32 mg·L⁻¹ or with daminozide concentrations from 4,000 to 8,000 mg·L⁻¹, even though they were two to three times taller than the pot height of 12.5 cm. Flowering was delayed with the 32 mg·L⁻¹ uniconazole and 8,000 mg·L⁻¹ daminozide sprays. The choice of PGRs to control the growth of potted sunflowers should be based on the response of the plant and the cost of the PGR (Table 1). The desired control of growth was obtained for the lowest cost by using daminozide at the cost of \$0.36 to \$0.71/100 1.2-L pots, which was 45% to 72% less expensive than uniconazole.

At the concentrations used, paclobutrazol had little effect on plant height, and substrate drench treatments or higher spray concentrations—although delay in flowering should be expected—should be considered for effective growth control. There was no significant difference in plant height between 'Pacino' plants grown in 650-mL or 1.2-L pots. For 'Pacino' to be suitable when grown in 650-mL pots, a smaller sized plant will have to be produced. This may be possible by applying PGRs earlier in the production cycle.

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