Vegetatively Propagated Geraniums Respond Similarly to Drench Applications of Paclobutrazol or Uniconazole

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SUMMARY. Drench applications of paclobutrazol or uniconazole were applied at doses of 0, 0.0025, 0.005, 0.01, 0.02, or 0.04 mg a.i./pot (28,350 mg = 1.0 oz) to vegetatively propagated 'Aurora', 'Medallion Dark Red', and 'Pink Satisfaction' geranium (*Pelargonium* × *hortorum* L.H. Bailey). Geranium total plant height, leaf canopy height, and plant diameter responded similarly to drench applications of either paclobutrazol or uniconazole. There was a significant quadratic relationship between plant growth regulator (PGR) dose and total plant height and leaf canopy height for 'Aurora' and 'Medallion Dark Red', with total plant height and leaf canopy height being shorter as paclobutrazol

or uniconazole doses increased up to 0.02 mg. However, doses of ≥0.02 mg had little additional effect on total plant height and leaf canopy height. Most of the total height control achieved by the use of PGRs was primarily due to a reduction of leaf canopy height, rather than inflorescence height. Doses of 0.005 to 0.01 mg of either PGR produced marketable sized potted plants of 'Medallion Dark Red' and 'Pink Satisfaction'. 'Aurora', which was the most vigorous cultivar, required doses of 0.01 or 0.02 mg of either paclobutrazol or uniconazole to produce marketable sized potted plants.

Chemical plant growth regulators (PGRs) are applied to both seed and vegetatively propagated geraniums to control plant height and improve overall appearance. Paclobutrazol ((+)-(R*,R*)-β([4-chlorophenyl]methyl)-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol) (Bonzi, Uniroyal Chemical, Middlebury, Conn.) drenches of 0.01 to 0.5 mg a.i./pot suppressed plant height of seed propagated geraniums (Shanks, 1980). Cox and Keever (1988) conducted studies with paclobutrazol to control height of seed propagated geraniums and found root substrate drenches of 0.0075 or 0.015 mg or a single foliar spray of 20 or 40 mg·L⁻¹ (ppm) were effective in controlling height and producing a marketable plant. Excessively short plants resulted when higher drench or foliar spray doses were used. Nørremark and Andersen (1990) also found paclobutrazol drench applications of ≥0.05 mg resulted in seed geraniums which were excessively short and new growth continued to be retarded throughout the summer. Uniconazole ((E)-1-(p-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)) (Sumagic, Valent USA, Marysville, Ohio) drenches of 0.025 to 0.1 mg were applied to two cultivars of seed geraniums and doses of 0.025 were found to be effective for growth control, while higher doses were excessive (Starman et al., 1994).

Vegetatively propagated geraniums are typically more vigorous than seed propagated geraniums. A limited number of scientific studies have been conducted on the response of vegetatively propagated geraniums to paclobutrazol or uniconazole substrate

drenches. Foliar applications of paclobutrazol at 15 mg·L⁻¹, applied twice, or uniconazole at 10 mg·L⁻¹, applied twice, resulted in effective height control and the production of marketable plants (Tayama and Carver, 1990). The same doses of these PGRs applied as substrate drenches resulted in excessive suppression of growth (Tayama and Carver, 1990). A similar study indicated that uniconazole applied at 0.6 to 1.2 mg as a substrate drench was excessive on vegetatively propagated geraniums, however this study did not include lower doses and a recommended commercial rate was not given (Tayama and Carver, 1992). While some studies have involved either paclobutrazol or uniconazole, none have directly compared similar doses of both chemicals over a wide range of concentrations on vegetatively propagated geraniums. This study was conducted to compare the effectiveness of paclobutrazol and uniconazole drenches at similar doses on plant growth of vegetatively propagated geraniums.

Materials and methods

Rooted vegetative cuttings of 'Aurora', 'Medallion Dark Red', and 'Pink Satisfaction' geraniums were potted into 0.6-L (0.16-gal), 10-cm-diameter (4-inch), square pots on 18 Feb. 1996. The root substrate 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 155 N, 21 P, and 127 K. Greenhouse day/night set points were 24/18 °C (75/65 °F), and the plants were grown under natural daylength with average light levels of 250 μmol·m⁻²·s⁻¹ at 12:00 HR. Growth retardants were applied to the root substrates 21 d after planting. A volume of 89 mL (3 oz) of solution containing 0, 0.0025, 0.005, 0.01, 0.02 or 0.04 mg paclobutrazol or uniconazole was applied per container. The experiment was a completely randomized design with 10 single-plant replications of the 11 treatments. On 8 May, leaf canopy height (measured from the pot rim to the top of the foliage), total plant height (measured from the pot rim to the top of the inflorescence), and plant diameter (measured at the widest dimension, measured again after a turn of 90°, then averaged) were recorded for all plants.

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Table 1. Regression coefficients of models for total plant height and leaf canopy height of 'Aurora', 'Medallion Dark Red' and 'Pink Satisfaction' vegetatively propagated geraniums.^z

Plant part and cultivar ^y	Regression equation	r^2	Adjusted r^2	Regression F statistic
Total plant height (cm)				
Aurora	$y = 28.1^{***} - 480.46 (\text{conc})^{***} + 6431.45 (\text{conc}^2)^{***}$	0.714	0.709	146.2
Medallion Dark Red	$y = 24.17^{***} - 369.25 (\text{conc})^{***} + 4567.14 (\text{conc}^2)^{**}$	0.531	0.523	66.2
Pink Satisfaction	$y = 23.48^{***} - 170.98 (\text{conc})^{***}$	0.552	0.548	145.4
Leaf canopy height (cm)				
Aurora	$y = 19.13^{***} - 446.26 (\text{conc})^{***} + 6331.45 (\text{conc}^2)^{***}$	0.641	0.635	104.6
Medallion Dark Red	$y = 14.31^{***} - 246.2 (\text{conc})^{***} + 3299.46 (\text{conc}^2)^{***}$	0.523	0.515	64.1
Pink Satisfaction	$y = 13.79^{***} - 112.11 (\text{conc})^{***}$	0.477	0.473	107.8

^zThe plants were drenched with 0, 0.0025, 0.005, 0.01, 0.02, or 0.04 mg a.i./pot of paclobutrazol or uniconazole. Total plant height and leaf canopy height were not significantly influenced by plant growth regulator (PGR) type (paclobutrazol or uniconazole) and therefore the data were pooled across PGR type; 28,350 mg = 1.0 oz.

^y2.54 cm = 1.0 inch.

***Significant at $P \leq 0.01$ or 0.001, respectively.

DATA ANALYSIS. Data for the total plant height, leaf canopy height, and plant diameter were analyzed using analysis of variance by general linear model procedures (SAS Institute, Cary, N.C.). Means were separated by least significant differences (LSD) at $P \leq 0.05$.

Total plant height and leaf canopy height were not significantly influenced by PGR type (paclobutrazol or uniconazole) and therefore, data were pooled across PGR type. Total plant height and leaf canopy height values were regressed using the PROC REG procedure (SAS Institute, Cary, NC) to determine the best fit linear or quadratic model. Variables in the model were PGR concentration (conc) and indicator variables for cultivar (cult), with the full model being as follows: $\text{Concentration}_i = \beta_0 + \beta_1 \text{Cult}_2 + \beta_2 \text{Cult}_3 + \beta_3 \text{Conc} + \beta_4 \text{Conc} \times \text{Cult}_2 + \beta_5 \text{Conc} \times \text{Cult}_3 + \beta_6 \text{Conc}^2 + \beta_7 \text{Conc}^2 \times \text{Cult}_2 + \beta_8 \text{Conc}^2 \times \text{Cult}_3$ where concentration_i = PGR concentration (0, 0.0025, 0.005, 0.01, 0.02, or 0.04 mg), i = variable being regressed (total plant height or leaf canopy height); $\text{Cult}_2 = 1$ if cultivar = 'Medallion Dark Red', 0 otherwise (for 'Aurora' or 'Pink Satisfaction'); $\text{Cult}_3 = 1$ if cultivar = 'Pink Satisfaction', 0 otherwise (for 'Aurora' or 'Medallion Dark Red') (when $\text{Cult}_2 = 0$ and $\text{Cult}_3 = 0$, then $\text{Cult} = \text{'Aurora'}$); β_k = estimated coefficients ($k = 0$ to 8).

Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at $\alpha = 0.05$.

Plant diameter was not significantly influenced by either PGR type or cultivar and the data was pooled. The concentration values were regressed using the PROC REG procedure

outlined above to determine the best fit linear or quadratic model.

Results and discussion

There were significant cultivar $\times$ dose interactions for total plant height and leaf canopy height ($P \leq 0.001$). Therefore, the height data were analyzed by cultivar.

There was a significant quadratic relationship between the dose and total plant height for 'Aurora' and 'Medallion Dark Red', while 'Pink Satisfaction' responded linearly (Table 1).

Total plant height of 'Aurora' was reduced as paclobutrazol or uniconazole dose increased up to 0.02 mg. However, additional increases in dose had little effect on total plant height. 'Aurora' plants treated with 0.01 mg of paclobutrazol or uniconazole were 15% shorter than the untreated plants. Untreated control plants of 'Aurora' were 27.8 cm (10.8 inches), while 'Medallion Dark Red' and 'Pink Satisfaction' were shorter [23.9 cm (9.3 inches) and 23.3 cm (9.1 inches), respectively]. 'Medal-

Fig. 1. Effect of paclobutrazol or uniconazole (mg a.i./pot) on plant diameter of vegetatively propagated geraniums. Data pooled across plant growth regulator (PGR) type and cultivar. Plant diameter significant at $P \leq 0.001$ for the PGR dose and LSD ($\alpha \leq 0.05$) is 1.0 cm (0.39 inch). The adjusted r^2 for plant diameter was 0.59. *Significant at $P \leq 0.001$. L = linear and Q = quadratic; 28,350 mg = 1.0 oz.**

lion Dark Red' and 'Pink Satisfaction' were shorter cultivars, however they had a response similar to 'Aurora' for total plant height as the PGR dose increased. Excessive height retardation of all three cultivars was evident at doses of 0.04 mg, with plants being 31%, 30%, and 28% shorter than the untreated control, respectively, for 'Aurora', 'Medallion Dark Red', and 'Pink Satisfaction'. These results were similar to other experiments which indicated excessively short plants of seed or vegetatively propagated geraniums resulted from drench applications of either paclobutrazol (Nørremark and Anderson, 1990; Tayama and Carver, 1990) or uniconazole (Starman et al., 1994; Tayama and Carver, 1990; 1992) at doses of ≥ 0.05 mg.

At 19.5 cm (7.6 inches), the leaf canopy height of untreated control plants of 'Aurora' were taller than either 'Medallion Dark Red' or 'Pink Satisfaction', which were 14.8 cm (5.8 inches) and 13.9 cm (5.4 inches), respectively (Table 1). Leaf canopy height of 'Aurora' and 'Medallion Dark Red' were 32% and 26% shorter than the untreated control, respectively, as paclobutrazol or uniconazole doses increased up to 0.02 mg. However, additional increases in dose had little effect on leaf canopy height of 'Aurora' and 'Medallion Dark Red'. Most of the height control achieved by the use of PGRs was primarily due to a reduction of leaf canopy height, rather than inflorescence height and similar results were reported with uniconazole drenches on seed propagated geraniums (Starman et al., 1994).

Plant diameter of vegetatively propagated geraniums was significantly different ($P \leq 0.001$) only for PGR dose, therefore the data was pooled across cultivars and PGR type. There was a significant quadratic relationship for plant diameter as the PGR dose increased (Fig. 1). Plant diameter was smaller as the PGR dose increased, with plants treated with 0.02 mg were 22% smaller than the untreated control, and those treated with 0.04 mg were 31%

smaller than the untreated control. Plants treated with 0.04 mg of paclobutrazol or uniconazole had smaller, darker green leaves and stunted growth.

Conclusions

The vigor and responsiveness of vegetatively propagated geranium cultivars should be considered when determining the optimal drench dose of a PGR. 'Aurora' was the most vigorous cultivar, with a total plant height of 27.8 cm (10.8 inches) for the untreated control. Drench doses of paclobutrazol or uniconazole of 0.01 to 0.02 mg per container produced marketable sized potted plants. Both 'Medallion Dark Red' and 'Pink Satisfaction' were less vigorous, and lower paclobutrazol or uniconazole drench rates of 0.005 to 0.01 mg/container produced marketable plants. Our recommendation of 0.01 to 0.02 mg of paclobutrazol or uniconazole per container on vegetatively propagated 'Aurora' geraniums is similar to those for seed propagated geraniums of 0.025 mg of uniconazole recommended by Starman et al. (1994) and the range of 0.0075 to 0.015 mg of paclobutrazol by Cox and Keever (1988). Based upon our results and those of Cox and Keever (1988), and Starman et al. (1994), we have concluded that vegetative and seed propagated geraniums respond similarly to paclobutrazol or uniconazole drenches. This conclusion is in contrast to the responses of many ornamental species in which an equivalent dose of uniconazole resulted in greater height reduction compared to paclobutrazol (Barrett et al., 1986; Wilfret, 1990).

Growers have a number of PGRs available for controlling plant growth. The type of PGR used to control growth of vegetatively propagated geraniums should be based on the response of the plant and the cost of the PGR. In foliar PGR experiments, Whipker et al. (1997) recommended paclobutrazol foliar sprays between 5 and 15 mg·L⁻¹ at a PGR cost of less than \$0.001 per 0.6-L (0.16-gal) pot. Based on the cost of \$97/L (\$102/qt) for paclobutrazol or

\$74/L (\$78/qt) for uniconazole, the 0.02-mg drench would also cost less than \$0.001 per 0.6-L (0.16-gal) pot. With a similar degree of growth control and similar costs per pot available with either paclobutrazol or uniconazole drench doses of 0.005 to 0.02 mg or paclobutrazol foliar sprays between 5 and 15 mg·L⁻¹, growers would find the chemical cost of any of these PGR application methods to be economical.

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