Post-production Performance of Uniconazole-treated Zinnia and Marigold Plugs

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Summary. Plugs of *Zinnia elegans* Jacq. 'California Giant' and *Tagetes erecta* L. 'Golden Climax' and 'Grange Lady' were treated with foliar sprays of uniconazole solutions at 0, 5, 25, or 50 mg·liter⁻¹ (spray volume = 120 ml·m⁻²). Ten days later individual plants were transplanted to OS-liter pots for evaluation of subsequent growth and flowering. All uniconazole treatments reduced height 10 days after application; the extent of reduction depended on uniconazole spray concentration. With zinnia, only the 50-mg·liter⁻¹ foliar spray caused undesirable stunting for at least 1 month after transplanting. None of the uniconazole treatments affected time to anthesis for zinnia. With both marigold cultivars, all uniconazole treatments reduced growth the 2 weeks following transplanting. The highest concentration reduced marigold shoot growth during this period to 25% to 30% of untreated controls. Between 2 and 4 weeks after transplanting growth of all uniconazole-treated marigolds recovered to levels similar to the control. Time to anthesis was increased by the 50 mg·liter⁻¹ treatment for both marigold cultivars. These results suggest that foliar sprays of uniconazole at 5 to 25 mg·liter⁻¹ can control plug height during production without adversely affecting subsequent growth and flowering. With both zinnia and marigold, a single GA₃ foliar spray of 100 mg·liter⁻¹ at transplanting partially reversed the adverse post-production effects of the 50 mg·liter⁻¹ uniconazole foliar spray.

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Uniconazole (Sumagic, Chevron Chemical, Richmond, Calif.) is a triazole gibberellin-biosynthesis-inhibitor with potent growth-regulating properties (Davis et al., 1988). The triazoles have several potentially important horticultural applications, including promoting compactness and maintaining the quality of bedding plants prior to sale (Barrett and Nell, 1986, 1987b; Cox and Keever, 1988; Hammer and Kirk, 1987; Keever and Cox, 1989; Tayama and Carver, 1990). Uniconazole is expected to be available for this use in 1991. At present, ancymidol (A-Rest, Elanco Products, Greenfield, Ind.), daminozide (B-Nine, Uniroyal, Bethany, Conn.), chlormequat chloride (Cycocel, American Cyanamid, Princeton, N. J.), and paclobutrazol (Bonzi, ICI, Goldsboro, N.C.) are registered for use on bedding plants. The high cost of ancymidol, the rising cost of daminozide, and the occasional inconsistency of chlormequat chloride have increased interest in triazole growth regulators such as paclobutrazol and uniconazole.

The production of bedding plants from plugs has become common practice. Plugs have limited soil volume and can obtain an undesirable root : shoot ratio rapidly, which results in poor quality plants. Thus, there is a need for further information regarding the regulation of plug growth to add flexibility to production timing.

To the best of my knowledge, there are no published data on the use of triazole growth regulators during plug production. In particular, one aspect of growth regulator usage that has received insufficient attention is that of post-production effects. Compounds such as uniconazole are quite persistent and, although they may retard growth effectively during production, their use also may result in undesirable stunting following trans-

planting. The ideal situation would be to apply a growth regulator dosage that will control plug growth adequately, but that will dissipate rapidly following transplanting.

The objective of this research was to determine the influence of uniconazole concentration on height and subsequent post-production growth and flowering of zinnia and marigold plugs. The ability of gibberellic acid (GA₃) treatments at transplanting to overcome uniconazole-induced growth inhibition also was tested.

Seeds of 'California Giant' (90-cm garden height) zinnia and 'Golden Climax' (90-cm garden height) and 'Orange Lady' (50-cm garden height) marigolds were planted in 200-cell square plug trays containing a commercial peat-perlite growing medium (Metro Mix 200, Grace Horticultural Products, Cambridge, Mass.). The plug trays were placed in a 27/19C ± 3C unshaded greenhouse and watered daily. A water-soluble fertilizer (Peters 20N-10P-20K, Peters Fertilizer Products, Fogelsville, Pa.) was applied weekly during irrigation.

Two separate growth regulator studies were conducted. In the dose-response study, 18- to 20-day-old seedlings were treated with uniconazole foliar sprays of 0, 5, 25, or 50 mg·liter⁻¹. These dosages were chosen based on previous experience with uniconazole (Davis and Andersen, 1989). The sprays were applied at a volume of ≈ 120 ml·m⁻². At the time of treatment, the plants were 4 to 6 cm tall. Ten days after treatment, the plants were transplanted to 0.5-liter plastic pots filled with commercial soilless medium (Metro Mix 200). The plants were grown in a greenhouse with a day/night temperature of 25/17C ± 3C.

For the GA₃ reversal study, seedlings were treated with uniconazole foliar sprays of 0 or 50 mg·liter⁻¹. Imme-

Table 1. Height (cm) of uniconazole-treated zinnia and marigold plugs at the end of production.

Plant material	Uniconazole foliar spray concn (mg·liter ⁻¹)				Significance ²
	0	5	25	50	
California Giant zinnia	5.2 a ¹	4.4 b	3.9 b	3.8 b	L, Q
Golden Climax marigold	7.2 a	6.2 ab	5.6 bc	5.1 c	L, Q
Orange Lady marigold	7.4 a	6.5 b	6.1 bc	5.7 c	L, Q

¹Treatment effects were significant at the 5% level and were linear (L) or quadratic (Q) as determined by regression analyses.

²Means within a row with a common lowercase letter are not significantly different at the 5% level as determined by Scheffe test (n = 13 for zinnia, n = 15 for 'Golden Climax' marigold, n = 17 for 'Orange Lady' marigold).

diately following transplanting the uniconazole-treated plants were sprayed with GA₃ solutions of 0, 10, or 100 mg·liter⁻¹ applied at a spray volume of ≈ 120 ml·m⁻². The plants were grown in a greenhouse with a day/night temperature regime of 28/20C $\pm$ 3C. In both studies, plant height was measured 0, 2, and 4 weeks after transplanting. Shoot growth (defined here as an increase in plant height) was calculated from the height data. In addition, the date of anthesis was recorded for each plant. Both studies were conducted three times in a randomized complete block experimental design. Each block contained one plant from each treatment. The number of individual plants per treatment is given in the tables. Data from the three replicated experiments were pooled for statistical analysis. Mean separation was accomplished using Scheffe tests (ABstat, Release 6, Anderson-Bell Corp., Parker, Colo.). For the uniconazole dose-response study, data also were subjected to linear and nonlinear regression analyses (Statistical Analysis System, SAS Institute, Cary, N.C.).

All uniconazole treatments reduced plug height at the end of production, except for the 5-mg·liter⁻¹ treatment on 'Golden Climax' marigold (Table 1). The 25- and 50- mg·liter⁻¹ uniconazole foliar sprays reduced plug height by 1.3 to 2.1 cm compared to the control. The 5 mg·liter⁻¹ treatment reduced plug height by ≈ 1 cm.

The control zinnias increased in height by ≈ 7 cm during the first 2 weeks after transplanting (Table 2). Shoot growth of the zinnias treated

Table 3. Number of days to anthesis following transplanting of zinnia and marigold treated with uniconazole during plug production.

Plant material	Uniconazole foliar spray concn (mg·liter ⁻¹)				Significance ^a
	0	5	25	50	
California Giant zinnia	26 a ^y	27 a	26 a	29 a	NS
Golden Climax marigold	21 a	21 b	23 ab	25 a	L, Q
Orange Lady marigold	18 b	19 b	20 ab	21 a	L, Q

^aTreatment effects were significant (L = linear, Q = quadratic) or nonsignificant (NS) at the 5% level as determined by regression analyses.

^yMeans within a row with a common lowercase letter are not significantly different at the 5% level as determined by Scheffe test (n = 13 for zinnia, n = 15 for 'Golden Climax' marigold, n = 17 for 'Orange Lady' marigold).

with uniconazole at 5 or 25 mg·liter⁻¹ was not significantly different from the control. In contrast, growth of the zinnias treated with uniconazole at 50 mg·liter⁻¹ was only $\approx 50\%$ of the untreated control. Between 2 and 4 weeks after transplanting, control zinnia growth was not significantly affected by the earlier treatments with uniconazole at 5 or 25 mg·liter⁻¹. In contrast, growth of the zinnias treated with uniconazole at 50 mg·liter⁻¹ was still only $\approx 60\%$ of the untreated control between 2 and 4 weeks after transplanting. This uniconazole dosage, therefore, resulted in relatively long-term growth inhibition of zinnia.

Shoot growth of the two marigold cultivars during the first 2 weeks following transplanting decreased inversely with uniconazole dosage (Table 2). Although the two cultivars were chosen to represent tall and short types, they responded similarly to uniconazole. At the highest uniconazole concentration, growth was only 25% to 30% of the untreated controls. Between 2 and 4 weeks after transplanting, however, shoot growth of all the

uniconazole-treated marigold plants recovered to levels similar to the control. This occurred even with the highest uniconazole concentration. Thus, following a 2-week period of reduced growth, the marigolds recovered rapidly from the uniconazole-induced growth inhibition.

With zinnia, the number of days to anthesis was not affected by the uniconazole treatment applied during the plug stage (Table 3). In contrast, the time to anthesis was increased consistently by 3 to 4 days in the 50 mg uniconazole/liter treatment for both of the marigold cultivars. None of the uniconazole treatments caused any noticeable effects on flower size or longevity with either species.

The data suggest that a foliar spray of uniconazole at 50 mg·liter⁻¹ may be an overdose that results in reduced growth and/or delayed flowering after transplanting. Uniconazole foliar sprays at 5 to 25 mg·liter⁻¹ appear more suitable for controlling plug height, with less risk of undesirable long-term effects. It is interesting to note that the uniconazole foliar spray concentration needed for suitable height control is much less than that used with the closely related compound paclobutrazol for zinnia (Cox and Keever, 1988) and marigold (Barrett and Nell, 1987a; Keever and Cox, 1989). This is in agreement with previous studies with other species (Barrett and Nell, 1990; Bassi et al., 1986; Davis and Andersen, 1989; Davis et al., 1987).

The uniconazole foliar spray at 50 mg·liter⁻¹ reduced subsequent growth of both zinnia and marigold in the GA₃ reversal study (Table 4). Growth of both the control and uniconazole-treated plants during the month following transplanting was greater in the GA₃ reversal study than in the uniconazole dose-response study. This is likely due to the slightly higher green-

Table 2. Growth (cm) of uniconazole-treated zinnia and marigold during specified periods following transplanting.

Plant material/ time after transplanting	Uniconazole foliar spray concn (mg·liter ⁻¹)				Significance ^a
	0	5	25	50	
California Giant zinnia					
0–2 weeks	7.3 a ^y	6.7 a	6.0 a	3.9 b	L, Q
2–4 weeks	19.1 a	19.2 a	17.3 a	12.2 b	L, Q
Golden Climax marigold					
0–2 weeks	12.5 a	8.6 b	5.0 c	3.3 c	L, Q
2–4 weeks	9.0 a	10.7 a	11.8 a	9.2 a	NS
Orange Lady marigold					
0–2 weeks	8.7 a	5.6 b	4.1 bc	2.7 c	L, Q
2–4 weeks	5.6 a	5.9 a	6.6 a	6.3 a	NS

^aTreatment effects were significant (L = linear, Q = quadratic) or nonsignificant (NS) at the 5% level as determined by regression analyses.

^yMeans within a row with a common lowercase letter are not significantly different at the 5% level as determined by Scheffe test (n = 13 for zinnia, n = 15 for 'Golden Climax' marigold, n = 17 for 'Orange Lady' marigold).

Table 4. Increase in plant height during the month immediately following transplanting and number of days to anthesis of zinnia and marigold. Plants were treated with uniconazole at 50 mg liter⁻¹ (UNI) during plug production and then sprayed with 0, 10, or 100 mg liter⁻¹ gibberellic acid (GA) at transplanting.

Plant material	Treatment			
	Control	UNI	UNI + GA (10)	UNI + GA (100)
California Giant zinnia				
Height increase (cm)	50.3 a ^z	38.9 b	41.0 ab	47.6 a
Days to anthesis	28 a	31 a	31 a	30 a
Golden Climax marigold				
Height increase (cm)	40.4 a	16.7 c	27.7 b	35.1 ab
Days to anthesis	30 c	41 a	36 b	35 b
Orange Lady marigold				
Height increase (cm)	25.4 a	15.0 c	21.0 b	23.5 ab
Days to anthesis	33 b	36 a	35 ab	34 b

^zMeans within a row with a common lowercase letter are not significantly different at the 5% level as determined by Scheffe test (n = 11 for zinnia, n = 9 for 'Golden Climax' marigold, n = 12 for 'Orange Lady' marigold).

house temperatures and longer photoperiods during the GA₃ reversal study, which was conducted in mid- to late-spring, compared to the uniconazole dose-response study, which was conducted during winter and early spring.

With zinnia, the foliar spray of GA₃ at 10 mg liter⁻¹ at transplanting did not increase significantly the growth of plants that had been treated previously with uniconazole at 50 mg liter⁻¹ (Table 4). The 100-mg liter⁻¹ foliar spray of GA₃, however, reversed the uniconazole-induced growth inhibition following transplanting. With the marigold cultivars, both the 10- and 100- mg liter⁻¹ foliar sprays of GA₃ were effective in partially reversing uniconazole-induced growth inhibition following transplanting. Growth of the uniconazole-treated plants sprayed with GA₃ at 100 mg liter⁻¹ at transplanting was similar to that of the untreated controls. None of the GA₃ treatments caused undesirable stretching or weak growth of either zinnia or marigold. In fact, the plants treated with GA₃ at 100 mg liter⁻¹ were virtually indistinguishable from the untreated controls within 1 month after transplanting. Thus, as was observed with sunflower (Wample and Culver, 1983) and apple (Steffens et al., 1985), triazole-induced growth inhibition of zinnia and marigold can be reversed effectively by GA₃.

The number of days to anthesis for control and uniconazole-treated plants was somewhat greater in the GA₃ reversal study than in the uniconazole dose-response study. Nevertheless, the effect of uniconazole on time to anthesis was qualitatively

the same as in the dose-response study. With zinnia, the foliar spray of uniconazole at 50 mg liter⁻¹ did not delay flowering significantly (Table 4). Likewise, the GA₃ treatments had no significant effect on time to anthesis of zinnia. With marigold, the 50 mg liter⁻¹ uniconazole treatment during the plug stage delayed flowering of both cultivars. With Golden Climax, GA₃ foliar sprays at both 10 and 100 mg liter⁻¹ decreased the time to anthesis compared to the uniconazole-treated plants that were not sprayed with GA₃. Despite this, flowering was still 5 to 6 days later in the GA₃-treated plants compared to the untreated controls. Hence, GA₃ only reversed the uniconazole-induced delay in flowering of this cultivar partially. With Orange Lady, time to anthesis in GA₃-treated plants was the same as for the untreated controls.

This research suggests that uniconazole can be used to control zinnia and marigold height effectively during plug production. Foliar sprays at 5 and 25 mg liter⁻¹ had only short-term (<2 weeks) effects on subsequent growth upon transplanting. Furthermore, these concentrations had little effect on time to anthesis. With higher uniconazole concentrations, slow growth and delayed flowering following transplanting are potentially serious problems. It is important to note that spray volume influences the efficacy of triazole-type growth regulators (Barrett and Nell, 1990). Because plugs are small with limited foliage, the uniconazole used in the current study was applied in a spray volume (≈120 ml m⁻²) that is 60%

of the recommended spray volume (200 ml m⁻²) for bedding plants produced in standard 32- or 48-cell flats. Because triazoles are highly persistent in soils (Davis et al., 1988), use of higher spray volumes may cause serious stunting of plugs due to run-off. Although GA₃ is a potentially useful antidote for uniconazole-induced stunting and delayed flowering, it is not registered for this use at present.

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