HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

Controlling Height and Seedling Emergence of French Marigold and Celosia Plugs with Plant Growth Regulators[1]

Stanislav V. Magnitskiy[2], Claudio C. Pasian[3], Mark A. Bennett[4], and James D. Metzger[4]
Department of Horticulture and Crop Science
The Ohio State University, 2001 Fyffe Court, Columbus, OH 43210

Abstract

Soaking French marigold seeds in growth regulator solutions produced larger reductions in seedling height than foliar sprays. Seeds soaked in 1 to 5 ppm uniconazole solutions for 0.15, 5, or 45 min resulted in plants that were up to 23% shorter than controls at 30 DAS, whereas foliar applications of 10 to 20 ppm uniconazole solutions resulted in plants 18% shorter than controls at 14 DAS. French marigold seedlings from seeds soaked in 60 pm ancymidol for 5 or 45 min were 5 or 6%, respectively, shorter than controls. Foliar spray applications of 25 or 100 ppm ancymidol to French marigold seedlings resulted in plants 8% shorter than controls. Chlormequat solutions applied either as a seed soak (1000–5000 ppm) or foliar spray (500–3000 ppm) did not reduce French marigold seedling height. Emergence of French marigold seedlings from seeds soaked in uniconazole, ancymidol, or chlormequat solutions was not different from that of control seeds. No effect on seedling height or emergence was found when soaking celosia seeds in uniconazole, ancymidol, or chlormequat solutions. Spraying celosia seedlings with uniconazole, ancymidol, or chlormequat solutions did not reduce seedling height.

Index words: soaking seeds, foliar spray, plant growth regulator, bedding plant, seedling height, seedling emergence.

Species used in this study: 'Bonanza Gold' French marigold (*Tagetes patula* L.); 'New Look' celosia (*Celosia cristata* L.).

Chemicals used in this study: Sumagic (uniconazole), (E)-(+)-(S)-1(4-chlorophenyl)4,4-dimethyl-2(1,2,4-triazol-1-yl)pent-1-ene-3-ol; A-Rest (ancymidol), α-cyclopropyl-α-(p-methoxyphenyl)-5-pyrimidinemethanol; Cycocel (chlormequat chloride), 2-chloroethyltrimethylammonium chloride.

Significance to the Nursery Industry

Soaking French marigold seeds in 1 to 5 ppm uniconazole solutions for 0.15, 5, or 45 min effectively controlled plug height without reductions in seedling emergence. The benefits of applying uniconazole directly to seeds included control of seedling height at the early stages of plant growth, use of small amounts of a.i., simplicity of application, and lack of field contamination with PGR residues. Results of the study may be of interest to plug producers of ornamental bedding plants.

Introduction

Controlling excessive seedling height is a challenge in plug production of marigold and celosia. A common practice to prevent plug stretching consists of treating plugs with plant growth regulators (PGR). The largest commercially used group of PGR, including triazole-type (uniconazole, ancymidol), and onium-type (chlormequat) compounds, are

[1]Received for publication March 8, 2006; in revised form May 20, 2006. We thank Monica Kmetz-Gonzalez for excellent technical assistance during the study and Bert Bishop for help in statistical analysis of data.

[2]Assistant Professor. Current address: Department of Agronomy, National University of Colombia, Building 500, Bogotá, Colombia.

[3]Associate Professor.

[4]Professor.

inhibitors of gibberellin (GA) biosynthesis (4, 16). Applications of these chemicals to ornamental crops effectively reduced shoot overgrowth, changed branching patterns and time of flowering, increased seed yield and plant resistance to a variety of stresses (4).

PGR are primarily applied to bedding plants as soil drenches or foliar sprays. Uniconazole applied as a soil drench or a 10–20 ppm foliar spray effectively retarded shoot growth of marigold (1, 8). Common disadvantages of such applications of PGR are soil absorption or drift of a.i. (4). Treating seeds with PGR before sowing is an alternative method of PGR delivery (9, 10, 11, 12). Advantages of seed treatments with PGR include small amounts of a.i. required for controlling plug height and reduced uncontrolled drift into the environment (4, 13), whereas disadvantages include possible delays and reductions in seedling emergence. Seeds of *Matthiola incana* L. soaked in 100, 200, or 400 ppm uniconazole solutions for 24 hr produced short seedlings, but seedling emergence was reduced by 81, 82, or 84%, respectively (6). Soaking pea (*Pisum sativum* L.) seeds in uniconazole solutions resulted in shorter plants, smaller leaf area, and greater stem thickness, but delayed germination (7). Seeds of blueberry (*Vaccinium myrtillus* L.) germinated in a medium containing 2.5 ppm ancymidol or 2.7 ppm uniconazole experienced up to 95% reduction in germination (5). Germination of biennial celery (*Apium graveolens* L.) was completely prevented in the presence of 5 ppm ancymidol, whereas lower ancymidol concentrations (0.05–0.5 ppm) caused a reduction in germination (15). There is a limited knowledge on usage of chlormequat as a seed soaking treatment for controlling plug height. One study indicated that treating barley (*Hordeum vulgare* L.) seeds with chlormequat reduced height and seedling emergence (17). Soaking or priming marigold seeds in paclobutrazol solutions was associated with reductions in plant height without reductions in seedling emergence (11, 12). However, no data are available on the effects of soaking marigold seeds in other PGR on seedling height. No published information was found on controlling seedling height in celosia when PGR other than paclobutrazol were applied as seed treatments. The objective of the present study was to determine effects of different application methods of uniconazole, ancymidol, and chlormequat (seed soaking vs. foliar sprays) on plug height and seedling emergence of marigold and celosia.

Materials and Methods

Soaking seeds. Seeds of 'Bonanza Gold' French marigold and 'New Look' celosia were soaked in water or uniconazole, ancymidol, or chlormequat water solutions, while unsoaked seeds represented the controls. Each soak treatment consisted of 100 seeds placed in a glass beaker with 50 ml solutions of 1, 2, or 5 ppm uniconazole, 10, 20, or 60 ppm ancymidol, or 1000, 3000, or 5000 ppm chlormequat for 0.15, 5, or 45 min (marigold) or 5, 45, or 180 min (celosia). These PGR rates were chosen based on the literature (5, 7, 14) and preliminary experiments. While soaking the seeds, beakers were constantly agitated (40 rpm) on a slow variable rotating shaker Koala-Ty (Accurate Chemical and Scientific Corp., Westbury, NY). After soaking, seeds were transferred to a sieve and dried on filter paper (Whatman International Ltd., Maidstone, England) for 24 hr on an open bench at 20C (68F). Soaking for 0.15 min was followed by quick (15 min) seed drying in an air current at 25C (77F) to minimize the time of seed contact with a PGR solution.

Within 2 days after soaking, seeds were sown one per cell in plastic 288-cell plug trays (3 cm depth) filled with plug growth mix (Sunshine LP5, Sun Gro Horticulture, Bellevue, WA). Each treatment consisted of 100 seeds divided into four replicates randomly distributed among trays. Seeds were covered with a small portion of the same substrate and placed in a greenhouse under intermittent mist at 25C (77F) for 1 day. Plug trays were then moved to a greenhouse with a set point temperature of 25C (77F) and randomly arranged on a mat-covered bench under natural light conditions. Plugs were irrigated as needed with tap water and fertilized with a Peters Professional water-soluble fertilizer 20N:8.7P:16.7K (N–P_2O_5–K_2O Scotts-Sierra Horticultural Products Co., Marysville, OH) at a rate of 200 ppm N every third irrigation. Subsamples of 20 seedlings in each treatment were taken to measure percentage seedling emergence or seedling height. Seedling emergence percentages were determined at 2 and 10 days after sowing (DAS) for marigold, 4 and 14 DAS for celosia. Plug height was measured from the substrate surface 10 and 30 DAS.

Foliar sprays. One thousand untreated marigold and celosia seeds were sown in plug trays as described above. At 30 and 26 DAS, marigold and celosia plugs, respectively, were sprayed once with 0, 10, or 20 ppm uniconazole, 0, 25, or 100 ppm ancymidol, or 0, 500, or 3000 ppm chlormequat solutions at a rate of 204 ml/m^2 (2 qt/100 ft^2). Each foliar treatment was applied to 100 plugs divided into four replicates randomly distributed among trays. At time of spraying, the plug surface was covered with aluminum foil to minimize contact of PGR solutions with the substrate. Plug height measurements were taken at 7 and 14 days after spraying (DASP). Experiments with PGR applications as seed soaks and foliar sprays were conducted simultaneously in July–August of 2004 in the greenhouses of The Ohio State University (Columbus, OH).

Statistical analysis. Plug height and percentage seedling emergence as a response to PGR concentration and soaking time were analyzed to test for significant linear effects using polynomial contrasts in the general linear model procedure in SAS (SAS Institute, Cary, NC). Mean comparisons by LSD were used to evaluate the effect of water treatments (water-treated (0 ppm PGR) vs. non-treated plants) on plant height and seedling emergence.

Results and Discussion

Marigold. Seedling emergence of unsoaked and water soaked controls was similar. Emergence of seedlings from uniconazole, ancymidol, or chlormequat soaked seeds was uniform and similar to that from control seeds. Mean germination percentages were 88 (4 DAS) and 94% (14 DAS) for celosia, or 95 (2 DAS) and 97% (10 DAS) for French marigold. PGR concentration and soaking time had no effect on final percentage seedling emergence (results not shown). At 10 DAS, increasing soaking times in uniconazole solutions were associated with shorter seedlings, while at 30 DAS this effect was less noticeable (Table 1). By 30 DAS, seeds soaked in 1 ppm uniconazole solutions during 0.15, 5, or 45 min produced seedlings that were 17, 23, or 22% shorter than controls, respectively (Table 1). Increasing uniconazole concentration resulted in shorter seedlings (Table 1). At 30 DAS, soaking seeds in 60 ppm ancymidol solutions for 5 or 45 min

Table 1. Height of 'Bonanza Gold' French marigold (*Tagetes patula* L.) seedlings from seeds soaked in uniconazole, or ancymidol, or chlormequat solutions for 0.15, 5, or 45 min. Means are representative of 20 single plant replicates.

	Shoot height (cm)							
	10 DAS[z]				30 DAS[z]			
Treatment	0.15 min	5 min	45 min	L[y]	0.15 min	5 min	45 min	L[y]
Uniconazole								
0 ppm	2.5	2.6	2.5	NS[w]	7.2	7.3	7.3	NS
1 ppm	2.3	2.3	2.0	***	6.0	5.6	5.7	*
2 ppm	2.4	2.3	2.0	***	5.7	5.6	5.6	NS
5 ppm	2.2	2.0	1.9	***	5.6	5.5	5.6	NS
L[x]	**	***	***		***	***	***	
Ancymidol								
0 ppm	2.5	2.6	2.5	NS	7.2	7.3	7.3	NS
10 ppm	2.5	2.6	2.7	**	7.0	7.1	7.0	NS
20 ppm	2.7	2.6	2.6	NS	7.0	7.0	7.1	NS
60 ppm	2.6	2.6	2.6	NS	7.1	6.8	6.9	NS
L[x]	NS	NS	NS		NS	***	***	
Chlormequat								
0 ppm	2.5	2.5	2.5	NS	7.2	7.3	7.3	NS
1000 ppm	2.6	2.6	2.6	NS	7.1	7.3	7.2	NS
3000 ppm	2.7	2.6	2.7	NS	7.2	7.0	7.1	NS
5000 ppm	2.6	2.7	2.7	NS	7.0	7.2	7.2	NS
L[x]	*	***	***		NS	*	NS	
Untreated		2.6				7.3		

[z]Seedling height measurements were taken at 10 and 30 days after sowing (DAS).

[y,x]Linear models for the PGR concentration effects and soaking time, respectively.

[w]***,**,*, NS: significant at $P \leq 0.001$, ≤ 0.01, ≤ 0.05, and nonsignificant, respectively.

reduced seedling height by 5 or 6% compared to controls, respectively (Table 1). Soaking seeds in chlormequat solutions did not reduce seedling height, but a slight increase in height was observed at 10 DAS (Table 1). Reduction in seedling height was similar when uniconazole or ancymidol was applied as seed soaking or one-time foliar spray. At 14 DASP, seedlings treated with 20 ppm uniconazole or 100 ppm ancymidol solutions were 18 or 7% shorter than the controls, respectively (Table 2). Spraying French marigold seedlings with chlormequat solutions had no effect on seedling height (Table 2).

Celosia. Plant height was not reduced when seeds were soaked in increasing rates of PGR (data not shown). Increasing seed soaking time in ancymidol, chlormequat, or uniconazole solutions did not affect seedling height or seedling emergence. Celosia seedlings exhibited no height reduction 26 DAS when they were sprayed once with uniconazole, ancymidol, or chlormequat solutions (data not shown).

Reductions in seedling height have been observed when treating seeds with increasing PGR rates and/or soaking times (6, 7, 9, 10, 12). This effect might be attributed to increased PGR penetration into seeds with increasing duration of soaking. Since French marigold seedling emergence was not affected (data not shown), we suggest that PGR amounts in the seeds were not toxic to the embryo. However, it may be possible that short (0.15 min) soaking times resulted in most of the PGR molecules being adsorbed to the seed coats rather than penetrating to the internal seed parts (11). After sowing, PGR might further diffuse into seeds or substrate and then be absorbed by a developing root (9, 10, 11, 12). According to this hypothesis, seed coats acted as a carrier for PGR (9, 10, 11).

Treating French marigold seeds with ancymidol or chlormequat presents less practical value for controlling plant height than similar application of uniconazole. The three PGR used in this study have a similar mode of action (16), but they had different effects on French marigold (Table 2) and celosia (no effect) plug height. It can be speculated that soaking celosia seeds in PGR solutions did not influence plug height because of the seed coat properties. Seed coats represent a barrier for some PGR (14). For example, chlormequat inhibited germination only in decoated celery seeds, whereas paclobutrazol, uniconazole, or ancymidol inhibited germination of both intact and decoated seeds (15). Soaking melon seeds in ancymidol or uniconazole solutions delayed germination, but the delay was less noticeable in the presence of seed coats (3). A semipermeable membrane underneath the seed coats could be an additional structure restricting penetration of certain PGR into seeds (2, 18). Chlormequat penetration into seeds may be also reduced due to the fact that the chlormequat molecule has a permanent positive charge, while other studied PGR are represented by neutral molecules (16). Therefore, the seedling height response to PGR might vary depending on the chemical nature and concentration of the PGR, duration of seed treatment, and seed coat permeability to a particular PGR.

The inability of controlling celosia seedling height with the PGR evaluated in this study could be also attributed to active GA biosynthesis in seeds at a rate that rendered the PGR effect not observable. High seed GA content made PGR ineffective in inhibiting germination regardless of the pres-

Table 2. Height of 'Bonanza Gold' French marigold (*Tagetes patula* L.) seedlings one-time sprayed 30 DAS with uniconazole, or ancymidol, or chlormequat solutions. Means are representative of 20 single plant replicates.

Treatment	Shoot height (cm)	
	7 DASP[z]	14 DASP[z]
Uniconazole		
0 ppm	7.4	9.2
10 ppm	6.2	7.8
20 ppm	6.0	7.6
L[y]	***[x]	*
Ancymidol		
0 ppm	7.4	9.2
25 ppm	7.0	8.6
100 ppm	6.6	8.2
L[y]	*	*
Chlormequat		
0 ppm	7.4	9.2
500 ppm	7.0	8.6
3000 ppm	7.2	8.8
L[y]	NS	NS
Untreated	7.2	9.2

[z]Seedling height measurements were taken at 7 and 14 days after spraying (DASP).

[y]Linear model for the PGR concentration effects.

[x]***,**,*, NS: significant at $P \leq 0.001$, ≤ 0.01, ≤ 0.05, and nonsignificant, respectively.

ence of seed coats (3). It could be also suggested that the levels of GA precursors downstream from the site of GA biosynthesis pathway, which was blocked by the PGR, were sufficient for germination and seedling development at least in the short term. Most likely, celosia was insensitive to the PGR used in this study, since spraying with uniconazole, ancymidol, or chlormequat solutions did not affect seedling height.

Our study indicated that the benefits of soaking French marigold seeds in uniconazole are control of the size of young plants and reduction in the dose of PGR. Future studies should be focused on finding a suitable method of controlling celosia height with PGR applications.

Literature Cited

1. Barrett, J.E. and T.A. Nell. 1992. Efficacy of paclobutrazol and uniconazole on four bedding plant species. HortScience 27:896–897.

2. Beresnievicz, M.M., A.G. Taylor, M.C. Goffinet, and W.D. Koeller. 1995. Chemical nature of semipermeable layer in seed coats of leek, onion, (Liliaceae), tomato and pepper (Solanaceae). Seed Sci. Technol. 23:135–145.

3. Edelstein, M., Y.B. Tal, M. Wodner, and J. Kigel. 1995. Role of endogenous gibberellins in germination of melon (*Cucumis melo*) seeds. Physiol. Plant. 95:113–119.

4. Fletcher, A., A. Gilley, N. Sankhla, and T. Davies. 2000. Triazoles as plant growth regulators and stress protectants. p. 55–138. *In*: J. Janick (Editor). Hort Reviews. AVI Publishing Co., Inc., Westport, CT.

5. Giba, Z., D. Grubisic, and R. Konjevic. 1993. The effect of white light, growth regulators and temperature on the germination of blueberry (*Vaccinium myrtilis* L.) seeds. Seed Sci. Technol. 21:521–529.

6. Grzesik, M. 1995. Effect of growth regulators on plant growth and seed yield of *Matthiola incana* L., 'Brilliant Barbara'. Seed Sci. Technol. 23:123–134.

7. Hathout, T.A. 1995. Diverse effects of uniconazole and nicotinamide on germination, growth, endogenous hormones and some enzymatic activities of peas. Egypt. J. Physiol. Sci. 19:77–95.

8. Holcomb, E.J. and M.A. Rose. 1990. Height control of selected bedding plants with uniconazole. Acta Hort. 272:279–284.

9. Pasian, C.C. and M.A. Bennett.1999. Seed coats as plant growth regulator carriers in bedding plant production. Acta Hort. 504. 93–97.

10. Magnitskiy, S.V., C.C. Pasian., M.A. Bennett and J.D. Metzger. 2006. Controlling plug height of verbena, celosia, and pansy by treating seeds with paclobutrazol. HortScience 41:158–161.

11. Pasian, C.C. and M.A. Bennett. 2001. Paclobutrazol soaked marigold, geranium, and tomato seeds produce short seedlings. HortScience 36:721–731.

12. Pill, W.G. and J.A. Gunter. 2001. Emergence and shoot growth of cosmos and marigold from paclobutrazol-treated seed. J. Environ. Hort.19:11–14.

13. Pombo, G., M.D. Orzolek, L.D. Tukey, and T.P. Pyzik. 1985. The effect of paclobutrazol, daminozide, glyphosate and 2,4-D in gel on the emergence and growth of germinated tomato seeds. J. Hort. Sci. 60:353–357.

14. Pressman, E., R. Shaked, and M. Negbi. 1988. Germination of seeds of annual and biennial celery (*Apium graveolens* L.). Physiol. Plant. 72:65–69.

15. Pressman, E. and R. Shaked. 1991. Interactive effects of gibberellins, cytokinins and growth retardants on the germination of celery seeds. Plant Growth Reg. 10:65–72.

16. Rademacher, W. 2000. Growth retardants: effects on gibberellin biosynthesis and other metabolic pathways. Ann. Rev. Plant Physiol. Plant Mol. Biol. 51:501–531.

17. Smith, D.L and S. Leibovitch. 1990. Effect of plant growth regulator seed treatment on seedling development of winter cereals. Canad. J. Plant Sci. 70:326.

18. Yim, K.-O. and K.J. Bradford. 1998. Callose deposition is responsible for apoplastic semipermeability of the endosperm envelope of muskmelon seeds. Plant Physiol. 118:83–90.