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Emergence and Shoot Growth of Cosmos and Marigold from Paclobutrazol-treated Seed[1]

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Abstract

This study was conducted to determine whether treating seeds of 'Sensation Mixed' cosmos (*Cosmos bipinnatus* Cav.) and 'Bonanza Gold' marigold (*Tagetes patula* L.) with paclobutrazol (PB) could suppress seedling growth. Seeds were soaked in solutions of 0, 500 or 1000 mg PB/liter (ppm PB) for 16 hours at 25C (77F) or they were primed [–0.5 MPa (–5 bars) for 7 days at 20C (68F)] in Grade 5 exfoliated vermiculite moistened with 0, 500 or 1000 ppm PB solltuions. Soaked and primed seeds were dried for 1 day at 19C (65F) and 25% relative humidity. These seeds and control (non-treated) seeds were sown into plug cells containing peat-lite. Increasing PB concentration decreased cosmos shoot height at 32 days after planting (DAP), but decreased emergence percentage, responses that were more pronounced with priming than with soaking. A 1 ppm PB growth medium drench [30 ml/cell(0.2 mg PB/cell)] and, to a greater extent a 10 mg PB/liter (ppm PB) shoot spray [2 ml/shoot (0.02 mg PB/shoot)], both applied at 10 DAP, resulted in greater cosmos shoot height suppression at 32 DAP than treatment of seeds with 1000 ppm PB. Soaking marigold seeds in 1000 ppm PB failed to decrease shoot height below those of plants from non-treated seeds at 32 DAP. However, exposure to 1000 ppm PB during priming of marigold seeds resulted in a similar shoot height suppression (13%) as the growth medium drench, and similar shoot dry weight reduction (21%) as the shoot spray. Suppression of shoot growth by this seed treatment was short-term since by five weeks after transplanting into 15 cm (6 in) pots, only marigold plants that had received the growth medium drench or shoot spray were smaller than those of control plants. Treating marigold seeds with 1000 mg ppm PB used about one-fifth the PB used to drench the growth medium.

Index words: bedding plants, Bonzi, *Cosmos bipinnatus*, bedding plants, plant growth regulator, seed priming, stand establishment, *Tagetes patula*, triazole.

Species used in this study: 'Sensation Mixed' cosmos (*Cosmos bipinnatus* Cav.); 'Bonanza Gold' marigold (*Tagetes patula* L.).

Chemicals used in this study: β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol (paclobutrazol; Bonzi, Uniroyal Chemical Co., Middlebury, CT).

Significance to the Nursery Industry

Matrically primed seeds of cosmos exposed to 1000 ppm PB during priming reduced seedling shoot height but markedly decreased emergence percentage during plug production. This same treatment reduced seedling shoot height of marigold without affecting emergence, and provided the same growth suppression as a growth medium drench of PB. Compared to the growth medium drench, seed treatment should reduce material costs for marigold plug production costs because it used about one-fifth the PB per plant. Growth retardation from priming marigold seeds with 1000 ppm PB was short-term since shoot heights and shoot dry weights of these plants were similar to those of plants from non-treated seeds by 67 days after planting.

Introduction

Growth retardants are commonly applied to bedding plants to maintain quality and compactness before sale, and to extend the marketing period. The triazoles, which includes paclobutrazol (PB) and uniconazole, are more potent and persistent than most other growth retardants so that relatively low rates are required to inhibit growth (2). These 'antigibberellin' compounds, characterized by a ring structure containing three nitrogen atoms, a chlorophenyl, and a carbon side chain, are highly active in reducing shoot growth of many bedding plant species, increasing root-shoot ratio, and increasing stress tolerance and post-transplanting survival (2, 7).

Spray applications of PB are used most commonly in commercial practice but non-uniform plant size can result from non-uniform spray application (7). Many solid forms of growth retardants such as capsules, gels, tablets, granules, and encapsulated slow-release materials have been evaluated. For instance, Barret et al. (1) noted that PB drenches and spikes were effective for *Caladium* x *hortulanum*, *Codiaeum variegatum*, *Brassaia actinophylla*, *Euphorbia pulcherrima* and *Impatiens wallerana* with a similar concentration response for all, except that drenches had greater efficacy than spikes on caladium, a rapidly growing crop. Sanderson et al. (17) noted that PB drenches were more effective in retarding *Chrysathemum* x *morifolium* plant height than PB incorporated as gypsum tablets, injected hydrogels, and gelatin capsules all applied at the same rate.

Fletcher and Hofstra (6) noted that imbibing wheat (*Triticum aestivum*) seeds for 20 hr in 1 ppm uniconazole reduced plant height and decreased shoot dry weight that lead to increased root to shoot dry weight ratio. Pasian and Bennett (14) imbibed seeds of 'Bonanza Gold' marigold (*Tagetes patula*) and 'Cherry Orbit' geranium (*Pelargonium hortorum*) for 6 to 24 hr in 0 to 1000 ppm PB. They found that increasing PB concentration decreased marigold seedling height, with imbibition period and PB concentration having little effect on seedling emergence percentage. For geranium, they found that seedling height was inversely proportional to PB rate; but seedling emergence was decreased markedly following 24-hr imbibition in 1000 ppm PB.

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Seed priming is a low-water potential seed treatment that permits partial seed hydration so that pregerminative metabolic activities proceed but germination is prevented (11, 13, 15). Seed vigor has been enhanced by priming so that rate and percentage of seedling emergence from such seeds were greater than from non-primed seeds, especially under adverse seedbed conditions, including low temperature (16) and reduced water availability (8). Finch-Savage et al. (5) reported that plant growth regulators (gibberellic acid and/or benzyladenine) were more effective when added to the polyethylene priming solution than when applied as a pre-soak in reducing mean seedling emergence time of five bedding plant species and in increasing emergence percentage of primula and impatiens. Davis et al. (3) observed that priming tomato seeds in salt solutions containing 10 ppm uniconazole resulted in 20% shorter shoots than controls at 20 DAP, but did not protect seedlings against chilling damage. Souza-Machado et al. (18) noted that soaking tomato seeds in 50 ppm PB resulted in shorter seedlings with thicker stems and greater root to shoot ratio than non-treated seeds, but resulted in 15% lower seedling emergence.

The purpose of this study was to compare emergence and growth responses of cosmos and marigold following presoaking or priming of seeds in PB solutions.

Materials and Methods

Fifty-seed batches of 'Bonanza Gold' marigold (*Tagetes patula L.*) and 'Sensation Mixed' cosmos (*Cosmos bipinnatus* Cav.) (Park Seed Co., Greenwood, SC) were soaked in 0, 500, or 1000 ppm PB (Bonzi; Uniroyal Chemical Company, Middlebury, CT) for 16 hr at 25C (77F) in transparent polystyrene boxes containing two layers of germination paper (Seed Germination Blotters No. 385, Seedburo Co., Chicago, IL) moistened to saturation [15 ml (1.2 oz)] with the solutions. The seeds then were rinsed from the boxes and allowed to air dry for one day in an air-conditioned laboratory [19C (66F), 25% relative humidity]. These treatments were reported by Pasian and Bennett (14). Other fifty-seed batches were primed matrically in Grade 5 exfoliated vermiculite (W.R. Grace, Cambridge, MA) at –0.5 MPa (–5 bars) for 7 days at 20C (68F). Seeds were mixed at a dry weight ratio of 1:2, seed:vermiculite [50 seed weight = 307 mg (0.011 oz) for cosmos and 138 mg (0.005 oz) for marigold] in 33 ml (2.6 oz) plastic souffle cups (Solo Cup Company, Urbana, IL). An equal weight of 0, 500 or 1000 mg PB/liter (ppm PB) solution was added to the vermiculite, which represented –0.5 MPa (–5 bar) matric potential according to the moisture characteristic curve established by Khan et al. (12). The mg PB per seed for the 500 and 1000 mg PB/liter (ppm PB) applications during priming were, respectively: Cosmos, 6.14×10^{-3} and 1.23×10^{-2}; marigold, 2.76×10^{-3} and 5.52×10^{-3}. The small seed-to-vermiculite ratio was selected to minimize the reduction in matric potential of the vermiculite during priming. The seeds, liquid and vermiculite were mixed thoroughly by stirring. Aluminum foil was secured over the cup tops to minimize evaporative loss. Vermiculite moisture concentration after priming was within 2% of the original value.

Primed seeds were transferred from the boxes to a sieve and rinsed for 2 min to remove adhering vermiculite. Seeds then were allowed to air-dry for 1 day [19C (66F), 25% relative humidity]. Soaking and priming treatments were scheduled so that seed sowing for the emergence assay started at the same time.

Primed, soaked and control (neither soaked nor primed) seeds were sown in peat-lite medium (Redi-Earth Seedling and Plug Mix; Scotts, Marysville, OH) contained in 50-cell plug trays, each cell being inverted truncated pyramids [5 cm × 5 cm × 6 cm depth (90 cm^3); 2 in × 2 in × 2.4 in (5.5 in^3)]. Each treatment (flat) consisted of 50 seeds (one per plug cell) planted about 1 cm (0.4 in) deep, and the trays were surface irrigated. Two additional flats per replication were sown with non-treated seeds for growth medium drench and shoot spray applications of PB at 10 DAP. Treatments for each species were replicated four times and arranged in randomized complete block design. Flats were placed in a greenhouse with average 23.5/19.5C (74.3/67.1F) day/night and natural light supplemented with 1000-watt high pressure sodium lamps 1.5 m (4.9 ft) above the bench from 0600 to 2000 hr (March through May, 2000).

The numbers of seedlings emerged (hypocotyl arch visible) were recorded daily until no further emergence occurred. From these data, final emergence percentage of seedlings (FEP) and its angular transformation, and days to 50% FEP (E_{50}, an inverse measure of emergence rate) were calculated and subjected to analysis of variance. At 10 days after planting (DAP), plants from non-treated seeds were treated with a 1 ppm PB growth medium drench [30 ml/cell; 03 mg PB/cell (1×10^{-6} oz)] and a 10 ppm PB shoot spray [2 ml (.07 oz) per plant, 0.02 mg PB (7×10^{-7} oz) per plant]. The shoot spray was applied to both stems and leaves to almost runoff with care taken to avoid PB application to the growth medium.

Shoots in each one-half of the plug trays were cut at the peat-lite surface at 32 DAP. Shoot height (to the apical meristem) was measured and shoots were dried [2 weeks at 65C (149F)]. Shoot height and dry weight data were subjected to analysis of variance.

Table 1. Final emergence percentage (FEP) and its angular transformation and days to 50 percent of FEP (E_{50}) of cosmos and marigold in response to seed treatment with paclobutrazol (PB) and seed matric priming.

Treatment	Cosmos		Marigold	
	FEP [% (deg.)]	E_{50} (days)	FEP [% (deg.)]	E_{50} (days)
Soaked seeds				
0 ppm PB	85 (67)	2.6	95 (78)	2.4
500 ppm PB	73 (59)	3.3	97 (83)	2.8
1000 ppm PB	71 (57)	3.4	94 (77)	2.8
Primed seeds				
0 ppm PB	69 (56)	2.5	97 (81)	2.5
500 ppm PB	33 (35)	3.2	96 (78)	2.7
1000 ppm PB	21 (27)	5.2	97 (83)	2.9
Control seeds	73 (59)	3.5	96 (78)	2.5
1-way $LSD_{0.05}$[z]	(9)***	0.6***	(9)NS	0.2***
Factorial treatments[z]				
Soak/prime (SP)	(***)	NS	(NS)	**
PB linear	(***)	*	(NS)	***
PB quadratic	(***)	**	(NS)	**
SP × PB linear	(*)	NS	(NS)	NS
SP × PB quadratic	(**)	NS	(NS)	NS

[z]***, **, *, NS: significant at $P \leq 0.001$, ≤ 0.01, ≤ 0.05 or not significant, respectively.

Table 2. Shoot height and dry weight at 32 days after planting in response to seed, shoot and growth medium treatments with paclobutrazol (PB) and seed matric priming.

Treatment	Cosmos		Marigold	
	Shoot height (cm)	Shoot dry wt (mg/shoot)	Shoot height (cm)	Shoot dry wt (mg/shoot)
Soaked seeds				
0 ppm PB	29.2	451	15.0	448
500 ppm PB	27.7	388	13.3	442
1000 ppm PB	25.3	370	13.2	423
Primed seeds				
0 ppm PB	31.4	508	14.6	462
500 ppm PB	28.0	459	13.5	435
1000 ppm PB	24.9	436	12.5	335
Growth medium drench (1 ppm PB)[z]	21.2	390	12.4	401
Shoot spray (10 ppm PB)[y]	14.8	291	8.5	344
Control seeds	28.3	454	14.3	431
1-way $LSD_{0.05}$[x]	2.8***	55*	1.4***	63*
Factorial treatments[x]				
Soak/prime (SP)	NS	***	NS	*
PB linear	***	***	***	**
PB quadratic	NS	**	**	***
SP × PB linear	*	**	*	*
SP × PB quadratic	NS	*	*	**

[z]Growth medium drench = 0.03 mg PB/plant.

[y]Shoot spray = 0.02 mg PB/plant.

[x]***, **, *, NS: significant at $P \leq 0.001$, ≤ 0.01, ≤ 0.05 or not significant, respectively.

Table 3. Shoot height and dry weight at 5 weeks after transplanting in response to seed, shoot and growth medium treatments with paclobutrazol (PB) and seed matric priming.

Treatment	Cosmos		Marigold	
	Shoot height (cm)	Shoot dry wt (g/shoot)	Shoot height (cm)	Shoot dry wt (g/shoot)
Soaked seeds				
0 ppm PB	110.4	15.9	26.7	10.0
500 ppm PB	103.6	17.6	25.0	11.2
1000 ppm PB	102.4	12.9	25.5	10.8
Primed seeds				
0 ppm PB	107.0	15.5	26.4	11.2
500 ppm PB	103.6	13.3	26.5	11.0
1000 ppm PB	103.2	11.6	25.7	10.0
Growth medium drench (1 ppm PB)[z]	89.2	13.5	23.9	11.3
Shoot spray (10 ppm PB)[y]	88.8	11.8	21.9	7.8
Control seeds	106.9	15.0	26.3	11.2
1-way $LSD_{0.05}$[x]	8.9***	5.0[NS]	1.3***	1.5***
Factorial treatments[x]				
Soak/prime (SP)	NS	NS	NS	NS
PB linear	*	NS	NS	*
PB quadratic	*	NS	NS	NS
SP × PB linear	NS	NS	NS	NS
SP × PB quadratic	NS	NS	NS	NS

[z]Growth medium drench = 0.03 mg PB/plant.

[y]Shoot spray = 0.02 mg PB/plant.

[x]***, **, *, NS: significant at $P \leq 0.001$, ≤ 0.01, ≤ 0.05 or not significant, respectively.

The remaining plugs from each tray were transplanted into 15-cm (6 in) diameter standard pots containing Pro-Mix BX (Premier Horticulture, Red Hill, PA) which received 250 mg N/liter (ppm N) weekly from 21N–2.2P–16.6K ($21N–5P_2O_5–20K_2O$). After 5 weeks, shoot heights and dry weights were determined as described above.

Results and Discussion

Cosmos. Soaking or priming cosmos seeds in water resulted in similar FEP to that of control seeds, but in faster emergence (lower E_{50}) (Table 1). Seed priming frequently increases germination/emergence rate, particularly under stressful seedbed conditions (8, 16). Subjecting seeds to increasing PB concentration reduced FEP and increased E_{50}, these effects being more pronounced for primed than soaked seeds. The longer exposure of seeds to PB during priming (7 days) than soaking (16 hr) may have allowed more PB to enter the seeds. Reduced emergence following seed priming with 50 ppm PB was noted in tomato (18). Subjecting geranium seeds to higher PB dosage (1000 vs 500 ppm PB) and longer imbibition (24 vs 16 hr) reduced germination percentage (14). These authors speculated that PB stays on the seed coats then moves from the seed coats to the growth medium and is absorbed by seedling roots following germination and emergence. In our study, longer exposure of seeds to PB during priming than during soaking may have permitted the active ingredient to reach the embryo where it may exert a greater toxic effect on germination.

Soaking or priming seeds in 1000 ppm PB resulted in 11% or 12% shorter shoots, respectively, than those of control plants at 32 DAP (Table 2). Growth medium drench or shoot application of PB at 10 DAP respectively reduced shoot heights by 75% and 52%, and shoot dry weights by 14% and 36%, compared with values for control plants. Thus, shoot growth retardation from spray and drench applications of PB were much more pronounced than from seed treatment. The seed treatment PB concentration that reduced shoot height also reduced seedling emergence percentage and rate.

By 5 weeks after transplanting, seed treatment (soak or prime with or without PB) had no effect on shoot height (Table 3). Growth medium drench and shoot spray with PB reduced shoot height by 17%, but had no effect on shoot dry weight. Keever and Foster (10) noted that post-transplanting growth suppression of five bedding plant species treated with uniconazole during plug production was species- and dosage-dependent, and lasted five or more weeks.

Marigold. Final emergence percentage, averaging 96%, was unaffected by seed treatment with PB, although soaking or priming in 500 or 1000 ppm PB delayed emergence slightly (0.3 to 0.4 days) relative to that of control seeds (Table 1). Thus, soaking or priming with PB had little effect on marigold emergence. Pasian and Bennett (14) also reported that imbibing seeds of 'Bonanza Gold' marigold for up to 24 hr in 1000 ppm PB had no effect on percentage seedling emergence. Drewes and Van Staden (4) reported only slight re-

duction of germination with continuous exposure of *Tagetes minuta* seeds to 10^{-6} M PB, and almost complete inhibition with 10^{-4} M PB. Soaking seeds in 500 or 1000 mg PB/liter (ppm PB) failed to decrease shoot height or dry weight at 32 DAP below that from control seeds. However, seed exposure to 1000 mg ppm PB during priming resulted in 13% shorter, and 22% lighter shoots (Table 2). Pasian and Bennett (14) noted a 40% shoot height reduction of 'Bonanza Gold' marigold at 36 DAP from seeds that had been imbibed in 1000 ppm PB for 16 hr. Compared to responses from control seeds, exposure of seeds to 1000 ppm PB during priming resulted in similar shoot height suppression (13%) as the growth medium drench and similar shoot dry weight reduction (21%) as the shoot spray (Table 2). The low water potential [–0.5 MPa (–5 bar)] during matric priming may have permitted greater PB sorption by seeds during the 7-day exposure while preventing germination. Davis et al. (3) noted 20% shorter shoots at 14 DAP from salt-primed tomato seeds [KNO_3 and K_3PO_4, 6 days at 25C (77F)] with only 10 ppm PB compared to that from salt-primed seeds without PB.

By 5 weeks after transplanting, only the growth medium drench and shoot spray applications of PB resulted in shorter shoots (9% and 17%, respectively) than those of control plants (Table 3). Keever and Cox (9) reported that growth medium drench application of PB resulted in more persistent marigold shoot height suppression (16% at 18 weeks after treatment) than a shoot application of equal PB dosage. Thus, seed exposure to 1000 ppm PB during priming exerted a short-term effect in suppressing marigold shoot growth.

Our results show that marigold and cosmos responded differently to PB application to seeds. Exposure of cosmos seeds to 1000 ppm PB during soaking or priming reduced seedling shoot height but also reduced seedling emergence percentage, responses that were greater with the longer exposure during priming than during soaking. While soaking marigold seeds for 16 hours in 1000 ppm PB failed to decrease seedling shoot height below that of control plants, exposure to 1000 ppm PB during priming reduced seedling shoot height without reducing seedling emergence percentage. This suppression of shoot height was similar to that achieved with a growth medium drench, but less than that achieved with a shoot spray. On a per plant basis, exposure of marigold seeds to 1000 ppm PB during priming used about one-fifth of the PB used for drenching the growth medium (5.52×10^{-3} mg/seed vs 3.0×10^{-2} mg/cell). Seed treatment with PB gave shorter-term growth suppression and less spread of the chemical in the environment than the growth medium application. Seed treatment with PB also eliminates conventional fungicide seed coating treatment since the triazoles themselves are potent fungicides (7). Treatment of seeds with PB may increase seedling protection against chilling or drought as reported in wheat using 1 ppm uniconazole (6).

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