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Full Length Research Paper

Height suppression of tomato plug seedlings by an environment friendly seed treatment of plant growth retardants

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Experiments were conducted to investigate appropriate concentrations of plant growth retardants (PGRs) and duration of seed soaking in order to suppress hypocotyl length and plug seedling height of 2 tomato cultivars (*Lycopersicum esculentum* Mill. cv. Seogeon and Seokwang). Daminozide (B-9), uniconazole (Sumagic) and ethephon (Florel) were used as PGRs. Seeds were first soaked in 15 ml PGR solutions in an environment controlled chamber (25°C) for 1, 3, or 5 days. Then seeds were washed in tap water and were dried in a 5°C chamber for 1 day. Finally, dried seeds were used in both a germination test in a chamber and a growing test in a greenhouse. Differences among cultivars in response were observed in germination and seedling growth. Although germination in petri dishes and seedling emergence in plug trays declined, suppression of hypocotyl length and seedling height was evident in uniconazole treatments in both cultivars, duration of seed soaking in PGRs solutions had greater influence than the concentration. Differences in percent germination and percent emergence were also observed as affected by PGRs. Uniconazole treatments suppressed hypocotyl length and seedling height very significantly. Seeds soaked in PGRs solutions germinated in petri dishes, but tended not to emerge well in plug trays.

Key words: Daminozide (B-9), emergence, ethephon (florel), germination, *Lycopersicum esculentum,* uniconazole (sumagic).

INTRODUCTION

Because of the merits of reduction of labor in raising transplants mass production of uniform transplants and specialization of transplant production, plug transplants have been used by many growers. From the early 90 s, specialized nurseries in Korea have produced an increasing proportion of plug seedlings of vegetables and flowers for the horticulture industry due to their efficiency and economies of scale (Choi et al., 1997). Unfortunately, the high intensities at which the seedlings are grown, together with either low natural radiation levels during the rainy season (June - July) and winter or high greenhouse temperature in summer, often result in batches of badly stretched seedlings being produced (Kim et al., 2008).

Chemical control of growth and/or flower of commercial flower crops became a reality about 30 years ago. Therefore, many people nowadays take it for granted to use these chemicals at lower concentrations. Many methods including PGR, withholding water or nutrients, temperature control, clipping shoots and mechanical stimulation (brushing) are used to control transplant height (Garner and Bjorkman, 1996). Many PGR could be used for height control of many plant species. If PGRs are used to control plant height, height can be influenced by concentration (LeCain et al., 1986; McDanniel, 1986; Ruter, 1992), time of application (Miranda and Carlson, 1980; Gilbertz, 1992), mode of application (Cathey, 1975), formulation (McDaniel, 1986; Ruter, 1992) and media com-

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Table 1. The chemicals and their concentrations used in the nutrient solution for the culture of tomato plug seedlings.

Chemical	Concentration ($mg \cdot L^{-1}$)
$Ca(NO_3)_2 \cdot 4H_2O$	472
KH_2PO_4	272
$MgSO_4 \cdot 7H_2O$	246
KNO_3	202
NH_4NO_3	80
Fe-EDTA	15
$MnSO_4 \cdot 4H_2O$	2.1
H_3BO_3	1.4
$ZnSO_4 \cdot 7H_2O$	0.8
$CuSO_4 \cdot 5H_2O$	0.2
$Na_2MoO_4 \cdot 2H_2O$	0.1

position (Barrett, 1982). In many cases, by the time growers apply PGR, stretching of the hypocotyl has already occurred and application to seedlings are ineffective (Pasian and Bennett, 2001). Hence, time of application is very important to use Plant growth regulators (PGRs) because the effect of PGRs depends on time. In addition, the optimal rate of application and sensitivity of plants to each PGR may vary greatly from one species to another (Wang and Blessington, 1990).

Seedling height can be controlled by applying the PGR directly to the seed (Pasian and Bennett, 2001; Pill and Gunter, 2001; Still and Pill, 2003). Treatment to tomato seeds with hypertonic solutions containing uniconazole (0.1, 1, or 10 mgl^{-1}) was of little practical value in protecting seedlings from freeze damage, although T_{50} (days) and seedling height was reduced (Davis et al., 1990). Soaking seeds in 1000 mgl^{-1} paclobutrazol for 6, 16, or 24 h, growth restriction was 61, 37 and 76% in geranium, 30, 38 and 41% in marigold and 31, 31 and 40% respectively. Therefore, PGR application to geranium, marigold and tomato seeds may be feasible using a 6 or 16 h soak in 500 mgl^{-1} paclobutrazol (Pasian and Bennett, 2001). Soaking pepper seeds in 1-100 mgl^{-1} uniconazole for 24, 72 or 120 h significantly suppressed hypocotyls length and seedling growth (Shin and Jeong, 2002). Cucumber seeds soaked in 250, 500, 1000 or 2000 mgl^{-1} paclobutrazol for 6, 12 or 24 h reduced hypocotyls length, stem elongation, leaf area, fresh and dry weight (Cho et al., 2002). Soaking tomato seeds in 50 - 1000 mgl^{-1} paclobutrazol for 48 h resulted in lower percentage of germination or emergence than soaking seeds for 24 h (Still and Pill, 2003). Soaking seeds in 50 mgl^{-1} paclobutrazol effectively controlled plug height in tomato (Still and Pill, 2006), whereas soaking tomato seeds in 100 mgl^{-1} paclobutrazol for 1 h prevented early hypocotyls stretch of tomato seedlings with no long term effects on plant growth (Brigard et al., 2006). Despite these previous studies, there is little information available on the effects of daminozide, ethephon and uniconazole application to control stretching in seedlings. This study was conducted to evaluate the effect of seed soaking treatment with PGRs for controlling stretching of tomato seedling.

MATERIALS AND METHODS

Tomato (*Lycopersicum esculentum* Mill. cv. Seogeon and Seokwang) seeds were put in a petri dish (87 mm × 15 mm) filled with 15 ml of PGR solutions and were placed in an environment controlled chamber (25℃, 80% RH, dark) for 1, 3, or 5 days. Daminozide (B-9) at 10,000, 20,000 or 30,000 mgl^{-1}, uniconazole (sumagic) at 100, 200 or 300 mgl^{-1}, and ethephon (florel) at 1,000, 2,000 and 3,000 mgl^{-1} were used. After soaking treatment, seeds were washed in tap water and were dried in growth chamber (25℃, 80% RH, dark) for 1 day.

Seeds treated with PGRs solutions were placed in a petri dish with a sheet of filter paper (Whatman no. 2). Then seeds were placed in an environment controlled chamber (25℃, 80% RH, dark) in a completely randomized design. Equal amount of distilled water was supplied to all treatments. Germination of tomato seeds was checked once a day for 9 days. Percent germination, mean daily germination (MDG), T_{50}, and mean germination time (MGT) were evaluated.

Treatments which caused precocious germination during the seed soaking process and treatments which gave percent germination less than 50% in germination experiment were excluded in growth experiment. Seeds were sown in 200-cell (11cc) plug trays containing plug medium (Tosilee medium, Shinan Grow Co., Korea). 3 replicates per treatment and 50 seeds per replicate were used. Seed-sown trays were placed on germination beds with a fogging system for three days in a glasshouse. After seedlings had been emerged, trays were laid out in a completely randomized block design on beds in a glasshouse. A nutrient solution was supplied uniformly for all treatments once a day through a mat subirrigation system. The composition of nutrient solution was based on the formulation used in commercial plug greenhouses (Table 1).

Temperatures of a greenhouse were measured during the experimental period by digital thermometers (Thermo Recorder TR-71S, T and D Crop., Japan). Maximum, minimum and mean temperatures of a greenhouse during the culture period were 35.4, 12.6 and 24.4℃, respectively.

Emergence was checked for 10 days and growth measurement on seedlings was conducted at 32 days after sowing. Emergence, hypocotyl length, plant height, leaf area, number of leaves, % dry matter, T/R ratio, fresh and dry weights of shoot, root and whole plant and chlorophyll concentration were measured. Leaf area was determined with a leaf area meter (LI-3100 Area meter, LI.COR. Inc., Lincoln, Nebraska USA). Dry weight was measured after 72 h of drying at 60℃ in a dry oven. For measurement of chlorophyll concentration, vigorous and uniform leaves were sampled and extracted with 80% (v/v) acetone for 24 h. Total chlorophyll concentration was determined by measuring absorbance of the extracted solution at 645 nm and 663 nm with a spectrophotometer (Uvikon 922, Kotron Instruments, Italy) according to the procedure developed by Arnon (1949). Chlorophyll concentration ($\mu g \cdot mg^{-1}fw$) = $[(20.29 \times A_{645}) + (8.02 \times A_{663})] \times$ [volume of acetone (ml) ÷ fresh weight (mg)], where A_{645} and A_{663} are absorbance at 645 and 663 nm, respectively.

Data collected were analyzed for statistical significance by the SAS (Statistical analysis system, V. 6.12, Cary, NC, USA) program. The experimental results were submitted to an analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Soaking seeds in water or PGRs solution reduced germi-

Table 2. Effect of seed treatment of plant growth retardants on percent germination, mean daily germination (MDG), number of days to 50% germination (T_{50}), mean germination time (MGT) and percent emergence of 'Seogeon' tomato seeds.

Growth retardant	Concentration (mgl^{-1})	Soaking Duration (day)	Germination (%)	MDG (day)	T_{50} (day)	MGT (day)	Emergence (%)
Control (unsoaked)		0	98.7 a[1]	5.0 a	2.6 de	4.7 cd	96.3 a
Distilled water		1	94.0 ab	4.7 ab	2.9 de	3.4 dg	91.7 a
		3	89.7 bc	4.5 ab	2.7 de	3.2 dg	97.0 a
Daminozide	10,000	1	27.3 e	1.4 e	5.6 c	5.9 bc	-[2]
		3	8.0 g	0.4 g	6.1 c	6.6 b	-
		5	2.0 g	0.1 g	6.7 bc	6.7 b	-
	20,000	1	34.7 e	1.7 e	5.8 c	6.3 b	-
	30,000	1	19.3 f	1.0 f	6.7 bc	6.8 b	-
Uniconazole	100	1	81.3 c	4.1 c	5.9 c	6.6 b	54.7 b
		3	3.0 g	0.2 g	7.3 ab	8.3 a	-
	200	1	51.3 d	2.6 d	7.8 a	8.1 a	30.0 c
Ethephon	1,000	1	95.3 ab	4.8 ab	3.2 de	3.9 f	95.3 a
		3	98.7 a	4.9 a	2.4 e	2.4 g	9.6 d
	2,000	1	96.7 ab	4.8 ab	3.6 d	4.1 de	95.3 a
		3	81.3 g	4.1 c	2.6 de	3.0 eg	7.4 d
	3,000	1	94.7 ab	4.7 ab	3.1 de	3.6 dg	94.0 a
		3	88.7 bc	4.4 bc	3.4 e	2.6 fg	5.3 d
F-test			***	***	***	***	***

[1] Mean separation within columns by Duncan's multiple range test at P = 0.05.
[2] Not measured because of no germination.
NS, *,**,*** Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

nation percentage in both cultivars when compared to the control. Table 2 show a progressive decrease in the rate of germination resulting from the seed treatment with water. Soaking for 5 days killed all the seeds. The water causes the cells to become turgid, the entire seed grows in volume and the seed coat becomes more permeable to oxygen and carbon dioxide. However, over soaking of seeds can damage seeds and unable to exchange gases, which caused inhibition in the metabolic activities, thus germination percent reduced significantly. Soaking seeds of tomato resulted in a gradual loss of germination, however, increased emergence percentage and reduced mean germination time (MGT) when compared to the control. These results are in agreement with previous report (Sabongari and Aliero, 2004).

Seeds of 'Seogeon' tomato did not germinate in 100 mgl^{-1} (5 days soaking), 200 mgl^{-1} (3 and 5 days soaking) and 300 mgl^{-1} (1, 3 and 5 days soaking) uniconazole solutions and 2,000 and 3,000 mgl^{-1} (3 and 5 days soaking) daminozide solutions. These results are in agreement with (Pasian and Bennett, 2001; Shin and Jeong, 2002; Still and Pill, 2003), they reported that seed germination was lower with an increase in PGRs concentration and soaking duration of seeds. Seeds of 'Seogeon' tomato soaked in ethephon solution for 5 days germinated during soaking process (Table 2). Percent germination in ethephon treatment was slightly lower than that in the control, but was higher than that in other PGRs treatments. The MDG, T_{50}, and MGT in ethephon treatment were similar to those in the control. Percent seedling emergence was lower than percent germination in all treatments in the one day ethephon treatment which had similar percent germination and percent emergence as those in the control (Table 2).

Seeds of 'Seogeon' tomato in 100 mgl^{-1} (1 and 3 days soaking) and 200 mgl^{-1} (1 day soaking) uniconazole solutions germinated, but percent germination was greater than 80% only in the 100 mgl^{-1} (one day soaking) uniconazole solution. In addition, percent emergence in these treatments was less than 50%. Although seeds of 'Seogeon' tomato germinated in petri dishies, seedlings did not emerge in trays, especially in 10,000 mgl^{-1} and 30,000 mgl^{-1} daminozide solution and 100 mgl^{-1} (3 days soaking) uniconazole treatment (Table 2).

Table 3 shows similar trends in 'Seokwang' tomato. Most seeds of 'Seokwang' tomato soaked in uniconazole solutions did not germinate except for uniconazole 100 mgl^{-1} (one day soaking) and percent germination was less than 3%. Percent germination more than 88% was obtained only in the 100 mgl^{-1} (one day soaking) uniconazole solution. In the present study, soaking seeds in PGRs reduced germination percentage significantly in

Table 3. Effect of seed treatment of plant growth retardants on percent germination, mean daily germination (MDG), number of days to 50% germination (T_{50}), mean germination time (MGT) and percent emergence of 'Seokwang' tomato seeds.

Growth retardant	Concentration (mgl^{-1})	Soaking Duration (day)	Germination (%)	MDG (day)	T_{50} (day)	MGT (day)	Emergence (%)
Control (unsoaked)		0	99.3 a[1]	5.0 a	2.6 de	4.7 cd	97.3 a
Distilled water		1	95.3 ab	4.8 ab	3.0 de	3.5 dg	92.7 a
		3	92.7 ab	4.5 ab	2.8 de	3.3 dg	98.0 a
Daminozide	10,000	1	84.7 c	4.2 c	5.5 bd	5.4 be	86.7 a
		3	20.0 e	1.0 e	6.2 ac	6.7 ac	-[2]
		5	22.7 e	1.1 e	6.1 ac	6.3 ad	-
	20,000	1	67.3 d	3.4 d	5.7 bd	6.2 ad	62.0 bc
		3	2.0 f	0.1 f	7.5 ab	7.5 ab	-
		5	6.7 f	0.3 f	4.5 cg	4.8 cf	-
	30,000	1	82.0 c	4.1 c	5.6 bd	6.1 ad	52.0 c
		3	6.7 f	0.3 f	5.3 be	6.5 ac	-
Uniconazole	100	1	88.0 bc	4.4 bc	6.0 ac	6.7 ac	48.7 c
		3	2.7 f	0.1 f	4.2 ch	3.3 eg	-
	200	1	2.7 f	0.1 f	8.2 a	8.2 a	-
		3	2.0 f	0.1 f	5.0 cf	3.5 eg	-
Ethephon	1,000	1	98.7 a	4.9 a	3.0 ei	3.6 eg	98.7 a
		3	96.0 a	4.8 a	2.6 gi	2.9 eg	87.3 a
	2,000	1	97.3 a	4.9 a	3.4 di	3.9 dg	95.3 a
		3	97.3 a	4.9 a	1.5 l	2.1 g	62.0 bc
	3,000	1	96.7 a	4.8 a	3.4 di	3.9 dg	97.3 a
		3	93.3 ab	4.7 ab	3.6 di	3.9 dg	68.7 b
F-test			***	***	***	***	***

[1] Mean separation within columns by Duncan's multiple range test at P = 0.05.
[2]Not measured because of no germination.
[NS,*,**,***]Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

both cultivars when compared to the water soaking. This might be due to inhibition of gibberellins biosynthesis. Gibberellins are known to stimulate germination of dormant as well as non-dormant seeds of several plant species (Bewley and Black, 1982). The growth retardants paclobutrazol, ancymidol, uniconazole are known to block the oxidation of ent-kaurene to ent-kaurenoic acid which are steps in the GA synthesis pathway of gibberellins (Pressman and Shaked, 1991).

Of the 3 PGRs tested, uniconazole was shown to be the most effective retardant followed by ethephon and daminozide. Table 4 shows that hypocotyl length and plant height of 'Seogeon' tomato seedlings were remarkably suppressed in the 100 mgl^{-1} (1 day soaking) and 200 mgl^{-1} (1 day soaking) uniconazole treatments as compared to the control and other treatments. The plant growth retardant uniconazole is known to affect the levels of endogenous gibberellins. Gibberellins are known to induce elongation (Kurepin et al., 2006), while triazole PGRs reduces gibberellins levels and causes a decrease in shoot growth (Davis and Curry, 1991). Uniconazole reduce stem length in many plant species such as hibiscus (Wang and Gregg, 1991), chrysanthemum (Schuch, 1994), kalanchoe (Hwang et al., 2008, 2009), pepper (Shin and Jeong, 2002). An increase in ethephon concentration from 1000 to 3000 mgl^{-1} resulted in a significant decrease in hypocotyls length when compared to the control, however, plant height did not affect significantly at any concentrations of ethephon. Fresh and dry weights of shoot significantly decreased when seeds were soaked in 100 or 200 mgl^{-1} uniconazole. At 100 mgl^{-1} uniconazole fresh weight of root did not affect when compared to the control, but dry weight reduced significantly. When seeds were treated in 1000 mgl^{-1} ethephon root fresh weight increased significantly, but dry weight of root was not changed. At 2000 mgl^{-1} ethephon fresh and dry weights of shoot significantly decreased (Table 4). Leaf area and number of leaves were not reduced when the seeds were treated with ethephon, but significantly reduced by uniconazole treatment. Ethephon treatment (1000 or 2000 mg) increased chlorophyll content when compared to the control. However, at 3000 mg ethapon chlorophyll content was not increased. When the seeds were soaked in uniconazole for 1 day chlorophyll content was reduced when

Table 4. Effect of seed treatment of plant growth retardants on growth of 'Seogeon' tomato seedlings measured at 32 days after sowing in plug trays.

Growth retardant	Concentration ($mg \cdot L^{-1}$)	Soaking Duration (day)	Hypocotyl Length (cm)	Plant Height (cm)	Fresh wt. (g)		Dry wt. (g)	
					Shoot	Root	Shoot	Root
Control (unsoaked)		0	8.5 a[1]	30.1 a	3.3 a	0.29 c	0.25 a	0.02 ab
Distilled water		1	7.0 c	27.9 a	2.6 b	0.44 ab	0.20 ab	0.02 a
		3	7.7 bc	30.4 a	3.3 a	0.35 c	0.22 ab	0.02 ab
Uniconazole	100	1	3.4 d	6.7 b	1.0 c	0.30 c	0.08 c	0.01 b
	200	1	3.4 d	5.4 b	0.5 c	0.12 d	0.03 d	0.01 c
Ethephon	1,000	1	8.0 ab	28.2 a	3.2 a	0.48 a	0.22 ab	0.02 a
	2,000	1	7.2 bc	28.8 a	2.5 b	0.31 c	0.18 b	0.02 b
	3,000	1	6.8 c	28.4 a	3.1 a	0.33 c	0.20 ab	0.02ab
F-test			***	***	***	***	***	***

[1] Mean separation within columns by Duncan's multiple range test at P = 0.05.
NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

Table 5. Effect of seed treatment of plant growth retardants on growth of 'Seogeon' tomato seedlings measured at 32 days after sowing in plug trays.

Growth retardant	Concentration ($mg \cdot L^{-1}$)	Soaking Duration (day)	Leaf area (cm^2)	No. of leaves	Chlorophyll ($\mu g \cdot mg^{-1} fw$)	Dry matter (%)	T/R ratio
Control (unsoaked)		0	44.1 a[1]	4.1 a	2.64 bc	7.24 ab	13.94 a
Distilled water		1	40.3 a	4.0 ab	3.12 a	7.37 a	9.62 bd
		3	42.9 a	4.0 ab	2.75 ab	6.51 ac	11.53 ab
Uniconazole	100	1	21.3 b	3.6 c	2.20 d	7.35 a	5.64 d
	200	1	4.5 c	3.0 d	2.27 cd	5.85 c	7.05 cd
Ethephon	1,000	1	43.4 a	4.0 ab	3.09 a	6.73 ac	9.62 bd
	2,000	1	39.9 a	4.0 ab	3.08 a	6.79 ac	11.84 ab
	3,000	1	43.8 a	3.9 b	2.79 ab	6.30 bc	11.15 ac
F-test			***	***	***	*	***

[1] Mean separation within columns by Duncan's multiple range test at $P = 0.05$.
NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

compared to the control (Table 5). Chlorophyll content was enhanced by PGRs treatment (Starman et al., 1990; Tekalign and Hammes, 2004). In contrast, chlorophyll content was reduced by PGRs treatment (Knypl, 1969; Davis et al., 1988). Differential effect of PGR on chlorophyll content may be due to its accumulation and endogenous level of cytokinins. Percent dry matter was significantly lower in 200 mgl^{-1} uniconazole treatment. T/R ratio slightly decreased in 100 mgl^{-1} (1 day soaking) and 200 mgl^{-1} (1 day soaking) uniconazole treatments (Table 5).

Table 6 and Figure 1 show that hypocotyl length and plant height of 'Seokwang' tomato seedlings were remarkably suppressed in 100 mgl^{-1} (1 day soaking) uniconazole treatment as compared to the control and other treatments. Plant height was increased in 10,000 mgl^{-1} daminozide for 1 day when compared to the control. Soaking seeds in 2000 or 3000 mgl^{-1} ethephon for 1 day plant height increased. However, 3 days soaking decreased plant height. The results are in agreement with (Shin and Jeong, 2002; Still and Pill, 2003) they reported that plant height decreased as soaking period increased. Leaf area, number of leaves, and T/R ratio slightly decreased in 100 mgl^{-1} (1 day soaking) (Table 6).

Chlorophyll concentration and percent dry matter were not significantly different in all treatments (Table 7). Uniconazole was effective in inhibiting seedling height of both cultivars at a very low concentration than that of daminozide and ethephon, but significantly affect the emergence percentage. Hence, further studies are needed in order to obtain maximum emergence and this may be possible by reducing uniconazole concentration.

In conclusion, the growth of tomato seedlings was efficiently regulated by uniconazole 100 mgl^{-1} (1 day soaking) treatment. These results should be helpful in allowing plant nurseries to control the stretching of tomato seedling. Although these methods successfully control stretching, seeds soaked in PGR solutions germinated, it tended not to emerge well. A seed soaking

Table 6. Effect of seed treatment of plant growth retardants on growth of 'Seokwang' tomato seedlings measured at 32 days after sowing in plug trays.

Growth retardant	Concentration (mgl^{-1})	Soaking Duration (day)	Hypocotyl Length (cm)	Plant Height (cm)	Fresh wt. (g)		Dry wt. (g)	
					Shoot	Root	Shoot	Root
Control (unsoaked)		0	7.8 a[1]	28.7 a	2.7 a	0.37bc	0.18 a	0.02 b
Distilled water		1	6.8 ac	28.8ac	2.4 a	0.34bd	0.16 c	0.02 b
		3	7.3 ab	30.0 b	2.7 a	0.52 a	0.19 a	0.09 a
Daminozide	10,000	1	7.1 ac	31.5 a	2.8 a	0.31bd	0.19 a	0.02 b
	20,000	1	6.3 bc	28.1ac	2.8 a	0.31bd	0.15ac	0.02 b
	30,000	1	6.6 ac	24.4 d	2.3 a	0.41ab	0.16ab	0.02 b
Uniconazole	100	1	3.2 d	6.0 e	0.8 b	0.22 d	0.05 d	0.01 b
Ethephon	1,000	1	6.9 ac	28.2ac	2.4 a	0.39ac	0.16ac	0.02 b
		3	6.0 c	26.7bd	2.2 a	0.27bd	0.12 c	0.01 b
	2,000	1	7.4 ab	30.4 a	2.8 a	0.41ab	0.19 a	0.02 b
		3	5.9 c	24.6 d	2.2 a	0.25cd	0.13bc	0.01 b
	3,000	1	7.0 ac	29.4ac	2.7 a	0.39ac	0.19 a	0.02 b
		3	6.3 bc	26.4cd	2.3 a	0.31bd	0.12 c	0.02 b
F-test			***	***	*	**	***	NS

[1] Mean separation within columns by Duncan's multiple range test at $P = 0.05$.
[N]S,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

Figure 1. Tomato 'Seokwang' cultivar grown with different plant growth retardant (daminozide, uniconazole, and ethephon) soaking concentration treatment harvested at 32 days after sowing in plug tray. Soaked seeds were placed for one day.

Table 7. Effect of seed treatment of plant growth retardants on growth of 'Seokwang' tomato seedlings measured at 32 days after sowing in plug trays.

Growth retardant	Concentration (mgl^{-1})	Soaking Duration (day)	Leaf area (cm^2)	No. of leaves	Chlorophyll ($\mu g\ mg^{-1}fw$)	Dry matter (%)	T/R ratio
Control (unsoaked)		0	48.4 b[1]	4.0 a	2.54 a	6.79 b	11.89 ab
Distilled water		1	38.6 df	4.0 ab	2.53 a	6.46 b	9.00 ae
		3	46.5 bc	4.1 ab	2.53 a	8.88 a	9.00 ae
Daminozide	10,000	1	41.5 cd	4.0 a	2.19 a	6.79 b	10.92 ad
	20,000	1	33.7 f	4.1 ab	2.34 a	5.42 b	12.08 a
	30,000	1	39.4 de	4.0 b	2.38 a	6.74 b	7.40 cg
Uniconazole	100	1	13.8 h	3.1 c	2.26 a	6.42 b	4.15 fi
Ethephon	1,000	1	42.0 cd	4.1 ab	2.32 a	6.41 b	7.91 bf
		3	28.6 g	4.0 ab	2.36 a	5.46 b	8.95 ae
	2,000	1	45.0 bc	4.2 a	2.33 a	6.82 b	9.00 ae
		3	35.3 ef	4.1 ab	2.25 a	5.93 b	7.22 cg
	3,000	1	41.6 cd	4.0 b	2.21 a	6.72 b	6.08 eh
		3	56.1 a	4.0 b	2.46 a	5.40 b	8.77 ae
F-test			***	***	NS	*	*

[1] Mean separation within columns by Duncan's multiple range test at $P = 0.05$.
NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, or 0.001, respectively.

method which is effective in suppressing hypocotyl length and seedling height without affecting germination and seedling emergence significantly would be ideal and it is necessary to research effects that a seed soaking method makes on flowering and fruit setting as well as general growth.

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