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Full Length Research Paper

Effect of soaking of seeds in potassium silicate and uniconazole on germination and seedling growth of tomato cultivars, Seogeon and Seokwang

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Experiments were conducted to investigate the effects of soaking seeds in potassium silicate and uniconazole on seed germination and seedling growth of two tomato cultivars. Tomato (*Lycopersicum esculentum* Mill. 'Seogeon and Seokwang') seeds were put in a Petri dish filled with 15 ml of a solutions containing either 50 or 100 mg L^{-1} potassium silicate or uniconazole and were placed in an environment controlled chamber (25°C, 80% RH, dark) for 12 or 24 h. After the soaking treatment, seeds were washed in distilled water and were dried in a growth chamber (25°C, 80% RH, and in the dark) for 4 h. Seeds were sown in 288-cell (11 cc) plug trays containing a Tosilee medium and trays were layed out in a randomized complete block design on beds in a glasshouse. A nutrient solution was supplied uniformly for all treatments once a day through a sub-irrigation system. Soaking seeds in potassium silicate or uniconazole solution reduced germination percentage in both cultivars when compared to the control. In both cultivars, soaking treatment of uniconazole significantly reduced length of stem, hypocotyls, internode, leaf area and dry weight of stem and root, as compared to the control and other treatments. Root length increased significantly in all treatments when compared with the control. Hypocotyl length and plant height of 'Seogeon' seedlings were suppressed in the 100 mg L^{-1} potassium silicate treatment as compared to the control and water soaking. In contrast, height of 'Seokwang' seedlings increased by potassium silicate treatment. The chlorophyll fluorescence ratio (Fv/Fm) increased by low concentration of uniconazole treatment as compared to the control and other treatments. The growth of tomato seedlings was efficiently regulated by uniconazole 50 mg L^{-1} (12 h soaking) treatment.

Key words: Chlorophyll fluorescence, plant growth retardants, plug plants, potassium silicate, seed treatment, silicon, uniconazole.

INTRODUCTION

As a result of the merits of reduction of labor in mass production of uniform transplants and specialization of transplant production, plug transplants have been used by many growers. However, one of the problems in plug transplant production is stretchiness of transplants caused by high plant densities in plug trays. Many methods, including plant growth retardants (PGRs), with-holding water or nutrients, temperature control, clipping shoots and mechanical stimulation (brushing), are used to control transplant height. Among many methods used for the control of plant height, the use of PGRs is most popular. If PGRs are used to control plant height, height can be influenced by concentration (LeCain et al., 1986; McDaniel, 1986; Ruter, 1992), time of application (Miranda and Carlson, 1980; Gilbertz, 1992), mode of

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Table 1. Treatments used in this experiment.

Treatment	Chemical	Concentration (mg L^{-1})	Soaking duration (h)
1	Control (unsoaked)	0	0
2	Distilled water	0	12
3		0	24
4	Potassium silicate	50	24
5		100	24
6	Uniconazole	50	12
7		50	24
8		100	12
9		100	24

application (Cathey, 1975), formulation (McDaniel, 1986; Ruter, 1992), and media composition (Barrett, 1982). In many cases, by the time growers apply PGR, stretching of the hypocotyl had already occurred and application to seedlings are ineffective (Pasian and Bennett, 2001). 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 of tomato seeds with hypertonic solutions containing uniconazole (0.1, 1, or 10 mg L^{-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 pepper seeds in 1 to 100 mg L^{-1} uniconazole for 24, 72 or 120 h significantly suppressed hypocotyls length and seedling growth (Shin and Jeong, 2002). In our previous study, the growth of tomato seedlings was efficiently regulated by 100 mg L^{-1} uniconazole (one day soaking) treatment, but significantly affected the percent emergence.

Silicon (Si) is the second most abundant element both on the surface of the Earth's crust and in the soils. Although silicon has not been considered to be an essential element for higher plants (Epstein, 1999), yet its beneficial effects have been demonstrated for many plants, especially when they are subjected to biotic or abiotic stresses (Ma and Yamaji, 2006; Sivanesan et al., 2011). Application of silicon has been reported to enhance stress (Gunes et al., 2007; Romero-Aranda et al., 2006), and disease resistance (Dannon and Wydra, 2004) in tomato. Addition of Si either increased or decreased plant height in many plant species (Kim et al., 2002; Gong et al., 2003; Mattson and Leatherwood, 2010). In marigold, application of silicon decrease seedlings height (Sivanesan et al., 2010).

This study was conducted to evaluate the effect of seed soaking treatment with potassium silicate and uniconazole on seed germination and seedlings growth of two tomato cultivars.

MATERIALS AND METHODS

Tomato (*Lycopersicum esculentum* Mill. 'Seogeon' and 'Seokwang') seeds were placed in a Petri dish (87 x 15 mm) filled with a 15 ml solution containing either 50 or 100 mgL^{-1} potassium silicate or uniconazole (MB cell, Seoul, Korea) (Table 1), and were placed in an environment controlled chamber (25°C, 80% RH and in the dark) for 12 or 24 h. After soaking, seeds were washed in distilled water and dried in a growth chamber (25°C, 80% RH, in the dark) for 4 h. Seeds were sown in 288-cell (11 cc) plug trays containing a commercial germination medium (Tosilee medium; Shinan Grow, Jinju, Korea), and were placed on germination beds with a fogging system for three days in a glasshouse. After seedlings had emerged, trays were laid out in a randomized complete block design on beds in a glasshouse. Each treatment consisted of three replicates. Nutrient composition (Shin et al., 2009) was supplied uniformly for all treatments once a day through a sub-irrigation system. Plant height, stem diameter, hypocotyls length, number of leaves, leaf area, root length, and fresh and dry weights of shoot and root were recorded after 32 days of cultivation. 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°C in a dry oven. Chlorophyll fluorescence parameters were measured using a chlorophyll fluorometer (PAM-2100, Walz, Germany). Seedlings were dark adapted for at least 30 min before the chlorophyll fluorescence measurements. Temperatures of the greenhouse were measured during the experimental period by digital thermometers (Thermo Recorder TR-71S, T&D Crop., Japan). Maximum, minimum and mean temperatures of the greenhouse during the culture period were 35.4, 12.6 and 24.4°C, 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

Differences among the two cultivars in their responses were observed in germination and seedling growth. Soaking seeds in potassium silicate or uniconazole solution reduced germination percentage in both cultivars when compared with the control. However, high concentration (100 mg L^{-1}) of uniconazole and 24 h soaking period decreased germination percentage significantly (Figure 1). These results are in agreement with other report (Pasian and Bennett, 2001; Shin and Jeong, 2002; Still and Pill, 2003; Shin et al., 2009); they reported that seed germination was lower with an increase in PGRs concentration and soaking duration of seeds. This might

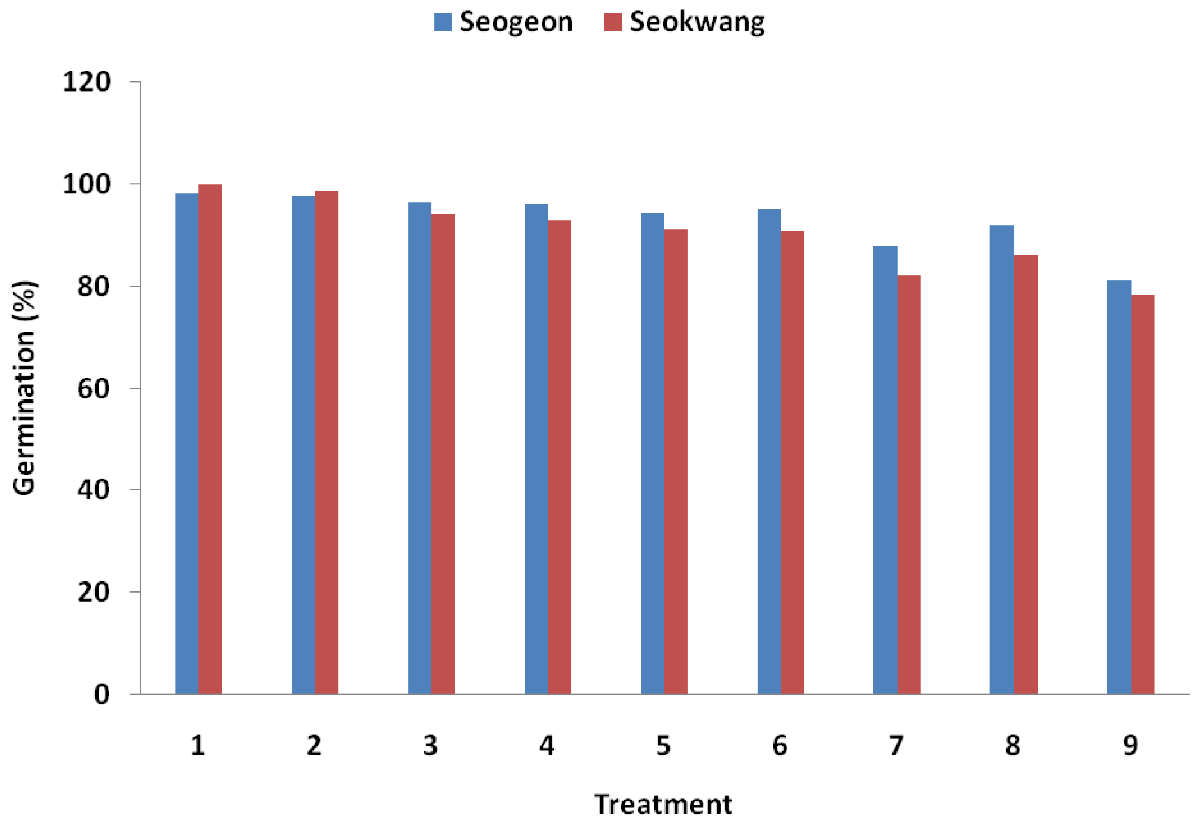

Figure 1. Effect of soaking seeds in potassium silicate and uniconazole on germination of tomato seeds recorded at 9 days after sowing in plug trays.

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 and uniconazole are known to block the oxidation of ent-kaurene to ent-kaurenoic acid which is a step in the GA synthesis pathway of gibberellins (Pressman and Shaked, 1991).

Plant height, length of hypocotyl and inter node, number of leaves and leaf area were significantly affected by the treatments (Figure 2). In 'Seogeon', plant height and internode length were suppressed in the 100 mg L^{-1} potassium silicate treatment, as compared to the control and distilled water soaking, while plant height was not reduced in 'Seokwang'. Application of Si either increased or decreased plant height in many plant species (Kim et al., 2002; Gong et al., 2003; Mattson and Leatherwood, 2010). Uniconazole treatment reduced plant height and internode length of the two tomato cultivars when compared with other treatments and control, however, increasing concentration of uniconazole or soaking duration did not affect the plant height significantly (Table 2). Therefore, soaking seeds in the 50 mg L^{-1} uniconazole solution significantly reduced plant height with good germination percentage. 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 cause 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) and pepper (Shin and Jeong, 2002). In both cultivars, soaking seeds in distilled water, potassium silicate or uniconazole solution reduced stem diameter and number of leaves when compared with the control. Leaf area was not reduced when the seeds were treated with potassium silicate, but significantly was reduced by uniconazole treatment when compared with the control (Table 2).

Root length was increased in all treatments when compared with the control. When seeds were treated with potassium silicate at 50 and 100 mg L^{-1}, there was increase in root length in 'Seogeon' and 'Seokwang', respectively (Table 3). The highest root length was observed in 'Seogeon' when seeds were soaked in distilled water for 12 h, while in 'Seokwang', at 50 mg L^{-1} uniconazole, there was significant increase in the root length when compared with the control. Fresh and dry weights of shoot significantly decreased when seeds were soaked in 50 or 100 mg L^{-1} uniconazole. Soaking seeds in potassium silicate solution increased the fresh

Figure 2. Effect of seed treatment with potassium silicate and uniconazole on growth of tomato seedlings measured at 32 days after sowing in plug trays. A, 'Seogeon'; B, 'Seokwang'

Table 2. Effect of seed treatment in potassium silicate and uniconazole on growth characteristics of tomato seedlings measured at 32 days after sowing in plug trays.

Cultivar (A)	Treatment (B)	Plant height (cm)	Stem diameter (mm)	Hypocotyl length (cm)	Internodal length (cm)	Number of leaf	Leaf area (cm^2)
	1	27.2^{bc1}	2.60^{cd}	7.53^{b}	9.91^{bc}	4.2^{e-g}	38.0^{de}
	2	27.8^{b}	2.54^{cd}	8.12^{a}	10.40^{ab}	4.1^{fg}	39.9^{b-d}
	3	28.1^{ab}	2.50^{d}	8.46^{a}	10.43^{ab}	3.9^{g}	35.8^{e}
Seogeon	4	25.3^{d}	2.53^{cd}	6.59^{c}	8.76^{e}	3.9^{g}	36.2^{de}
	5	17.1^{e}	2.28^{e}	4.77^{d}	4.64^{f}	4.0^{g}	27.5^{f}
	6	11.1^{f-i}	2.10^{f}	3.42^{e}	2.13^{g}	4.0^{g}	20.2^{g}
	7	10.5^{hi}	2.28^{e}	3.31^{e}	2.20^{g}	$4.1f^{g}$	19.3^{g}

Table 2. continues.

	8	10.6^{hi}	2.13^{ef}	3.39^{e}	1.99^{g}	4.0^{g}	18.4^{g}
	9	10.4^{i}	2.14^{ef}	3.36^{e}	1.96^{g}	4.0^{g}	18.9^{g}
Seokwang	1	25.1^{d}	2.88^{a}	6.96^{c}	8.92^{de}	5.1^{a}	43.9^{a}
	2	29.0^{a}	2.69^{bc}	7.97^{ab}	10.69^{a}	4.8^{a-c}	43.2^{ab}
	3	27.8^{b}	2.59^{cd}	7.92^{ab}	10.05^{a-c}	4.7^{b-d}	42.2^{a-c}
	4	24.9^{d}	2.68^{bc}	6.96^{c}	9.56^{cd}	4.7^{b-d}	39.1^{c-e}
	5	26.7^{c}	2.84^{ab}	8.44^{a}	10.23^{a-c}	4.9^{ab}	45.4^{a}
	6	12.0^{f}	2.26^{ef}	3.33^{e}	2.07^{g}	4.6^{b-d}	20.6^{g}
	7	10.9^{g-i}	2.28^{e}	3.28^{e}	1.99^{g}	4.4^{d-f}	19.6^{g}
	8	11.8^{fg}	2.21^{ef}	3.54^{e}	1.96^{g}	4.1^{fg}	19.2^{g}
	9	11.5^{f-h}	2.13^{ef}	3.30^{e}	2.00^{g}	4.5^{c-e}	18.3^{g}
A		***	***	**	***	***	***
B		***	***	***	***	***	***
A*B		***	***	***	***	*	***

[1]Means separation within columns by Duncan's multiple range test (P≤0.05). NS, non-significant; *significant at P = 0.05; **P = 0.01; *** P = 0.001, respectively.

Table 3. Effect of seed treatment in potassium silicate and uniconazole on root length, fresh and dry weights of tomato seedlings measured at 32 days after sowing in plug trays.

Cultivar (A)	Treatment (B)	Root length (cm)	Fresh weight (mg)		Dry weight (mg)	
			Shoot	Root	Shoot	Root
Seogeon	1	8.20^{c-f1}	2.42^{bc}	0.31^{b-e}	0.16^{bc}	0.025^{a-c}
	2	10.26^{a}	2.41^{bc}	0.30^{c-f}	0.15^{cd}	0.027^{a}
	3	9.42^{a-d}	2.18^{d}	0.27^{d-g}	0.14^{de}	0.017^{c-e}
	4	9.04^{a-d}	2.22^{cd}	0.29^{c-g}	0.14^{c-e}	0.017^{c-e}
	5	8.52^{b-f}	1.80^{e}	0.32^{b-d}	0.12^{ef}	0.018^{c-e}
	6	8.81^{b-e}	1.27^{f}	0.32^{b-d}	0.10^{f-h}	0.019^{c-e}
	7	9.52^{a-c}	1.38^{f}	0.37^{ab}	0.09^{gh}	0.020^{b-d}
	8	9.17^{a-d}	1.28^{f}	0.38^{a}	0.08^{gh}	0.025^{ab}
	9	9.67^{ab}	1.26^{f}	0.32^{b-d}	0.07^{h}	0.022^{a-c}
Seokwang	1	7.65^{ef}	2.56^{ab}	0.24^{g}	0.19^{a}	0.013^{e}
	2	8.65^{b-f}	2.52^{ab}	0.26^{e-g}	0.17^{bc}	0.016^{c-e}
	3	8.75^{b-e}	2.53^{ab}	0.32^{b-d}	0.18^{ab}	0.017^{c-e}
	4	8.93^{a-e}	2.28^{cd}	0.30^{c-f}	0.17^{bc}	0.018^{c-e}
	5	9.37^{a-d}	2.69^{a}	0.33^{a-c}	0.20^{a}	0.014^{de}
	6	9.46^{a-c}	1.27^{f}	0.24^{g}	0.09^{hg}	0.018^{c-e}
	7	8.34^{c-f}	1.30^{f}	0.32^{b-d}	0.12^{ef}	0.025^{ab}
	8	8.12^{d-f}	1.20^{f}	0.25^{fg}	0.08^{gh}	0.017^{c-e}
	9	8.48^{b-f}	1.23^{f}	0.29^{c-g}	0.10^{fg}	0.018^{c-e}
A		**	***	***	***	**
B		*	***	*	***	NS
A*B		*	***	**	***	**

[1]Means separation within columns by Duncan's multiple range test (P≤0.05). NS, non significant and significant; * P = 0.05; ** P = 0.01; *** P = 0.001.

weight of shoot in 'Seokwang', while it was decreased in 'Seogeon' when compared with the control. In both cultivars, fresh weight of root increased significantly when seeds were treated with uniconazole, however, root dry

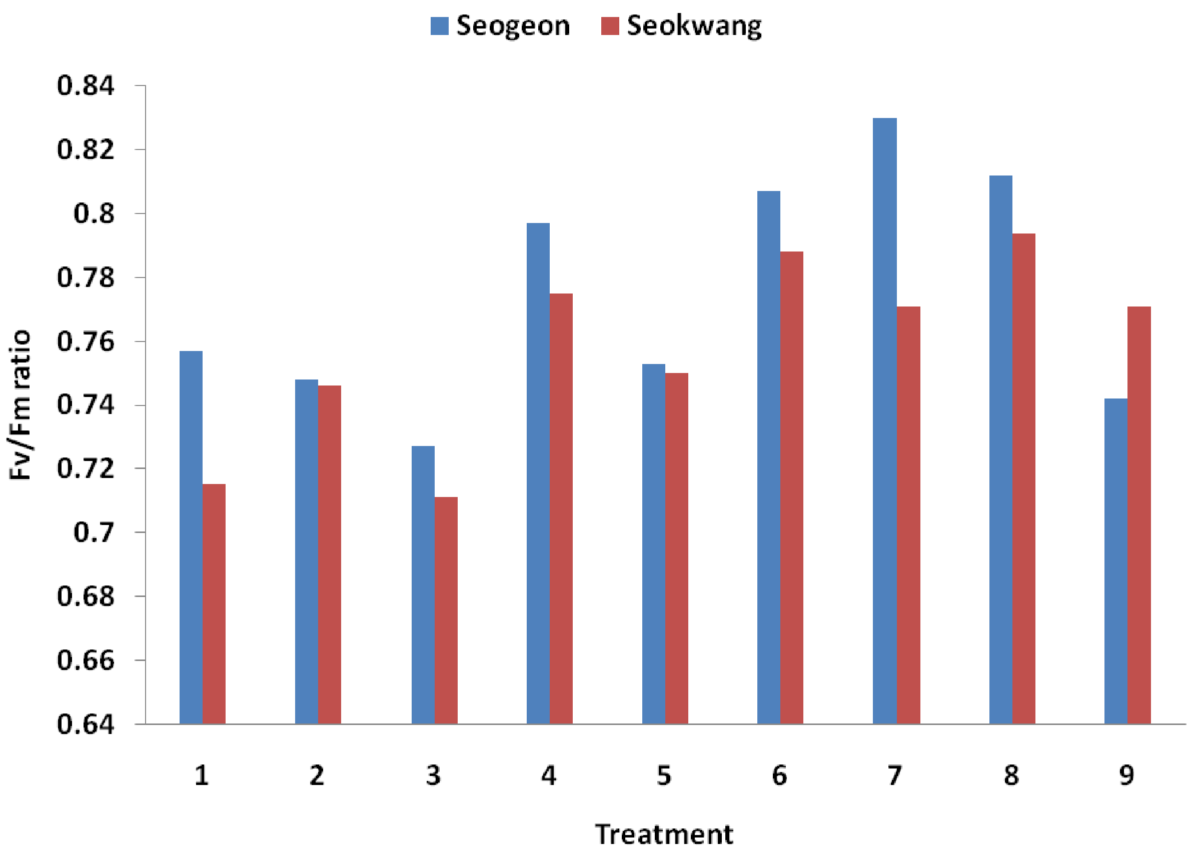

Figure 3. Treatments induction changes in chlorophyll fluorescence (Fv/Fm) ratio of tomato seedlings.

weight was reduced in 'Seogeon' (Table 3).

Photosynthesis is an important parameter used to monitor plant response to abiotic stress. Chlorophyll fluorescence is a rapid, non-destructive method to detect changes in the photosynthetic systems induced by stress. Measurement of Fv/Fm ratio value varied between the two cultivars (Figure 3). In 'Seogeon', distilled water and the 24 h uniconazole (100 mg L^{-1}) soaking treatment decreased Fv/Fm ratio, while potassium silicate and uniconazole (50 mg L^{-1}) soaking treatment increased the Fv/Fm ratio when compared with the control. In 'Seokwang', all the treatments increased the Fv/Fm ratio, except 24 h soaking in the distilled water when compared with the control. Low concentration of potassium silicate increased the Fv/Fm ratio in both cultivars. High concentration of uniconazole and the 24 h soaking period decreased the Fv/Fm ratio in both cultivars which reflected stressful condition of seedlings, while low concentration of uniconazole increased the Fv/Fm ratio, indicating that the seedlings were normal.

In conclusion, a soaking treatment of uniconazole 50 mg L^{-1} significantly reduced seedlings height with good germination percentage and a mean value of Fv/Fm ratio was typical of a well functioning photosynthetic apparatus. Hypocotyl length and plant height of 'Seogeon' were suppressed in the 100 mg L^{-1} potassium silicate treatment as compared to the control. These results would be helpful in allowing plant nurseries to control the stretching of tomato seedling.

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