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The Effects of Pre-sowing Treatments on Emergence and Seedling Growth of Tomato Seed (*Llycopersicon esculentum* Mill.) Under Several Stress Conditions

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Abstract: Effects of seed treatments of priming, soaking and hydration-dehydration on emergence and seedling growth of fresh-market and processing tomatoes (*Lycopersicon esculentum* Mill. cvs H_{2274} and Rio Grande) were evaluated under stress conditions of low temperature, drought and salinity. Seed treatment × stress condition interaction was not significant for all of the criteria tested. For both cultivars, while the seed treatments did not result in significant increases on emergence percentage compared with untreated seeds, the treated seeds on the other hand emerged faster, and were greater in seedling length, fresh weight, and diameter compared to non-treated seeds. The results indicated that the seed pretreatments tested may be an alternative of choice to improve emergence and seedling growth, and stress factors can be exploited in the manipulation of seedling development.

Key words: *Lycopersicon esculentum* Mill, seed, pre-treatment, stress conditions

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is adapted to a wide range of climatic and soil conditions and a warm season crop requiring a relatively long seasons (Yamaguchi, 1983). According to the world production records of FAO, ≈ 97 millions metric tones were produced on ≈ 3.5 millions ha land in 1999 and is the most produced vegetable in the world. Similarly, tomato is one of the most important vegetable crops in Turkey and is grown in almost all parts of the country both in the field and greenhouse. In Turkey, while for greenhouse production tomato plants are grown from seedlings, they are initiated either from seeds or seedlings in the open field production. In processing tomato production in which once or two times harvest are the common practice, production via direct seeding is in the increase (Duman and Yoltas, 1993), but in this method, the seeds, after sowing, may be subject to physical stresses such as extreme temperatures, excess or deficit of water, salinity or soil crusting and biological stresses including pathogens, insects and weeds, which can decrease or even prevent seed emergence and seedling establishment. However, obtaining of uniform and vigorous plant stand is necessary for maximum yield and harvest efficiency. Expensive F_1 hybrid seeds are used in the greenhouse tomato production therefore growers and companies producing vegetable seedlings are interested in rapid and healthy seedling emergence, uniformity in seedling size and appearance, and resistance to environmental conditions. In the evaluation of these characteristics that is in the determination of the quality of seedlings, seedling size, length, stem diameter, earliness and uniformity are credited as the criteria.

In last decades interest has grown in the use of pre-germination treatments involving partial or total seed imbibitions for vegetable crops with small seeds and small embryos such as tomato, onion and carrot, aimed at accelerating emergence. Among these studies, the osmotic conditioning, also known as 'priming', is based upon controlled hydration of seeds with a solute such as PEG, KNO_3 etc. to a level that permits pre-germinative metabolic activity to proceed, but that prevent actual emergence of the radicle. The hydration-dehydration treatment, also called 'hardening' or 'advancing', carried out by pre-imbibition of seeds, prior to seeding in distilled water without any solute were the most used, and, using the above mentioned methods, various studies are available on pre-treatment of vegetable seeds (Heydecker and Coolbear, 1977; Hegarty, 1978; Khan *et al*., 1978; Georghiou *et al*., 1982; Haigh *et al*., 1986; Bradford, 1986; Alvarado *et al*., 1987; Passam *et al.,* 1989; Odell *et al.,* 1992; Penàloza and Eira, 1993; Bradford and Haigh, 1994), but little information has been reported on seedling production and development of tomato following seed treatments.

The purpose of this investigation was to evaluate the effects of soaking, priming, and hydration-dehydration treatments to seeds as methods to improve seedling emergence and growth of fresh-market and processing tomato plants under the stress conditions of low temperature, lack of water, and salinity.

Materials and Methods

This research was conducted in the laboratory and unheated glasshouse of Department of Horticulture, Faculty of Agriculture, University of Trakya in 1999.
Tomato seeds (*Lycopersicon esculentum* Mill.) cv H $_{2274}$ (for fresh market) and Rio Grande (for processing) used in this study, were obtained from May Seed Company (Bursa-Turkey). Germination blotter and 9 cm petri dishes for germination tests, filter papers and glass boxes for the seed treatments, wooden boxes of 40×35×10 cm dimensions for seedling development and the potting mixture, characteristics of which is presented in Table 1, were used in the experiments.

Table 1: Some properties of seedling growth media

pH	N (ppm)	P_2O_5 (ppm)	K_2O (ppm)	EC (μS/cm)
6.0-6.5	240	270	310	1545

Seed pre-treatments: All seed treatments were realized on filter paper speared glass boxes at 20±1 °C and the treatment time was until the observation of 1% germination in seed lots. The time required for 1% germination was accepted as the most suitable treatment period (Muhyaddin and Wiebe, 1989; Arin and Salk, 1993). Five gram seeds of both cultivars were used (The weight of thousand seed were 3.18 g for H_{2274} and 3.27 g for Rio Grande). After treatments, seeds were dried for two days at room temperature and mean water content of the seeds decreased to 6-7%. All groups of seeds, including untreated control, were then stored at 6±1 °C until needed.

Soaking: Fifty ml distilled water was given to boxes containing five gram seeds. The treatment was completed at the end of 2 nd day since 1% germination was observed then in both cultivars.

Hydration-dehydration treatments: The seeds of the two cultivars were subjected to three hydration-dehydration cycles at one day intervals and treatment time was three days for both cultivars (until 1% germination was observed).

Priming: Seeds of each cultivar were primed in a solution (10 ml g^{-1} of seed) of 2% KNO_3 (w/v) at 20±1 °C until 1% germination was observed in the seed lots (Alvarado and Bradford, 1988; Cano *et al.,* 1991; Arin and Salk, 1993). The treatment period was five days for Rio Grande and six days for H $_{2274}$. After priming, the seeds were rinsed in distilled water and dried to 6-7% moisture content.

Emergence tests: Non treated (control) and pretreated seeds of each variety were sown at a dept of 2 cm in flats containing 4000 g potting soil with a distance of 5 cm between rows. Maximum Water Capacity (MWC) of the potting mixture used was determined pre- and after sowing according to Mitscherlich method. Flats were moistened with water to obtain 70% of MWC and then placed in unheated greenhouse. The water content of flats was checked daily by weighing of the flats and later held constant at this value by moistening. Daily mean temperatures ranged from 15 to 28°C during the experiment. Daily emergence counts (cotyledon leaves unfolded) were taken until no further emergence for three consecutive days. Following completion of the emergence, the seedlings were thinned to single seedlings 5 cm apart.

Stress conditions

Salinity: The initial moisture level of the flats was maintained during the experiment and water, containing 1 000 ppm NaCl, used for irrigation also provided the salt treatment.

Drought: Sowings were made to trays having an initial moisture level which then allowed dropping off to a 20% level of MWC, and it was held constant at this value throughout the emergence and seedling growth.

Low temperature: Initial moisture level of the trays was maintained by irrigation throughout the experiment, and in order to determine the effects of cold stress on the development of tomato seedlings, trays were exposed to low temperature at the 1st true leaf stage at 4±1 °C for six hours.

Analytical procedure and statistical analysis: First of all, germination percentages of both varieties were determined. Germination tests were conducted on filter paper discs in 9 cm Petri dishes at 20±1. Each dish contained 100 seeds, and there were four replicates. The germination percentages were 87% and 82% for the cultivars Rio Grande and H $_{2274}$, respectively.
Emergence percentage was calculated over the total number of seeds planted. Although the data, for statistical analysis purposes, were submitted to arc sin of the square root transformation, the results were shown as percentage means of the original data for better understanding. Mean days to emergence (MDE) were calculated according to $?_i (n_i t_i) / ?_i n_i$, where n_i is the number of newly emerged seeds at time t_i (Seale and Cantliffe, 1986; Alvarado *et al.,* 1987). Forty days after sowing, following measurements were performed on random samples of 10 seedlings. Seedling length (from cotyledon leaves to hypocotyls), seedling fresh weight (seedlings were cleaned from the potting soil and washed with distilled water), seedling dry weight

Table 2: Main effects of seed treatments and stress conditions on emergence percentage, Mean Days to Emergence (MDE), seedling length, seedling fresh weight, seedling dry weight and seedling diameter for H_{2274}

Treatment	Emergence percent	Mean days to emergence (days)	Seedling length (cm)	Seedling fresh weight g	Seedling dry weight g	Seedling diameter (mm)
Seed treatment						
Hydration-dehy.	70	5.7b	20.6a	4.3a	1.20	3.84ab
Soaking	69	5.6b	20.5a	4.3a	1.34	3.80ab
Priming	69	5.3b	19.8ab	4.6a	1.68	3.96a
Non-treated	65	6.2a	18.7b	3.5b	1.28	3.61b
	NS				NS	
Stress condition						
Salinity	65b*	5.7b	17.7c	3.5c	1.55	3.64b
Drought	60b	5.9a	20.8a	4.8a	1.26	3.88a
Low temperature	72a	5.8ab	19.2b	4.0bc	1.17	3.84ab
Control	77a	5.4c	21.9a	4.4ab	1.54	3.84ab
					NS	

*Significant at the level of $p < 0.05$. NS: non-significant.

Table 3: Main effects of seed treatments and stress conditions on emergence percentage Mean Days to Emergence (MDE), seedling length, seedling fresh weight, seedling dry weight and seedling diameter for Rio Grande

Treatment	Emergence percentage	Mean days to emergence (days)	Seedling length (cm)	Seedlilng fresh weight g	seedling dry weight g	Seedling diameter (mm)
Seed treatment						
Hydration-dehy.	74	6.3b	22.0a	4.8ab	1.27	3.49ab
Soaking	75	6.5b	20.7b	4.4b	1.16	3.33b
Priming	79	6.3b	21.7a	5.4a	1.30	3.66a
Non-treated	73	7.3a	19.5c	3.3c	0.78	3.06c
	NS				NS	
Stress condition						
Salinity	71b*	6.2c	19.0c	3.6b	1.47a	3.30bc
Drought	70b	7.2a	22.2a	5.6a	0.96b	3.66a
Low temperature	85a	6.5b	20.3b	3.5b	0.66c	3.08c
Control	84a	6.5b	22.5a	5.2a	1.42a	3.48ab

*Significant at the level of $p < 0.05$. NS: non-significant

(seedlings were cleaned and oven-dried at 80 °C for 24 h), seedling stem diameter (diameter measurements were made just above cotyledon leaves) were determined.

Emergence and seedling growth experiments were arranged in a split-plot design, with stress conditions as the main plots and seed treatments as subplots. Statistical analysis of variance (mean separation of significant differences) was conducted at 0.05 confidence level using MSTAT statistical package.

Results

Seed treatment × stress condition interactions were non significant for all the criteria, because of which only the main effects of seed treatments and stress conditions were presented in the tables.

Seed treatments had no significant effect on the emergence percentage of none of the cultivars, but the emergence percentage of non-treated seeds was lower, not significantly though, than the treated ones. In both cultivars, the emergence percentage of seedlings, which were grown under low temperature conditions, was similar to the control due to the low temperature treatment which was applied at the 1st true leaf stage of the seedlings, but salinity and drought reduced seedling emergence percentage.

Despite the fact that the emergence of the pretreated seeds was more rapid, differences between treatments were not significant, but KNO_3 treated seeds displayed the lowest MDE values. Drought delayed the emergence time of seedling resulting in higher MDE for all the cultivars.

Statistically significant differences, with regards to seedling length, were observed among the seed treatments and the non-treated seeds resulted in the shortest seedlings. By contrast, seedlings grown at normal conditions had greater seedling length than those from stress conditions.

Seedlings from pretreated seeds were heavier than those from non-treated seeds and KNO_3 treated seeds resulted in the highest values (4.6 g for H_{2274} and 5.4 g for Rio Grande). In both cultivars, fresh weight of seedlings, which were grown at normal and drought conditions, was higher than those from the other conditions.

Although not significant, dry weight of seedling from pretreated seeds was higher than those from non-treated seeds except for the hydration-dehydration treatment for H_{2274}. While differences among average dry weight of seedlings grown under stress conditions were not statistically significant for H_{2274}, saline and normal conditions conferred higher seedling dry weight than the other conditions for Rio Grande.

There were significant differences in seedling diameter among seed treatments, and the highest value was obtained from the seeds primed with KNO_3 (3.96 mm for H_{2274} and 3.66 mm for Rio Grande). Drought conditions resulted in wider seedling diameter in each of the cultivars.

Discussion

According to the results of this experiment, none of the interactions was significant for all the data analyzed. As the main effects, pretreatment did not increase emergence percentage significantly in either of the cultivars. However, emergence percentage of the pretreated seeds was higher than the untreated seeds. This result is in agreement with Bradford (1986), Alvarado *et al.* (1987), Sundstrom and Edwards (1989), Frett *et al.* (1991), Arin and Salk (1993), Duman *et al.* (1999), working with vegetable seeds such as tomato, carrot, pepper, onion, who found that pretreatment was not effective in increasing the emergence percentage. Emergence percentage decreased under the stress conditions (except for low temperature that stress was applied at seedling growth stage) because of difficulty in water uptake. Also, Odell *et al.* (1992) reported that under most soil environmental conditions, seed treatment or soil amendment did not improve total emergence of tomato seeds, even in the extremely warm soils.

All of the pretreatment had lower MDE compared with untreated seeds and the lowest value was obtained from KNO_3 treated seeds and similar results are available dealing with tomato seed treatment (Bussell and Gray, 1976; Ghate and Phatak, 1982; Haigh *et al.*, 1986; Alvarado *et al.*, 1987; Haigh and Barlow, 1987; Penàloza and Eira, 1993; Cavallaro *et al.*, 1994). In addition, Hegarty (1970), has shown that maize seeds soaked in dilute salt solutions resulted in earlier emergence than those soaked in water alone. Khan *et al.* (1981) reported that the presence of nitrate during imbibition may provide additional substrate for amino acid and protein synthesis for the enhancement of germination during priming and time to emergence of seedlings, which was grown to drought conditions, was longer than those of saline conditions which was probably due to low salt concentration during the initial period of emergence.

Seedlings from treated seeds had greater mean seedling length, fresh weight and diameter than those from untreated seeds. This result is consistent with reports of Hegarty (1977) and Parera and Cantliffe (1994), where, in general, the major effect of seed treatment on seedling growth observed was due to faster emergence, giving seedlings a longer time to develop. Muhyaddin and Wiebe (1989) suggested that the enzymes are activated with an accompanying mobilization of reserve materials ending in transport of the reserve materials in the embryo by osmotic conditioning, and thus stronger seedlings are obtained as a result of embryo growth. Haigh and Barlow (1987), and Wellbaum and Bradford (1990) reported that embryo and radicle growth could be accomplished by an increase in the ability of embryo to take up water, by weakening of the endosperm restraint, or by a combination of both. Dahal and Bradford (1990) explained that the main effect of priming in tomato seeds was by shortening the time required for final endosperm wakening to occur, and Cayuela *et al.* (1996) concluded that in tomato plants priming of seeds with salt solutions induced physiological changes such as sugar and organic compound accumulation in the leaves and ion accumulation in the roots.

The seedling length decreased and seedling fresh weight and diameter increased under the stress conditions. In terms of seedling dry weight, significant differences were observed between the treatments only for Rio Grande, and dry weight of seedlings which were grown in saline conditions was similar with the control. This can be explained by the increases in ion uptake. The creating of stress condition in seedling production media can be a useful tool in the manipulation of seedling development (especially with regards to seedling length and diameter). As a result, it can be said that emergence and seedling growth is improved by treatment of tomato seeds (especially with KNO_3), and pretreatment is a good alternative for producers which have to attain good stand and seedling, but seed treatments cause no beneficial effect on emergence and seedling development under different seeding and growing conditions.

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