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Seed Germination and Yield of Tomato (*Lycopersicum esculentum* Mill.) as Affected by Physical Priming Techniques

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ABSTRACT

Positive effects of seeds exposed to physical priming methods on rapid seed emergence and yield improvement of field crops has been previously reported. To evaluate the effects of some physical seed priming materials (ultrasonic, gamma, beta, laser irradiation, magnetic field and hydro-priming) on germination, growth and yield of tomato, laboratory and field experiments were conducted in Islamic Azad University, Tabriz branch, Iran, during 2011-2012. The results revealed that the highest seed germination percent occurred by those seeds treated with laser and magnetic field for exposure time of 15 min. and the lowest from ultrasonic irradiation. Seeds treated by magnetic field for 5 and 10 min. resulted in chlorophyll content index of about 68.5 and 74.3, respectively. Fruit yield of tomato good responded to magnetic field and the highest yield obtained from exposure time of 10 min. It may be concluded that tomato producers could improve crop yield by seed priming with magnetic field for 5 min.

KEYWORDS: Chlorophyll content index, Irradiation, Leaf area, Magnetic field.

INTRODUCTION

An increasing number of investigations are becoming interested in seed biology with the aim of understanding and improving many aspects of seed germination and seedling establishment. Tomato is one of the most widely grown vegetable crops in the world. Seed priming has been reported to enhance growth of plants. It is suggested that seed priming generally causes faster germination and field emergence, which have practical agronomic importance in crop production especially under adverse environmental conditions (Basra et al., 2003). Farooq et al. (2008) conducted a study to explore the possibility of yield improving in late sown wheat crop by seed priming. Dubey et al. (2007) showed that plant height, number of leaves and branches per plant of okra (*Abelmoschus esculentus*) were increased when seeds exposed to different doses of gamma rays. Ultrasonic irradiation of carrot (*Daucus carota* L.) seeds resulted in the earlier ripening of roots by 5–10 days (Aladjadjiyan 2002). Farahvash et al. (2007) reported that gamma irradiation of wheat seeds positively affected its productivity. Magnetic field treatment of seeds, as reported by Aladjadjiyan (2007), Dhawi et al. (2009) and Vasilevski (2003), stimulates not only seed germination and improves yielding potential of different crop plants, but also compensates the need for chemical fertilizer application and mitigates the effects of environmental pollution. It is thus decided to evaluate the effects of physical seed treatments of tomato on seed germination, growth and fruit yield of tomato in the following study.

MATERIALS AND METHODS

Two separate experiments were conducted at the biotechnology laboratory and research station of the Islamic Azad University, Tabriz Branch on a sandy-loam soil with EC of 0.74 $ds.m^{-1}$ and pH of 7.9 using completly randomized and randomized complete block designs in laboratory and field conditions respectively, both with three replications during growing seasons of 2011 and 2012. The climate of the region is semi-arid and cold with an average annual precipitation of 270 mm. The tomato cultivar under study was Atabey-F_1, a medium ripening variety with growth period of 115-125 days. Some weather conditions during five months for two years of experiment (April-August) are depicted in Table 1.

Prior to sowing, the seeds were surface sterilized with a 5% sodium hypochloride (NaOCl) solution for 5 min. to avoid fungal invasion and then washed immediately with distilled water. Petri dishes and filter papers were also disinfected by NaOCl and UV radiation for 24 hours in a sterile hood before their incubations. For each treatment, twenty five treated seeds in 9-cm Petri dishes were placed into a germinator with 20 °C temperature for 14 days. Two days after beginning of experiment, germinated seeds were counted daily. In this experiment a seed germinated was defined as when at least 5 mm of radical emerged. Seedling vigor index was calculated by the following equation proposed by Abdul Baki and Anderson (1973):

Seedling vigor index = germination percent × seedling length

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The experimental field was first ploughed in the fall and manured with 12 $t.ha^{-1}$. It was then cultivated, disked and furrowed in the early spring before transplanting of tomato seedlings. Based on soil analysis the experimental field were fertilized with 110 $kg.ha^{-1}$ urea, (50% at planting time and the rest at 4-5 leaves stage), 50 $kg.ha^{-1}$ P_2O_5 and 25 $kg.ha^{-1}$ K_2O in 2011 and same rates of N and P fertilizers plus 35 $kg.ha^{-1}$ K_2O in 2012. The seeds with 85% viability were differently treated by ultrasonication[1] for 10 min., laser[2] irradiation for 5, 10 and 15 min., magnetic field[3] for 5, 10 and 15 min., gamma and beta[4] irradiations both for 10 min. and distilled water for 24 hours as a hydro-priming treatment. Seeds receiving no treatment served as control. Seedlings of 40 days old were transplanted in the field on 1st May 2011 and 29th April 2012 in rows 60 cm apart and 30 cm on the rows. Plots were irrigated based on 80 mm evaporation from pan class A. Weeds were hand removed during growing seasons and plants were harvested during 2-10 September of both years. Leaf area index was determined 75 days after seedling emergence.

Traits measured in the laboratory experiment were germination percentage, seedling length and seedling vigor index and in the field were chlorophyll content index (CCI), leaf area index, biomass of above-ground parts, number of fruits per plant and fruit weight. Analysis of variance of data collected was made by the software MSTAT-C, graphs were drawn by excel software and means of traits were compared by using LSD test at $P < 0.05$.

RESULTS

Laboratory assay

Seed germination percentage

Analysis of variance of the traits studied is depicted in Table 2. It shows that germination percentage was affected by seed primings at 1% level of probability. Highest percentage of germination (92.2%) was obtained due to seed treatment with magnetic field for 15 min. exposure time, and the lowest from seeds treated by beta irradiation (21.4%). While, laser irradiation and magnetic field treatments resulted in 63% more seed germination than control (Figure 1).

Seedling length

Seedling length of tomato significantly influencd by seed priming by gamma irradiation (Table 2). Maximum seedling length with gamma irradiation was measured to be about 12.7 cm, which was 9.33 cm longer than control. However, difference among other priming agents was not significant statistically (Figure 2).

Seedling vigor index

Seedling vigor index (SVI) of tomato affected by seed priming methods (Table 3). When seeds were primed by gamma irradiation, SVI of tomato plantlets increased by 74% more than non-primed one. SVI of plants irradiated by gamma was significantly higher than the averaged values for other priming treatments (Figure 3).

Field study

Leaf area index

The effects of seed priming methods on crop leaf area index (LAI) were significant at 1% level of probability (Table 3). Means for LAI also revealed that seeds treated by magnetic field for both 10 and 15 min. exposure times resulted in higher LAI (4.3 and 4.6 respectively) than other priming agents. Lower leaf area index was observed for seeds under hydro-priming for 24 hours (Table 4).

Chlorophyll content index

Exposure time of physical priming agents affected chlorophyll content index (CCI) of tomato leaves significantly at 1% level of probability (Table 3). Seeds primed by magnetic field for 15 min. produced leaves with higher CCI (70.5) as compared with other exposure durations (Table 4).

Number of fruits

Number of fruits per plant of tomato is also affected by physical methods of seed treatments significantly (Table 3). Highest number of tomato fruits per plant was produced when seeds were primed by magnetic field for 5 min. and lowest from hydro-priming for 24 hours (Table 4).

Fruit Yield (Wet fruit weight)

Fruit yield of tomato was also affected significantlly by seed priming treatments (Table 3). Mean yield of fruits due to different seed treatments are presented in Table 3. Highest yield (6918 kg ha^{-1}) was obtained from those seeds treated by magnetic field for 5 min. and lowest (2514 kg ha^{-1}) from hydro-primed one (Table 4).

Above ground biomass

Seed priming by physical agents influenced biomass of above ground parts of tomato significantly at 1% level of probability (Table 3). Highest biomass (199 kg ha^{-1}) was produced due to magnetic field treatment of seeds for 5 min. exposure time; while, the lowest (98 kg ha^{-1}) from hydro-priming treatment (Table 4).

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[1]-50-60 Hz, 1.5 v.
[2] He-Ne, IR 2000, 6328 A°, 220 V, 50 Hz
[3] 40 mT,3 A, 2.7 V
[5]Co_{60} and Sr_{90} 2 micro-cory

Table 1: Some of weather data for experimental site during growing seasons of 2011-2012

Year	Month	Temperature (°C)	Precipitation (mm)	Relative humidity (%)
	April	12.9	37.1	**49.0**
	May	20.3	28.5	**62.0**
2011	June	23.9	21.0	**46.3**
	July	28.9	3.5	**32.7**
	August	31.1	3.0	**30.7**
	Total	-	93.1	-
	April	15.0	36.4	**44.4**
	May	18.8	32.9	**60.4**
2012	June	25.5	22.8	**50.0**
	July	30.0	5.0	**35.2**
	August	30.9	2.2	**30.6**
	Total	-	**99.3**	-

Table 2: Variance analysis of effects of physical priming techniques on germination attributes of tomato under laboratory conditions

SOV	df	Germination (%)	Seedling length	Vigor index (SVI)
Treatment	10	639.73**	9.66**	**78901.47****
Error	22	18.91	1.03	**4307.22**
CV (%)	-	8.38	13.49	**16.27**

** means significant at 1% probability levels.

Table 3: Variance analysis of the effects of physical priming techniques on some of tomato traits under field condition

SOV	df	Leaf Area Index	Chlorophyll Content Index	Number of Fruit per plant	Fruit Yield	Above Groun Biomass
Block	2	0.16	9.86	17.48	63407.30	**29.60**
Treatment	10	6.99**	894.41**	427.05**	5220351.47**	**2189.53****
Error	20	0.06	19.04	8.41	86588.18	**222.18**
CV (%)	-	11.37	9.58	11.43	6.13	**9.58**

** means significant at 1% level of probability.

Table 4: Mean Comparison for effects of seed priming on some traits of tomato

Priming agents and duration of exposure	Leaf area index	Chlorophyll content index (CCI)	Number of fruit per plant	Fruit yield (kg ha^{-1})	Above ground biomass (kg ha^{-1})
magnetic field 5 minutes	3.28	64.10	42	6918	199
magnetic field 10 minutes	4.34	68.90	38	5856	195
magnetic field 15 minutes	4.61	70.50	38	5646	180.4
Laser 5 minutes	2.35	50.70	35	5520	162.2
Laser 10 minutes	2.69	51	36	5340	116.4
Laser 15 minutes	2.14	20.56	18	4170	153.6
Gamma10 minutes	1.13	26.40	22	5280	142.8
Ultrasonic10 minutes	2.72	22.80	20	5280	149.8
Beta10 minutes	0.43	24.50	18	3672	146.4
Hydro-priming 24 hours	0.22	21.70	10	2514	98
Control (distilled water)	0.28	53	14	3600	148
LSD 5%	0.42	7.43	4.93	501.2	25.39

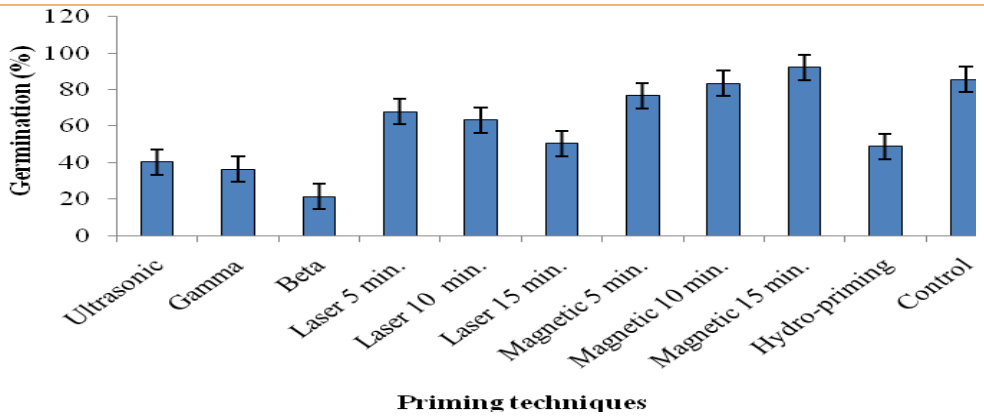

Fig. 1: Tomato seed germination percentages as affected by different priming techniques

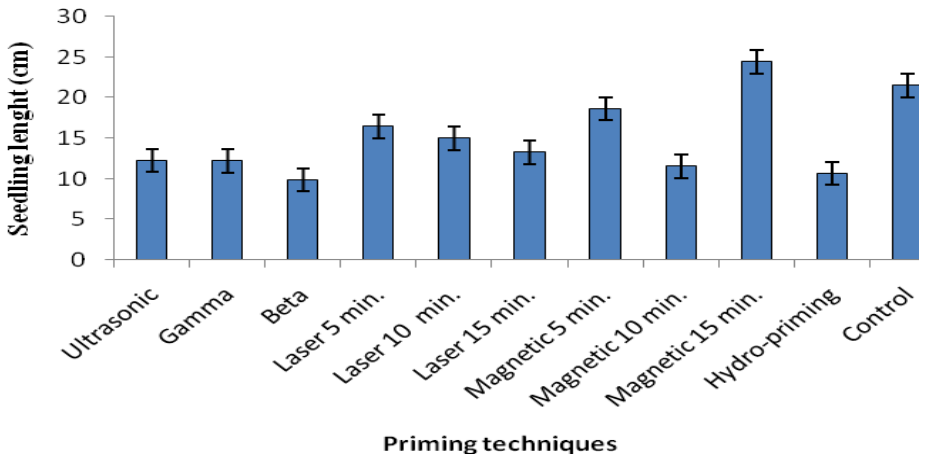

Fig.2: Seedling length of tomato as affected by different priming techniques

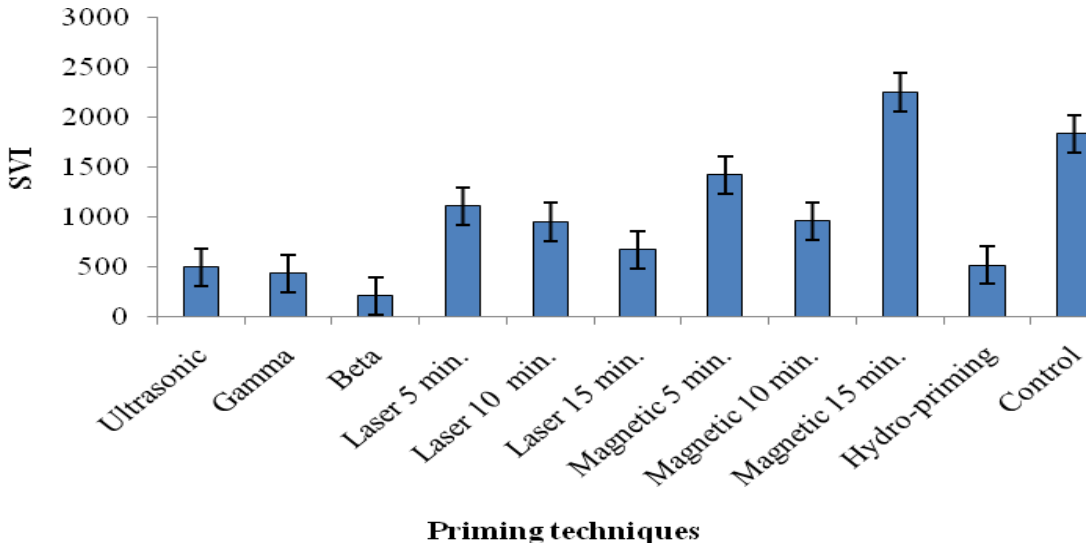

Fig. 3: Seedling vigor index of tomato as affected by different priming techniques

DISCUSSION

Pre-treatment of seeds by magnetic field showed uniform percentage of germination, faster seedling growth and enhanced fruit yield of tomato plant as compared to the control. This indicates that higher percentage of seed germination would result in good stand establishment and plant growth in field condition. This is in confirmity with the results of Moon and Sook (2000) in tomato and Podleony et al. (2004) in bean plants where they stated that seeds primed by electrical and magnetic field increased seed germination percentage. Similar results were also observed in cucumber seedlings by Yinan et al. (2005).

Garcia et al. (2001) observed that pre-treatment of lettuce (*Lactuca sativa*) seeds by a stationary magnetic field, due to their increase in water uptake rate germinated faster than the un-treated seeds. Norfadzrin et al. (2007) showed that tomato seeds irradiated by gamma rays, affected positively their growth of seedlings. Treating seeds with gamma irradiation may result in a significant increase in seedling length and vigor.

Gamma rays belong to ionizing radiation and are the most energetic form of such electro-magnetic radiation, having the energy level from around 10 kilo electron volts (keV) to several hundred keV. Therefore, they are more penetrating than other types of radiation such as alpha and beta rays (Kova´cs & Keresztes, 2012). Vashista and Nagarajan (2008) in a study on the effects of 200 Gy gamma radiation on chickpea seeds reported that seedling lengths increased significantly, while with increasing of gamma intensity it was appreciably reduced. Melki and Marouani (2009) also reported an improvement of 32% in root length of wheat at the 20 Gy dose of gamma ray. Similarly, Florez et al. (2007), Vashista and Nagarajan (2010) recorded enhancement in seedling vigor, shoot and root growth of maize, chickpea and sunflower when seeds treated magnetically before

sowing. Soltani et al. (2006 a, b) suggested that magnetic field treatment of seeds had a positive effect on seed germination and seedling growth of aspargus (*Asparagus officinalis)* and basil (*Ocimum Basilicum*).

In another study conducted by Vashisth and Nagarajan (2010) rate and speed of seed germination of sunflower treated with magnetic fields of 50-250 MT for 1 hour were increased by 5-9%. Similar results presented by Fischer et al. (2004) on sunflower. Constant exposure of seeds to 125 and 250 mT had a significant stimulating effect on the initial growth stages of wheat plants (Martinez et al. 2002).

In our study magnetic field treatment of seeds for 5 and 10 min. resulted in higher CCI of about 69 and 64 respectively. Racuciu et al. (2008) in their study of priming corn seeds with different intensities of magnetic field concluded that chlorophyll content of the leaves were decreased by its lower doses (50 MT), while it was improved by using higher irradiation doses (100-250 MT). The results obtained from our study indicate that magnetic field irradiation of tomato seeds had positive effect on growth of above ground parts of the plant, which is in conformity with reports of Alajadjiyan and Ylieva (2002) in tobacco (*Nicotiana tabaccum*) and Atak et al. (2003) in soybean (*Glycine max*). Magnetic field treatment for 10 min. also resulted in improved tomato fruit yield significantly. This is in good agreement with the results observed by De Souza et al (2006) where they reported that the fruit weight and whole plant dry weight of tomato responded positively to magnetic field priming methods. Hag et al. (2012) resulted that seeds primed by magnetic field showed uniform germination, faster seedling growth and enhanced yield of radish (*Raphanus sativus*) plant as compared to check plots.

Florez et al. (2007) concluded that obtaining better results from magnetic field seed priming depends on the combined effect of its appropriate strength and exposure time. Marks and Szecówka (2010) reported that seed priming by magnetic field stimulates growth of above ground parts and also tuber yield of potato (*Solanum tuberosum*), as we observed in the present study. Similar results have also been reported by Atak et al. (2003) in flax (*Linum usitatisimum*) and Moon and Chung (2000) in tomato. Data obtained from the study conducted by Mirshekari et al. (2014) on sunflower indicated that highest grain yield produced from seeds treated with laser (419.7 g m^{-2}) and magnetic field (379.8 g m^{-2}) for 5 min., but with increasing duration of magnetic field from 5 to 10 min. yield reduced significantly. This result emphasizes that priming would affect speed and percent of seed germination, and finally seed yield, in several crop plants.

CONLUSION

Based on the results obtained from this study it can be concluded that treating tomato seeds by magnetic field under lower exposure times increases its growth and fruit yield more than other irradiation agents used. Additional investigations are needed to warrant the preferability of magnetic field priming of tomato seeds over other physical priming techniques.

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