

THE EFFECT OF PHYSICAL PRIMING OF SEED ON TRAITS AND YIELD OF CORN (*ZEAMAYS* L.) UNDER WATER DEFICIT CONDITIONS IN IRAN

SIYAMI, R.¹ – MIRSHEKARI, B.^{1*} – FARAHVASH, F.¹ – RASHIDI, V.¹ – TARINEJAD, A.²

¹*Department of Agronomy and Plant Breeding, Tabriz Branch, Islamic Azad University
Tabriz, Iran*

²*Department of Agricultural Biotechnology, Faculty of Agriculture, Azarbaijan Shahid Madani
University, Tabriz, Iran*

**Corresponding author
e-mail: mirshekari@iaut.ac.ir*

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Abstract. In order to study the effect of physical priming of seed on traits and yield of corn under water deficit conditions, a two years experiment was conducted during 2014- 2015 as a split plot with three replications in Iran. The main factor includes two levels of irrigation (70 and 110 mm evaporation from pan class A as control and water deficit, respectively) after 8-9 leaves stage of corn and sub-factor includes corn seed treatment with gamma and beta rays, laser wave, magnetic field and ultrasonic waves, all in time intervals of 5 and 10 min. along with a non-primed control. Results indicated that maize seed priming under magnetic field of 5 and 10 min. and gamma and laser rays for 5 min. in normal irrigation regime were the best treatments with 20%, 18%, 16% and 13% increase value, respectively, while seed priming with gamma and laser rays for 10 min. under water deficit condition had the lowest grain yield. To increase corn grain yield in both normal and water deficit conditions, seed priming with the magnetic field in both time intervals, gamma and laser rays only in a short time is recommended.

Keywords: *evaporation, gamma ray, grain, laser wave, magnetic field*

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world therefore its cultivation is economically important and also due to its agricultural importance many fundamental researches have been conducted in a century on this plant (Marcu et al., 2013). According to Khan et al. (2008) seed priming is a pre-sowing strategy to improve germination and seedling establishment through priority of metabolic activities before emergence of radicle that often leads to more moisture, nutrients, and sunlight absorption and ultimately lead to increased yield.

According to Aladjadjiyan (2014), use of some physical elements are considered as a modern method for achieving higher yields in agricultural systems. Interest for use of ecological factors influencing plant products such as laser radiation, ultra violet, magnetic and electric fields has been increased (Faqenabi et al., 2009). Paolo and Rinaldi (2008) stated that the adverse effects of water stress on growth and development and yield of corn depends on the time of stress, stress tension, plant developmental stage, and its genotype. In a research study, the lowest grain yield of corn was obtained from those plants that under water deficit in flowering stage (Rabbani and Imam, 2011). Despite existence of limited information on physical methods of seed treatment, interest and willingness to use of these methods for seed priming crop plants has increased in recent years (Hernández et al., 2010).

Gamma ray is the most important physical treatment that increases production in crop plants such as rice (*Oryza sativa*), corn, bean (*Phaseolus vulgaris*), and potato (*Solanum tuberosum*) (Mokobia and Anomohanran, 2005). Potato tubers pre-treated with gamma ray before sowing improved plant growth characteristics (Hamideldin and Hussin, 2014). Increase in the height and fresh weight of corn and followed by increase in the performance has been reported by seed treatment with magnetic fields (Racuciu et al., 2008). In an experiment conducted by Pietruszewski and Kania (2010) use of some physical treatments including magnetic field and laser radiation before sowing the seed increased grain yield of wheat. Exposure of sunflower (*Helianthus annuus*) seeds to magnetic fields gave rise to positive effects on plant growth and increased yield (Vashisth and Nagarajan, 2013). Rochalska (2008) reported that sugar beet (*Beta vulgaris*) seed priming with magnetic field leads to more rapid plant growth, due to the intensity of metabolic processes, and finally yield improvement.

Since the physical priming is one of the effective methods in improving the crop yield in preserving the natural environment and biological safety, then the specific aims of this study were:

- Evaluation effect of the studied treatments on morpho-physiological traits of corn
- Response of biomass and grain yields of corn crop to biophysical studied treatments

Materials and Methods

Maize is a tall, monocious annual plant of *Poaceae* family. It has staminate spikelets in long spike-like racemes that form large spreading terminal tassels and pistillate inflorescences in the leaf axils (Anonymous, 2015).

Site description

This research was carried out in two years (2014- 2015) at the Agricultural Research Station of Islamic Azad University, Tabriz Branch, Iran. The regional climate is semi-arid and cold. The location of this experiment was 1560 m above sea level by 38°5' N and 46°17' E geographical latitude and longitude, respectively.

Experimental design and variables

The experiments were carried out as split plot based on the randomized complete blocks design with three replications on the corn SC260. The main factor includes irrigation time (70 mm as normal treatment, and 110 mm evaporation from pan class A as water deficit treatment after 8-9 leaves stage of corn) and sub-factor was in 11 levels of seed treatment with gamma (cobalt 60) (Farahvash et al., 2007) and beta rays (strontium 90) (Bradford, 1995), both with constant intensity of two microcurie, continuous wave helium-neon laser with a wavelength of 6328 angstroms (Chen et al., 2002), magnetic field of 40 mT (Iqbal et al., 2012), and ultrasonic waves with a maximum of three Wcm^{-1} (Yaldagard and Mortazavi, 2008) all in 5 and 10 min. intervals along with control.

Equipment's used and seed treatment

Before applying the treatments, corn seeds were put in hypochlorite sodium 5% for two minutes for disinfection and then were washed three times with distilled water. The seeds were kept in dark place for 24 h in distilled water at a temperature of 25°C (Artola et al., 2003) and then physical treatments were applied on the seeds inside petri dishes in Physics Laboratory. In order to pre-treatment of seeds with gamma and beta rays, laser wave, magnetic field, and ultrasonic wave were used lead syringe source of LEYBOLD (Germany), laser device IR2000 (Iran), transformer 2086 (Iran) and ultrasonic device of Sa-Iran company, respectively.

Land preparation

The experimental area was ploughed in the fall and then disked in early spring. After preparing the experimental plots, treated seeds were sown immediately in the field. Sowing was conducted every two years on May 10 at a distance of 75 cm between the rows on the rows of 20 cm at density of 67000 P ha⁻¹ and a depth of 3-4 cm. Based on the results of soil analysis, ammonium phosphate and potassium sulfate fertilizers were used as 110 and 100 kg ha⁻¹, respectively before sowing and nitrogenous fertilizer was added as 80 kg ha⁻¹ from urea source in two equal parts at each stage of sowing and on the corn stem elongation (4-5 leaves stage) as strips to the soil. Weeds control was carried out manually as needed two times during the growing season. Irrigation was conducted from the time of sowing the seeds until the beginning of water deficit treatment equally in all treatments based on 70 mm evaporation from pan and then continued to the end of the growing season depending on the type of treatment based on the 70 and 110 mm of evaporation.

Studied traits

At the time of ripening, plant height, time of tasseling, leaf area index (LAI), stem dry weight, leaf proline concentration, biomass and grain yield were measured based on standard procedures. Also, LAI was measured by the method of described by Acquah (2002). Leaf proline concentration was determined using a spectrophotometer at a wavelength of 520 nm (Bates et al., 1973).

Statistical analysis

Variance analysis of data was achieved using MSTAT-C software (Alizadeh and Tarinejad, 2010) and Duncan Multiple Range Test at 5% was used for mean comparisons. Excel software was used to drawing the figures.

Results

Combined variance analysis on the effects of irrigation levels and physical seed treatments on the studied traits in corn revealed that the year effect on all traits, the effect of irrigation level on stem dry weight and grain yield, interaction of year and irrigation level on the plant height and leaf proline concentration, the effect of physical pre-treatment on all traits, interaction of irrigation level in physical pre-treatment on the biomass and grain yield per unit area was significance at $p < 0.05$ (Table 1).

Table 1. Combined variance analysis of irrigation levels and seed physical pre-treatments on studied traits of corn in two years of experiment.

(S.O.V)	Degree of freedom (df)	Plant height	Time of tasseling	LAI	Stem dry weight	Leaf proline concentration	Biomass per unit area	Grain yield
Y	1	15356.54**	1749.09**	1.94*	8754.73**	33.83*	1368843.66**	191496.71**
R/Y	4	139.93	80.01	0.19	119.93	2.85	13289.17	2750.50
A	1	6119.33 ^{ns}	643.72 ^{ns}	17.03 ^{ns}	7500.18*	54.49 ^{ns}	1191680.03 ^{ns}	517338.92*
A×Y	1	264.20*	4.18 ^{ns}	0.63 ^{ns}	9.28 ^{ns}	4.22**	10945.48 ^{ns}	279.27 ^{ns}
A/Y×R	4	14.61	38.62	0.13	2.60	0.04	6795.96	5733.10
B	10	4107.17**	424.19**	4.16**	1969.54**	5.39**	162520.51**	64373.34**
B×A	10	51.35 ^{ns}	5.96 ^{ns}	0.03 ^{ns}	55 ^{ns}	0.76 ^{ns}	3505.61*	422.40*
B×Y	10	112.29 ^{ns}	16.12 ^{ns}	0.09 ^{ns}	28.82 ^{ns}	0.46 ^{ns}	2167.48 ^{ns}	539.69 ^{ns}
B×A×Y	10	31.40 ^{ns}	2.76 ^{ns}	0.04 ^{ns}	30.76 ^{ns}	0.43 ^{ns}	1146.40 ^{ns}	140.32 ^{ns}
B/YA×R	80	164.45	29.86	0.13	79.15	0.95	14430.58	5296.97
C.V. (%)	-	6.03	7.80	10.69	12.01	21.26	9.50	11.26

ns, *, and ** are non-significant, significant at 5% and 1% probability levels, respectively.

Y, R, A, and B mean year, replication, irrigation levels and physical pre-treatments, respectively.

Plant height

Based on the comparing the means, seed treatment with magnetic fields for 5 and 10 min. and laser radiations and gamma for 5 min. had the highest plant height while the lowest value from 10 min. treatment with gamma radiation (*Table 2*).

Table 2. Mean comparisons of seed physical pre-treatments on studied traits of corn in two years.

Seed pre-treatment	Plant height (cm)	Time of tasseling (day)	LAI	Stem dry weight (g)	Leaf proline concentration (µmol/g)
Control	202.68 cd	69.70 bc	3.16 d	66.66 e	4.30 cd
Gamma 5 min.	227.45 b	66.43 cd	3.85 b	84.27 b	5.73 a
Gamma 10 min.	180.64 e	80.06 a	2.37 e	51.97 f	3.85 de
Beta 5 min.	204.18 c	71.58 b	3.38 cd	72.50 cd	4.31 cd
Beta 10 min.	209.97 c	70.22 bc	3.52 c	76.25 c	4.98 bc
Laser 5 min.	229.66 ab	63.56 de	4 ab	82.50 b	4.98 bc
Laser 10 min.	193.35 d	78.52 a	2.59 e	56.45 f	3.48 e
Magnetic 5 min.	238.87 a	62.25 e	4.16 a	91.77 a	4.94 bc
Magnetic 5 min.	236.18 ab	62.77 de	4.10 ab	90.52 a	5.32 ab
Ultrasonic 5 min.	202.81 cd	72.14 b	3.18 d	70.10 de	4.50 cd
Ultrasonic 10 min.	211.70 c	72.43 b	3.36 cd	71.56 cde	4.04 de
LSD %5	9.64	3.652	0.280	4.884	0.622

Means in each column with similar letters have not significant difference based on DMRT at 5% probability level.

Time of tasseling

Minimum tasseling time obtained from those seeds treated with magnetic fields for 5 and 10 min., laser radiations and gamma for 5 min., while the maximum time to tasseling was measured in gamma and laser rays for 10 min., so that the use of them leads to happening 6 days earlier and 10 days delay in the adventure of tasseling, respectively compared to the control (*Table 2*).

LAI

LAI increased by corn seed priming with magnetic field in both time intervals and laser and gamma rays for 5 min., as 22.27%, and 32%, respectively compared to the control. Extending of duration of seed priming with both gamma and laser rays from 5 to 10 min. led to reduction of corn leaf area compared to the control as 25% and 18%, respectively (*Table 2*).

Stem dry weight

Stem dry weight of corn decreased by 15% due to water deficit compared to the normal irrigation (*Figure 1*). The highest dry weight obtained from those seeds under magnetic field treatments of 5 and 10 min. followed by gamma and laser rays for 5 min. The reducing effect of gamma and laser for 10 min. on dry weight was significant. So that, seed treatment with the above radiations led to 22% and 16% reduction on dry

weight. Seed treatment with beta radiation in both time intervals revealed better efficacy compared with ultrasonic wave and 9.59 g and 5.84 g increase in stem dry weight compared to the control (Table 2).

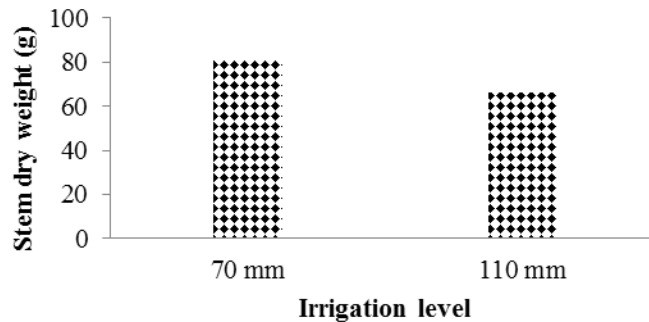


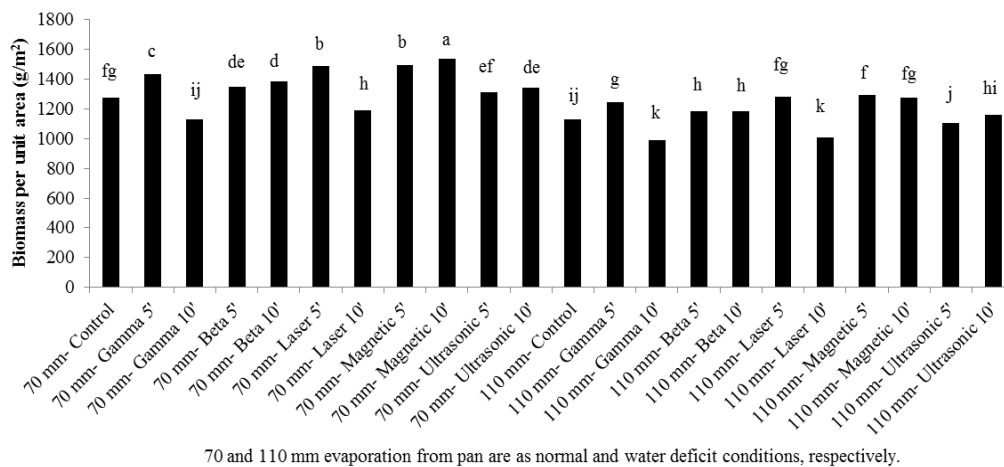
Figure 1. Effect of irrigation levels on stem dry weight. 70 and 110 mm evaporation from pan are as normal and water deficit conditions, respectively.

Leaf proline concentration

Seed priming with gamma radiation for 5 min. and magnetic field for 10 min. led to increase in the concentrations of proline by 1.43 and 1.02 $\mu\text{mol g}^{-1}$ of fresh weight compared to the control. Additionally, the laser radiation for 10 min. was more destructive than other treatments, so that the leaf proline concentration decreased by 19% compared with control and there was no statistically significant difference between other treatments and the control (Table 2).

Biomass

Interaction of irrigation and physical treatments during two years of experiment demonstrated that the maximum biomass per unit area was obtained from normal irrigation and seed priming with magnetic field in both intervals of 10 and 5 min., and laser and gamma rays of 5 min., respectively while the minimum amount was obtained from water deficit and seeds primed under gamma and laser rays for 10 min. (Figure 2).



70 and 110 mm evaporation from pan are as normal and water deficit conditions, respectively.

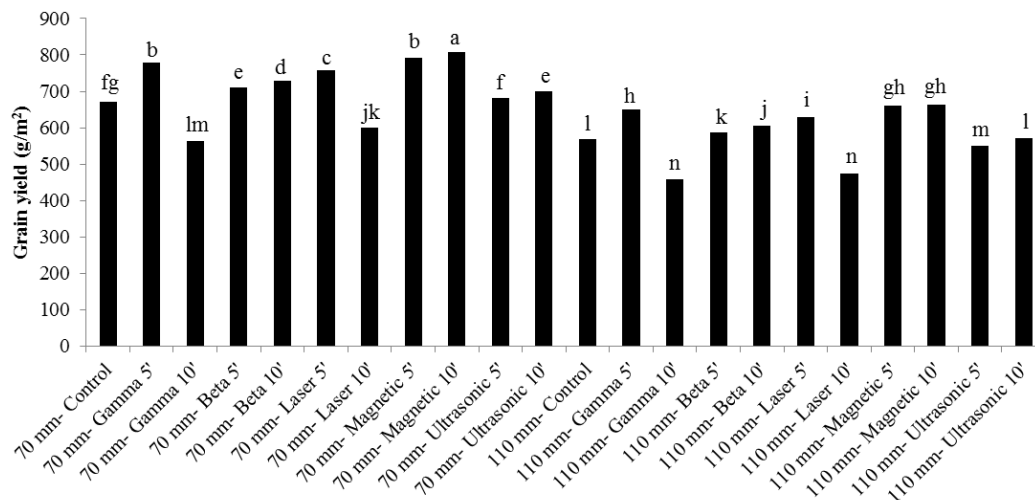
Figure 2. Mean comparisons of physical pre-treatments × irrigation levels on corn biomass. Means with similar letters in each column are not significant with together by DMRT at 5% probability level.

Water deficit led to reduction of biomass compared to normal irrigation in all treatments. In normal irrigation and water deficit conditions primed seeds under magnetic field for 10 and 5 min., laser and gamma rays for 5 min. crop biomass increased as 17% and 13% compared to the control, while in those seeds primed with gamma and laser rays for 10 min. biomass reduced 9% and 12% compared to the control in both irrigation levels (*Figure 2*).

Based on means comparison (*Figure 2*) interaction of irrigation level with priming of gamma and laser rays for 10 min. had major reducing effect on corn biomass.

Grain yield

The highest grain yield was obtained in normal irrigation and seed priming with magnetic fields for 10 and 5 min. and gamma and laser rays for 5 min. by 808, 790.9, 778.2, and 758.4 g/m² and the lowest value was obtained from water deficit and priming with gamma and laser rays for 10 min. by 458.4 and 473.1 g/m², respectively. Also, seed priming with magnetic field for 10 and 5 min. and gamma and laser rays for 5 min. along with the implementation of normal irrigation increased grain yield by 20, 18, 16 and 13%, respectively and was considered as the best treatments while priming with gamma ray and laser wave for 10 min. with water deficit showed 32 and 30% decrease and was considered as the most harmful treatments in grain yield compared with the control. Additionally, water deficit and irrigation implementation based on 110 mm evaporation reduced yield in all treatments compared with the normal irrigation (*Figure 3*).



70 and 110 mm evaporation from pan are as normal and water deficit conditions, respectively.

Figure 3. Mean comparisons of physical pre-treatments × irrigation levels on corn grain yield. Means with similar letters in each column are not significant with together by DMRT at 5% probability level.

Orthogonal comparison

Based on the orthogonal comparison results there is a significant difference between 5 and 10 min. physical treatments except to leaf proline concentration. In this study 5 min. interval in all studied traits was better than 10 min. (*Table 3*).

Table 3. Orthogonal comparison between 5 and 10 minutes physical pre-treatments, drought and no drought condition of 5 minute magnetic treatment, and finally magnetic and non-magnetic treatment.

Traits								
	5 and 10 minutes	Plant height (cm)	Time of tasseling (day)	LAI	Stem dry weight (g)	Leaf proline concentration ($\mu\text{mol/g}$)	Biomass per unit area (g/m^2)	Grain yield (g/m^2)
Physical pre-treatments	5 min.	220.60 a	67.29 a	3.72 a	80.23 a	4.05 a	1319.2 a	679.76 a
	10 min.	206.38 b	72.8 b	3.19 b	69.35 b	3.58 a	1220.5 b	617.38 b
a1 a2	5 min.	225.86 a	69.31a	4.09 a	89.08 a	3.48 b	1416.3 a	744.3 a
	magnetic	215.34 a	65.08 b	3.34 b	71.37 b	4.62 a	1222.9 b	615.3 b
All data	no-magnetic	202.7 b	69.71 a	3.16 b	66.67 b	3.49 a	1201.9 b	620.54 b
	magnetic	237.5 a	62.51 b	4.14 a	91.15 a	4.23 a	1401 a	730.94 a

a1=normal condition (70 mm evaporation from pan)

a2=drought stress condition (110 mm evaporation from pan)

Discussion

Plant height

In this research, plant height increased by magnetic field and gamma ray which is in agreement with those reported by Racuciu et al. (2008) on corn and Pasangka (2013) on soybean (*Glycine max*). Increasing plant height is probably related to stimulating phytohormones like auxin, cytokinin and gibberellin in plant.

Time of tasseling

In order to premature emergence of radical and plumule of plantlets in field, priming by gamma ray resulted in earlier tasseling. In the Pasangka (2013) experiment flowering stage happened 18 day earlier under gamma ray treatment.

LAI

The result of this research on corn LAI are in good agreement with findings of Hoseini et al. (2013) on lemon (*Melissa officinalis*) and Rochalska et al. (2008) on sugar beet (*Beta vulgaris*). This may a probably result of reported by magnetic field probably since the optimum growth of root in the end of nutrient absorption from soil and finally resulted nutrition transport from stem to leaves as described by Rochalska et al. (2008).

Stem dry weight

Stem dry weight decline of corn by water deficit like this study, reported by Nesmith and Ritchi (1992) and Singh and Usha (2003). As well increasing of stem dry weight enhanced by seed priming by magnetic field in advance was stated by Florez (2007).

Biomass

Reduction in crop biomass under water deficit conditions reported by Rabbani and Imam (2011) and Pirevatlou et al. (2010) on corn and wheat (*Triticum aestivum*), which is probably resulted from decline in photosynthesis area and assimilate production. Seed priming by magnetic field and laser radiation resulted in higher biomass due to its positive and significant effect on corn LAI. Similar results have reported by Iqbal et al. (2012) in pea (*Cicer aritinum*) and Hernandez et al. (2010) on corn using magnetic field and laser radiation.

Grain yield

Based on the results of this study, due to the water deficit from increased irrigation duration from 70 to 110 mm evaporation, corn grain yield reduced in all treatments, and increasing of duration of seed priming with gamma and laser rays from 5 to 10 min. and accompanying that treatments with water deficit led to significant grain yield loss. Therefore corn seeds priming with magnetic field in both time intervals or under gamma and laser rays only for 5 min. can be used to improvement of grain yield in normal and stress irrigations. Seed priming by magnetic field and laser radiation caused yield improvement via enhancement of growth and LAI followed by increasing of photosynthesis rate. Grain yield increasing reported by Racuciu et al. (2008); Iqbal et al. (2012); Faqenabi et al. (2009) on corn, chickpea and safflower, respectively; using seed priming with magnetic field. According to Pasangka (2013), average grain yield of soybean increased from 2.5 to 4.5 ton/ha via seed priming by gamma ray.

Comparison of physical treatment on groups for 5 min. then 10 min. under both normal and drought conditions demonstrated that for most agronomic traits such as grain yield physical treatments for 5 min. was better than 10 min. and on the other hand comparison of seeds priming with magnetic field with non-treated seeds revealed increases of some important agronomic traits such as grain yield and the biomass.

Conclusions

As a conclusion from this study, to increase corn grain yield in both normal and water deficit conditions, seed priming with the magnetic field in time intervals of 5 and 10 min., gamma and laser rays only in a short time is recommended. The future studies should be extended to evaluation the response of corn yield when seed exposed under lower intervals of the biophysical treatments.

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