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The Effect of Seed Priming on Plant Traits of Late-Spring Seeded Soybean (*Glycine max* L.)

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Abstract: In order to determine the effect of seed priming on plant traits of late-spring seeded soybean, field and laboratorial studies were conducted at the Agricultural Research Farm and Laboratory of Razi University, Kermanshah, Iran. In the laboratorial study, soybean seeds were primed with 1% solution each of ammonium, calcium, potassium and sodium nitrate for twenty four hours, at 20° C. Non-primed (control) and hydroprimed (for twenty four hours, at 20° C) seeds were also included in the study for comparison. All seeds were subjected to four different temperatures consisted of 5, 15, 25 and 35° C for 8 days, then seed germination percentage (GP), germination rate (GR) and seedling dry weight (SDW) were measured. In the field study, soybean seeds which primed as explained for the laboratorial study were planted in late spring and plant traits including height, leaf area index (LAI), yield and yield components were evaluated. According to the results obtained from the laboratorial study, GP, GR and SDW were improved when temperature was increased up to 25° C. However, at 35° C soybean seeds failed to germinate. Seed priming significantly improved the soybean plant traits. In both field and laboratorial studies, seeds primed with potassium nitrate showed the highest values for all of the evaluated traits. This treatment increased GP, GR, SDW, height, LAI, the number of pods per plant, the number of seeds per pod, 1000-seed weight and yield 28.3, 129.4, 58.1, 43.4, 47.4, 56.5, 23.8, 6.2 and 44.3%, respectively as compared to control. Although, there were no significant differences between this treatment and the seeds primed with ammonium nitrate for all of the traits under study. Among the priming treatments, the lowest values of the traits were obtained when the seeds primed with sodium nitrate. This study revealed that seed priming can be used as a beneficial method to improve seed performance and plant traits of late-spring seeded soybean.

Key words: Nitrate · Seed priming · Soybean

INTRODUCTION

Soybean (*Glycine max* L.) is one of the most important oil seed crops, which is planted in many areas of Iran. It is a valuable source of edible oil and protein for human nutrition. However, in Iran it is commonly planted as an after crop (i. e. after winter cereal or canola harvesting in late spring). At that time air temperature is high and adversely affects seed germination and seedling establishment of soybean, which results into low crop growth and yield.

Several studies have indicated that seed priming with mineral solutions is a beneficial method to improve seed performance and growth of field crops. Kattimani *et al.* [13] found that seed primed with nitrate solutions produced more vigorous seedlings, higher dry matter accumulation and root length as compared to non-primed seeds. According to Demir and Van De Venter [5] nitrate priming has the beneficial effects on germination of watermelon (*Citrullus lanatus*) seeds under temperature and osmotic stress. Other researchers reported that seed priming treatments using salts have been effective in improving seed germination at low temperatures [15,16,18].

Singh and Rao [20] stress that potassium nitrate effectively improved germination, seedling growth and seedling vigor index of the seeds of sunflower varieties with low germination. Olouch and Welbaum [17] suggested that priming can be a valuable process for improving germination and uniformity of heterogeneously matured seed lots. Guzman and Olave [8] reported that seed priming with nitrate solutions resulted in an improved germination rate, radicle growth and germination index. Harris *et al.* [10, 11, 12] found that priming in maize led to better crop establishment and growth, earlier flowering and greater yields. Therefore, in an unfavorable condition, it is possible that primed seedlings may experience less stress due to advancement of germination and growth.

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The present study was conducted to evaluate the effect of priming on seed performance and plant traits of late-spring seeded soybean.

MATERIALS AND METHODS

The experiments were carried out at the Agricultural Research Farm and Laboratory of Razi University, Kermanshah, Iran.

Laboratorial Experiment: The soybean cultivar used was Williams (a soybean cultivar which is widely planted in the region). Soybean seeds were primed with 1% solution each of ammonium, calcium, potassium and sodium nitrate for twenty four hours, at 20° C. After priming, seeds air dried to remove the surface moisture at an ambient temperature [13]. Non-primed and hydroprimed (for twenty four hours, at 20° C) seeds were included in the experiment for comparison. Primed and non-primed seeds were placed in 12 cm glass petri dishes on a layer of filter paper (Whatman # 41). Twenty seeds were placed in each petri dish. The petri dishes were subjected to four different temperatures consisted of 5, 15, 25 and 35° C. The experiment was a factorial with two factors (priming and temperature) on the basis of a completely randomized design with four replications.

Seed germination was recorded daily up to day 8 after the start of the experiment. A seed was considered germinated when radicle emerged by about 2 mm in length. Then the mean germination rate was calculated according to the following equation [7]:

$$R = \Sigma n / \Sigma Dn$$

Where R is mean germination rate, n is the number of seeds germinated on day and D is the number of days from the start of test.

Moreover, germination percentage was determined in the end of test. To determine the seedling dry weight, after the 8^{th} day, seedlings produced in each petri dish were separated from the seeds, dried at 70°C to a constant weight and then weighed.

Field Experiment: Seeds primed as explained in the laboratorial experiment were planted on 20 June 2005. The land was plowed and disced before planting. Fertilizers were applied according to the soil test recommendation. Experimental design was a randomized complete block with four replications. Each plot consisted of five rows (5 m per row) planted 50 cm apart, with 7 cm between plants in the same row. Weeds hand weeded as needed. Irrigation was carried out according to the crop needs. At flowering, the plant growth traits including leaf area index and height were measured on 10 randomly selected plants in each plot. At maturity the soybean plants located at 2 m from the three center rows of each plot were harvested by hand, allow to dry at 80° C to a constant weight, then threshed and seed yield ($kg.ha^{-1}$) was determined. Additionally, 100-seed weight was determined according to the recommendations of the International Seed Testing Association (ISTA) [6]. Before harvesting the number of pods per plant and the number of seeds per pod were measured on 10 randomly selected plants in each plot. Data analyses were carried out using SAS [19].

RESULTS AND DISCUSSION

Laboratorial Experiment: Analysis of variance (Table 1) indicated that both temperature and priming have the significant effects on germination percentage, germination rate and seedling dry weight of the soybean seeds. However, priming x temperature interaction was not statistically significant for the traits under study (Table 1). The traits under study were improved when temperature was increased up to 25° C. At 25° C, germination percentage, germination rate and seedling dry weight were increased 26.7, 60.0 and 102.6% as compared with 5° C. However, at 35° C soybean seeds failed to germinate (Table 2).

Germination process is strongly related to enzymatic activities. The conformation of enzymes is essential step in the enzymatic reaction and this conformation depends on temperature. At low temperatures the enzyme protein is not flexible enough and therefore not in a position to carry out the conformation change required for the reaction. At high temperatures the enzyme coagulates and the new structure obtained is not able to catalyze the reaction [1].

Overall, seed priming treatments led to improved seed germination percentage, germination rate and seedling dry weight (Table 4). Among the priming treatments, seeds primed with potassium nitrate showed the highest values for all of the traits under study. This priming treatment increased germination percentage, germination rate and seedling dry weight 28.3, 129.4 and 58.1%, respectively, as compared to control (non-primed seeds). However, there were no significant differences between this treatment and ammonium nitrate treatment for all of the traits under study (Table 4). Moreover, there was no significant difference between this treatment and calcium nitrate treatment for germination percentage (Table 4).

Table 1: Analysis of variance of the laboratorial traits under study

	Mean Square		
Source of Variance	Germination percentage	Germination rate	Seedling dry weight
Priming	753.54 **	0.1174 **	0.00090 **
Temperature	48701.04 **	1.0122 **	0.02441 **
Priming x Temperature	88.54 ns	0.0119 ns	0.00004 ns
Error	43.40	0.0041	0.00002

ns and **: Non significant and significant and the 0.01 level of probability.

Table 2: Mean comparisons of the laboratorial traits under different temperatures

Temperature	Germination percentage	Germination rate (per day)	Seedling dry weight (g)
25	98.75 a	0.48 a	0.077 a
15	88.75 b	0.37 b	0.047 b
5	77.92 c	0.30 c	0.038 c
35	0.00 d	0.00 d	0.000 d
LSD (0.05)	3.79	0.04	0.003

Similar letters at each column indicate the non-significant difference at the 0.05 level of probability.

Among the priming treatments, the lowest values of the traits under study occurred when the seeds primed with sodium nitrate (Table 4). This can be attributed to the harmful effect of Na^+ ion on the germinating seeds as suggested by Khajeh-Hosseini *et al.* [14]. In the present study, hydropriming also improved the soybean seed performance. This treatment increased germination percentage, germination rate and seedling dry weight 9.8, 41.2 and 29.0 %, respectively, as compared to control (Table 4).

It is concluded that the priming is a beneficial method to improve the soybean seed performance. Improved seed performance may be due to altered physiological condition of the embryo. It may be also due to libration of enzymes, thus rapidly increasing in the production of soluble food nutrients, the whole system is already in motion so that when the seeds are sown developmental processes go on more rapidly than in case of non-primed seeds [13].

There are several indications that many physiological mechanisms are involved in seed priming, the repair of the age related cellular and sub-cellular damage that could accumulate during seed development [2, 3] and an

Table 3: Analysis of variance of the traits evaluated in the field

	Mean Square					
Source of Variance	SY	NPPP	NSPP	1000-SW	H	LAI
Replication	28845.82 ns	6.82 ns	0.007 ns	14.60 ns	17.17 ns	0.14 ns
Treatment (priming)	518981.44**	108.14**	0.151 **	62.54 **	221.00 **	1.59 **
Error	34685.55	5.99	0.013	7.36	14.13	0.10

Abbreviations: SY, seed yield; NPPP, number of pod per plant; NSPP, number of seed per pod; 1000-SW, 1000-seed weight, H, height; LAI, leaf area index.
ns and **: Non significant and significant and the 0.01 level of probability.

Table 4: Mean comparisons of the laboratorial and the field traits under study

	Laboratorial traits			Field traits					
Treatment(priming)	GP(%)	GR(per day)	SDW(g)	SY($kg.ha^{-1}$)	NPPP	NSPP	1000-SW (g)	H(cm)	LAI
Potassium nitrate	73.75 a	0.39 a	0.049 a	2993.3 a	36.00 a	2.73 a	146.25 a	65.25 a	5.05 a
Ammonium nitrate	73.13 a	0.35 ab	0.046 ab	2832.8 ab	33.75 ab	2.62 ab	144.25 ab	63.00 ab	5.00 a
Calcium nitrate	70.00 a	0.34 b	0.045 b	2612.3 bc	31.00 bc	2.61 ab	144.50 ab	59.50 bc	4.83 a
Distilled water(hydroprimed)	63.13 b	0.24 c	0.040 c	2522.8 c	27.75 cd	2.53 b	141.00 bc	56.00 cd	4.28 b
Sodium nitrate	60.63 bc	0.23 c	0.033 d	2171.5 d	24.25 de	2.35 c	136.50 d	51.25 d	4.20 b
Control(non-primed)	57.50 c	0.17 d	0.031 d	2074.8 d	23.00 e	2.20 c	137.75 cd	45.50 e	3.43 c
LSD (0.05)	4.64	0.05	0.004	280.7	3.69	0.17	4.09	5.67	0.48

Abbreviations: GP, germination percentage; GR, germination rate; SDW, seedling dry weight; SY, seed yield; NPPP, the number of pod per plant; NSPP, the number of seed per pod; 1000-SW, 1000-seed weight; H, height; LAI, leaf area index.
Similar letters at each column indicate the non-significant difference at the 0.05 level of probability.

Table 5: Correlation coefficients between the traits under study

	SY	NPPP	NSPP	SW	H	LAI	GP	GR	SDW
SY	1	0.99 **	0.97 **	0.95 **	0.98 **	0.91 **	0.96 **	0.93 **	0.98 **
NPPP		1	0.95 **	0.96 **	0.98 **	0.93 **	0.98 **	0.96 **	0.98 **
NSPP			1	0.93 **	0.99 **	0.94 **	0.94 **	0.93 **	0.97 **
SW				1	0.92 **	0.86 *	0.94 **	0.91 **	0.98 **
H					1	0.97 **	0.98 **	0.96 **	0.98 **
LAI						1	0.96 **	0.97 **	0.94 **
GP							1	0.98 **	0.98 **
GR								1	0.95 **
SDW									1

Abbreviations: SY, seed yield; NPPP, number of pods per plant; NSPP, number of seeds per pod; SW, seed weight; H, height; LAI, leaf area index, GP, germination percentage; GR, germination rate; SDW, seedling dry weight.

* and **: Significant at the 0.05 and 0.01 level of probability, respectively

advancement of metabolic events during the prolonged lag phase-II imbibition that repairs the radicle protrusion [4]. Some morphological changes also occur in the primed seeds which are helpful in the later growth of embryo, e.g. a portion of the seed endosperm is hydrolyzed during priming that permits faster embryo growth [3].

Field Experiment: According to the results obtained from the analysis of variance (Table 3) priming had the significant effects on height, LAI, yield components and yield of soybean plants. The plants produced from the seeds primed with potassium nitrate showed the highest values of the traits under study. This treatment enhanced height, LAI, the number of pods per plant, the number of seeds per pod, 1000-seed weight and yield 43.4, 47.4, 56.5, 23.8, 6.2 and 44.3%, respectively, as compared to control (Table 4). However, there were no significant differences between this treatment and seeds primed with ammonium nitrate for all of the traits under study (Table 4). Moreover, there were no significant differences between potassium nitrate and calcium nitrate seed treatments for the number of seeds per pod, 1000-seed weight and LAI (Table 4).

Among the pre-sowing seed treatments, the plants resulted from the seeds primed with sodium nitrate showed the lowest values for the traits under study (Table 4). Seed priming with this solution increased height, LAI, the number of pods per plant, the number of seeds per pod and yield 12.6, 22.6, 5.4, 6.7 and 4.7%, respectively, as compared with control that were not statistically significant except for height and LAI. The 1000-seed weight was reduced by 0.9% compared to control when seeds primed with sodium nitrate. Although, this reduction was not significant from a statistical standpoint (Table 4). All of the traits under study except the 1000-seed weight had the lowest values for non-primed seeds (Table 4).

All of the traits under study showed the significant and positive correlations (at the 1% level of probability) with yield (Table 5). Among the yield components, the number of pods per plant showed the highest correlation with yield indicating the notable effect of this component on soybean yield. Moreover, there were the positive and significant correlations between the traits measured at the laboratory with those evaluated in the field (Table 5). It is concluded that the field traits improvements can be due to the enhancement of the laboratorial traits resulted from the seed priming treatments. In other words, increase germination percentage, germination rate and seedling dry weight due to the seed priming treatments led to the earlier establishment of soybean plants and production a developed crop canopy on the soil surface. This can be attributed to the better seed performance resulted from the seed priming process. According to Halmer [9] typical responses to priming are faster and closer spread of times to emergence overall seedbed environments and wider temperature range of emergence, leading to better crop stands and hence improved yield and harvest quality, especially under suboptimal and stress growing conditions in the field.

Harris *et al.* [10, 11, 12] reported that priming in maize (*Zea mays* L.) led to better crop establishment and growth, earlier flowering and greater yields. In particular, the benefits later in the growth of the crop were much greater than might be expected from the earlier emergence. Indirect effects of priming would depend solely on the extent to which priming affected germination and early growth to emergence. In an unfavorable condition, it is possible that primed seedlings may experience less stress due to advancement of germination and growth.

Overall, this study revealed that the seed priming is an effective method to enhance the germination percentage, germination rate and seedling dry weight of soybean. Improvement of these traits can promote the later plant growth and development which consequently the yield produced by soybean is increased. This can be attributed to increased radiation absorption by soybean plants, improved soybean competitive ability against weeds and reduced water evaporation from the soil resulted from the earlier establishment and production of a developed canopy of soybean plants in the field.

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