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Research Article
Influence of Priming Treatments on Seed Germination of Sesame (*Sesamum indicum* L.) Under Osmotic Conditions

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Abstract
Background and Objective: Germination is the first stage in a plant's life, which can be affected by stress and conditions. Seed priming has been shown effective in producing earlier germination, better establishment in a range of crops in many diverse environments. This experiment was conducted to find out the effects of priming treatments on sesame seed germination under a range of drought conditions. **Materials and Methods:** Seeds were primed using sodium chloride (-2 bar) for halopriming, polyethylene glycol 6000 (PEG) (-2 bar) for osmopriming, distilled water for hydropriming for two exposing duration of 8 and 16 h and unprimed seeds for control. Germination percentage (Gmax), germination rate (R50), mean germination time (GMT), vigor index, Germination Index (GI), Germination Stress Index (GSI), energy of germination, root and shoot length and seedling weight were studied under 6 drought stress conditions (0.0, -3.0, -4.5, -6.0, -7.5 and -9.0 bar). Data were analyzed by means of SAS Software (9.1 versions) (SAS Institute 2001). Mean comparisons were carried out by Duncan's New Multiple Range Test at the 0.05 probability level. **Results:** When osmotic potential declined to -9 bar PEG Gmax (47%), R50 (82%), GSI (41%), root length (92%), shoot length (98%) and seedling weight (76%) were reduced. PEG applied was the most efficient method in improving germination and emergence in all tests. Gmax, R50, root and shoot length and seedling weight were considerably improved, respectively (1, 2, 10, 10 and 8%) by this treatment. **Conclusion:** Results of this study showed that osmopriming with duration of 16 h enhanced the germination and seedling growth of sesame seeds under drought stress conditions. Based on these results seed priming with PEG may be considered as a reliable procedure to increase the sesame drought tolerance.

Key words: Sesame, halopriming, germination characteristics, drought stress, polyethylene glycol

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is probably the most ancient oil seed known and has been used by human as food material[1]. This important annual oil seed crop has been cultivated for centuries, particularly in developing countries of Asia and Africa, for its high content of both excellent quality edible oil (42-54%) and protein (22-25%)[2]. Sesame oil has two important components as sesamin and sesaminol, which play a major role in its oxidative stability and antioxidant activity[3].

Seed characteristics are usually essential elements in seedling establishment and plant development to obtain high seed yield[4]. One of the major constraints to seed germination is availability of water. Water deficit conditions have been reported, that adversely affect seedling growth by altering carbohydrate metabolism and the transport of sucrose in seedling[5]. Parera and Cantliffe[6] reported that rapid and uniform field emergence is an essential prerequisite to achieve the yield potential, quality and ultimately high profit from annual crops. However, growth regulators like Gibberllic acid and Kinetin may partially reverse effects of water deficit stress during germination by inducing changes in the activities of enzymes of carbohydrate metabolism[7]. Seed priming, which is also called seed hardening, is a physiological seed enhancement method[8]. Priming allows seed hydration to initiate early events of germination, but does not permit radicle emergence, by drying back to initial moisture[9]. Several different priming methods have been commercially used, such as water or osmotic treatment using aqueous solutions, e.g., KCl, $CaCl_2$, priming and solid matrix priming which appear to have the greatest effect on seed and seedling vigor of some crops[6]. There are reports, that seed priming enables early DNA replication, increasing RNA and protein synthesis enhances embryo growth, repairs deteriorated seed parts and reduce leakage of metabolites[10]. Farooq *et al*.[11] and Basra *et al*.[12] demonstrated that both the rate of germination and emergence were improved for rice under adequate moisture conditions. Yari *et al*. [13] reported that the direct benefits of seed priming for almost all crops are faster emergence, uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. According to Hussain *et al*.[14] hydro and osmopriming are the most promising priming techniques, as these techniques decrease mean emergence time and increase final emergence percentage and achene yield of hybrid sunflower. Nevertheless, different priming methods for the priming germination improvement were not yet completed. Thus, the aim of this study was to evaluate the effect of three priming treatment on the germination dynamics and subsequent seedling growth of sesame under drought conditions.

MATERIAL AND METHODS

This study was carried out at the seed technology Laboratory of College of Agriculture, Isfahan University of Technology. Seed moisture content was determined by grinding the seeds and then drying at 130°C for 4 h and was recorded to be 2.94% on a fresh weight basis. The seeds were stored in a cold room and maintained at 4°C and 30% RH. The experimental design was 3 factorials ($4\times2\times6$) arranged in a completely randomized design, with 3 replication and 50 seeds per replicate. The first factor was priming treatment (osmopriming with PEG -2 bar, Halopriming with NaCl -2 bar, hydropriming and control), the second treatment, priming period (8 and 16 h) and the third treatment was osmotic potential levels (0.0, -3.0, -4.5, -6.0, -7.5 and -9.0 bar PEG). Seeds of sesame (genotype Varamin) were divided into seven sub-samples. One sub-sample was kept as the control (unprimed) and the six other sub-samples were subjected to osmopriming, halopriming and hydropriming for 8 and 16 h. The ratio of seed weight to solution volume was 1:5 (g mg^{-1})[15]. Seeds were dried back into their original moisture content (2.94%) after treatment at room temperature. The PEG was prepared according to Michel and Kaufmann[16].

Three replications of 50 seeds placed on filter paper on petri dish 90 mm that was wet with 3 mL of respective test solutions and germinated in germinator at 25°C and 16 h light for 14 days. Germination was considered when the radicles were 2 mm long[17]. Germination percentage was recorded every 24 h for 6 days. Germination rate[11], mean germination time[18], germination index[19], germination stress index[20], energy of germination[21] and vigor were measured. Root and shoot length and weight of seedling were recorded after 14 days of sowing.

Statistical analysis: Data were analyzed by means of SAS Software (9.1 versions) (SAS Institute). Mean comparisons were carried out by Duncan's New Multiple Range Test at the 0.05 probability level[22].

RESULTS

A significant three-way interaction (priming treatment, priming period and stress) was found ($p<0.05$, 15 d.f.) for all study parameters. Seed treatments improved all study

Table 1: Effect of priming treatments on some germination parameters of sesame seeds

	Parameters									
Priming type	Gmax (%)	R50 (d^{-1})	MGT (d)	Vigor	GI	GSI (%)	GE (%)	Root length (mm)	Shoot length (mm)	Seedling weight (mg)
Halopriming	80.83^{ab}	11.59^{ab}	3.59^{b}	1927.29^{ab}	3.49^{a}	126.48^{ab}	1.17^{b}	13.11^{b}	7.76^{a}	8.27^{b}
Osmopriming	81.16^{a}	11.68^{a}	3.55^{b}	1976.75^{a}	3.48^{a}	128.79^{a}	1.27^{a}	13.87^{a}	7.78^{a}	8.41^{a}
Hydropriming	80.61^{ab}	11.60^{ab}	3.64^{a}	1886.84^{bc}	3.51^{a}	125.19^{b}	1.16^{bc}	13.06^{b}	7.32^{ab}	8.02^{c}
Unprimed	80.38^{b}	11.51^{b}	3.67^{a}	1813.02^{c}	3.51^{a}	121.95^{c}	1.15^{c}	12.69^{b}	7.05^{b}	7.82^{d}
LSD	0.61	0.09	0.04	77.72	0.05	3.00	0.01	0.43	0.55	0.08

Gmax: Germination percentage, R50: Germination rate, MGT: Mean germination time, GI: Germination index, GSI: Germination stress index and GE: Energy of germination. Means within columns with the same letters are not significantly different at 5% level

Table 2: Effect of priming period on some germination parameters of sesame seeds

	Parameters									
Priming time	Gmax (%)	R50 (d^{-1})	MGT (d)	Vigor	GI	GSI (%)	GE (%)	Root length (mm)	Shoot length (mm)	Seedling weight (mg)
8 h	80.75^{a}	11.57^{a}	3.66^{a}	1917.31^{a}	3.52^{a}	125.95^{a}	1.18^{a}	13.28^{a}	7.59^{a}	8.13^{a}
16 h	80.75^{a}	11.62^{a}	3.57^{b}	1834.64^{a}	3.48^{a}	125.26^{a}	1.19^{a}	13.09^{a}	7.36^{a}	8.12^{a}
LSD	0.43	0.06	0.03	54.96	0.04	2.12	0.01	0.30	0.39	0.06

Gmax: Germination percentage, R50: Germination rate, MGT: Mean germination time, GI: Germination index, GSI: Germination stress index and GE: Energy of germination. Means within columns with the same letters are not significantly different at 5% level

Table 3: Effect of osmotic potential on some germination parameters of sesame seeds

	Parameters									
Osmotic potential	Gmax (%)	R50 (d^{-1})	MGT (d)	Vigor	GI	GSI (%)	GE (%)	Root length (mm)	Shoot length (mm)	Seedling weight (mg)
-3 bar	92.58^{b}	17.87^{b}	1.73^{d}	2908.21^{b}	2.54^{e}	227.89^{a}	1.87^{b}	23.18^{b}	8.20^{b}	10.64^{b}
-4.5 bar	89.91^{c}	12.52^{c}	2.87^{c}	1154.19^{c}	3.51^{c}	183.03^{b}	1.66^{c}	8.53^{c}	4.30^{c}	6.85^{c}
-6 bar	80.58^{d}	7.86^{d}	4.39^{b}	490.86^{d}	4.40^{b}	94.84^{d}	0.97^{d}	4.34^{d}	1.74^{d}	5.48^{d}
-7.5 bar	73.91^{e}	5.75^{e}	5.67^{a}	325.77^{e}	4.97^{a}	88.31^{e}	0.38^{e}	3.29^{e}	1.11^{de}	5.00^{e}
-9 bar	51.08^{f}	3.92^{f}	5.70^{a}	174.88^{f}	3.35^{d}	59.56^{f}	0.28^{f}	2.87^{e}	0.55^{e}	4.00^{f}
Control	96.41^{a}	21.64^{a}	1.31^{e}	6351.97^{a}	2.21^{f}	100.00^{c}	1.95^{a}	36.89^{a}	28.97^{a}	16.81^{a}
LSD	0.75	0.11	0.05	95.19	0.07	3.68	0.02	0.52	0.67	0.10

Gmax: Germination percentage, R50: Germination rate, MGT: Mean germination time, GI: Germination index, GSI: Germination stress index and GE: Energy of germination, Means within columns with the same letters are not significantly different at 5% level

parameters excluding Germination Index (GI) as compared with control (Table 1). Priming period had no significant effect on study parameters except mean germination time (Table 2). All of the study parameters values decreased with decreasing of osmotic potential of PEG (Table 3). When osmotic potential declined to 9 bar PEG, Gmax and germination rate (R50) decreased by 47 and 82%, respectively (Table 3). However osmopriming improved Gmax and R50 under drought stress but no significant differences of both parameters observed between the seeds subjected to halopriming, hydropriming and unprimed seeds (Table 2).

Mean Germination Time (MGT) and Germination Index (GI) increased as osmotic potential in PEG solutions decreased (Table 3). However seed priming shortened the time to seed germination but this decrease, due to osmo and halopriming, was more evident as compared to hydropriming especially under low osmotic (Table 1). Results showed that these parameters were increased up to -7.5 bar and then decreased to -9 bar PEG in halo and osmoprimed seeds (Table 4). Results showed that minimum MGT was obtained from seeds primed for 16 h (Table 2). These differences were quite evident under low osmotic potential (Table 5).

Drought stress caused a significant ($p<0.05$) reduction in vigor, Germination Stress Index (GSI) and energy of germination (GE) (Table 3). However, priming treatments had stimulation effects on these parameters under stress and non-stress conditions (Table 2). This stimulation effect on vigor was evident under low osmotic potential (Table 4). In between priming treatment, the effect of osmopriming was more obvious than with halo and hydro priming (Table 1). Root and shoot length and seedling weight were affected by osmotic stress and both were reduced with increasing drought levels up to 9 bar (Table 3). Although priming treatment enhanced these two parameters, root length halopriming and hydropriming had no significant differences with unprimed seeds. Results also showed that for all three parameters (Root

Table 4: Interactive effects of priming treatment and osmotic potential on the MGT, vigor, GI root length, shoot length and seedling weight

	Parameters						
Priming treatment	Osmotic potential	MGT (d)	Vigor	GI	Root length (mm)	Shoot length (mm)	Seedling weight (mg)
Halopriming	-3 bar	1.73^{j}	3062.2^{c}	2.54^{j}	23.48^{cd}	9.43^{d}	10.80^{d}
	-4.5 bar	2.79^{i}	1116.7^{e}	3.45^{f-h}	8.43^{ef}	4.06^{f}	6.77^{fg}
	-6 bar	4.30^{f}	548.3^{fg}	4.31^{d}	4.71^{gh}	2.11^{g}	5.58^{hi}
	-7.5 bar	5.69^{b}	314.6^{g-i}	4.95^{b}	3.03^{ij}	1.20^{gh}	4.99^{lm}
	-9 bar	5.70^{b}	166.2^{i}	3.40^{gh}	2.65^{j}	0.60^{gh}	4.83^{m}
	Control	1.33^{k}	6355.9^{b}	2.27^{k}	36.26^{ab}	29.15^{b}	16.68^{bc}
Osmopriming	-3 bar	1.72^{j}	3123.8^{c}	2.55^{j}	24.08^{c}	9.25^{d}	10.96^{d}
	-4.5 bar	2.84^{hi}	1119.2^{e}	3.47^{e-g}	8.46^{ef}	4.76^{f}	6.98^{f}
	-6 bar	4.40^{e}	608.9^{f}	4.49^{c}	5.51^{g}	1.96^{g}	5.62^{h}
	-7.5 bar	5.64^{bc}	429.8^{f-h}	4.97^{ab}	4.03^{hi}	1.75^{gh}	5.00^{lm}
	-9 bar	5.43^{d}	262.1^{hi}	3.24^{i}	3.53^{h-j}	1.60^{gh}	4.83^{m}
	Control	1.28^{k}	6236.8^{b}	2.21^{k}	37.61^{a}	27.35^{c}	17.05^{a}
Hydropriming	-3 bar	1.73^{j}	2728.7^{d}	2.55^{j}	22.78^{cd}	6.76^{e}	10.40^{e}
	-4.5 bar	2.95^{g}	1229.5^{e}	3.54^{ef}	9.60^{e}	4.06^{f}	6.93^{fg}
	-6 bar	4.44^{e}	363.0^{f-i}	4.42^{cd}	3.26^{ij}	1.23^{gh}	5.31^{jk}
	-7.5 bar	5.55^{c}	232.3^{hi}	4.89^{b}	2.76^{ij}	0.40^{gh}	4.86^{m}
	-9 bar	5.85^{a}	135.1^{i}	3.46^{e-g}	2.65^{j}	0.00^{h}	3.73^{n}
	Control	1.30^{k}	6632.3^{a}	2.21^{k}	37.33^{ab}	31.50^{a}	16.90^{ab}
Unprimed	-3 bar	1.73^{j}	2718.1^{d}	2.50^{j}	22.40^{d}	7.36^{e}	10.40^{e}
	-4.5 bar	2.92^{gh}	1071.3^{e}	3.58^{e}	7.63^{f}	4.31^{f}	6.73^{g}
	-6 bar	4.43^{e}	441.3^{f-h}	4.38^{cd}	3.88^{h-j}	1.66^{gh}	5.39^{ij}
	-7.5 bar	5.81^{a}	326.3^{g-i}	5.08^{a}	3.33^{ij}	1.09^{gh}	5.17^{kl}
	-9 bar	5.82^{a}	136.2^{i}	3.32^{hi}	2.65^{j}	0.00^{h}	2.63^{o}
	Control	1.31^{k}	6182.9^{b}	2.23^{k}	36.26^{b}	27.91^{bc}	16.60^{c}

MGT: Mean germination time, GI: Germination index, Means within columns with the same letters are not significantly different at 5% level

Table 5: Interactive effects of priming period and osmotic potential on the MGT (%) and GI

	Osmotic potential							
Parameters	Time (h)	-3 bar	-4.5 bar	-6 bar	-7.5 bar	-9 bar	Control	LSD
MGT	8	1.73^{g}	2.86^{f}	4.40^{e}	5.73^{b}	5.93^{a}	1.30^{h}	0.07
	16	1.73^{g}	2.88^{f}	4.39^{e}	5.62^{c}	5.48^{d}	1.31^{h}	
GI	8	2.53^{e}	3.49^{c}	4.41^{b}	5.00^{a}	3.47^{c}	2.22^{f}	0.10
	16	2.54^{e}	3.53^{c}	4.39^{b}	4.94^{a}	3.24^{d}	2.23^{f}	

MGT: Mean germination tiem, GI: Germination index, Means within rows with the same letters are not significantly different at 5% level

and shoot length and seedling weight) effect of osmopriming was more evident than halopriming and hydropriming (Table 1). This enhancement was obvious under low osmotic potential (Table 4).

DISCUSSION

This study revealed that three priming treatments positively affect germination parameters under both normal and stress conditions. Nearly all the germination parameters values were higher in osmoprimed seeds than hydro and haloprimed seeds, suggesting that osmopriming of sesame seed may be an effective method to improve seed vigor and establishment in dry areas. In consistent with this study results, Shim *et al.*[23] showed that osmopriming with PEG 6000 improved germination percentage and germination rate under normal conditions in sesame.

In many crops, pre-soaking improves germination and seedling establishment. In many plant species seeds, trypsin-like proteolytic enzymes, which should be produced during seed development, are important during seed development and germination. The activity of such enzymes, however, is often prevented by trypsin inhibitors, which may be present in the seed and play regulatory roles in protein mobilization during germination. Priming, however, may reduce the inhibitory activities of such enzymes and promote germination. For example in sorghum, soaking seed in distilled water or salt solution reduces the inhibitory activities of trypsin and chymotrypsin, although the latter treatment showed greater effects[9]. According to McDonald[10], the major pre-germination steps such as DNA and RNA synthesis are accomplished in seeds during the priming states, consequently the seeds are physiologically close to germination and have fewer steps to complete than unprimed seeds.

Priming treatments showed enhanced performance under stress conditions. Whereas drought stresses showed adverse effects on germination parameters in primed and non-primed seeds. These results confirm the findings of Farooq *et al.*[11], for tomato, Yagmur and Kaydan[7] for triticale and Mutsushima and Sakagami[24] for rice. Similar to our results, Janmohammadi *et al.*[25] reported that both salinity and drought stress affected germination adversely while the effects of drought stress were more severe than salinity stress. They also reported that compared to the control osmo and hydropriming resulted in enhanced performance under stress conditions. Ghanbari and Lee[26] also reported that primed seeds of sesame could germinate faster and produce longer seedling compared with untreated seeds.

Priming treatments increased energy of germination (GE) under normal and stress conditions. Similar to these results Farooq *et al.*[11], reported that the highest energy of germination was from those seeds that were subjected to pre-sowing treatment. Ruan *et al.*[21], also reported that seed priming with PEG 8000 were not able to invigorate rice seeds, but resulted in a higher energy of germination and germination index compared with untreated seeds. For wheat, primed seeds have higher vigour level, which resulted in earlier start of emergence and finally positive correlation between seed vigour and field performance[27].

Seed priming with PEG severely diminished seedlings dry weight. Consequently, this treatment was omitted during seedling dry weight evaluation. In general, water stress treatment decreased seedling dry weight. Salt deposit in the root growing medium is the main reason for physiological drought and subsequently lower cell division and enlargement in the root growing region and ultimately low root growth[28]. Seedling dry weight enhancement may be one of reasons that drive positive effects of priming on seed performance under adverse environmental conditions. Similar to this study, Sadeghian and Yavari[29] reported that seedling growth severely diminished under drought stress however genetic differences were monitored among the sugarbeet varieties. Yagmur and Kaydan[7] reported that hydropriming induced three-four more growth for root and shoot length in comparison with seedlings obtained from non-primed seeds. Improve seedling fresh and dry weight might be due to increased cell division within the apical meristem of seeding roots, which caused an increase in plant growth[30]. Beneficial effects of hydropriming under normal and stress conditions could be due to earlier timing of metabolic activities, faster imbibitions and less mechanical restriction of seed coat as a result of softening of seed coat[10]. The most effective priming agent to increase germination was PEG and the optimum priming duration was 16 h in view of mean germination time and germination index. Seed osmopriming is a simple economical way to the seedling establishment of sesame plant.

CONCLUSION

Results clearly indicated that the highest germination characteristics were attained osmoprimig under control and drought conditions. Osmopriming increased germination characteristics as compared to the unprimed seeds. Thus, it is conceivable to suggest that this priming is the best treatment for invigoration of sesame seeds.

SIGNIFICANCE STATEMENT

This study discovers the seed treatment with PEG -2 bar for 16 h improved seed germination performance under drought stress in sesame seed than normal conditions, thus can be beneficial for cultivating sesame in the arid area.

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