Open Journal of Soil Science, 2018, 8, 137-146
http://www.scirp.org/journal/ojss
ISSN Online: 2162-5379
ISSN Print: 2162-5360

Amelioration of Salinity Stress in Maize Seed Germination and Seedling Growth Attributes through Seed Priming

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How to cite this paper: Akter, L., Fakir, O.A., Alam, M.K., Ul Islam, M., Chakraborti, P., Alam, M.J., Rashid, M.H., Begum, M. and Kader, M.A. (2018) Amelioration of Salinity Stress in Maize Seed Germination and Seedling Growth Attributes through Seed Priming. *Open Journal of Soil Science*, **8**, 137-146.
https://doi.org/10.4236/ojss.2018.85011

Received: May 2, 2018
Accepted: May 28, 2018
Published: May 31, 2018

Abstract

Germination of seeds and growth of seedling respond to seed priming as priming can guard the damage of salinity stress. A study conducted in the net house of the Department of Agronomy, BAU, Mymensingh during the period from November 2012 to April 2013 investigated the ameliorative effect of seed priming on seed germination and seedling attributes of maize under various salinity stress conditions. The experiment consisted of five seed priming and four salinity levels (NaCl) and laid out in a Completely Randomized Design (CRD) with three replications. Seed germination and seedling attributes of maize varied due to salinity stress and priming. The highest seed germination (95.7%) was recorded when no stress was imposed under hydropriming (48 hours). The germination of seeds performed even well (92.3%) when treated with hydropriming (48 hours) and NaCl@0.25 $dS \cdot m^{-1}$ which was followed by hydropriming (24 hours) under no salinity imposed and NaCl@0.25 $dS \cdot m^{-1}$ salinity. Hydropriming for 48 hours without salt stress performed the best on number of leaves $seedling^{-1}$ (8), shoot length (28.2 cm), root length (14.5 cm), fresh weight (100.8 g) and dry weight of seedling (50.3 g). The germination and seedling growth parameters were reduced with the increase in salinity levels irrespective of priming while all seed priming treatments showed ameliorative effects. However, reduction in seed germination and seedling attributes were minimal with hydropriming for 48 hours. The results revealed that priming of maize seeds could be used for amelioration of salinity stress and hydropriming for 48 hours appeared as the best seed priming treatment.

Keywords

Germination, Halopriming, Hydropriming, Osmopriming, Seedling Attributes

1. Introduction

Maize (*Zey mays* L.) is one of the most important cereal crops in the world. The average global production of maize in 2010 was 0.84 billion tones as compared to 0.696b tons of rice and 0.654 tons of wheat [1]. In Bangladesh, maize cultivated in about 376 thousand acres and total annual production is 887 thousand Mt with an average yield of 2.36 t $acre^{-1}$ [2]. Every year, the acreage and production are increasing. Because of rising poultry industry in Bangladesh the demand for maize is going to increase very sharply as maize is an important constituent of poultry feed.

Soil salinity is one of the great concerns in arid and semi-arid regions in the world as well as in Bangladesh. According to studies, 7% of the world lands are saline and 3% is high saline, because of low precipitation, high evaporation and irrigation by saline waters, soil salinity is getting increased [3]. The most important problems for economic crop production in arid and semiarid regions are high concentration of ions especially NaCl either in soil or in irrigation water [4]. It is estimated that about one-third of world's cultivated land is affected by salinity [5]. Development of methods to induce salt stress resistance and tolerance in plants is so important. Salt tolerance of plants can be increased by seed treatment with different osmotic solution (inorganic salts, sugars, growth regulators and polyethylene glycol) known as seed priming. Among different priming techniques (hydropriming, osmoconditioning, matripriming, etc.), seed acceleration (priming with plant growth regulators) has been shown to be much effective under both normal and stressed environments [6] [7] [8] [9]. The most important priming treatments are osmopriming and hydropriming. Osmopriming refers to soaking seed in solutions of sugars, polyethylene glycol (PEG), glycerol, sorbitol [10] or fertilizers such as urea [11], followed by drying the seed before sowing. Hydropriming involves soaking of seed in water before sowing. Previous work [12] [13] [14] [15] suggest that the adverse and depressive effects of salinity and water stress on germination can be alleviated by various seed priming treatments. The salinity-tolerance of maize is very limited, and high-salt stress alters its growth responses [16], especially in seedlings, which may be less tolerant to salt-stress than adults [17]. However, the abnormal effects of salinity stress on germination can be diminished by various seed priming agents [15]. Halo-priming of seeds in pre-sowing treatments in an osmotic solution allows seeds to absorb water, but restricts radicle occurrence through testa until the primed seeds are sown for germination under salt stress conditions. Primed seeds usually show improved germination parameters [18]. Although the effects of priming treatments on germination of some seed crops have been studied, but little information is available on the invigorating maize seed under salt stress. With these facts in mind, the present study was undertaken with the following objectives:

1) to assess the germination percentage and seedling attributes of maize under various levels of salinity stress;

2) to study the effect of seed priming on germination percentage and seedling attributes of maize under salinity stress.

2. Materials and Methods

2.1. Experimental Design and Lay out

The experiment was set up in a completely randomized design (CRD) with three replications. The experimental treatments consisted of different seed priming techniques under various levels of salinity stress as below (Table 1).

2.2. The Physical and Chemical Properties of the Soil

The soil samples (used in pot) were dried at room temperature mixed thoroughly, grinded, sieved with a 2 mm sieve and preserved in plastic containers for subsequent laboratory analysis. Bulk density was determined through volume basis. Texture, porosity and particle size were done though hydrometric, stochastic and sieving method, respectively. Particle size, bulk density, porosity and texture of the soil were 2.57, 1.42, 44.7 and silty loam, respectively (Table 2). Chemical properties of soil like pH, OM, total-N, P, K and S were determined through glass electrode pH meter method [19], wet oxidation method [20], kjeldahl method [19], $SnCl_2$ reduction method [21], NH_4OAC method [22] and turbidimetric method [23], respectively. The pH, OM and total N, K of the soil were slightly acidic (5.8), low (1.3) and low (0.101), low (0.12), respectively, while P, S, Zn, B were above critical limit (Table 2).

2.3. Pot Preparation

The experiment was carried out in small plastic tray under natural light in the net house of the Department of Agronomy; BAU. The trays were filled by sand. The inert materials, visible insect pests and plant propagules were removed. Clean and dry plastic trays of 2 L were used for each treatment.

Table 1. Treatments assigned in the study.

Factor A: Seed priming	Factor B: Salinity level
I. No priming	A. Control (without salinity)
II. Hydro-priming for 24 hours	B. NaCl 0.25 $dS \cdot m^{-1}$
III. Hydro-priming for 48 hours	C. NaCl 0.5 $dS \cdot m^{-1}$
IV. Halo-priming for 48 hours (1% NaCl solution)	D. NaCl 1.0 $dS \cdot m^{-1}$
V. Osmo-priming for 48 hours (2% sugar solution)	

Table 2. The physical and chemical properties of initial soil.

Constituents	Results	Constituents	Results
Particle size analysis	2.57	Soil pH	5.8
Bulk density (g/ce)	1.42	Organic matter (%)	1.30
Porosity (%)	44.7	Total nitrogen (%)	0.101
Sand (%) (0.0 - 0.02 mm)	21.75	Available phosphorus (ppm)	27
Silt (1%) (0.02 - 0.002 mm)	66.60	Exchangeable potassium (me/100 g soil)	0.12
Clay (%) (<0.002 mm)	11.65	Available Sulphur (S)	22.7
Soil textural class	Silty loam	Available Zn (mg·kg^{-1})	0.85
Colour	Dark grey	Available B (mg·kg^{-1})	0.16
Consistency	Grounder		

2.4. Salinity Development

Salt solution was prepared artificially by dissolving calculated amount of commercially available NaCl with tap water to make 0.25, 0.5 and 1.0 dS·m^{-1} NaCl solution. The salt solution was applied as per treatment specification. Similar moisture content of each tray was maintained by adding water every day.

2.5. Priming Techniques (Seed Priming)

Required number of maize seeds were soaked in distilled but cool water for 0 hours, hydro-priming 24 hours, hydro-priming 48 hours, halo-priming 48 hours (1% NaCl solution), osmo-priming 48 hours (2% sugar solution) at around room temperature as per treatments. After priming seeds in water then taken out and water at seed surface was wiped out. Twenty five seeds were sown in each tray for seedling emergence.

2.6. Fertilization

All fertilizers used (urea, TSP, MoP, Gypsum, Zinc sulphate and Boric acid) according to requirement on soil test basis using fertilizer recommendation guide 2005 [24].

2.7. Data Collection and Analysis

The analysis of variance (ANOVA) for various crop characters and also were done following the principle of F-statistics. Mean comparison of the treatments were adjudged by the Duncan's Multiple Range Test [25].

3. Results and Discussion

3.1. Effect of Seed Priming and Salinity Stress on Seed Germination

Seed germination percentage varied due to seed priming treatments and various salinity stress levels showed significant difference (**Table 3**). The maximal

Table 3. Effect of seed priming and level of salinity stress on percentage of seed germination of maize.

Seed priming	Salinity level	Germination (%)
No priming	No salt	72.0 d
	NaCl 0.25 $dS \cdot m^{-1}$	41.7 g
	NaCl 0.5 $dS \cdot m^{-1}$	19.3 h
	NaCl 1.0 $dS \cdot m^{-1}$	0.00 i
Hydropriming 24 hrs	No salt	85.7 b
	NaCl 0.25 $dS \cdot m^{-1}$	78.3 c
	NaCl 0.5 $dS \cdot m^{-1}$	51.7 f
	NaCl 1.0 $dS \cdot m^{-1}$	0.00 i
Hydropriming 48 hrs	No salt	95.7 a
	NaCl 0.25 $dS \cdot m^{-1}$	92.3 a
	NaCl 0.5 $dS \cdot m^{-1}$	82.0 bc
	NaCl 1.0 $dS \cdot m^{-1}$	15.3 h
Halo priming 48 hrs	No salt	79.0 c
	NaCl 0.25 $dS \cdot m^{-1}$	52.7 f
	NaCl 0.5 $dS \cdot m^{-1}$	42.3 g
	NaCl 1.0 $dS \cdot m^{-1}$	0.00 i
Osmopriming 48 hrs	No salt	70.0 d
	NaCl 0.25 $dS \cdot m^{-1}$	64.0 e
	NaCl 0.5 $dS \cdot m^{-1}$	39.3 g
	NaCl 1.0 $dS \cdot m^{-1}$	0.00i
$^{LSD}0.05$		4.91
Level of significance		**
CV (%)		3.45

** = significant at 1% level of probability. In a column figures followed by same letter(s) are statistically identical as per DMRT at 5% and dissimilar letter(s) showed significant different among them.

percentage of seed germination (95.7%) was found in hydro-priming for 48 hrs without salinity stress while statistically similar percentage of seed germination (92.33%) was obtained with similar priming in 0.25 $dS \cdot m^{-1}$ salinity stress level. Hydro-priming of seeds for 48 hrs also gave substantial seed germination (82%) at 0.5 $dS \cdot m^{-1}$ salinity level, which was much higher than any other priming technique at the same salinity level. Hydro-priming for 24 hrs also performed better in seed germination under salinity stress of 25 and 0.5 $dS \cdot m^{-1}$ NaCl. Halo-priming and osmo-priming were also superior in seed germination under salinity stress compared to that of no priming treatment. However, at 1.0 $dS \cdot m^{-1}$ salinity stress, no seed priming except hydro-priming for 48 hrs was capable of giving seed germination (Table 3). These results revealed that all seed priming techniques positively ameliorate salinity stress in terms of seed germination. [26] reported that the effects of seed priming on seed germination of maize under different salt concentration were significant. Seed priming compensated the negative effects of salinity on seed germination.

In a column figures followed by same letter(s) are statistically identical as per DMRT at 5% and dissimilar letter(s) showed significant different among them.

3.2. Effect of Seed Priming and Salinity Stress on Number of Leaves Seedling^{-1}

Number of leaves seedling^{-1} showed significant variation due to seed priming techniques and salinity stress levels at seedling stage of maize (**Table 4**). The maximal number of leaves seedling^{-1} (8.0) was found due to hydro-priming for 48 hrs without salinity stress (without NaCl), while without salinity stress of hydro-priming for 24 hrs also produced statistically identical maximal leaves seedling^{-1} (7.0). On the other hand, without priming but applying salinity stress level of 0.5 dS·m^{-1} NaCl and hydro-priming for 48 hrs in salinity stress level of 1.0 dS·m^{-1} NaCl produced similar number of leaves seedling^{-1} (1.33), while all priming techniques except hydro-priming for 48 hrs in salinity stress level of 1.0 dS·m^{-1}NaCl did not produce any leaves during the study. This might be due to failure to germinate any seedling under the high level of salinity stress. These results reveal that leaf production significantly decreased in increasing salinity level at each priming technique. Similar result was also obtained by [26] where they found that leaves plant^{-1} was significantly affected by the effect of seed priming techniques under various salinity (NaCl) levels.

3.3. Effect of Seed Priming and Salinity Stress on Shoot Length

Shoot length varied due to seed priming treatments and various salinity levels in this study at seedling stage (**Table 4**). The longest shoot (28.2 cm) was recorded in treatment of without salinity stress and hydro-priming for 48 hrs which was statistically different from other all interaction treatments. On the other hand, salinity stress of NaCl @ 1.0 dS·m^{-1} in hydro-priming for 48 hrs produced significantly the shortest shoot (1.0 cm) at seedlings stage. The similar result was also obtained by [27] who found that the hydro-priming and KNO_3 produced significantly the greatest shoot length (19.5 cm). Thus, maize see dS·may be treated with KNO_3 (0.2%) and hydropriming + thiram (0.25%) to enhance seed quality and stand establishment in the field. [28] also found similar result regarding to shoot length in case of the higher length of shoot of maize (14.7 cm) was found in seeds primed with 1% KH_2PO_4 for 6 h which was higher than other treatments.

3.4. Effect of Seed Priming and Salinity Stress on Length of Root

A significant variation was found due to combined effect between seed priming and salinity level in respect of root length (**Table 4**). Among the combined

Table 4. Effect of seed priming and salinity level on numbers of leaves seedlings^{-1}, shoot length, root length, fresh and dry weight of maize seedlings.

Seed priming	Salinity level	No. of leaves seedling^{-1}	Shoot length (cm)	Root length (cm)	Fresh weight (g·seedling^{-1})	Dry weight (g·seedling^{-1})
No priming	No salt	2.67 f	16.18 c	9.22 d	62.01 d	28.3 e
	NaCl 0.25 dS·m^{-1}	2.67 f	9.28 f	4.81 h	54.0 e	16.2 h
	NaCl 0.5 dS·m^{-1}	1.33 g	5.68 g	1.97 j	40.9 fg	8.90 i
	NaCl 1.0 dS·m^{-1}	0.00 h	0.00 h	0.00	0.00 j	0.00 j
Hydropriming 24 hours	No salt	7.00 a	21.16 b	12.51 b	99.0 a	37.0 c
	NaCl 0.25 dS·m^{-1}	5.67 bc	14.12 d	8.80 f	71.3 c	24.7 f
	NaCl 0.5 dS·m^{-1}	4.00 ef	11.31ef	4.93 h	40.2g	19.8 g
	NaCl 1.0 dS·m^{-1}	0.00 g	0.00 h	0.00	0.00 j	0.00 j
Hydropriming 48 hours	No salt	8.00 a	28.23 a	14.45 a	100.8 a	50.3 a
	NaCl 0.25 dS·m^{-1}	5.00 bc	23.00 b	9.80 d	70.2 c	40.3 b
	NaCl 0.5 dS·m^{-1}	3.00 ef	17.01c	5.71 j	45.2 f	30.6 d
	NaCl 1.0 dS·m^{-1}	1.33 g	1.00 h	1.37 k	6.78 i	1.76 j
Halopriming 48 hours	No salt	4.67 bcd	18.2 c	10.80 c	86.9 b	31.9 d
	NaCl 0.25 dS·m^{-1}	4.33 cd	13.2 de	5.52 g	60.4 d	23.1 f
	NaCl 0.5 dS·m^{-1}	3.67 def	9.44 f	3.91 i	40.92 fg	16.5 h
	NaCl 1.0 dS·m^{-1}	0.00 h	0.00 h	0.00	0.00 j	0.00 j
Osmopriming 48 hours	No salt	4.67 bcd	17.8 c	9.60 de	89.8 b	31.2 d
	NaCl 0.25 dS·m^{-1}	4.33 cd	14.2 d	4.96 h	59.08 d	25.1 f
	NaCl 0.5 dS·m^{-1}	4.00 cde	10.5 f	2.34 j	31.44 h	19.6 g
	NaCl 1.0 dS·m^{-1}	0.00 h	8.0 h	0.00	0.00 j	0.00 j
	$LSD_{0.05}$	1.19	1.93	0.39	4.34	1.99
	Level of significance	**	**	**	**	**
	CV (%)	5.53	10.2	4.31	5.49	5.95

**= significant at 1% level of probability. In a column figures followed by same letter(s) are statistically identical as per DMRT at 5% and dissimilar letter(s) showed significant different among them.

treatments, the longest root of maize was found in hydro-priming for both 24 and 48 hrs without salinity stress (46.16 and 45.68 cm, respectively) while the seeds of hydro-priming for 48 hrs grown under salinity stress level of 1.0 dS·m^{-1} NaCl produced significantly the shortest root (3.17 cm) which was statistically different from all other interactions.

On the other hand, no priming, hydro-priming for 24 hrs, halo-priming for 48 hrs and osmo-priming for 48 hrs did not show any seedling due to unableness to germinate under salinity stress of 1.0 dS·m^{-1} NaCl. The findings of the present study are similar to that of [29]. They reported that saline water (6.0 dS·m^{-1}) and subsequent exposure to salinity stress had a significant ($p < 0.05$) effect on root length where root length significantly decreased with the increasing salinity stresses. These results suggest that priming seeds of maize with NaCl before sowing induced physiological and biochemical changes, which resulted in better performance when subsequently exposed to different levels of salinity.

3.5. Effect of Seed Priming and Salinity Stress on Fresh and Dry Weight of Seedling

A significant variation was also observed regarding fresh and dry weight of seedling at 14 DAS due to seed priming and salinity levels (Table 4). It is evident that the highest weight of fresh and dry seedling (100.8 and 50.3 g seedling^{-1}) was found in interaction of hydro-priming and without salinity stress level while statistically identical fresh weight of seedling (99.00 g seedling^{-1}) was obtained by the interaction of the similar priming for 24 hrs and similar (without salinity) salinity stress. However, hydro-priming for 48 hrs under salinity stress level of 1.0 dS·m^{-1} NaCl recorded the lowest weight of fresh and dry seedling (6.78 and 1.76 g seedling^{-1}). Any other seed priming did not produce any seedling at salinity stress level of 1.0 dS·m^{-1} NaCl. [27] reported that maize seeds treated with KNO_3 (0.2%) and hydropriming + thiram (0.25%) to enhance seed quality and stand establishment in the field. [30] also found that maximal seedling dry weight (0.61 g) was observed in seeds primed with $Na_2S_2O_3$.Similarly, [31] also found significant variation in seedling dry weight of maize due to seed priming and salinity effect.

4. Conclusions

Hydro-priming of maize seeds for 48 hrs had highly significant influence for better germination and superior performance of various seedlings attributes at 14 DAS. On the other hand, salinity stress exerted negative effect on seed germination and seedling attributes of maize. Hydro-priming of maize seeds for 48 hrs was effective in ameliorating salinity stress, especially at level up to 50 dS·m^{-1} NaCl. So, it is suggested that hydro-priming for 48 hrs would be highly effective seed priming techniques for amelioration of salinity stress in maize.

Acknowledgements

The authors would like to thank technical staffs, laboratory attendants and labours of the laboratory of Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh. The authors also thank Bangladesh Agricultural University for the financial support in conducting the research.

Conflicts of Interest

The manuscript authors hereby profess that there are no conflicts of interest for any reasons, such as personal, institutional and financial relationships, academic competition, or intellectual passion. Gender issues were also avoided in publishing this manuscript.

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