

Full Length Research Paper

Improving emergence and early seedling growth of two cool season grasses affected by seed priming under saline conditions

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Soil salinity threatens initial stages of emergence and early seedling growth in cool season grasses, although it may be tolerant in its adult stages. Today, seed priming has been known as an effective technique for improving seed germination, seedling vigor, and emergence rate and seedling establishment under different environmental stresses. A pot experiment was conducted to evaluate osmopriming effects in ameliorating emergence rate (ER) and final emergence percentage (FEP), seedling growth, Na⁺ and K⁺ accumulated in shoot at early growth stages of two cool season grasses including tall wheat grass (*Agropyron elongatum* Host.) and bulbous barley (*Hordeum bulbosum* L.) when seeds were imbibed with CaCl₂, -1.5 MPa, and NaCl, -1 MPa for a duration of 2 and 5 days respectively, in response to seven salinity concentrations of NaCl (0, 50, 100, 150, 200, 250 and 300 mM) under greenhouse conditions. With increasing salinity levels, ER and FEP and seedling growth were significantly decreased in both grasses for primed and non-primed (control) seeds ($p < 0.01$). But under severe salinity stress (300 mM) seed priming improved with regards to ER, FEP, accumulation of Na⁺, Na⁺:K⁺ ratio in shoot, root dry weight, shoot dry weight, root length and shoot length 62.6, 30.5, 44.7, 34.8, 42.5, 43.7, 31.7 and 20.9% when compared with non primed seeds, respectively. The relationships between salinity levels and ion accumulation showed that there was no significant correlation between Na⁺ accumulated in shoot and shoot dry weight in primed seeds ($r = -0.15$, $P > 0.05$) but for non-primed seeds increasing the accumulation of Na⁺ in shoot, led to significant decline ($r = -0.62$, $P < 0.01$) of shoot dry weight. The results suggest that seed priming could significantly improve the threshold value especially for FEP in both grasses under different levels of salinity. Also, it seems that seed priming could better improve root and shoot growth at early seedling growth stage perhaps by decreasing toxicity of Na⁺ concentration and adjusting Na⁺ and K⁺ ratio under saline conditions.

Key words: Early seedling growth, emergence rate, seed priming, salinity stress, cool-season grasses.

INTRODUCTION

Extreme salinity of soil is a major limiting factor for the renovation of arid and semi-arid regions. Approximately 95 million ha in the world are affected by saline conditions (Jeannette et al., 2002; Othman et al., 2006). Soil salinity through ion toxicity or reduction of water uptake affects seed germination, emergence uniformity, seedling establishment, survival and forage and grain yield in plants (Shokohifard et al., 1989). The seed germination of

grasses is usually limited at concentrations of NaCl from 250 to 350 mM (Lombardi et al., 1998). Several researchers believed that one of the most important strategies in overcoming salinity is the evaluation of genetic variability of wild species to identify a tolerant genotype (Epstein et al., 1980; Foolad et al., 1999; El-Kharbotly et al., 2003; Yildirim and Guvenc, 2006). However, the inhibition effects of salinity may be a major constrain at

early growth stages in these species. Today, seed priming technique (halopriming) has been shown to improve seed germination, emergence rate, and seedling vigor and establishment under saline conditions for different plants (Strogonov, 1964; Cayuela et al., 1996; Taylor, 1997; Rehman et al., 1998; Hill, 1999; Guzmán and Olave, 2004; Iqbal, 2006). Seed priming can be defined by controlling water uptake in a dry seed for promoting germination without removing the root from it (Taylor, 1997). Strogonov (1964) demonstrated that plant salt tolerance could be increased by treating seeds with NaCl solution prior to sowing. Also, pre-sowing seed treatment with inorganic salts (halopriming) is an easy way, low cost, and low risk technique, and it is being used effectively to overcome the salinity problem in agricultural lands.

Ashraf and Rauf (2001) reported that seed priming of maize for 8 h in distilled water or in 200 meq·L⁻¹ of NaCl, KCl, CaCl₂·2H₂O, improved germination and initial establishment, if it is carried out with water or osmotic solution in corn under salinity stress conditions. Sivritepe et al. (2003) demonstrated that primed melon seeds with 18 dS·m⁻¹ NaCl solution for 3 days at 20°C, significantly increased seedling emergence percentage and emergence rate and root dry weight under salinity conditions when compared to non-primed seeds. Omami (2005) found that seed priming of two species of Amaranth for 3 h, with solution of CaCl₂ and CaSO₄ and their mixture with similar osmotic potentials (-1.3 MPa), resulted in increased germination and emergence of growing plants under Salinity conditions.

Paul and Choudhury (1991) observed that seed soaking with 0.5 to 1% solutions of KCl or potassium sulfate (K₂SO₄) significantly increased plant height and yield attributes in wheat. Harris et al. (2001) approved that seed priming prior to sowing significantly improved germination and initial establishment under unfavorable conditions of marginal land.

Also, both naturally and artificially aged F1 seed of rice cultivar (Shan you 63), when primed with PVA (polyvinyl alcohol) and potassium nitrate, improved the seed germination, seedling establishment and biochemical characters (SOD, POD and CAT) and significantly decreased the content of MDA and soluble sugar in seed leakage of the primed seed (Zhu et al., 2010). Gorham (1993) stated that all plants prefer sometime between K⁺ and Na⁺ one. Salt excretion and its relation with salinity tolerance in plants, special

role preference and Na⁺: K⁺ ratio are principles of important stress salinity tolerance (Greenway, 1965; Munns et al., 1988; Mirmohammadi-Maibody, 1996). Some reports have also been shown that with increasing concentrations of Ca⁺ and K⁺ in seeds of plants such as wheat (Chaudhuri and Wiebe, 1968), rye grass (Marcar, 1986), maize (Alberico and Cramer, 1993), rice (Lin and Kao, 1995) and tomato (Al-Harbi, 1995), seed germination are enhanced under high saline conditions.

Two species of grasses including tall wheatgrass (*A. elongatum* Host, syn. *Elymus elongatum*) and bulbous barley (*H. bulbosum* L.) are cool season forage grasses that are used for rehabilitation of rangelands in Iran. Since the most perennial grasses at initial stages of germination and seedling emergence are more sensitive to different environmental stresses than adult stages (Gazanchian et al., 2006 and 2007), we have hypothesized that osmopriming could improved seedling characteristics under high saline conditions. The objective of this study was to evaluate the effectiveness of osmopriming in improving seedling emergence rate and factors relating to tolerance against salinity stress in two grasses species.

MATERIALS AND METHODS

Seeds of two perennial native cool-season grasses species including *A. elongatum* Host and *H. bulbosum* L. were used for renovating rangelands and were obtained from Agricultural and Natural Resources Research Center of Northern Khorassan. The experiment was conducted under a greenhouse conditions at the Islamic Azad University of Bodjnord in Iran, on September 2007.

Preliminary experiment

The optimum osmopriming conditions were determined based on a preliminary experiment. Firstly, the seeds of both grasses were imbibed in twelve treatment combinations including NaCl and CaCl₂ salt solutions at three osmotic potential (-1, -1.5, and -2 MPa) for a duration of 2 and 5 days at room temperature. Secondly, after seed priming, seeds were washed and dried until they retained their original seed moisture.

Thirdly, the seeds were germinated to determine high germination rate and seedling vigor under normal conditions in an incubator at 20° C for 10 days. Finally, the best treatments for *A. elongatum* Host; CaCl₂, -1.5 MPa, for 2 days and for *H. bulbosum* L.; NaCl, -1 MPa for 5 days were determined.

Greenhouse experiment

Twenty five seeds of two grasses of primed or non-primed (control), based on the results of preliminary experiment, were planted at 1-cm depth in 1-L plastic pots (10 cm diameter and 15 cm long) which were filled with silica sand. The initial soil was washed off by tap water and then distilled water was used to remove all external salt. The pots were placed in a greenhouse where the temperature ranged between 18 (night) and 31° C (day) with relative humidity between 70 and 85% and 14 h photoperiod. The pots were irrigated daily with 0, 50, 100, 150, 200, 250, and 300 mM NaCl solutions when added a nutrient solution Sicoperplex (SAP INTERNATIONAL

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Abbreviations: ER, Emergence rate; FEP, final emergence percentage; RDW, root dry weight; RL, root length; SL, shoot length; SDW, shoot dry weight.

CORPORATION S.A.) including Nitrogen = 2%; Magnesium = 0.30%; Sulphur = 2.5%; Boron = 0.15%; Cooper = 0.05%; Iron = 0.20%; Manganese = 0.10%; Zinc = 0.50%; Betaines = 0.10%; Seaweed = 5%; Amino acids = 0.25%; Carbon = 1.25%; and little Vitamin B1). The pots were daily irrigated to near field capacity before draining water from the bottom of pot for a period 30 days.

Measurements

Seedling emergence was counted daily with exit of the first leaf from the soil surface during the experiment. Emergence Index (EI) was calculated to determine emergence rate according to Maguire (1962) by the following equation:

$$EI = \sum (E_i / T_i)$$

Where E_i is the number of emerged seedling every day other than the last day, and T_i is the corresponding day of counting.

At the end of the experiment, the seedlings from each pot were harvested and their roots and shoots separated. The shoot length (from seed to tip of the upper leaf) and the longest root length for five samples were measured and then dry weight was separately determined for all of the shoots and roots from each pot by oven drying at 70°C for 72 h. Also, the root to shoot ratio were calculated for both length and dry weight characters.

The amounts of Na^+ and K^+ concentrations were measured on 3.0 g of shoot (washed with distilled water) when oven dried and then were mashed in a mortar. The mashed samples were ashed in a muffle furnace at 550 °C for 6 h and the ions were extracted in 2 M HCl solution. Readings were made using a flame photometer.

Data Analysis

The experimental design was factorial based on a completely randomized design, with four replications. Data were analyzed using SAS software (PROC ANOVA; SAS, 1996). The differences between the mean scores were compared using Duncan's Multiple Range Test ($p < 0.05$) by the MSTATC software (Michigan State Univ., East Lansing, MI and USA). Correlation coefficients was calculated for the relationship between early seedling growth characteristics and Na^+ , K^+ accumulated in shoot in response to primed and non-primed seeds across two cool season grasses under saline conditions. Also, a regression model was fitted to determine the relationships between salinity concentrations and all seedling characters and also Na^+ and K^+ accumulated in shoot under both primed and non-primed seeds. Since no significant differences occurred for salinity \times species \times priming interactions for all characters except Na^+ : K^+ ratio accumulated in shoot and also both of the grasses had similar responses to seed priming, so all characters were pooled across two grasses in fitting model.

RESULTS AND DISCUSSION

All measurements were significantly affected by salinity levels (Table 1). The seed priming effect was strong significantly on all of characters except amount of K^+ and accumulated Na^+ : K^+ ratio in shoot ($p < 0.01$). Two species differed significantly for FEP, ER, RL, SL, SDW and Na^+ accumulated in shoot ($p < 0.05$) in this experiment. However, there were no species \times priming interactions for any of the parameters measured with the

exception of SDW. In this study based on mean square values, the FEP and ER measurements were more responsive to seed priming than both species, their salinity factors and interactions (Table 1). On average under saline conditions, the seed priming improved FEP, ER, RL, SL, RDW, SDW and Na^+ accumulated in shoot, 28.7, 35.7, 20.4, 13.4, 27.0, 23.2 and 17.1, respectively (Table 2). Similar findings were reported in Cucumber (Passam and Kakouritis, 1994), muskmelon (Nascimento and West, 1999) and Amaranth (Omami, 2005). These authors believed that seed priming improved earlier germination and early seedling growth due to reducing of seed coat viscosity. The most important purposes of seed priming are high germination rate, synchronization and rapid seedling emergence, more vigorously growth, and better performance in adverse conditions (Desai et al., 1997).

These changes are induced by enhancing protein and DNA synthesis that may be effective in increasing cell membrane stability in embryo. Also, phospholipids in cell membrane of embryo can increase the resistance and permeability of cell membrane (Bradford, 1995).

Seed priming \times grasses species interaction in response to salinity of different levels showed that with increasing salt concentrations, all studied characters were significantly decreased for both primed and non-primed seeds. Salinity stress injuries can be observed not only due to osmotic potential and oxidative stress, but also toxic ions and nutrient deficiency effects, which caused changes in certain enzymatic or hormonal activities of the seed (Greenway et al., 1980; Van et al., 1982; Munns et al., 1988; Ashraf et al., 1990). In this study, two grasses responses to seed priming were similar and positive, however *A. elongatum* Host was more salt tolerant than *H. bulbosum* L. (Table 3). For example, with increasing salinity levels from 0 to 300 mM NaCl solution in *A. elongatum* Host, FEP ranged from 100 to 54% for primed seed and from 99 to 14% for non-primed seeds, respectively. Also, FEP improved up to 22% under severe salinity after seed priming in *H. bulbosum* L. (Table 3). Similar results were obtained which indicate that seed priming could enhance the seedling growth of both the root and shoot parts in the studied grasses under salt stress (Table 3). Also, at the highest salinity level, seed priming strongly improved both FEP and ER than the other characters for two grasses.

However, with increasing salinity, accumulations of Na^+ , K^+ and Na^+ to K^+ ratio in shoot were increased when seeds were primed with $CaCl_2$ for *A. elongatum* Host and NaCl for *H. bulbosum* L. Several studies have shown that osmoregulation may play an important role of inducing salt tolerance in plants so that seed priming with $CaCl_2$ and NaCl may decrease the negative effects of salt stress by influencing Ca^{2+} on permeability of cell membrane and regulating hormone homeostasis (abscisic and salicylic acids). Also osmoregulation may occur in plants by active uptake of inorganic ions such as Na^+ , K^+

Table 1. Mean squares from analysis of variance for measured seedling characteristics in primed and non-primed seeds of two grasses in response to salt stress under greenhouse conditions.

Source of variation	df	Mean square								
		Final emergence (%)	Emergence rate (day)	Root length (mm)	Shoot length mm	Root dry weight (g)	Shoot dry weight (g)	Na ⁺ (mg.g-1 SDW)	K ⁺ (mg.g-1 SDW)	Na ⁺ : K ⁺ (mg.g-1 SDW)
Priming (Pr)	1	23086 **	14.9**	48223 **	49308 **	126.4 **	110.0 **	6.9 **	0.001ns	4.6 ns
Species (Sp)	1	19557 **	12.1**	5348.9 *	7458.89**	6.5 ns	9.7 *	12.1 **	0.6 ns	2.4 ns
Pr × Sp	1	276.6 ns	0.08 ns	160.3 ns	100.3 ns	3.9 ns	21.4 **	0.7 ns	0.6 ns	0.5 ns
Salinity (Sa)	6	10883 **	10.6**	40013**	25525 **	215.3 **	147.2 **	12.8**	8.4 **	38.9 **
Pr × Sa	6	918.6 **	0.4 ns	2047.4 *	2680.7 **	0.7 ns	4.4 ns	4.1 **	0.5 ns	11.1 **
Sp × Sa	6	542.8 *	0.2ns	1710.6 ns	892.2 ns	4.6 ns	6.4 *	3.1 **	2.6 **	19.7 **
Pr × Sp × Sa	6	456.9 ns	0.3 ns	1682.9 ns	885.8 ns	3.3 ns	3.2 ns	0.7 ns	0.4 ns	4.3 *
CV (%)		22.7	27.1	16.4	18.2	21.9	20.4	26.7	33.6	47.7

* Indicates significance at $p < 0.05$ level.** Indicates significance at $p < 0.01$ level.

ns, not significant.

Table 2. Main effect of seed priming on seedling emergence, early seedling growth characteristics and Na⁺, K⁺ accumulated in shoot, averaged across of two cool season grasses and salinity levels.

Main effect	Final emergence	Emergence rate	Root length	Shoot length	Root dry weight	Shoot dry weight	Na ⁺	K ⁺	Na ⁺ : K ⁺
	%	day	mm		g		mg.g-1 SDW		
Primed seed	80.2 a‡	2.04 a	203.5 a	121.71 a	7.73 a	8.25 a	2.87 a	1.49 a	2.82 a
Non-primed seed	51.5 b	1.31 b	162 b	105.39 b	5.64 b	6.34 b	2.38 a	1.57 a	2.76 a

Means with the same letter within each column are not significantly different ($p < 0.05$).

and Cl⁻ or synthesis of organic solutes like sugars, free amino acid and proline (Redman, 1974; levitt, 1980; Meyer and Boyer, 1981; Hasegawa et al., 1986; Iqbal et al., 2006). Our results support that seed priming could be reduced to injury salinity stress on seedling emergence (FEP and ER) and early growth parameters in two grasses species (Table 3). Hariss et al. (1999) reported that emergence rate and early seedling growth characters

are enhanced by seeds treatment of maize, rice and chickpea with NaCl solution prior to sowing under salt stress conditions.

Similarly, Yagmur and Kydan (2008) observed that pre treatment of hexaploid triticale with potassium hydrophosphate (KH₂PO₄) and water resulted in improving the seed germination and seedling growth in both low stresses of drought and salinity conditions.

Traits relationships

All negative or positive correlations among seedling emergence characters (FEP and ER), early seedling growth parameters (RL, SL, RDW, and SDW) and the accumulation of ions in shoot (Na⁺, K⁺ and its ratio) were improved as influenced by seed priming (Table 4). For instance, a high negative correlation occurred between Na⁺

Table 3. Interaction effects of seed priming × species × salinity on seedling emergence, early seedling growth characteristics and Na⁺, K⁺ accumulated in shoot of two cool season grasses under greenhouse conditions.

Species x Salinity	Final emergence		Emergence rate		Root length		Shoot length		Root dry weight		Shoot dry weight		Na ⁺		K ⁺		Na ⁺ / K ⁺	
	P†	NP	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
	%		day		mm		mm		g		g		mg.g ⁻¹ SDW		mg.g ⁻¹ SDW		mg.g ⁻¹ SDW	
A. <i>elongatum</i>																		
0 (mM)	100a ‡	99 a	3.13a	3.00ab	254.0ab	225.8a-e	170.0ab	172.50a	14.8a	14.2a	13.1a	12.4ab	0.65j	0.55j	1.7c-g	1.83c-f	0.40i	0.34i
50	100a	92ab	2.73a-c	2.40a-d	250.3a-c	194.5d-h	160.0a-c	172.50a	10.4b	7.8d-f	10.6bc	8.3c-f	1.78hi	1.88g-i	1.3e-i	2.21cd	1.79g-i	0.83i
100	100a	93ab	2.68a-c	2.23cd	217b-f	220.8a-e	176.8a	136.5b-g	9.7b-d	6.6e-g	7.5e-h	7.2f-i	1.94g-l	2.19f-i	1.66d-g	1.82c-f	1.43g-i	1.31g-i
150	100a	77a-c	2.3b-d	1.85de	235.3a-d	204.0b-g	143.8a-g	150.0a-e	6.6e-g	6.5e-g	8.5c-f	8.3c-g	2.6d-h	2.3e-i	1.89c-f	2.17cd	1.39g-i	1.05 hi
200	99a	51de	2.3b-d	1.05g-i	178.5e-i	148.5h-k	124.25d-h	119.5e-h	5.4fg-l	2.8j-l	5.9g-j	4.97ij	2.7c-h	2.25e-i	1.1f-k	1.17f-j	3.4d-g	2.09f-i
250	90ab	38ef	2.15c-e	0.85h-j	169.8f-j	128.3j-m	117.8e-h	10.5g-j	4.8g-j	3.1i-l	5.8h-j	5.1ij	3.4a-e	3.5a-d	1.2f-l	0.93 f-k	3.07e-h	5.3b-d
300	54c-e	14g-i	1.13f-i	0.30k	176.5e-j	52.3 n	99.75h-k	29.75mn	3.1i-l	1.6 l	5.1ij	2.7kl	4.28a	3.04b-g	0.55i-k	0.49jk	7.77a	6.2ab
H. <i>bulbosum</i>																		
0	100a	75a-c	3.1a	2.15cd	267.50a	245.8ac	144.5a-g	148a-f	13.6a	11.01b	11.97ab	10.4b-d	1.17ij	0.57j	3.15ab	3.62a	0.37i	0.16i
50	91ab	77a-c	2.25cd	2.00c-e	232.3a-d	202.0c-g	128.5c-h	155.5a-d	10.01bc	7.9c-e	10.6bc	9.5cde	3.3a-f	3b-g	2.51bc	2.34cd	1.32g-i	1.31g-i
100	84ab	55c-e	2.05c-e	1.43e-h	222.5a-e	200.8c-g	115.0f-l	11.00g-j	7.7d-f	7.01e-g	9.1c-f	8.2d-g	3.3a-f	3.4a-e	1.6d-h	2.09c-e	2.23f-i	1.73g-i
150	78a-c	25f-h	1.8d-f	0.58i-k	206.3b-g	144.0i-l	101.75h-j	69.00kl	6.7e-g	3.2i-l	8.9c-f	5.2h-j	3.42a-d	4.38a	1.6d-h	0.70i-k	2.22f-i	6.22ab
200	69b-d	5f-i	1.68d-g	0.33jk	148.8h-k	10.3k-m	83.75i-l	68.50kl	5.6e-h	3.3i-l	6.9f-i	4.5jk	3.78a-c	3.38a-e	0.65i-k	0.81h-k	5.82bc	4.5b-e
250	36e-g	9hi	0.75h-j	0.20jk	159.75g-j	98.3 lm	81.25j-l	29.25mn	5.7e-h	2.2kl	6.7f-j	1.6 lm	4.11ab	4.01ab	0.95g-k	0.76i-k	4.44b-e	5.28b-d
300	22f-i	1i	0.55i-k	0.03k	130.75i-m	93.0mn	57.00 lm	3.00 n	4.2h-k	1.6 l	4.8i-k	3.3 m	3.95ab	5.12d-h	0.98g-k	0.83h-k	4.03c-f	2.37f-j

† P, primed seed and NP, non-primed s

‡ Means with the same letter within each column are not significantly different ($p < 0.05$).

accumulated in shoot and all seedling growth parameters and K⁺ accumulated in shoot for non-primed seeds.

In contrast, there were no significant correlation ($p > 0.05$) between Na⁺ accumulated in shoot and RL ($r = -0.21$), SL ($r = -0.14$), SDW ($r = -0.15$) and K⁺ accumulated in shoot ($r = -0.15$) when the seeds are primed

(Table 4).

Regression analysis

Regression analysis indicated that all characters responded to salinity increase as a curvilinear equation. In

brief, salt stress had a significant effect in reducing most of the traits in both primed and non-primed seeds, but this reduction was less in primed seeds when compared with control. For instance, seed priming could improve the threshold value for FEP from 100 to 200 Mm NaCl concentrations. On the other hand, the regression equation for FEP showed that linear slop

Table 4. Correlation coefficients among early seedling growth characteristics and Na⁺, K⁺ accumulated in shoot in response to seed priming of two cool season grasses under saline conditions.

Treatment	Traits	Correlation coefficients							
		ER	RL	SL	RDW	SDW	Na ⁺	K ⁺	Na ⁺ :K ⁺
Primed seed	FEP†	0.97**	0.85**	0.86**	0.80**	0.84**	-0.25ns	0.67**	-0.44**
	ER		0.84**	0.82**	0.87**	0.86**	-0.32*	0.67**	-0.49**
	RL			0.81**	0.81**	0.84**	-0.21ns	0.78**	-0.49**
	SL				0.75**	0.87**	-0.14ns	0.71**	-0.39**
	RDW					0.91**	-0.39**	0.72**	-0.53**
	SDW						-0.15ns	0.77**	-0.38**
	Na ⁺							-0.15ns	0.76**
	K ⁺								-0.52**
Non-primed seed	FEP	0.94**	0.56**	0.71**	0.53**	0.47**	-0.61**	0.43**	-0.55**
	ER		0.64**	0.77**	0.71**	0.60**	-0.75**	0.51**	-0.64**
	RL			0.66**	0.65**	0.71**	-0.59**	0.53**	-0.62**
	SL				0.65**	0.54**	-0.73**	0.44**	-0.62**
	RDW					0.75**	-0.78**	0.64**	-0.74**
	SDW						-0.62**	0.52**	-0.62**
	Na ⁺							-0.42**	0.71**
	K ⁺								-0.76**

(X coefficient) decreased up to 2.3 fold as influenced by seed priming (Figure 1). The same results were obtained for ER. Although seedling growth were decreased with increasing salinity levels, seed priming could significantly improve the RL and SL (2.9 and 4.9 fold) and RDW and SDW (2.3 and 3.3 fold), respectively, at the highest salinity levels (Figure 1). The grasses response to salinity levels of NaCl from 0 to 300 mM also showed that with salinity increase the accumulation of K⁺ was strongly decreased, while both the accumulation of Na⁺ and Na⁺:K⁺ ratio were significantly increased in shoot for both primed and non-primed seeds. The amount of Na⁺ accumulated in shoot for primed seeds showed a lower linear slop at moderate salinity but increased up to 1.46 times at the highest salinity level (300 mM) when compared with the non primed seeds (Figure 2). Similar findings have been reported on the ion content by seed priming in plants of Amaranth (Omami, 2005), celery (Pardossi et al., 1999), eggplant (Chartzoulakis and Klapaki, 2000) and tomato (Romero-Aranda et al., 2001) under saline conditions.

Conclusion

It seems that seed priming could improve seedling vigor

and has subsequently enhanced the capacity of Na⁺ uptake especially under severe saline conditions. Some researchers believe that the regulation of ion concentrations with accumulation of Na⁺ and Cl⁻ in shoot and K⁺ in root is one of the mechanisms of salinity tolerance in several salt tolerant species (Greenway, 1965; van Steveninck et al., 1982; munns et al., 1988; Ashraf et al., 1990). In conclusion, the results of this study suggest that in the two grasses priming seeds osmotic solutions (CaCl₂ and NaCl) could enhance characters of seedling emergence percentage and rate, and better root and shoot growth by decreasing ion toxicity, enhancing the capacity of Na⁺ uptake and adjusting Na⁺ and K⁺ ratio in shoot. This can be effective for inducing salt stress tolerance under salinity conditions. Therefore, seed priming could be used to optimize early seedling growth and seedling establishment of cool season grasses that may be sensitive in this stage under saline soils.

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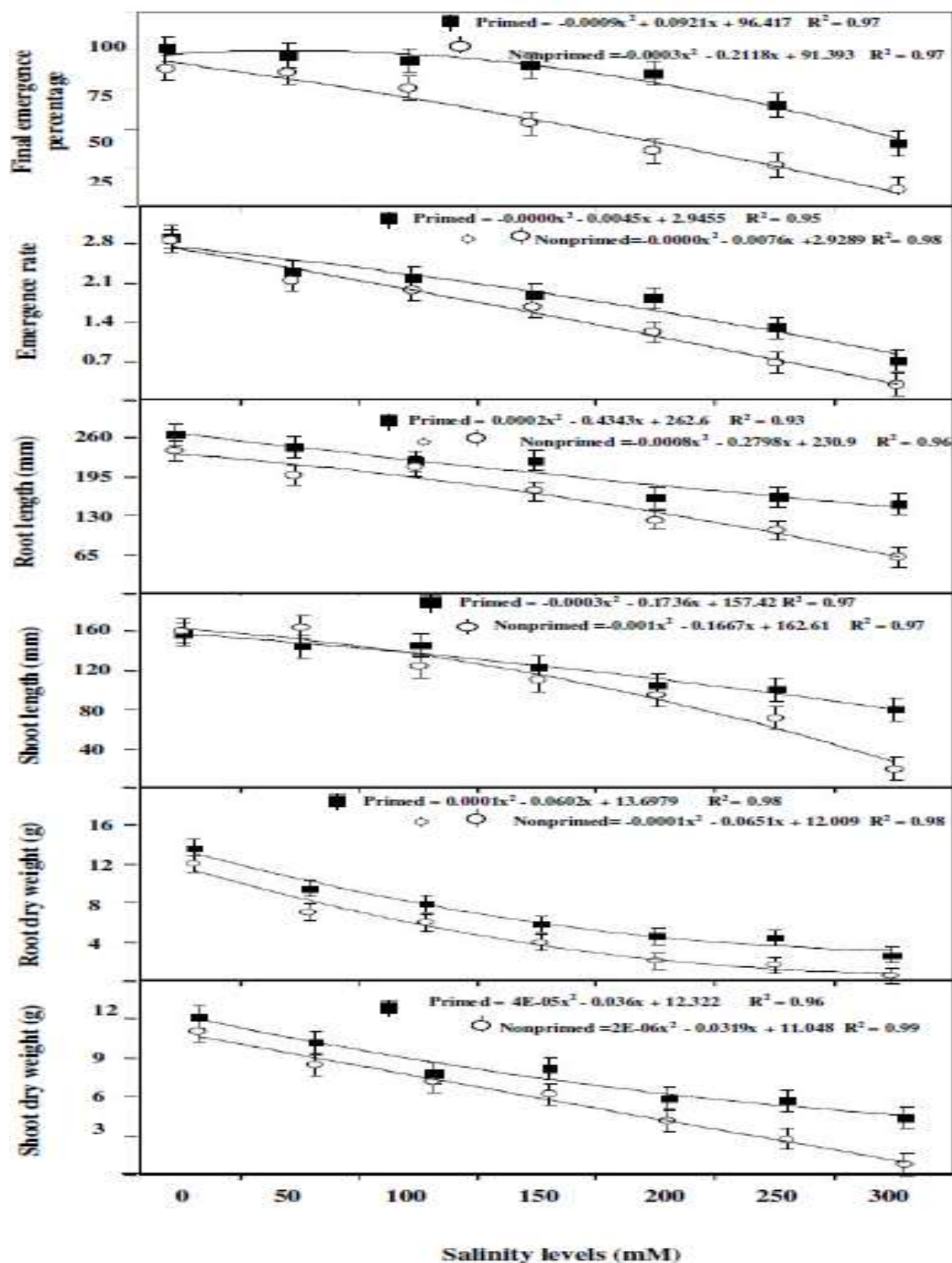


Figure 1. Regression relationships between salinity levels and FEP, ER, RL, SL, RDW and SDW as affected by seed priming at early seedling growth stage. Each data point is the mean of two cool season grasses and vertical lines indicate standard errors of means (n=8).

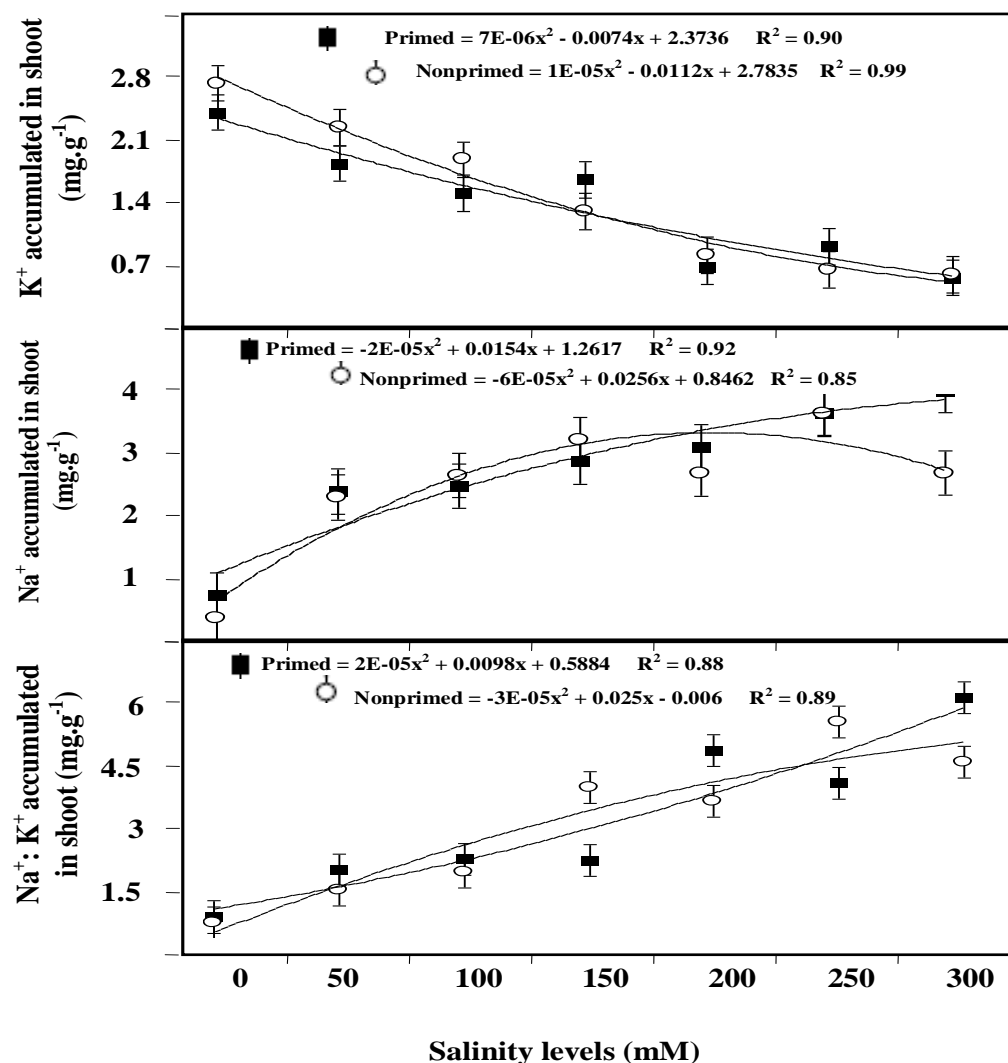


Figure 2. Regression relationships between salinity levels and K⁺, Na⁺ and Na⁺: K⁺ ratio accumulated in shoot as affected by seed priming at early seedling growth stage. Each data point is the mean of two cool season grasses and vertical lines indicate standard errors of means (n=8).

REFERENCES

- Al-Harbi AR (1995). Growth and nutrient composition of tomato and cucumber seedlings as affected by sodium chloride salinity and supplemental calcium. *J. Plant Nutr.*, 18: 1403-1416.
- Alberico GJ, Cramer GR (1993). Is the salt tolerance of maize related to sodium exclusion? I. Preliminary screening of 7 cultivars. *J. Plant Nutr.*, 16: 2289-2303.
- Ashraf M, McNeilly T, Bradshaw AD (1990). Patterns of ion distribution in selected NaCl tolerant and normal lines of four grass species. *Biol. Plant*, 32: 302-312.
- Ashraf M, Rauf H (2001). Inducing salt tolerance in maize (*Zea mays* L.) through seed priming with chloride salts: Growth and ion transport at early growth stages. *Acta Physiol. Plant*, 23: 407-414.
- Bradford KJ (1995). Water relations in seed germination. In: J. Kigel and G. Galili (eds.), seed development and germination. Marcel Dekker, New York, pp. 351-396.
- Cayuela E, Perez-Alfocea F, Caro M, Bolaryn MC (1996). Priming of seeds with NaCl induces physiological changes in tomato plants grown under salt stress. *Physiol. Plant*, 96: 231-236.
- Chartzoulakis K, Klapaki G (2000). Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. *Sci. Hortic.*, 86: 247-260.
- Chaudhuri M, Wiebe HH (1968). Influence of calcium pretreatment on wheat germination on saline media. *Plant Soil* 18: 208-216.
- Desai BB, Kotecha PM, Salunkhe DK (1997). *Seeds Handbook*. Marcel Dekker, Inc., New York, 4: 627.
- El-Kharbotly A, Mahgoub O, Al-Subhi A, Al-halhal A (2003). Indigenous grass species with potential for maintaining rangeland and livestock feeding in Oman. *Agric. Ecosyst. Environ.*, 95: 623-627.
- Epstein E, Norlyn J, Rush DW (1980). Saline culture of crops: a genetic approach. *Sci.*, 210: 399-404.
- Foolad MR, Hyman JR, Lin GY (1999). Relationships between cold-and salt-tolerance during seed germination in tomato: analysis of response and correlated response to selection. *Plant Breed.*, 118: 49-52.
- Gazanchian A, Khosh Kholgh-Sima NA, Malboobi MA, Majidi-Heravan E (2006). Relationships between emergence and soil water content for perennial cool-season grasses native to Iran. *Crop Sci.*, 46: 544-553.
- Gazanchian A, Hajheidari M, Khoshkholgh-Sima NA, Hosseini Salekdeh Gh (2007). Proteome response of *Elymus elongatum* to severe water stress and recovery. *J. Exp. Bot.*, 58:291-300.
- Gorham J (1993). Genetics and physiology of enhanced K / Na

- discrimination. In: P. Randall, P (ed), Genetic aspects of plant mineral nutrition, Kluwer, Dordrecht, pp. 151-159.
- Guzmán M, Olave J (2004). Effects of N-form and saline priming on germination and vegetative growth of Galia-type melon (*Cucumis melo* L. cv. primal) under salinity. *Acta Hortic.*, 659: 253-260.
- Greenway H (1965). Plant response to saline substrates. VII. Growth and ion uptake throughout plant development in two varieties of *Hordeum vulgare*, Aust. J. Biol. Sci., 18: 763-768.
- Greenway H, Muns R (1980). Mechanism of salt tolerance of non halophytes. *Annu. Rev. Plant Physiol.*, 31: 149-190.
- Harris D, Joshi A, Khan PA, Gothkar P, Sodhi PS (1999). On-farm seed priming in semi-arid agriculture: Development and evaluation in maize, rice and chickpea in India using participatory methods. *Exp. Agric.*, 35: 15-29.
- Harris D, Raghuwanshi BS, Gangwar JS, Singh SC, Joshi KD, Rashid A, Hollington PA (2001). Participatory evaluation by farmers of 'on-farm' seed priming in wheat in India, Nepal and Pakistan. *Exp. Agric.*, 37: 403-415.
- Hasegawa PM, Bressan RA, Handa AK (1986). Cellular mechanisms of salinity tolerance. *Hortic. Sci.*, 21: 1317-1324.
- Hill HJ (1999). Advances in seed technology. The Haworth Press, Inc. J. New Seeds, 1: 1.
- Iqbal M, Ashraf M, Jamil A, Rehman S (2006). Does seed priming induce changes in the levels of some endogenous plant hormones in hexaploid wheat plants under salt stress? *J. Integr. Plant Biol.*, 48: 181-189.
- Jeannette S, Craig R, Lynch JP (2002). Salinity tolerance of phaseolus species during germination and early seedling growth. *Crop Sci.*, 42: 1584-1594.
- Levitt J (1980). Response of plants to environmental stresses. Water, radiation, salt and other stresses. New York: Academic Press, 2: 607.
- Lin CC, Kao CH (1995). Levels of endogenous polyamines and NaCl inhibited growth of rice seedlings. *Plant Growth Regul.*, 17: 15-20.
- Lombardi T, Fochetti T, Onnis A (1998). Germination of *Briza maxima* L. seed: effects of temperature, light, salinity and seed harvesting time. *Seed Sci. Technol.*, 26: 463-470.
- Maguire JD (1962). Speed of germination aid in selection and evaluation for seedling emergence and vigor. *Crop Sci.*, 2: 176-177.
- Marcar NE (1986). Effect of calcium on the salinity tolerance of Wimmera rye-grass during germination. *Plant Soil*, 93: 129-132.
- Meyer RF, Boyer JS (1981). Osmoregulation, solute distribution, and growth in soybean seedlings having low water potentials. *Planta*, 151: 482-489.
- Mirmohammadi-Maibody SAM (1996). The detached inflorescence of *Cynodon dactylon* as a model system for reproductive studies under salt stress. Ph.D. Thesis, Univ. of London, p. 219.
- Munns R, Gardner PA, Tonnet ML, Rawson HM (1988). Growth and development in NaCl treated Plants. II. Do Na⁺ or Cl⁻ concentrations in dividing or expanding tissues determine growth in barley. *Aust. J. Plant Physiol.*, 15: 529-540.
- Nascimento WM, West SH (1999). Muskmelon transplant production in response to seed priming. *Hort. Tech.*, 9: 53-55.
- Omami EN (2005). Salt tolerance of Amaranth as affected by seed priming. Ph.D. Thesis Univ. of Pretoria etd.
- Othman Y, Al-Karaki G, Al-Tawaha AR, Al-Horani A (2006). Variation in germination and ion uptake in barley genotypes under salinity conditions. *World J. Agric. Sci.*, 2: 11-15.
- Passam HC, Kakouriotis D (1994). The effects of osmoconditioning on the germination, emergence and early plant growth of cucumber under saline conditions. *Sci. Hortic.*, 57:233-240.
- Pardossi A, Bagnoli G, Malorgio F, Campiotti CA, Tofnoni F (1999). NaCl effects on celery (*Apium graveolens* L.) grown in NFT. *Scientia Hortic.*, 81: 229-242.
- Paul SR, Choudhury AK (1991). Effect of seed priming with potassium salts on growth and yield of wheat under rainfed condition. *Ann. Agric. Res.*, 12: 415-418.
- Redman RE (1974). Osmotic and specific ion effects on the germination of alfalfa. *Can. J. Bot.*, 52: 803-808.
- Rehman SP, Harris JC, Bourne WF (1998). Effects of pre-sowing treatment with calcium salts, potassium salts, or water on germination and salt tolerance of Acacia seeds. *J. Plant Nutr.*, 21: 277-285.
- Romero-Aranda R, Soria T, Cuartero J (2001). Tomato plant-water uptake and plant-water relationships under saline growth conditions. *Plant Sci.*, 160: 265-272.
- SAS Inst. (1996). SAS/STAT User's guide, Release 6.12 Edition, Cary, NC.
- Shokohifard G, Sakagami KH, Matsumoto S (1989). Effect of amending materials on growth of radish plant in salinized soil. *J. Plant Nutr.*, 12: 1195-1294.
- Sivritepe N, Sivritepe HO, Eris A (2003). The effects of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. *Sci. Hortic.*, 97: 229-237.
- Strogonov BP (1964). Practical means for increasing salt tolerance of plants as related to type of salinity in the soil. In: Poljakoff-Mayber A., Meyer A.A., (eds). Physiological basis of salt tolerance of plants. Israel Program for Scientific. Translations Ltd, Jerusalem, pp. 218-244.
- Taylor AG (1997). Seed storage, germination and quality. In: Wien, H.C. (ed.), The physiology of vegetable crops. CAB International. Wallingford, UK. pp. 1-36.
- Van Steveninck RFM, Van Steveninck ME, Stelzer R, Lauchli A (1982). Studies on the distribution of Na⁺ and Cl⁻ in two species of lupin (*Lupinus luteus* and *Lupinus angustifolius*) differing in salt tolerance. *Physiol. Plant*, 56:465-473.
- Yildirim E, Guvenc I (2006). Salt tolerance of pepper cultivars during germination and seedling growth. *Turk. J. Agric. For.*, 30: 347-353.
- Yagmur M, Kaydan D (2008). Alleviation of osmotic stress of water and salt in germination and seedling growth of triticale with seed priming treatments. *Afr. J. Biotechnol.*, 7(13): 2156-2162.
- Zhu S, Hong D, Yao J, Zhang X, Luo T (2010). Improving germination, seedling establishment and biochemical characters of aged hybrid rice seed by priming with KNO₃ + PVA. *Afr. J. Agric. Res.*, 5(1): 78-83.