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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 $CaCl_2$, -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, $CaCl_2 \cdot 2H_2O$, 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 $CaCl_2$ and $CaSo_4$ 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 (K_2SO_4) 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 objecttive 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 $CaCl_2$ 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 20º C for 10 days. Finally, the best treatments for *A. elongatum* Host; $CaCl_2$, -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 31º 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:

$$EI = \Sigma (E_t / T_t)$$

Where E_t is the number of emerged seedling every day other than the last day, and T_t 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 70º 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 × species × 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 × 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 × 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, respecttively. 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 (KH_2PO_4) 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 Salinty	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. elongatum																		
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. bulbosum																		
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.

		Correlation coefficients							
Treatment	**Traits**	**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 ($CaCl_2$ 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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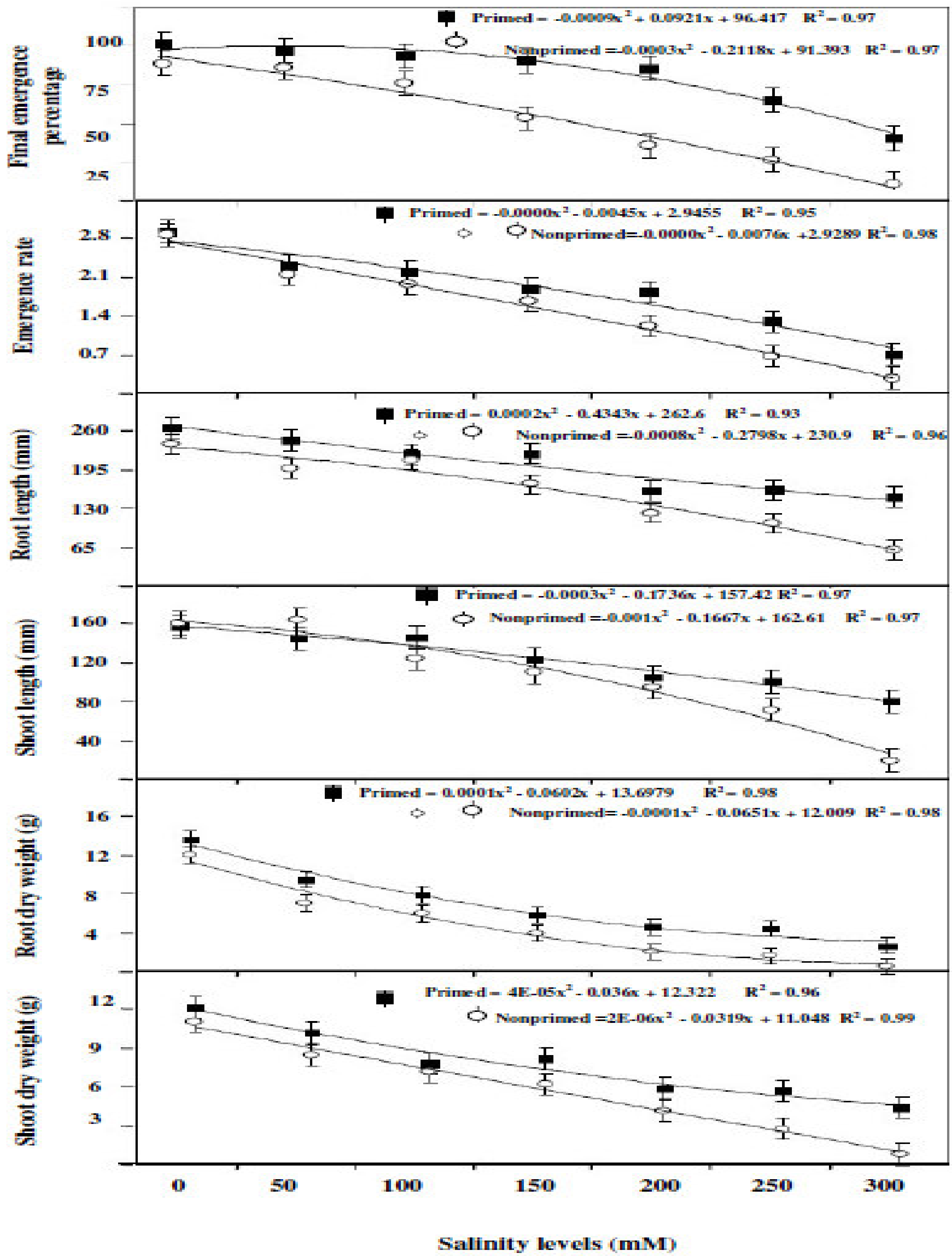

Figure 1. Regression relationships between salinity levels and FEP, ER, RL, SL, RDW and SDW as affected by seed priming at early seedling growth stage. Each data point is the mean of two cool season grasses and vertical lines indicate standard errors of means (n=8).

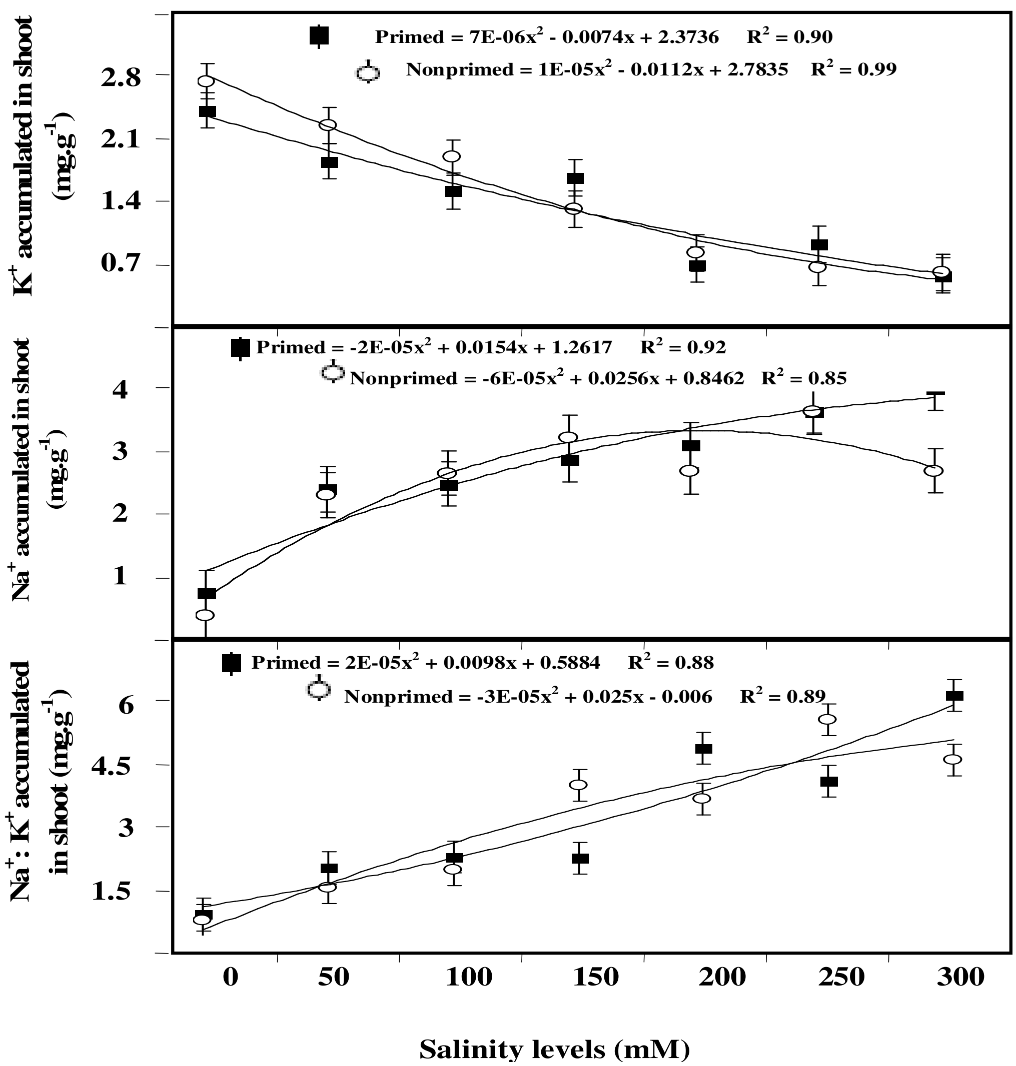

Figure 2. Regression relationships between salinity levels and K^+, Na^+ and Na^+: K^+ ratio accumulated in shoot as affected by seed priming at early seedling growth stage. Each data point is the mean of two cool season grasses and vertical lines indicate standard errors of means (n=8).

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