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IMPROVING YIELD PERFORMANCE OF LANDRACE WHEAT UNDER SALINITY STRESS USING ON-FARM SEED PRIMING

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Abstract

The low wheat yield in salt-affected soils is often attributed to low seed germination, emergence and poor seedling establishment. Seed priming technology has been found valuable but is not extensively used in salt affected areas. The priming experiment was conducted in farmer's field having two salinity levels (ECe 8.01 dSm^{-1} pH 8.10 and ECe 11.90 dSm^{-1} pH 8.01 respectively) with five landrace genotypes i.e. SALU1a, SALU1b, SALU2, SALU3, SALU4 and a local commercial variety TJ-83. The priming treatments resulted significant increased germination percentage as well as induced earliness of germination, emergence, heading and maturity of all the genotypes at both salinity levels. The genotype SALU4 was observed having the highest germination percentage under priming while SALU2 was the lowest. Similarly, the number of days to emergence, heading and maturity decreased significantly in primed seeds at both salinity levels while genotype SALU4 was found earliest emerging, heading and maturing. The priming increased 1000-grain weight (g) significantly and genotype SALU1b was observed with highest 1000-grain yield.

Introduction

Most of the irrigated lands of Pakistan, where wheat and rice are grown in same system, are facing the problem of increasing soil salinity and sodicity. About 8.133 million ha land is affected by salinity/sodicity (Azhar & Tariq, 2003) and majority of the areas are out of cultivation. The rate of increase in this problem is as high as about 40,000 ha of arable land are lost annually and even good quality irrigation water can add up to 5 tons salt $ha^{-1}year^{-1}$ (Ghassemi *et al*., 1995). The wheat is grown on all type of soils and is classified as a moderate salt tolerant crop (Mass & Hoffman, 1977). Since, the yield is a best measure of crop tolerance to salinity, therefore the yield losses of wheat on low salt-affected soils and moderate salt-affected soils are estimated 25% and 65% respectively (Qayyum & Malik, 1988). To develop the new high yielding wheat genotypes and the developed methods, which can increase the crop yield on such problem soils, is main objective of current research. A landrace is a mixture of genotypes of a crop that have resulted from natural selection or farmer's saving seed of the best lines for sowing again the next year, following centuries of cultivation in the presence of different environmental stresses, they are genetically well adapted to the stress environments. The salt tolerant abilities of landraces have been evaluated by many workers for eaxample Rana (1986) observed a number of high salt tolerant landraces from Rajasthan, India, whereas Martin *et al*., (1994) during screening 1700 wheat accessions found landraces more tolerant to salinity than others. The same results were reported by Kingsbury & Epstein (1984) evaluating 29 landrace lines from 5000 with high salt tolerance.

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Table 1. The origin of 5 Landrace genotypes and their sodium Na^+ content and potassium/ sodium (K^+/Na^+) ratio under controlled environment (n =4).

Variety	Origin under controlled conditions	Sodium Na^+ (150 $mol.m^{-3}$)		Potassium/Sodium K^+/Na^+	
		Mean	SE ±	Mean	SE ±
SALU1a	Landrace B25/4	57.5	6.45	5.54	0.86
SALU1b	Landrace B25/4	57.2	5.60	5.45	0.57
SALU2	Landrace B25/4	74.6	14.80	6.45	1.71
SALU3	Landrace B25/4	69.8	8.30	5.16	0.68
SALU4	Landrace B25/4	65.7	4.97	6.06	0.48

Source: Mahar (1999).

Mahar *et al.*, (2003) observed high salt tolerance as well as good yield potential in landraces. However, they reported that the yield was low than the commercially developed varieties. The major factor contributing to the limited yield in wheat, on salt-affected soils, is low germination and poor crop stand and establishment (Harris, 1992; Harris, 1996). The on-farm seed priming has been found a technology with minimum risk to enhance the pre-sowing seed metabolic activities (Gurusinghe *et al.*, 1999) thus the effects of salt stress are avoided at germination level. In result priming not only increases the germination percentage but also it enhances the earliness (Rashid *et al.*, 2002) which leads to better crop stand and consequently results in high yields. The present study was carried out with a primary objective to measure yield potential of landraces, and to analyze efficacy of on-farm seed priming technology in improving yield potential of landraces particularly on salt-affected soils.

Materials and Methods

The plant material: The five Landrace wheat genotypes i.e., SALU1a, SALU1b, SALU2, SALU3 and SALU4 along with local commercial TJ-83 as check were selected for this study. The selection of landrace genotypes was made on the basis of their previous performance to maintain high Na^+ content and high shoot Na^+/K^+ ratio when subjected to 150mM NaCl solution during their development under the controlled conditions of Pen-y-Ffrid field station, University of Wales, Bangor, UK (Table 1). The TJ-83 was added to the experiment with a high yield potential under local environmental conditions.

The germination experiment was conducted in laboratory of Botany Department, Shah Abdul Latif University, Khairpur, during 2005-2006. The seeds of 6 wheat cultivars i.e., SALU1a, SALU1b, SALU2, SALU3, SALU4 (All Landraces) and TJ-83 (local commercial) were sown in oven sterilized 90 mm Petri dishes lined with three layers of tissue paper covered by double layer of filter paper. The tissue papers were used to keep the environment saturated for long periods. The 30 seeds per dish per genotype were sown with four replications. The pre-sowing treatments were,

T1= Control i.e., dry seeds.

T2= Seeds soaked in double quantity of water for 10 hours.

The post-sowing treatments were,

T1= Irrigation with normal water.

T2= Irrigation with 200mM Nacl: Cacl solution with Na: Ca molar ratio of 20:1 (Gorham *et al.*, 1986).

The lid covered dishes were kept in growth chamber (Eylatron, Eyla Japan) at 20°C day/night constant temperature and were irrigated with the respective solutions when ever filter papers began to dry. The germination was recorded on the emergence of radicle up to 2mm. The data for germination percentage and rate was recorded after each 12 hours up to 72 hours.

The field experiment: During, fall 2005-2006, the seeds of all genotypes were soaked overnight in double quantity of tap water (described primed hereafter) and surface dried in shadow. Another seed set was kept un-soaked (described un-primed hereafter). The primed and un-primed seeds of each genotype were sown in two localities of village Lanishan having ECe 8.01 and 11.90 dSm^{-1} and pH 8.10 and 8.01 respectively. The complete randomized block design having priming and un-priming treatments in main plots and genotypes in sub-plots with four replications were used. The data for emergence (when 50% plants emerged from soil), heading (when 50% plants headed) and maturity (when 50% heads turned to golden colour) along with plant height (cm), grains per spike, grain weight per plant were recorded and subjected to statistical analysis.

Statistical analysis: The data was statistically analyzed for analysis of variance to assess the significant differences among variables. While the individual mean differences for treatments, genotypes as well as salinity levels were analyzed using least significant difference test at 0.05% probability (Steel & Torie, 1980).

Results and Discussions

Germination: The priming treatments showed significant increase ($p>0.01$) in germination of all genotypes (Fig. 1) as compared to the non-priming treatments. Despite restriction the primed seeds showed high germination under saline conditions. The salinity restricted all genotypes to reach 100% germination under un-primed conditions but however under primed conditions it was obtained in all genotypes. The seed water uptake is important factor for germination and it has been found that increasing salinities caused significant decrease in water uptake by rice seeds (Gonzalez & Ramirez, 1999). Gulnaz *et al*., (1999) observed that pre-sowing seed soaking in growth regulators could mitigate the germination reduction caused by salinity in wheat. In our study it has been maintained by pre-sowing seed priming and the similar findings has been reported by Rashid *et al*., (2002). The early and faster metabolic activities, induced by priming, are reported which increased rapid rates of radicle emergence (Heydecker & Coolbear, 1977; Bradford, 1986 and Khan, 1992). Thus seed priming has typically been used to enhance germination (Taylor *et al*., 1998). The priming hastened earliness of germination, as at 12 hrs there was no germination in un-primed seeds irrigated with either salt solution or water while at same time it started in the primed seeds. The primed seeds irrigated with water obtained 100% germination after 48 hours while it took 72 hours in un-primed seeds irrigated with water (Fig. 1). Under salt conditions the 100% germination was also obtained after 48 hrs in primed seeds while it did not reach to this point up to 72 hrs in un-primed seeds (Fig. 1).

The genotype SALU4 was observed with significantly higher ($p>1\%$) germination percentage under primed conditions irrigated with salt solution, (Fig. 2.) and took minimum time to reach the final percentage. Thus it was considered as early germinating genotype under salt stress if primed. The lowest germination % was observed in genotype SALU2 under primed and irrigated with solution. Thus it was found late germinating and most adversely affected by salt solutions despite priming.

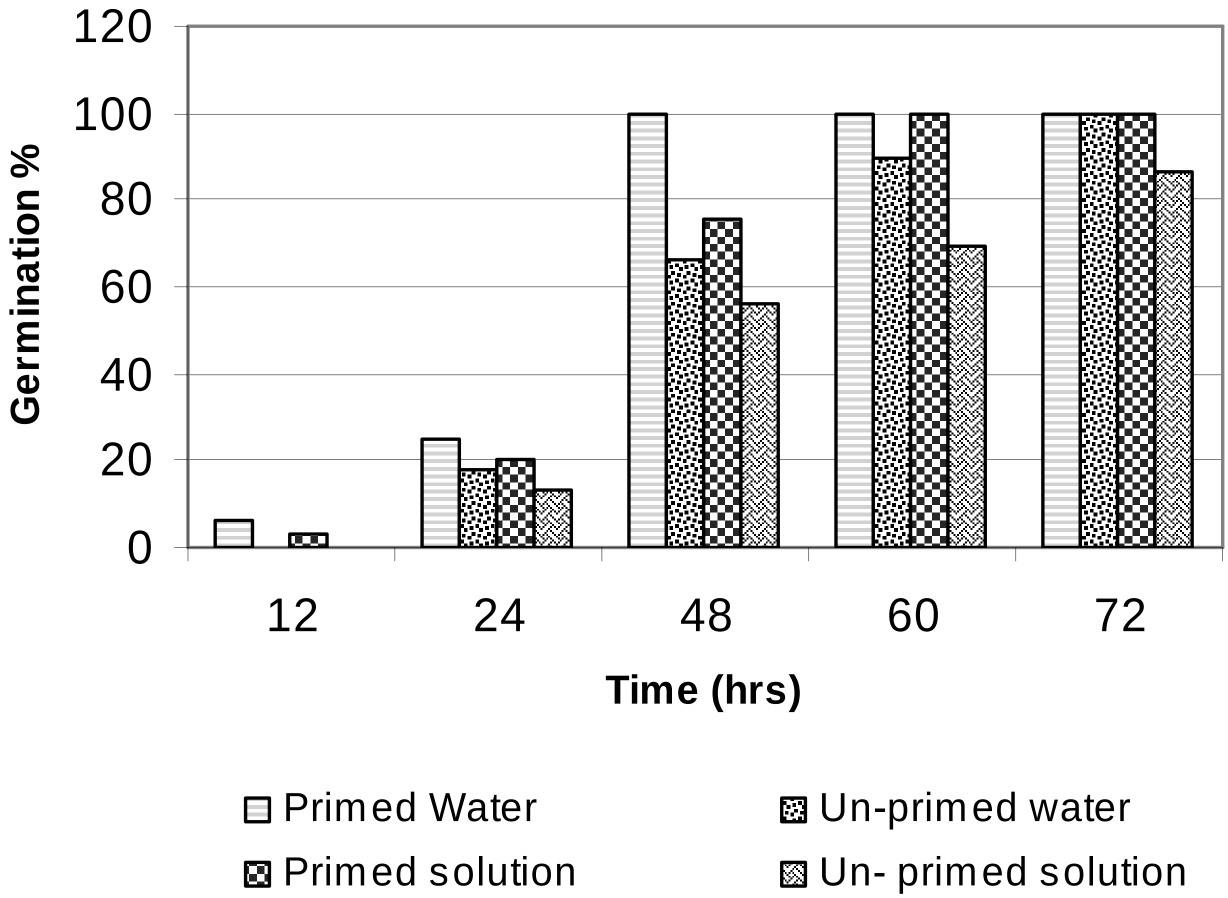

Fig. 1. Effects of priming treatments on the mean percentage germination of landrace wheat genotypes at various time intervals.

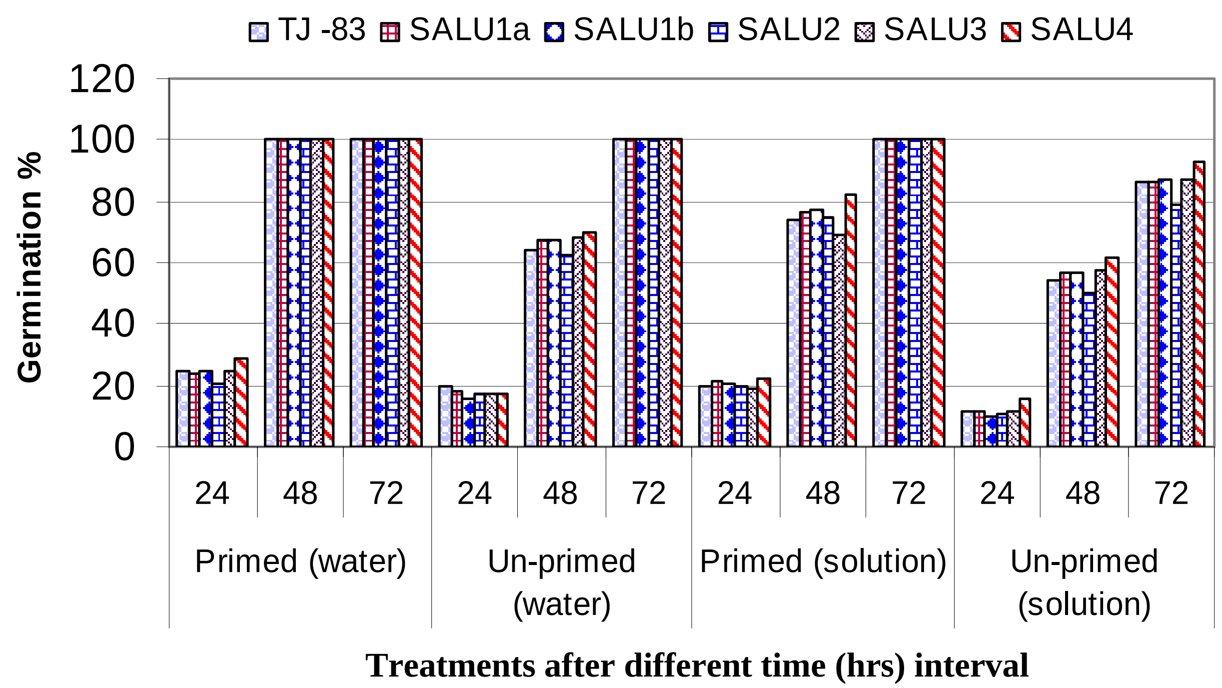

Fig. 2. Effects of seed priming on the germination percentage of six genotypes under different time intervals.

The field experiments: The analysis of variance showed highly significant differences (p>1%) for days to 50% emergence between treatments and genotypes (Table 2). The least significant test LSD (0.05%) showed high differences among mean values of treatments as well as genotypes at both higher and lower salinities. The LSD (0.05%) for sites, however, was found non-significant (Table 2). The number of days to heading significantly decreased in primed treatment at both salinity levels. The analysis of variance showed that treatments and genotypic differences were highly significant (p>1%) (Table 3). LSD (0.05%) indicated that there were high differences between individual means of genotypes as well as treatments (Table 3), while the non-significant differences were found between sites.

The genotype SALU4 was found earliest heading genotype with mean days to 50% heading 68.25 and 76.25 under primed treatments at site 1 and at site II, 67.50 and 74.12 under primed and non-primed treatments respectively (Table 3). The priming hastened early maturity in all genotypes. However, the genotype SALU4 was found earliest maturing at both sites under primed as well as non-primed treatments (Table 4). A significant difference at p>1% was found between treatments while the salinity levels didn’t produce significant differences. LSD (0.05%) confirmed the individual treatment mean differences as well as individual genotypic mean differences.

Despite positive effects on plant life cycle, the priming, however, did not show any effect on the agronomic characters like plant height and number of grains per plant while the genotypes and sites were observed highly significant for both the traits (Tables 5 and 6). The genotype SALU1b was found producing significantly higher above ground biomass and number of grains per plant at both sites although there was a significant decrease with increasing salinity stress (Tables 5 and 6). The priming affected grain weight (g) per plant positively and the significant percentage increase has been observed in the primed seeds as compared to non-primed seeds. The treatments, genotypes and sites were found significant at p>1% (Table 7). The genotype SALU1b was found producing highest grain weight (g) per plant. Since, the earliness is valuable particularly in areas of wheat cultivation where temperature increases during grain-filling periods. High temperature after anthesis, particularly in wheat and barley, is an important yield-limiting factor affecting grain size (Wardlaw *et al*., 1989). Although the plant height and number of grains per plant were not affected by priming but however the 1000-grain weight was observed highly positively affected. This ultimately leads to high grain yields of wheat genotypes particularly under low fertile soils.

It is concluded from the present study that the on-farm seed priming has enhanced germination in all genotypes including induced earliness in germination, emergence, heading as well as maturity of the genotypes. Due to the earliness and enhanced germination the overall grain yield increased significantly suggesting that the technique can be a valuable tool to enhance wheat yield on salt-affected soils.

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Table 2. The effects of seed priming on the days to 50% emergence of six wheat genotypes grown under two salinity levels. The values are mean of four replications.

Varieties	Site I		Site II		Mean	
	ECe 8.01 dSm^{-1} pH 8.10		ECe 11.90 dSm^{-1} pH 8.01			
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	3.75	7.25	3.50	6.75	5.50	5.13
SALU1b	4.25	7.25	4.00	7.75	5.75	5.88
SALU2	4.25	7.50	4.25	7.50	5.88	5.88
SALU3	5.00	6.75	4.75	7.75	5.88	6.25
SALU4	3.75	7.75	3.75	7.25	5.75	5.50
TJ-83	4.25	7.25	4.25	7.00	5.75	5.63
Mean	**4.21**	**7.29**	**4.08**	**7.33**	**5.75**	**5.71**
$LSD_{(0.05)}$ for treatments				0.28		
$LSD_{(0.05)}$ for varieties				0.48		
$LSD_{(0.05)}$ for sites				0.28		

Table 3. The effects of seed priming on the days to 50% heading of six wheat genotypes grown under two salinity levels. The values are mean of four replications.

Varieties	Site I		Site II		Mean	
	ECe 8.01 dSm^{-1} pH 8.10		ECe 11.90 dSm^{-1} pH 8.01			
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	82.25	94.25	82.25	90.21	88.25	86.23
SALU1b	85.75	95.25	85.75	96.25	90.50	91.00
SALU2	80.25	88.75	80.00	90.00	84.50	85.00
SALU3	85.25	93.64	85.25	93.69	89.45	89.47
SALU4	80.25	90.75	80.25	89.75	85.50	85.00
TJ-83	68.25	76.25	67.50	74.12	72.25	70.81
Mean	**80.33**	**89.81**	**80.08**	**89.00**	**85.07**	**84.58**
$LSD_{(0.05)}$ for treatments				0.28		
$LSD_{(0.05)}$ for varieties				0.48		
$LSD_{(0.05)}$ for sites				0.28		

Table 4. The effects of seed priming on the days to 50% maturity of six wheat varieties grown under two salinity levels. The values are mean of four replications.

Varieties	Site I		Site II		Mean	
	ECe 8.01 dSm^{-1} pH 8.10		ECe 11.90 dSm^{-1} pH 8.01			
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	115.75	124.75	115.25	124.75	120.25	120.00
SALU1b	124.75	132.50	122.50	132.25	128.63	127.38
SALU2	115.25	122.75	115.75	122.50	119.00	119.13
SALU3	132.50	136.00	130.75	134.25	134.25	132.50
SALU4	115.25	122.50	115.00	121.25	118.88	118.13
TJ-83	115.50	124.25	115.25	124.50	119.88	119.88
Mean	119.83	127.13	119.08	126.50	123.48	122.83
$LSD_{(0.05)}$ for treatments				0.29		
$LSD_{(0.05)}$ for varieties				0.50		
$LSD_{(0.05)}$ for sites				0.29		

Table 5. The effects of seed priming on plant height (cm) of six wheat varieties grown under two salinity levels. The values are mean of four replications.

Varieties	Site I ECe 8.01 dSm^{-1} pH 8.10		Site II ECe 11.90 dSm^{-1} pH 8.01		Mean	
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	76.38	75.25	65.25	62.75	75.81	64.00
SALU1b	99.38	97.25	91.25	91.00	98.31	91.13
SALU2	104.08	102.25	86.38	84.88	10.3.16	85.63
SALU3	76.33	75.75	63.13	62.75	76.04	62.94
SALU4	77.25	77.00	70.63	69.25	77.13	69.94
TJ-83	67.00	82.77	66.25	64.75	74.89	65.50
Mean	**83.40**	**85.05**	**73.81**	**72.56**	**84.22**	**73.19**
$LSD_{(0.05)}$ for treatments				2.01		
$LSD_{(0.05)}$ for varieties				3.48		
$LSD_{(0.05)}$ for sites				2.01		

Table 6. The effects of seed priming on number of grains per plant of six wheat varieties grown under two salinity levels. The values are mean of four replications.

Varieties	Site I ECe 8.01 dSm^{-1} pH 8.10		Site II ECe 11.90 dSm^{-1} pH 8.01		Mean	
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	61.50	61.75	53.25	52.00	61.63	52.63
SALU1b	75.00	72.00	68.25	67.25	73.50	67.75
SALU2	70.50	69.00	58.50	58.25	69.75	58.38
SALU3	66.00	64.75	54.75	54.75	65.38	54.75
SALU4	56.25	55.00	55.50	56.75	55.63	56.13
TJ-83	47.00	42.75	47.25	46.75	44.88	47.00
Mean	62.71	60.88	56.25	55.96	61.80	56.11
$LSD_{(0.05)}$ for treatments				2.37		
$LSD_{(0.05)}$ for varieties				4.11		
$LSD_{(0.05)}$ for sites				2.37		

Table 7. The effects of seed priming on grain weight (g) per plant of six wheat varieties grown under two salinity levels. The values are mean of four replications.

Varieties	Site I ECe 8.01 dSm^{-1} pH 8.10		Site II ECe 11.90 dSm^{-1} pH 8.01		Mean	
	Primed	Un-primed	Primed	Un-primed	Site 1	Site II
SALU1a	6.15	4.65	5.33	4.20	5.40	4.76
SALU1b	7.50	5.85	6.83	5.40	6.68	6.11
SALU2	7.05	5.78	5.85	4.88	6.41	5.36
SALU3	6.60	4.88	5.48	4.43	5.74	4.95
SALU4	5.63	4.58	5.55	4.05	5.10	4.80
TJ-83	4.70	4.28	4.75	3.83	4.49	4.29
Mean	6.27	5.00	5.63	4.46	4.74	5.05
$LSD_{(0.05)}$ for treatments				0.24		
$LSD_{(0.05)}$ for varieties				0.42		
$LSD_{(0.05)}$ for sites				0.24		

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