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Influence of halopriming on physiological traits and yield of wheat under saline condition

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Abstract

Soil salinity is a widespread production constraint for wheat in Pakistan. The feasible options to overcome soil salinity are salt tolerant varieties and treatment of seed with various priming agents. Concern for sustainable production of wheat crop led to renewed interest in management of soil salinity through salt tolerant varieties and seed priming. In order to address the problem the current study was carried out to investigate about the role seed priming (30 mM NaCl) in comparison with dry seed in ameliorating the impact of various levels of salt stress (control, 4, 6 and 8 dSm^{-1}) on growth and physiological traits of two wheat varieties (Bakhtawar and Auqab). Results of the study confirmed significant influence of salt stress and varieties on all the studied traits. Gradual increase of salt stress reduced all the traits gradually. Salinity level of 8 dSm^{-1} decreased spikes $plant^{-1}$ by 38%, grains $spike^{-1}$ by 37%, hundred grains by 24%, grain yield $plant^{-1}$ by 68%, biological yield $plant^{-1}$ by 56%, harvest index by 29%, and shoot K^+/Na^+ ratio by 60%. The impact of seed priming (30 mM NaCl) was only non-significant on grains $spike^{-1}$ and it had positively influenced spikes $plant^{-1}$, grains $spike^{-1}$, 100-grain weight, plant grain yield, biological yield, harvest index, and shoot K^+/Na^+ ratio by 8.52%, 0.97%, 4.245, 12.17%, 24%, 11.68%, and 12.28% respectively with highest influence on Bakhtawar. Bakhtawar performed better than Auqab and maximum spikes $plant^{-1}$ (3.18), grains $spike^{-1}$ (36.17), hundred grains weight (2.94 g), grain yield $plant^{-1}$ (3.66 g), biological yield $plant^{-1}$ (10.54 g), harvest index $plant^{-1}$ (34.33 %), and shoot K^+/Na^+ ratio (1.44) were confirmed for it. In conclusion it is stated that salinity stress had adversely influenced the yield and physiological traits of wheat varieties. However, seed treatment with NaCl had alleviated the negative effects of salt stress up to great extent.

Key words: Wheat, Soil salinity, Seed priming, Grain yield, Shoot K^+/Na^+ ratio.

1.0 INTRODUCTION

Soil salinity is a stringent problem that affects crops yield and distribution globally [1,2,3]. It is defined as salts accumulation in rhizosphere, mainly sodium (Na+) and chloride (Cl-) ions [4]. Recent studies have concluded that 33% of irrigated and 20% of the cultivated lands are highly saline, with 10% annual increase [5]. The seed germination process and its establishment can be significantly inhibited by increased salt stress due to specific ion effect and increased osmotic potential. Germination of seed and establishment of seedling are the most susceptible phases to saline stress [6]. Salt stress is resulted from various harmful cellular processes and may hinder plant growth directly by injuring the growing cells or it reduces water availability to growing regions and photosynthates [7]. The solutes osmotic potential is reduced and the plant become unable to extract optimum amount of water for its growth and development from the surrounding media, that leads to reduced, germination, productivity or plant death [8,9]. The osmotic effect and specific ionic effect due to saline stress lead secondary stresses like oxidative stress due to excessive production of reactive oxygen species [10].

Wheat is a moderately salt tolerant crop [11,12]. In Pakistan, wheat production has been declined in recent the years. Soil salinity has affected more than 4.5 Mha of agricultural land of Pakistan and an average of 65% yield reduction is noted in moderately saline affected areas of the country [13,14]. In Pakistan, horizontal growth in Agriculture through allocation of more land resources is not feasible option. In addition to that high use of fertilizers and pesticides beyond certain limits is not feasible due to national health and environmental problems. Vertical growth in agriculture in term of high yield through technological improvement and efficiency for high growth of agriculture is the only feasible option. If wheat genotypes with potential salt tolerance are identified, the yield production of slight and moderate salt affected regions can be increased manifold. Furthermore, the identification salt tolerant genotypes are a valuable and cost effective approach to overcome the salinity hazard [15]. Along this, various priming agents like $CaCl_2$, KCl and NaCl are found very useful to alleviate the influence of salinity in wheat production [16,17]. In general, seed priming enhances seed emergence and seedling growth [18]. Cayuela et al. (1996) discovered that NaCl priming of tomato seeds could play key role in early emergence of the crop in saline condition.

2.0 MATERIALS AND METHODS

To evaluate the effects of primed seeds with organic salts on various yield and physiological traits of wheat under saline conditions, the present research was conducted in a greenhouse at the The University of Agriculture Peshawar, Khyber Pakthunkhwa, Pakistan using completely randomized design with tree replications. In case of seed priming, seed of 2 wheat varieties (Auqab and Bakhtawar) were primed in 30 mM NaCl solution at 25 ^{0}C for twelve hours. The soil media using plastic pots of 380.28 cm^2 was applied with desired salinity levels of control (0.6 dSm^{-1}), 4 dSm^{-1}, 6 dSm^{-1} and 8 dSm^{-1} for sowing Primed (P) and unprimed (UP) seeds. Data were collected on, spikes per plant, grains per spike, 100-grain weight and shoot K^+ contents.

Spikes plant^{-1} data were recorded by counting spikes of three five random plant per treatment and after that the mean values were calculated. Grains of five randomly selected spikes per treatment were counted and then averaged to record grain per spike data. Weight of random hundred grains in each treatment was recorded to record 100 grain weight data. All the plants per treatment were harvested, sun dried, weighed and averaged to record biological yield plant^{-1} data. At the end spikes in each treatment were separated, dried, threshed, weighed and averaged to record grain yield per plant. For harvest index data the following equation was used.

$$\text{Harvest index} = \frac{\text{Economic yield (grain)}}{\text{Biological yield}} \times 100$$

Shoot Na^+ and K^+ contents were measured in accordance with US Salinity Staff (1954) techniques to result K^+/Na^+ ratio.

Statistical software MSTAT-C was used for analysis of data and measuring least significant difference (LSD). On the bases of F-test of the analysis of variance, the individual treatments means were compared at 5% probability level [19].

3.0 RESULTS AND DISCUSSION

Spikes plant^{-1}

Table-1 confirmed significant ($P \leq 0.05$) influence of salt stress on number of spikes plant^{-1}. The impact of seed priming and varieties on spikes plant^{-1} was also significant. Interactive effect among all possible combinations except salt stress x priming treatment x varieties was also found significant.

The number of spikes plant^{-1} was significantly reduced with gradual increase in salinity. Lowest spikes plant^{-1} (2.22) were recorded in the treatments of 8 dSm^{-1} as compared to 3.63 spikes plant^{-1} from control. The data showed highest spikes plant^{-1} of 2.93 from primed seed treatment when compared with dry seed treatment (2.70 spikes plant^{-1}). Significant response of varieties in term of spikes plant^{-1} was also observed. Bakhtawar exhibited highest spikes plant^{-1} of 3.18 when compared with 2.45 spikes plant^{-1} of Auqab.

Grains spike^{-1}

Data concerning the trait revealed consistent reduction in grains spike^{-1} in response of rising salinity levels. Minimum grains spike^{-1} (27.58) were noted in 8 dSm^{-1} and minimum were noted in control treatments (44.48 grains spike^{-1}). The data further reflected that seed priming slightly increased grains spike^{-1}. Maximum grains spike^{-1} of 35.27 were noted for primed treatments. Whereas, lowest number of 34.93 grains spike^{-1} was noted from dry seed treatments. The data further explored maximum grains spike^{-1} (36.17) for Bakhtawar when compared with Auqab (34.03 grains per spike).

100-grain weight (g)

Mean values presented in Table-1 shows that increasing salinity levels had consistently reduced 100 grains weight of wheat crop. Maximum value (3.30 g) was noted in control followed by 3.00 g and 2.73 g from the treatments of 4 dSm^{-1} and 6 dSm^{-1} respectively. While minimum value of 2.52 g was noted in 8 dSm^{-1}. Seed priming markedly increased 100-grain weight. Highest value of 2.95 g was noted for primed seed as compared to 2.83 g in no seed priming treatment. Inconsistent response of varieties in term of 100 grains weight was observed. It is evident from the data that Bakhtawar had attained maximum value of 2.94 g as compared to 2.83 g for Auqab.

Grain yield (g) plant^{-1}

Table-1 indicated marked reduction in grain yield with increasing level of salinity. Minimum grain yield plant^{-1} (1.71 g) was recorded in 8 dSm^{-1} level when compared with control (5.28 g grain yield plant^{-1}). The data further explored that seed priming had significantly enhanced the grain yield. Highest value of 3.41 g was noted for seed priming treatment while lowest grain yield per plant of 3.04 g plant^{-1} for unprimed seeds. The data further revealed minimum grain yield of 2.79 g plant^{-1} for Auqab when compared with Bakhtawar (3.66 g).

Table 1. Yield traits of wheat varieties as influenced by halopriming under saline environments.

Treatment	Spikes plant^{-1}	Grains per spike	100-grain weight (g)	Grain yield plant^{-1}
Bakhtawar	3.18 a	36.17 a	2.94 a	3.66 a
Auqab-2000	2.45 b	34.03 b	2.83 b	2.79 b
0	3.63 a	44.48 a	3.30 a	5.28 a
4	2.82 b	35.62 b	3.00 b	3.27 b
6	2.58 c	32.70 c	2.73 c	2.65 c
8	2.22 d	27.58 d	2.52 d	1.71 d
Primed	2.93 a	35.27	2.95 a	3.41 a
Un-primed	2.70 b	34.93	2.83 b	3.04 b
SxV	**	**	**	**
SxP	*	NS	**	**
PxV	**	NS	**	**
PxSxV	NS	NS	NS	NS

NS = Non-significant at 95% probability level.

Biological yield plant^{-1} (g)

The data showed consistent decrease in biological yield plant^{-1} with each increment of salt stress. Lowest biological yield (g) plant^{-1} of 6.06 g was observed in 8 dSm^{-1} followed by 9.50 g and 11.06 g from the treatments of 6 dSm^{-1} and 4 dSm^{-1} as compared with highest biological yield plant^{-1} of 13.87 g from control. Table-2 further showed marked impact of seed priming on biological yield plant^{-1} of various wheat varieties. Highest biological yield plant^{-1} of 10.24 g was recorded from primed treatments as compared to dry seeds (10.00 g plant^{-1}). The results further revealed highest biological yield plant^{-1} of 10.54 g for Bakhtawar and lowest biological yield (g) plant^{-1} of 9.70 g for Auqab.

Harvest index (%)

Mean values of the data confirmed highest harvest index (%) of 38.05 for control treatment while lowest harvest index (%) of 27.09 was recorded in salinity level of 8 dSm^{-1}. Seed priming positively influenced harvest index (%) at significant level. Seed priming treatments showed maximum harvest index (%) of 32.23 when compared with minimum harvest index (%) of 28.86 from dry seed treatments. Likely a variable affect of varieties on harvest index is also evident from mean values of the data. Bakhtawar produced highest value of 34.33 and Auqab produced lowest harvest index (%) of 26.76.

Shoot K^+/Na^+ ratio

According to our observations a stead reduction was noted in shoot K^+/Na^+ ratio with increasing levels of salinity. The data in table-2 revealed highest shoot K^+/Na^+ ratio of 2.03 for control treatment. Salinity levels of 4 and 6 dSm^{-1} were ranked 2nd and 3rd while lowest shoot K^+/Na^+ ratio of 0.81 was recorded in salinity level of 8dSm^{-1}. The influence of seed priming was also found significant and greater shoot K^+/Na^+ ratio of 1.28 was noted for seed priming while lowest shoot K^+/Na^+ ratio of 1.14 was recorded in dry seed treatment. The data further discovered significant influence of varieties on the ratio. The highest value of 1.44 was noted for Bakhtawar as compared to the lowest value of 0.99 for Auqab.

Table-2. Biological yield, harvest index, and shoot K^+/Na^+ ratio of wheat varieties as influenced by halopriming under saline environments.

Treatments	Biological yield	Harvest index (%)	Shoot K^+/Na^+ ratio
Varieties			
Bakhtawar	10.54 a	34.33 a	1.44 a
Auqab	9.70 b	26.76 b	0.99 b
Salinity (dSm^{-1})			
0	13.87 a	38.05 a	2.03 a
4	11.06 b	29.32 b	1.07 b
6	9.50 c	27.73 c	0.94 c
8	6.06 d	27.09 d	0.81 d
Seed Priming			
Haloprimed	10.24 a	32.23 a	1.28 a
Unprimed	10.00 b	28.86 b	1.14 b
Interactions			
S x V	**	**	**
S x P	*	**	*
P x V	*	**	**
P x S x V	NS	NS	NS

NS = Non significant at 95% probability level.

4.0 Discussion

Wheat is major staple crop that makes significant contribution to global food security. However, its successful production is seriously threatened by soil salinity and climate change [20,21]. In the present study, inconsistent response of varieties to salinity levels under different seed conditions regarding yield components was recorded. Our results revealed that Bakhtawar was on the top of the tolerant category when compared with Auqab. Seed priming with NaCl gradually reduced the negative impact of salinity. Positive impact of seed priming was more visible in Bakhtawar. Adverse impact on yield traits was due to higher salinity levels which decreased the water potential of the soil solution and consequently physiological drought occurred. To tackle this problem, plants used metabolic energy at the expense of their growth and yield reduction which ultimately reduced yield contributing traits of wheat crop [22]. Increased production of wheat may be attributed to enhanced translocation rate of photosynthates from leaves to grains due to pretreatment of hormones [23,24]. EL Sabagh et al. [25] exposed various wheat cultivars to salinity stresses. They reported that all agronomic and biochemical parameters were significantly reduced by salt stress. They further revealed that tolerant cultivars had markedly highest fertile tillers. Ahmad et al. [26] investigated that spike length and grain weight spike-1 were gradually decreased by salinity in comparison with control. Grains spike-1 and 1000 grain weight of wheat genotypes declined significantly with increasing application of salinity. However, salt sensitive genotypes showed marked reduction in these parameters [27]. Likely, Rady et al. [28] found seed treatment with biostimulants very useful in ameliorating the drastic impacts of salinity.

Salinity levels and halopriming had significantly affected plant harvest index. Bakhtawar was ranked first in term of highest harvest index when exposed to various salinity levels. Primed treatments resulted marked increase in harvest index plant-1. Salt stress impaired assimilation of photosynthates and efficiency of translocation [29]. The possible reason for yield in salinity stressed wheat are decrease in assimilates requirement of vegetative growth and effective utilization of assimilates [30]. Therefore improvement in grain yield of wheat genotypes in saline conditions suggests that sufficient carbohydrates source might have been available by halopriming to the grains in the stage of grain filling by decreasing assimilate requirements of vegetative organs [31].

Greater K+ contents is a good marker to measure salinity tolerance in a plant. And accumulation of Na+ ions can suppress uptake of K+ ions from soil while maintenance of appropriate K+/Na+ ratio is crucial for salt tolerance of plants [32]. To minimize the hazards of Na+, K+ concentration plays the role by improving plant water status [33]. Our findings pertained significant influence of halopriming and salt stress on shoot K+ content of different wheat varieties. Bakhtawar was graded first having maximum K+ contents in comparison Auqab. The key aspect of salinity tolerant species is their cells capability to keep optimum K+/Na+ ratio [34]. Through selective transport of ions from soil, the tolerant genotypes could avoid the salt stress by sustaining higher K+ contents versus Na+ to maintain a comparatively stable K+/Na+ ratio [35]. Ibrahim et al. [36] discovered significant increase in K+ content of different wheat varieties in saline stressed conditions. While the same increase was noted greater in salt tolerant cultivars and lower in salt sensitive cultivars by Bhatti et al. [37]. According to our findings, seed treatment with organic salt led to significant increment in shoot K+ contents reduction in Na+ contents to obtain highest K+/Na+ ratio with greater values for Bakhtawar. Iqbal et al. [38] reported significant increment of shoot K+ ions in salinity tolerant variety Inqilab-91 with seeds treatment with various priming agents (NaCl, CaCl2, distilled water, and KCl,).

5.0 CONCLUSION

Soil salinity adversely affected the growth, yield, and physiological traits of wheat, with increasing salinity levels causing progressive reductions in performance. Seed priming with NaCl (30 mM) effectively alleviated salinity-induced stress by improving yield components, biomass production, and ionic balance, particularly the shoot K^+/Na^+ ratio. Among the tested varieties, Bakhtawar showed greater tolerance to salinity than Auqab. These results indicate that the combined use of salt-tolerant varieties and NaCl seed priming is a viable approach for improving wheat productivity under saline conditions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

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