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IMPROVING THE PERFORMANCE OF WHEAT (*TRITICUM AESTIVUM* L.) BY SEED PRIMING IN SALT-AFFECTED SOILS IRRIGATED WITH SALINE-SODIC WATER

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ABSTRACT

Impact of different pre-sowing seed treatments viz. $CaSO_4$ (10 and 30 mM), gibberellic acid (20 and 60 ppm) and hydropriming (each for 12 h) on wheat growth by using saline-sodic water for irrigation was investigated in a pot experiment. Artificially prepared saline-sodic water was used for irrigation throughout the crop growth period. Seed germination was maximum with GA_3 (20 ppm) followed by $CaSO_4$ (10 mM) while it was minimum in untreated seeds (control). Similar trend was recorded for shoot yield. There was no effect of seed priming on the sodium concentration in leaves. Almost similar was the pattern of Mg^{2+} concentration in leaves but treatments differed significantly. The K^+ and Ca^{2+} concentration in leaves was statistically affected by treatments, decreasing order being GA–20 > Gyp–10 > Gyp–30 > Control > HP–12 > GA–60 for K^+ while GA–20 > HP–12 > Gyp–30 > Gyp–10 > GA–60 > Control for Ca^{2+}. Chloride concentration was the highest in leaf cell sap with median values of 150 ppm, while it was the lowest for $CaSO_4$ (30 mM) in wheat leaf at booting stage, with a median value of 125 ppm. The highest Na^+: K^+ ratio in the plant leaf was observed for the control (farmer practice) with a median value of 0.28 and lowest for $CaSO_4$ (10 mM) with a median value of 0.23. The Ca^{2+}:Mg^{2+} ratios were the highest for all the primed treatments compared to that with the control.

Key words: seed priming — wheat — salt-affected soil — saline-sodic water — germination.

INTRODUCTION

Seed germination and seedling emergence are serious problems in saline and for alkali soils mostly because of hard setting and crust formation (Qadir and Schubert 2002). Consequently, poor plant population and weak seedlings become susceptible to pests and diseases resulting ultimately in low economic yields.

Although Pakistan has the largest contiguous gravity flow canal system for irrigation, yet it is falling short of good quality water due to increased cropping intensity and droughts over the years (Farooq *et al.* 2009). In order to meet this shortage, more than 0.8 million tube wells have been installed in the Indus Basin of Pakistan (Anonymous 2007). The pumped water (70-80 %) is unfit for agricultural usage owing to high electrical conductivity (EC), sodium adsorption ratio (SAR) and/or residual sodium carbonate (RSC) which are adversely affecting crops (Latif and Beg 2004). Irrigation with such low quality waters promote hard setting and crust formation in soils which further help deteriorate soil physical condition and resultantly poor crop stands (Murtaza *et al.* 2006).

Seed priming has been proved a doable technology to enhance rapid and better emergence, high vigour, and better yields in several crops (Basra *et al.* 2006; Farooq *et al.* 2007a,b, 2008). This technology is commonly employed to decrease the time between seed sowing and seedling emergence and for synchronization of seedling emergence. Priming induces some biochemical and physiological changes to help better and faster germination (Khan *et al.* 2002). Stimulatory effect of hormone primers on wheat plants suggests that seed pre-soaking with auxins may be advantageous for germination and seedling development under saline-sodic conditions (Channa *et al.* 2002). The improved germination of primed seeds was attributed to enhanced counteraction of free radicals and re-synthesis of membrane bound enzymes compared to unprimed seeds (Srinivasan and Saxena 2001). In addition, harmful effects of salt stress on growth and carbohydrate metabolism in seedlings were alleviated through presoaking of seeds (Ashraf and Foolad 2005; Afzal *et al.* 2008).

Salt-affected soils are characterized by accumulation of high concentration of soluble salts in the upper soil layer during winter which is the growing season of wheat in Pakistan. Application of saline and/or sodic water through increasing soluble salts as well as exchangeable sodium in root medium which usually results in poor seed germination and seedling establishment (Rashid *et al.* 2006). It has been reported that soil application or pre-sowing seed treatment with essential nutrients ($Ca^{2+,}$ K^+. Zn^+) decreased adverse effects of soluble salts like Na^+ on seed germination and seedling establishment. By seed priming with gypsum, Ca^{2+} is absorbed as well as coated on seed surface which help alleviate Na^+ toxicity at this critical growth stage. Secondly Ca^{2+} helps increase the integrity of cell membrane of young seedlings to help better selectivity against salt stress. Gibberellic acid is well known to enhance the germination, reduce the sprouting time, and achieve faster growth. Therefore present studies were initiated to determine the crop performance in response to seed priming and use of poor quality water for irrigation.

MATERIALS AND METHODS

Experimental procedure: Soil used in the present study was collected from the research area, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. Soil properties (Table 1) were determined using methods described by the US Salinity Laboratory Staff (1954) and Page *et al.* (1982). In June 2004-2005, soil was sampled in bulk at 0-15 cm depth, sieved (< 2 mm) and transported to Soil and Water Chemistry Laboratory of the above mentioned Institute. The experiment was carried out in greenhouse following completely randomized design (CRD) with three replications and six treatments included: (1) control and (2) seed priming in 10 mM $CaSO_4$ solution (Gyp–10), (3) 30 mM $CaSO_4$ solution (Gyp–30), (4) 20 ppm solution GA_3 (GA–20), (5) 60 ppm solution GA_3 (GA-60) (6) water for 12 h (HP-12). Soil (12.50 kg) was filled in each experimental pot. In each treatment seed was soaked in respective solutions with aeration supplied by air pump for 12 h, thereafter seed was washed thoroughly with distilled water and air dried. Fertilizer NPK at 350, 150, 100 kg ha^{-1} as urea, DAP and murate of potash were applied uniformly in all the treatments. Full dose of P and K while half of N was applied at the time of sowing. The rest of N was applied at the booting stage. Salinity of irrigation water was developed by dissolving required amounts of NaCl, Na_2SO_4, $CaCl_2$, $MgSO_4.7H_2O$ and $NaHCO_3$ in the canal water to develop EC 3 dS m^{-1}, SAR 15 $(mmol\ L^{-1})^{1/2}$ and RSC 1 $mmol_c\ L^{-1}$. Ten treated wheat seeds were sown on November 26, 2003 in each pot and thinned to 7 after ten days of germination. The uprooted plants were cut into pieces and buried in the respective pots. The data regarding germination was recorded from December 13 to 22 December. Five irrigations were applied as and when needed. Parameter studied were germination, number of tillers per plant, plant height and shoot yield. Growth parameters, except germination, were recorded at booting stage. To control the attack of jassid, "Confidor" was sprayed twice. Different ions (K^+, Na^+, Ca^{2+} and Mg^{2+} and Cl^-) were determined in leaves at booting stage.

Physical and chemical properties of soil: Soil textural analysis was carried out after treatment of 30 g soil with 7% H_2O_2, removal of carbonate with 10% HCl, suspension in $[Na(PO_3)_6]$, sieved through a sieve having 63 µm diameter holes and finally weighed the sand fraction. The remaining sample <63 µm was processed further for clay and silt determination by a micro pipette method (Miller and Miller 1987). The pH of the saturated soil paste (pH_s) was measured using a pH meter (Model JENCO Model-671P). The EC_e was determined using EC meter (Model HANNA HI 8033). The concentration of Na^+, K^+, Ca^{2+} and Mg^{2+} was determined by atomic absorption spectrometry (Model Thermo S-Series, Thermo Electron Corporation, Cambridge, UK). Sodium adsorption ratio (SAR) was calculated using Equation 1 when concentration of ions expressed as $mmol_c\ L^{-1}$.

$$SAR = Na^+/\ [(Ca^{2+} + Mg^{2+})/2)]^{\ 1/2} \qquad (1)$$

Quality assurance: The pH meter was calibrated with buffer solutions of pH 4.02 and 9.00. The EC meter was calibrated with 0.01 *N* KCl solution. The Atomic Absorption Spectrophotometer was calibrated with a series of standard solutions supplied by the manufacturer (Thermo Electron Corporation, Cambridge, UK). All the determinations were made in triplicate.

Statistical analysis: Crop growth parameters and soil properties were analyzed statistically following ANOVA technique and treatment differences were evaluated using the Duncan's new multiple range test (MRT) at $P \leq 0.05$ (Steel *et al*. 1997).

RESULTS AND DISCUSSION

Seed germination was significantly higher with all the priming treatments compared to that with the control. Wheat seed primed with GA–20 resulted in maximum germination and was at par with HP–12 followed by Gyp–10, Gyp–30, GA–60 (Table 2). Tillers were similar to that with control for all the priming treatments except HP–12. Plant height was not statistically affected by treatments. Significantly the highest shoot weight was recorded for HP–12 followed by GA–20, GA–60, Gyp–10, Gyp–30 and control (22.59, 20.39, 19.89, 19.71, 19.38 and 16.50 g $pot^{-}1$, respectively).

Saline-sodic water irrigation adversely affects physical and chemical properties of soils that, in turn, adversely affect seed germination and seedling emergence (Rashid *et al.* 2006). Poor seed germination and seedling establishment in saline/saline-sodic growth medium could be due to (1) decrease in soil water potential, (2) accumulation of Na^+ to toxic levels, (3) disturbance in plant uptake of essential nutrients (4) poor soil physical conditions owing to high exchangeable Na^+ (Rashid *et al.* 2006). Seed germination increased with all the treatments compared to that with control. This could be attributed to various biochemical and physiological changes resulting from pre-sowing seed treatment with ($CaSO_4$, GA_3 and hydropriming (Khan *et al.* 2002). Presence and absorbance of Ca^{2+} by seeds from primer $CaSO_4$ resulted in better seed germination which seems enough to counter the adverse effects of Na^+ and other ions in salt-affected soils (Afzal *et al*. 2008). Germination of seeds primed with GA–20 was the highest and was the lowest for the control treatment (farmer practice). Gibberellic acid (GA_3) is the most important growth regulator, which breaks seed dormancy, and promotes germination, internodal length, hypocotyl growth and cell division in cambial zone and increases the size of leaves. The GA stimulates hydrolytic enzymes that are needed for the degradation of cells surrounding radical and thus speeds germination by promoting seedling elongation growth of cereal seeds (Afzal *et al*. 2002). Plant growth regulators (PGR) are organic compounds, which are produced in very small amounts in plants but play very important role in growth, development and yield of crops. Owing to these, PGR are becoming increasingly popular in agriculture. Similarly, hydropriming break down seed dormancy by the activation of hydrolytic enzymes (Farooq *et al*. 2006). In salt-affected soils, water absorption by seeds decreased due to osmotic differences. Even, high salt concentration in growth medium (particularly highly saline-sodic soil) could result in ex-osmosis from primed seeds, thus decreasing seed vigour and germination ability (Wyn Jones and Gorham 2002).

The treatments have non-significant effect on straw yield. The highest shoot weight was recorded with GA–60 and Gyp–30, which also have enhanced germination, seedling emergence and ultimately increased straw yield. The decrease in shoot weight under saline-sodic conditions could be attributed to poor water absorption under increased solutes in soil solution. An increase in ion concentration in leaf cell sap could cause retardation of enzymatic activities and processes (Naeem *et al*. 2006). The specific ion effect directly as well as induced toxic effects of Na^+ and Cl^- might have disturbed the metabolism which is essential for plant growth. Although the number of tillers with hydropriming treatment was low, yet plant height and high germination count favoured more straw yield. In addition, high Ca^{2+}: Mg^{2+}, low Na^+: K^+, low Cl^- and high Ca^{2+} in cell sap helped plant growth to yield high harvestable straw in this soil having post-crop EC_e and SAR in marginal range considered wheat tolerance.

At booting stage, the highest Na^+ concentration (50.3 ppm) in leaf cell sap was recorded for the control treatment followed by GA–20 (50.1 ppm), while the lowest Na^+ (44.3 ppm) was recorded for HP–12 and GA-10 treatments (Table 3). The highest K^+ concentration (222 ppm) in leaf cell sap was recorded for GA–20, while was the lowest for GA–60 (178 ppm). The highest Ca^{2+} concentration (9.9 ppm) was recorded in the leaf cell sap raised from seeds treated with GA–20 (Table 3), while it was the lowest (7.4 ppm) for the control and HP–12 treatments. Concentration of Cl^- was the highest in control plants (150 ppm) while it was the lowest (125 ppm) in plants raised from seeds treated with Gyp–30. The treatments differed non-significantly regarding concentration of Na^+ in leaf cell sap at booting stage.

Maximum Na^+ in leaf was for control while was minimum with Gyp–30 treatment. This higher Na^+ in leaf hampered the growth and development of leaves due to antagonistic effects mostly on K^+, Ca^{2+} and Mg^{2+} along with essential micronutrients, particularly Zn. The reason for lower Na^+ with all the primers seemed due to growth dilution. The high K^+ in leaves with GA–20 seems have promoted the enzymatic activities along with opening and closing of stomata. All these combined to favor the high straw yield that made plants to perform better by inducing growth dilution. Thus gypsum and GA_3 priming showed better growth of leaves mostly through inhibiting Na^+ absorption. Maximum Ca^{2+} in plant leaves at booting stage was for GA–20 while was the lowest for the control treatment. Calcium creates favorable conditions in the rhizosphere and also involves in the vigor of plants. It is worth to mention that all the priming treatment favored the absorption of Ca^{2+}. Al-Whaibi *et al*. (2012) concluded that GA_3 increased pigments like chlorophyll contents in plants grown under saline conditions and consequently photosynthetic rate was increased.

Maximum Cl^- concentration in plant leaves at booting stage was recorded with the control and minimum with Gyp–30 treatment (Table 3). Although Cl^- concentration was higher with all the treatments due to high EC of irrigation water, yet priming treatments helped keep Cl^- lower than that in control plants. Thus priming decreased the specific Cl^--ion effects. These results are also supported by the findings of Amador and Dieguez (2000). The Na^+:K^+ ratio showed non-significant variation among treatments but priming treatment lowered this ratio compared to that in control plants. There seems that gypsum and GA_3 enhanced seed germination (Table 2), growth and development of leaves and straw, decreased early senescence of leaves (Ashraf and Rauf 2001; Ashraf and Iram 2002).

The Ca^{2+}:Mg^{2+} ratio in plant leaves at booting stage was the highest with $CaSO_4$ primed treatments. It seems as $CaSO_4$ priming created favorable conditions for germination through antagonizing Na^+ absorption even at lower growth stages because of which growth was favored, mostly due to sustainable membrane integrity. The Na: K ratio was the highest in leaf cell sap for the control plants (0.28), while it was the lowest with GA–20 (0.23 ppm) treatment. The Ca^{2+}:Mg^{2+} ratio was the highest for Gyp–10 (0.41) while it was the lowest in leaves of the control plants.

The EC_e and SAR of the post-harvest soil were non-significantly affected by the treatments (Table 5). Maximum per cent increase in EC over the initial was with control and minimum with HP–12. The pH_s was non-significantly affected by treatments, being maximum with GA–60, HP–12, Gyp–10, control and Gyp–30 with non-significant difference among themselves while it was minimum for GA–20 treatment. Although there was a minor increase in soil EC$_e$, pH$_s$ and SAR at crop harvest, but treatment differences remained statistically similar. Since in one crop season, change in soil characteristics cannot be expected even without any leaching provision in pots.

Table 1. Chemical analyses of soil before the start of experiment

Characteristic	Unit	Value
pH$_s$	-	7.98
EC$_e$	dS m^{-1}	7.43
TSS	mmol$_c$ L^{-1}	80.8
CO_3^{2-}	mmol$_c$ L^{-1}	Absent
HCO_3^-	mmol$_c$ L^{-1}	3.8
Cl^-	mmol$_c$ L^{-1}	38.5
$Ca^{2+} + Mg^{2+}$	mmol$_c$ L^{-1}	17.5
Na^+	mmol$_c$ L^{-1}	63.3
SAR	(mmol L^{-1}) ^{½}	21.4

Table 2. Response of growth parameters of wheat to seed priming treatments

Treatment	Germination (%)	Tillers (No. plant^{-1})	Plant height (cm)	Shoot yield (g pot^{-1})
Control	80c	3	51	16.50
Gyp–10	90b	3	50	19.71
Gyp–30	99a	3	50	19.38
GA–20	100a	3	49	20.39
GA–60	99a	3	50	19.89
HP–12	100a	2	50	22.59
Critical value for comparison	5.27*	0.83^{NS}	3.08^{NS}	3.27^{NS}

Values in a column sharing same letter(s) are statistically similar at $P < 0.05$; ^{NS} Treatments differ non-significantly at $P < 0.05$; * Treatments differ significantly at $P < 0.05$.

Table 3. Chemical composition of wheat leaves at booting stage

Treatment	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	Na^+: K^+	Ca^{2+}: Mg^{2+}
			ppm				
Control	50.3	183b	7.4	27.5a	150	0.28	0.27
Gyp–10	48.3	189b	8.6	21.8b	133	0.27	0.41
Gyp–30	49.4	188b	8.8	21.9b	125	0.26	0.40
GA–20	50.1	222a	9.9	28.1a	138	0.23	0.35
GA–60	44.6	178b	7.8	20.3b	126	0.25	0.38
HP–12	44.3	181b	8.9	22. 8b	126	0.25	0.39
Critical value for comparison	9.20^{NS}	28.5*	1.28^{NS}	2.89*	27^{NS}		

Values in a column sharing same letter(s) are statistically similar at $P < 0.05$; ^{NS} Treatments differ non-significantly at $P < 0.05$; * Treatments differ significantly at $P < 0.05$.

Table 4. Chemical analyses of soil after harvest of wheat crop

Treatment	pH$_s$	EC$_e$ (dS m^{-1})	SAR (mmol L^{-1})$^{1/2}$
Control	7.91	19.80 (167)*	16.09
Gyp–10	7.96	17.80 (140)	16.05
Gyp–30	7.94	19.73 (166)	17.49
GA–20	7.89	18.05 (143)	16.42
GA–60	7.96	17.61 (1137)	16.44
HP–12	7.96	16.06 (116)	15.81
Critical value for comparison	0.04^{NS}	3.11^{NS}	2.26^{NS}

^{NS} Treatments differ non-significantly at $P < 0.05$; * Percent increase over initial values.

Conclusions: It is concluded that seed priming had beneficial effects on germination and seedling emergence, particularly under the salt stress conditions, mostly altering the absorption and sustaining plant metabolism in a favorable fashion to subsequent plant development and growth.

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