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Effect of Soluble Salts and Soil Conditioner (Polyacrylamide) on Some Soil Properties, Growth, Ion Uptake and Yield of Transplanted Wheat Seedlings

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Abstract: Effects of salt mixture (NaCl, $CaCl_2$ and $MgCl_2$) and $NaHCO_3$ with and without polyacrylamide (PAM) soil conditioner on the growth, ion uptake and yield of two hexaploid wheat varieties were investigated on a clay loam soil in a pot experiment. Salts had adverse effects on wheat growth and yield. However, the effects of $NaHCO_3$ salt generally on all parameters were severe than the mixture of NaCl, $CaCl_2$ and $MgCl_2$. Plants grown in salt treated pots accumulated more Na^+ and less K^+ which resulted in lower K/Na ratio. Addition of soil conditioner (PAM) to the $NaHCO_3$ salt treatment increased the percentage of water stable aggregates (WSA%), to some extent that improved the performance of plants. It is concluded from this study that the transplanted wheat seedlings however survived up to the maturity but they produced low yield.

Key Words: Growth, Salts, Polymers, Transplantation, Wheat, Yield

Introduction

Although it is difficult to transplant wheat seedlings under field conditions, however, this method may improve the performance of wheat in salt-affected soils (Farooq *et al.*, 1994). Salinity and sodicity resulted in marked decreases in seedling emergence, indicating that wheat is sensitive to these stresses at early growth stages (Rowell, 1994; Ray and Khaddar, 1995; Boubakar, 1996).

This study was conducted to determine the effects of salts on the growth of wheat after establishment and to determine if it is possible to obtain satisfactory growth and yield by avoiding stress at the germination and emergence stage by using transplanted seedlings. The Cl^- of Na^+, Ca^{2+} and Mg^{2+} have been reported as the predominant ions in the saline soils of Pakistan, especially in Sindh region, hence a mixture of salts (NaCl, $CaCl_2$ and $MgCl_2$) with equal amounts of Na^+, Ca^{2+} and Mg^{2+} (mmol l^{-1}) was used in this experiment. $NaHCO_3$ salt used in this study is one of the most common salts of sodic soils. To find out if there are differences in response to salts for the growth, ion uptake and yield, two wheat varieties (Kharchia-65 and Q-19) sown as transplanted seedlings. Poor soil structure has been found responsible for lower wheat yield in sodic soils by many researchers . Improved structure of sodic soils can improve plant performance (Rajpar and Wright, 1999; Wright and Rajpar, 2000). In previous years several workers including Carr and Greenland, (1975) have tried to achieve this by applying synthetic soil conditioners polymers. In present study an anionic polyacrylamide (PAM) soil conditioner was applied with $NaHCO_3$.

Materials and Methods

Soil preparation: The experiment was conducted in a clay loam soil with 3.8 % C and 0.28% N collected from a cultivated field. In one soil treatment a mixture of salts consisted of 1.24g NaCl, 1.55g $CaCl_2$ and 1g of $MgCl_2$ kg^{-1} of air dry soil was added (Rowell, 1994) to the original soil. To another soil treatment, the soil (clay loam) was treated with 1M $NaHCO_3$ following the method of Bains and Fireman (1964). To stabilize the structure of soil in presence of 1M $NaHCO_3$, soil was treated by spraying with anionic polyacrylamide (Soiltex L1, Allied Collieds Limited, Yorkshire, England UK) soil conditioner at the rate of 0.2kg/100 kg of soil. The experiment was performed in a well ventilated glasshouse without supplementary heating or lighting.

Raising and Transplanting of Seedlings: Sixteen days old seedlings were obtained from the nursery stock raised in the glasshouse using compost. Seedlings of two wheat varieties viz. Kharchia-65 and Q-19 were transplanted from the compost trays into the soil filled pots (52 x 23 cm surface x 16 cm deep). At the time of transplanting the seedlings had 5 leaves emerged and were 20 cm high. There was one pot for each treatment. Ten plants of each variety per pot were arranged in two adjacent lines at 4 cm row to row and plant to plant spacing.

Sampling, Preparation and Analyses of Ions in Plants: When the flag leaf was fully expanded, five plants of each variety were harvested at random from each treatment and their roots were separated. The height, number of tillers per plant and number of fully expanded leaves on the main stem of the harvested plants were recorded. The leaves and stems were oven dried, at 70 ^{0}C for 40 hr, ground and ashed overnight in a muffle furnace at 450 ^{0}C. The ash was then digested in acid (5M, HCl) for further ion (Na^+, K^+, Ca^{2+} and Mg^{2+}) analyses using an atomic absorption spectrophotomter (151aa/a spectrophotometer, Instrumentation Laboratories, Lexington , Mass 02173).

Final Harvest: At maturity, the remaining plants of both varieties from all treatments were harvested by cutting at soil level. Plants of the control soil treatment were harvested 15 days later because of delayed maturity. The harvested plants were oven dried at 82 ^{0}C for 48 hr. The ears were separated from straw and threshed by hand. Grains were cleaned and weighed and the number of grains per plant and straw dry weight per plant were determined.

Soil Analyses: Before sowing of plants, soil samples were collected and analysed for Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} (using Atomic absorption spectrophotometer), pH, EC_e (using digital meters), texture (by Bouyoucos hydrometer method) and water stable aggregate % (by Wet sieving method of Angers and Mehuys, 1993).

Statistical Analyses: All data were analysed for ANOVA using the Balanced anova in the Minitab statistical package version 10.51. Standard error of the difference between means (S. E. D.) and least significant difference (L. S. D.) were calculated. Significant levels are shown in the tables by *, ** and *** for 5% 1% and 0.1% probability levels respectively. The non-significant differences are denoted by N.S.

Results and Discussion

Soil Characteristics: The detailed results of soil analyses before sowing are described in Table 1. The chemical properties of the original soil before sowing showed a pH value typical of that a well managed agricultural soils and low value of ECe, SAR and ESP with 1.5% total C and 0.14% total N. However when the same soil was treated with 1M $NaHCO_3$ salt, it showed an increase in pH together with markedly higher values of ESP and SAR. The ECe (dS/m) of $NaHCO_3$ treated soil was also increased. The effects of PAM on pH, ESP and SAR were very slight. As sodicity increased WSA% decreased. Treatment of sodic soil with PAM resulted in a large increase in the WSA% so that the value obtained was similar to that of control. Following the addition of the salt mixture, there was a marked change in the chemical properties of soil. The value of ECe was typical of that highly saline soil, but the pH value was lower compared to that the control and sodic soil treatments. Although the SAR and ESP of the saline soil were higher than in the control, they were lower than the values of a typical sodic soils.

Effects on Survival, Growth and Development of Wheat Plants: Plants grown from the transplanted seedlings in each treatment showed 100 % survival up to maturity and all plants had ears. The effects of salt mixture and $NaHCO_3$ salt with and without PAM on the height, number of main stem leaves and number of tillers per plant are shown in Table -2. The plants in the salt treatments were significantly shorter than the control plants. The effect of $NaHCO_3$ was greater than salt mixture. Plants in $NaHCO_3$ soil treatment with PAM were slightly taller than the plants in soil without PAM treatment. The varieties exhibited a significant difference in plant height. Generally Kharchia-65 plants were significantly taller than those of Q-19. Plants in the salt treatments showed a small but non-significant increase in the number of fully expanded leaves on the main stem. Although in the control soil treatment Q-19 had fewer leaves than Kharchia-65, the differences between varieties and the interaction of soil treatments with varieties were not significant. In the control soil treatment both varieties produced three tillers and in the saline soil treatment only Kharchia-65 had a single tiller. There was no tiller formation in both varieties in all soil treatments with $NaHCO_3$ salt.

Effects on Ion Concentration: The concentrations of Na^{+} was significantly increased, while that of K^{+} and K^{+}/Na^{+} ratio were significantly decreased in the salt treatments (Table 3). The salt treatments had no effect on Mg^{2+} concentration of shoot dry matter. The concentration of Na^{+} was significantly higher and that of K^{+} and K^{+}/Na^{+} ratio were significantly lower in the plants of the $NaHCO_3$ than in the salt mixture. The concentration of Ca^{2+} was significantly higher in the plants of the salt mixture treatment than other treatments. In contrast treatment of soil with $NaHCO_3$ + PAM significantly decreased Na^{+} but increased K^{+}, Ca^{2+} and K^{+}/Na^{+} ratio in the plant dry matter. There were significant differences between the varieties in the concentration of K^{+}, but not other ions, where Q-19 had significantly higher K^{+} than Kharchia-65. The ANOVA in which the data for the control were excluded showed that Na^{+} was significantly decreased by PAM in Kharchia-65 but not in Q-19. The increase in K^{+}/Na^{+} ratio by PAM was also greater in Kharchia-65 than Q-19. However, in the salt mixture soil treatment Kharchia-65 had significantly higher Na^{+} and lower K^{+}/Na^{+} ratio than Q-19.

Effects on Grain Yield and Yield Components: In each soil treatment all plants survived to produce ears. Salt treatments significantly decreased grain yield and yield components (Table 4). The effects of variety and the variety x salt treatment interaction were not significant. Straw dry weight per plant and harvest index were also significantly decreased by salt treatments (Table 4). The effects of $NaHCO_3$ on yield and all yield components were greater than the effects of salt mixture. Although in the $NaHCO_3$ salt treatment plants had ears, there were no grains in them at all. Therefore the values for grain weight and harvest index were zero in this soil treatment for both varieties. Kharchia-65 had higher straw dry weight than Q19 in all soil treatments, although the difference between varieties was significant in the control only. Contrarily, in the salt mixture treatment, grain yield and other yield components were slightly higher in Q-

19 than Kharchia-65. Plants of Q19 in the $NaHCO_3$ + PAM treatment showed higher straw dry weight than plants in the $NaHCO_3$ soil treatment, but they produced no grain. Plants of Kharchia-65 produced few small grains in the $NaHCO_3$ + PAM treatment and also had higher straw weight than plants in the $NaHCO_3$ treatment.

Soil Properties: The soil used in this experiment was clay loam with 21% clay content and was low in organic matter content. When the soil was treated with salts it showed properties typical to those of saline and sodic soils of arid and semi-arid regions. After harvesting, the soil with salt mixture showed high EC_e, but the soils with $NaHCO_3$ in absence or presence of PAM showed low EC_e and pH but high SAR and ESP. De-Sigmond (1938) also reported that sodic soils can show pH as low as 6, but the ESP of these soils can still be very high (>15). He used the term degraded sodic for such soils. Application of PAM in the presence of high $NaHCO_3$ increased the % WSA, which confirms that the soil treated with polymer had an improved physical condition (stable structure) compared to the untreated soil with $NaHCO_3$.

Effect of Salts: The effects of salt treatments on some important parameters of transplanted wheat plants are summarised in Table 4. In experiments conducted by Rajpar and Wright (2000), seeds sown directly into the salt-affected soils decreased germination and establishment. However, in this study the survival percentage of transplanted plants was 100 % in all soil treatments. The increased survival of plants in salt treatments was probably due to the raising of seedlings passed the initial sensitive stage in compost and their later transfer into the salt treatments. It has been confirmed by other workers, including Sharma (1991) that wheat plants are more tolerant to sodicity and salinity at later stages than at initial (emergence and seedling) stages. Farooq *et al.* (1994) also observed that transplanted wheat seedlings performed well in salt-affected soils.

The results obtained in this study showed that overall the effects of $NaHCO_3$ salt on shoot height, number of tillers (Table 2), grain yield, yield components (Table 3) and straw dry weight (Table 4) were greater than the effects of salt mixture. Salt mixture and $NaHCO_3$ salt resulted in marked decreases in straw dry weight per plant (77 and 91 % respectively). Salt mixture treatment decreased grain yield per plant by 92 %, but in the $NaHCO_3$ salt treatment plants did not produce grains. Other workers (Farooq *et al.*, 1994) have also found that salinity (EC_e 9 to 32 dS/m) and sodicity (20 to 55 ESP) greatly decreased straw and grain yield of wheat. The plants in $NaHCO_3$ salt treatment produced straw and ears, but no grains, suggesting that $NaHCO_3$ had adverse effects on pollination, fertilisation and or seed setting.

The decrease in grain yield in the saline treatment was due to the absence of tillers, lighter and fewer grains, whereas the decreased grain yield in the sodic soil treatment was due to the empty ears and absence of tillers. It has also been reported by many workers (Joshi, 1976; Maas *et al.*, 1990) that decreased tillering is the main cause for low crop yield in salt-affected soils of arid and semi-arid regions.

The greater effect of $NaHCO_3$ than salt mixture on plants was associated with greater effects on ion content (Table 3). As was expected, the effect of salt mixture on plants was to increase Na^+, Ca^{2+} and decrease K^+ and K^+/Na^+ ratio but Mg^{2+} was unaffected compared to the control plants. The increase in Na^+ and Ca^{2+} content may be attributed to the increased amount of Na^+ and Ca^{2+} ions in the soil solution due to the addition of salt mixture during preparation. Although in the salt mixture treatment Mg^{2+} salt was also mixed into the soil, the plants did not show higher Mg^{2+} content than control plants, possibly because of higher Ca^{2+} uptake. Addition of $NaHCO_3$ salt resulted in a larger increase in Na^+ and a larger decrease in K^+, Ca^{2+} and K^+/Na^+ ratio than salt mixture. The concentration of Mg^{2+} was unaffected by adding $NaHCO_3$. The greater increase in Na^+ content was possibly due to the higher ESP level. The greater decrease in K^+ and Ca^{2+} may be due to the antagonistic effect of Na^+ or, as it is often found, (Gutschik and Kay, 1995), that nutrients are retained more in the root under stress conditions, than in the shoots. Similar effects of sodicity on ion content of various plants have been reported by many workers (Bains and Fireman, 1964; Lunt *et al.*, 1964). Ratner (1935) reported that wheat plants were unable to absorb Ca^{2+} from soil having an ESP of 40. In the case of Mg^{2+} some reports indicate a decrease in sodic soils while others (Moustafa *et al.*, 1966) indicate slight or no effect of sodicity on Mg^{2+}.

Effect of Soil Conditioner (PAM): Synthetic polymers improve the physical properties of sodic soils (Morsey *et al.*, 1991) and in return they improve plant performance. In this experiment anionic polyacrylamide soil conditioner (PAM) had a marked effect on the performance of wheat plants. Averaged over the 2 varieties, the treatment of $NaHCO_3$ salt with PAM increased straw weight by 59 %. Grain weight was 22 mg per plant compared to the same $NaHCO_3$ treatment in the absence of PAM where there was no grain yield. These results are also comparable with the findings of Lunt *et al.* (1964) who reported that the performance of plants in sodic soil was improved by using synthetic VAMA polymer.

Table 1: pH, EC_e (dSm^{-1}), SAR, ESP and Water Stable Aggregates (WSA%) of Soil used in the Study

Properties	Soil treatments: Control	Salt mixture	$NaHCO_3$	$NaHCO_3$ + PAM
pH	6.5	5.0	8.8	8.5
EC_e	3.6	18.6	8.3	6.7
SAR	1.3	10.6	64.1	58.2
ESP	<0.1	12.7	48.6	46.2
WSA %	71.0	not measured	38.0	73.0
Texture Clay loam (UK classification)				

Table 2: Effect of soluble salts and PAM on the height (cm), number of leaves and number of tillers $plant^{-1}$

Parameter	Soil treatment	Variety: Kharchia-65	Q-19	Mean
Height (cm)				
	Control	68.0	41.0	54.6
	Salt mixture	47.0	27.0	37.2
	$NaHCO_3$	26.0	16.0	21.3
	$NaHCO_3$ +PAM	30.0	20.0	25.0
	Mean	42.9	26.1	
Number of fully expanded main stem leaves $plant^{-1}$				
	Control	6.0	5.0	5.7
	Salt mixture	7.0	7.0	6.8
	$NaHCO_3$	7.0	7.0	6.8
	$NaHCO_3$ +PAM	7.0	7.0	6.7
	Mean		6.5	6.5
Number of tillers $plant^{-1}$				
	Control	3.0	3.0	2.9
	Salt mixture	1.0	0.0	0.5
	$NaHCO_3$	0.0	0.0	0.0
	$NaHCO_3$+PAM	0.0	0.0	0.0
	Mean	1.0	0.75	

	Soil treatment S. E. D.	Soil treatment L. S. D.	Variety S. E. D.	Variety L. S. D.	Soil trt * Variety S. E. D.	Soil trt * Variety L. S. D.
Height	2.6	5.3* * *	8.3	16.9* * *	3.7	7.5* *
No. of leaves	0.2	N. S	0.3	0.5* *	0.4	N. S
No. of tillers	0.2	N. S	0.3	0.6* * *	0.4	N. S

Treatment of sodic soil with PAM decreased Na^+ and increased K^+ and Ca^{2+} contents in the plants. Lunt *et al.*, (1964) have also reported a decrease in Na^+ and increase in K^+ and Ca^{2+} content of plants using polymers at a range of ESP (12 to 28) levels.

Varietal Response: The experiment tested two varieties, Kharchia-65 and Q19. In solution culture these varieties had been found to be resistant (Kharchai-65) and susceptible (Q19) to salinity (Rajpar and Sial, 2002). Several other workers have also reported that Kharchia-65 is resistant to both salinity (Joshi *et al.*, 1985) as well as sodicity (Singh and Rana, 1985; Sharma, 1987, 1991). However, in this study the reverse trend was found in the treatment with salt mixture. Q19 had both higher grain yield and a lower % decrease in grain yield over the control than Kharchia-65. The higher yield of Q19 than Kharchia-65 was due to having a greater number of heavier grains. In addition, straw yield was decreased by 80 % in Kharchia-65 but by only 70% in Q19. This variety (Q19) also had higher harvest index in both the control as well as in the saline treatment. The higher yield of Q19 was associated with lower Na^+, and higher K^+ and K^+/Na^+ ratio than Kharchia-65. However, there are no clear reasons why the relative performance of the varieties differed in the two culture systems, It could be due to several factors, for example, the involvement of various processes in ion uptake viz, contact exchange process that can only occur in the presence of colloidal particles.

This study also provided some evidence that the varieties also differed in response to sodicity and PAM. Although both varieties had no grains while the straw yield of both varieties decreased by 90 % under $NaHCO_3$ conditions. An improvement in grain yield and yield components by PAM was observed only in Kharchia-65. However the effects of PAM on straw weight were greater in Q19 than Kharchia-65. Treatment of $NaHCO_3$ soil with PAM resulted in a larger decrease in Na^+ in Kharchia-65 than in Q-19. The effects of PAM on concentrations of other ions were similar in the two varieties. Hence there were no consistent relationships between effects of PAM on growth, yield and ion concentrations.

Table 3: Effect of Soil Sodicity, Salinity and PAM on the Concentration (mg g^{-1}) of Ions in the Dry Matter (stem + leaves) of Two Wheat Varieties

Ion	Soil treatments	Variety		Mean
		Kharchia-65	Q-19	
Na^+				
	Control	0.9	1.2	1.07
	Salt mixture	5.0	1.9	3.45
	$NaHCO_3$	12.1	10.3	11.19
	$NaHCO_3$ +PAM	4.2	8.9	7.08
	Mean	5.55	5.85	
K^+				
	Control	40.1	54.2	47.15
	Salt mixture	23.6	32.2	27.92
	$NaHCO_3$	13.4	19.2	16.32
	$NaHCO_3$ +PAM	14.3	21.5	17.91
	Mean	22.9	31.6	
Ca^{2+}				
	Control	0.52	0.48	0.503
	Salt mixture	3.35	2.67	3.011
	$NaHCO_3$	0.07	0.09	0.078
	$NaHCO_3$+PAM	0.11	0.11	0.109
	Mean	1.011	0.839	
Mg^{2+}				
	Control	0.02	0.03	0.024
	Salt mixture	0.03	0.02	0.026
	$NaHCO_3$	0.02	0.04	0.028
	$NaHCO_3$+PAM	0.01	0.04	0.023
	Mean	0.020	0.033	
K^+/Na^+				
	Control	44.0	55.7	49.82
	Salt mixture	6.3	21.5	13.87
	$NaHCO_3$	1.1	2.0	1.56
	$NaHCO_3$ +PAM	3.9	2.8	3.36
	Mean	16.33	20.17	

	Soil treatment		Variety		Soil trt * variety	
	S. E. D	L. S. D	S. E. D	L. S. D	S. E. D	L. S. D
Na^+	1.01	2.05* * *	0.71	N. S	1.43	2.89**
K^+	3.09	6.29* * *	2.19	4.45* * *	4.38	N. S
Ca^{2+}	0.213	0.434* * *	0.151	N. S	0.301	N. S
Mg^{2+}	0.798	N. S	0.565	N. S	1.130	2.29*
K^+/Na^+	5.75	11.69* * *	4.07	N. S	8.14	N. S
Analyses excluding control soil treatment						
Na^+	1.16	2.39* * *	0.95	N. S	1.64	3.38**
K^+/Na^+	2.52	5.19* * *	2.05	4.24*	3.56	7.34** *

Table 4: Effect of Soluble Salts and PAM on the Number of Ears Plant^{-1}, Number of Grains Plant^{-1}, Grains Yield (mg) plant^{-1} and 1000 Grain Weight (g)

Parameter	Soil treatment	Kharchia-65	Q-19	Mean
Number of ears plant^{-1}				
	Control	3.4	3.2	3.30
	Salt mixture	1.0	1.0	1.00
	$NaHCO_3$	1.0	1.0	1.00
	$NaHCO_3$ +PAM	1.0	1.0	1.00
	Mean	1.65	1.55	
Number of grains plant^{-1}				
	Control	61.0	64.0	62.4
	Salt mixture	5.0	7.0	6.0
	$NaHCO_3$	0.0	0.0	0.0
	$NaHCO_3$ +PAM	3.0	0.0	1.4
	Mean	17.0	17.8	
Grain yield (mg plant^{-1})				
	Control	2691.0	2399.0	2545.1
	Salt mixture	150.0	252.0	201.0
	$NaHCO_3$	0.0	0.0	0.0
	$NaHCO_3$ + PAM	44.0	0.0	22.0
	Mean	721.3	662.8	
1000 grain weight (g)				
	Control	45.0	38.0	41.6
	Salt mixture	30.0	38.0	32.2
	$NaHCO_3$	0.0	0.0	0.0
	$NaHCO_3$ + PAM	10.0	0.0	4.8
	Mean	21.0	18.2	
Straw dry weight (mg plant^{-1})				
	Control	2360.0	1144.0	1752.0
	Salt mixture	468.0	342.0	405.0
	$NaHCO_3$	208.0	112.0	160.0
	$NaHCO_3$ + PAM	332.0	176.0	254.0
	Mean	842.0	443.5	
Harvest Index (%)				
	Control	53.0	67.0	60.2
	Salt mixture	24.0	40.0	31.8
	$NaHCO_3$	0.0	0.0	0.0
	$NaHCO_3$ + PAM	11.0	0.0	5.5
	Mean	21.9	26.7	

	Soil treatment		Variety		Soil trt * Variety	
	S. E. D	L. S. D	S. E. D	L. S. D	S. E. D	L. S. D
No. of ears/p	0.16	0.32***	0.35	N. S	0.22	N. S
No. of grains/p	4.3	8.7***	3.0	N. S	6.0	N. S
Grain wt./p	155.2	309.2***	107.6	N. S	215.2	N. S
1000 grain wt.	7.5	15.3***	1.7	N. S	3.4	N. S
Straw wt/p	94.4	191.1***	66.8	135.6	133.5	271.4***
H.I. (%)	3.2	6.6***	2.3	4.6	4.6	9.3**
Analyses excluding sodic soil treatment						
No. of grains/p	4.0	8.4***	5.0	N. S	7.0	N. S
Grain wt./p	143.5	296.1***	175.7	N. S	248.5	N. S
1000grain (g)	1.8	3.8***	2.3	N. S	3.2	N. S
H.I. (%)	3.1	6.3***	3.74	N. S	5.3	10.9**

Conclusion

The results obtained from this study suggest that seedlings transplanted into salt-affected soil can survive up to maturity, but the yield of survived plants is still low. The improvement of aggregation in sodic soil by using anionic polyacrylamide and the transplanting of wheat seedlings into this can also result in improved performance.

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