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Salt-tolerance of Wheat *(Triticum aestivum* L.) Genotypes: A Lysimeter Study

Javaid Akhtar, M. Zahid, S. Parveen and A. Naseem
Department of Soil Science, University of Agriculture, Faisalabad, Pakistan

Abstract: To see the effect of salinity on wheat lysimeter experiment was conducted by growing six wheat genotypes. The experiment included three treatments i.e. EC, =4.75 (control), 7.5 and 15.0 dS m^{-1} with four replications. Data regarding number tillers, grain and straw yield per plant were recorded at harvesting. Lead sap was extracted from leaf samples collected at booting stage and analyzed for N^+, K^+ and Cl^- concentration. Yield parameters and K^+ concentration decreased, while Na^+ and Cl^- concentration increased with an increase in salinity. Genotype 234-1 had the highest value of its yield parameters along with high concentration of Na^+ and Cl^- and was declared tolerant as it might had compartmentalized these ions. Two genotypes WC-73 and SAR-5 produced the lowest value of yield parameters and were declared sensitive. But the Na^+ and Cl^- concentrations of WC-73 was low while that of SARC-5 was high. This difference in their sensitivity could be attributed of genetic constitution.

Key words: Genetic constitution, lysimeter, salt-tolerance, sensitivity, wheat genotypes

Introduction

Salinity is one of the major soil problems confronting the agriculture of Pakistan where a large area has been rendered agriculturally unproductive due to high concentration of salts in the root zone. According to an estimate due to 1.2 mha affected by salinity/aodicity there was a loss of 2-3 million tones of grain. Annual losses of Rs. 6.5-20 million were computed for salt-affected soils in 16.3 mha of irrigated area in Indus Basin (Qayyum and Malik, 1985). According to Khan (1998) 6.67 mha in Pakistan are salt-affected. Pakistan is situated in the arid and semi-arid regions of the world where precipitation is insufficient for leaching the salts out of the root-zone (Sandhu and Qureshi, 1986) and soluble salts tend to accumulate in the soil profile with Na^+ as a dominant cation after the precipitation of Ca^{2+} and Mg^{2+}. Salinity is inimical to plant growth through numerous complex interactions including specific Ion toxicity, osmotic effect and nutritional imbalance (Jones and Storey, 1981; Flowers *et al*., 1991).

Wheat is an important staple food crop consumed throughout the world. It is moderately salt-tolerant (Maas and Hoffman, 1977; Qureshi and Barratt-Lennard, 1998) but its yield parameters like filleting capacity and grain weight are greatly reduced by high external salinity (Rashid, 1986). Salt-affected soils can be managed by reclamation, but due to insufficient and poor quality of irrigation water and high cost of amendments, this exercise is not feasible on a large scale. Thus in order to have an effective utilization of salt-affected soils, it is important to select such plant spp., crop/cultivars which can tolerate salinity stress. Keeping this In mind the following study was planned to see the salt-tolerance of six wheat genotypes in lysuneters.

Materials and Methods

An experiment was conducted in lysimeters to study the salt-tolerance of six wheat genotypes (234-1, WC-73, WC-38, WC-14, SACR-1 and SACR-1 and SARC-5). There were three salinity levels i.e. low (Ec_e = 4.5), medium (7.5) and high salinity (15.0 dS m^{-1}). The salinity was developed prior to sowing by adding calculated amounts of NaCl and final EC. Levels of 8.1 for medium and 15.4 dS m^{-1} for high salinity were achieved. Fertilizers at 120:80:60 kg ha^{-1} NPK were Wed as urea, SSP and K_2SO_4. Half nitrogen and full dose of P and K were incorporated before sowing, while Mt N was applied with let irrigation. There were for replications and one line of each genotype was sown in each lysimeter. At booting stage fully expanded flag leaves of all the genotypes from each replication and treatment were collected in separate 1.5 cm^3 polypropylene micro centrifuge tubes and stored at freezing temperature (Gorham *et al*., 1984).

The frozen leaf samples were thawed and crushed with metal rod having tapered end and sap was collected in other tubes. The sap was thawed and crushed with metal rod having tapered end sap was collected in other tubes. The sap was centrifuged at 6500 rpm. Leaf sap was diluted as required and Na^+ and K^+ concentration was measured using Jenway PFP-7 Flame Photometer and Cl^- by Sherwood 926 Chloride Analyzer. The crop was harvested at maturity and the data regarding number of tillers per plant, grain and straw yield per plant were recorded. Data thus obtained were analyzed statistically using completely randomized design (Steel and Torrie, 1980) and treatment means were compared using Duncan's Multiple Rand Test (Duncan, 1955).

Results

Plant Growth

Number of tillers per laten: Tillering capacity decreased with an increase in salinity level. Genotype 234-1 produce the maximum number of tillers, while SARC-5 produced the minimum number of tillers under low (4.45 dS ml^{-1} salinity. At medium (8.1 dS m^{-1}) and high salinity (15.4 dS m^{-1}) almost similar trend was observed. As far as varietal means are concerned genotype 231-1 produced the maximum number of tillers followed by WC-38 and WC-14, while WC-73 produced the least number of tillers (Table 1a).

Grain Yield: Grain yield decreased with increased salinity levels. Again genotype 234-1 produced maximum grain yield under all the three treatments while differed significantly from rest of the genotypes. The grain yield of all other genotypes was statistically non-significant. On relative yield basis, at medium salinity maximum grain was recorded for WC-38 and at high salinity for SARC-1, while 234-1 produced the minimum relative grain yield at both medium and high salinity levels (Table 1b).

Straw yield: Straw yield also decreased with an increase in salinity level. At medium and high salinity levels genotype 2341 produced maximum straw yield. Genotype SARC-5 at medium while WC-73 at high salinity produced the minimum straw yield. On genotypic means basis, genotype 234-1

Table I: Effect of NaCl salinity on wheat genotypes

Wheat genotypes	NaCl salinity level (dS m^{-l})			
	Control	7.5	15	Mean
a) Number of tillers per plant				
234-1	4.34a	4.12a	3.51a	3.99A
WC-38	3.64ab	3.60ab	2.95eb	3.40B
WC-14	3.36abc	3.15ab	2.58bc	3.02B
WC-73	2.54c	2.38c	1.90c	2.28C
SARC-1	3.06bc	2.74bc	2.72abc	2.82B
SARC-5	2.40c	2.23c	2.27bc	2.29C
Mean	3.22A	3.03A	2.655	
b) Grain yleld (g plant^{-1})				
234-1	6.38a	4.25.166)	3.57a(52)	4.73A
WC-38	2.20b	2.20c(100)	1.81b(82)	2.06C
WC-14	3.77b	3.34ab(88)	2.58eb(68)	3.238
WC-73	2.56b	1.98b(77)	1.63b(74)	2.06C
SARC-1	2.88b	2.76b(95)	2.45b(85)	2.70BC
SARC-5	2.19b	1.90b(85)	1.74b(79)	1.96C
Mean	3.33A	2.74B	2.998	
c) straw yield (g Plant^{-1})				
234-1	12.13a	11.66a	8.52a	10.73A
WC-38	11.85a	10.24a	6.20ab	9.43AB
WC-14	9.00b	7.89ab	6.00ab	7.638
WC-73	3.98d	3.50bc	3.05b	3.51C
SARC-1	5.04c	4.55bc	3.42b	4.34C
SARC-5	4.28cd	3.06c	3.46b	3.60C
Mean	7.71A	6.80AB	5.11B	

Values in (1 are % of respective control.

Table 2: Effect of NaCl salinity on ionic concentration of wheat genotypes

Wheat genotypes	NaCl salinity level (dS m^{-l})			
	Control	7.5	15	Mean
a) Na^+ concentration In leaf sap (mol m^{-3})				
234-1	60.86b	76.09ab	89.73a	75.568
WC-38	69.43a	72.30ab	75.28b	72.338
WC-14	67.72 b	73.84ab	78.69 ab	73.518
WC-73	77. 16bc	66.83b	68.53bc	70.848C
SARC-1	61.03b	79.37a	83.16ab	74.528
SARC-5	71.41a	80.86a	90.56a	80.97A
Mean	67.94A	74.868	81.05A	
b) K^+ concentration in leaf sap (mol m^{-3})				
234-1	204.986	197.66a	178.17ab	193. 60A8
WC-38	211.46a	196.31a	193.03a	200.26A
WC-14	195.40b	196.24ab	184.87a	188. 83A8
WC-73	182.95bc	158.73c	174.54ab	168.74C
SARC-1	191.13b	175.39b	169.49b	178.678
SARC-5	229.62a	169.62a	187.65a	204.62A
Mean	202.60A	185.168	181.298	
c) Cl^- concentration in leaf sap (mol m^{-3})				
234-1	126.28a	139.62ab	146.31b	137.90A
WC-38	82.73d	135.77b	143.0013	120.51 AB
WC-14	95.28c	99.99c	100.34c	92.538
WC-73	92.25c	118.18bc	151. 05ab	92.538
SARC-1	116.34b	126.68bc	162.43a	135.15A
SARC-5	112.27b	147.96a	156. 35 ab	138.88A
Mean	104.70B	128.04A	143.25A	

Means sharing similar letter(s) are non-significant at 5% probability level. Small letter indicate the comparison among varieties with in treatments Capital letters Indicate the over all comparison among treatments and varieties

gave the maximum, while WC-73 gave then minimum straw yield (Table 1c).

Chemical Composition

Sodium concentration: Sodium concentration was increased with an increase in salinity level. The highest Na^+ concentration was recorded in WC-73 under low salinity level, while under medium and high salinity level SARC-5 had the highest Na^+ concentration. The lowest Na^+ concentration was recorded in genotype 234-1 under low and in WC-73 under medium and high salinity levels (Table 2a).

Potassium concentration: Potassium concentration was decreased with an increase in salinity. The highest K^+ concentration was recorded in the case of SARC-5 under low salinity, while under medium and high salinity levels, genotypes 234-1 and WC-38 accumulated more K^+ than rest of the genotypes. The lowest K^+ concentration was recorded for WC-73 under low and medium salinity, while for SARC-1 under high salinity level (Table 2b).

Chloride concentration: Chloride concentration increased with an increase in salinity level. Genotype 234-1 accumulated maximum Cl^{-1} under low salinity, SARC-5 under medium and SARC-1 under high salinity level. On an over all mean basis 234-1, SARC-1 and SARC-5 accumulated maximum Clconcentration while WC-14 and WC-73 accumulated minimum chloride concentration (Table 2C).

Discussion

Grain yield in wheat is highly dependent upon the number of spike bearing tillers produced by each plant (Maas and Grieve, 1990). The reduced number of tillers with increased salinity could be attributed to toxic effects of Na^+ and Cl^- concentration in physiologically active parts of tissues due to inefficient compartment of these ions in vacuoles (Yeo and Flowers, 1986). Grain yield of wheat genotypes decreased with an increase in salinity which could be attributed to reduced number of tillers under salinity. The genotype 234-1 produced the highest number of tillers under all the treatments, also gave the maximum grain yield under these treatments. The genotypes, WC-73 and SARC-5 produced the lowest number of the tillers as well as the grain yield. It means yield is directly related to number of tillers. Root zone salinity affects the growth of wheat and reduces the number of fertile spikes per plant and hence the yield (Steppuhn and Wall, 1997) and according to Grieve *et al.* (1993) reduction occurs early in the plant life as salts hinder the development of primordia which determines the number of tillers per plant. The other possible reason of low grain yield could be the reduced grain weight due to poor development of seeds, because under saline environment the supply of essential metabolites is limited (Niane, 1987). The straw yield of 234-1 was also more at all the stress levels, while those of WC-73 and SARC-5 was less. The poor straw yield under saline conditions could be attributed to salt stress which induced shrinkage and even complete distortion of chloroplast (Timm *et al.*, 1991). Salts may affect the plant growth indirectly by decreasing the amount of photosynthates in the phloem (Zahid, 1976). The yield components of 234-1 were least affected by salinity to this genotype proved to be tolerant to salinity stress, while those of WC-73 and SARC-5 were affected the most and found sensitive.

Sodium and chloride concentration in leaf sap was maximum in case of 234-1 and SARC-5 and minimum in case of WC-73. While the yield of 234-1 was also high, which indicated that these two ions i.e., Na^+ and Cl^- might had been compartmentalized in the vacuoles or older leaves thus interrupted least the metabolic processes (Rashid *et al.*, 1999). On the other hand, high concentration of Na^+ and Cl^- ions interfered the growth processes and reduced the yield parameters in case of SARC-5. Genotype WC-73 had the minimum concentration of Na^+ and Cl^-, even then its yield parameters were suppressed which indicated that even low concentration of Na^+ and Cl^- ions were above the threshold level of this genotype and thus interfered its growth processes and reduced the yield. Salt-tolerant plants could better compartmentalized toxic ions than sensitive ones at the cellular level (Jones and Storey, 1981) or at the tissue level from leaf to leaf or within expanding or expanded tissues (Yeo and Flowers, 1982). Decreased K^+ concentration with increased salinity could be attributed to high external Na^+ concentration which suppressed K^+ absorption or due to efflux of cytosolic K^+ as the membrane integrity is lost due to displacement of Ca^{2+} by Na^+ (Cramer *et al*., 1985). Potassium concentration was high in case of SARC-5 followed by WC-38, 234-1 and WC-14, while low in case of WC-73 and SARC-1. High K concentration in SARC-5 indicated that this genotype possessed some mechanism of high rate of ion uptake, but high Na^+ and Cl^- concentration was not efficiently compartmentalized and hence interfered growth processes and ultimately reduced the yield. The K^+ concentration of 234-1 was also high along with Na^+ and Cl^-. The increased K^+ concentration could be due to efficient potassium absorption by selective inclusion of Na^+ by cortical cells (Schachtman and Munns, 1992). Expanded or expanding tissues accurate the toxic ions in their vacuoles and prevent their buildup in cytoplasm and thus do not become toxic to enzymes (Munns *et al*., 1995). Almost similar type of mechanism was exhibited by 234-1. The genotypes WC-38 and WC-14 could be declared moderately salt-tolerant because their yield parameters and ionic concentration were intermediate and toxic ions did not reduce growth of these genotypes more than others. The genotype SARC-1 had lower value of yield parameter sand ionic concentration and thus could be declared moderately sensitive. But the genotypes WC-73 and SARC-5 had the lowest value of yield parameters, but WC-73 had low and SARC-5 had high concentration of ions. Low Na^+ and Cl^- concentration of WC-73 reduced its yield as well as K^+ concentration. On the other hand SARC-5 had high Na^+ and concentration. High concentration of Na^+ and Cl^- reduced its yield even high concentration of K^+ could not help in its tolerance. These two genotypes were thus declared sensitive. Grain yield of wheat was mainly dependent on number of tillers. The genotypes with more number of tillers and straw yield under any salinity level also gave high grain yield. Differences in mechanisms of salt-tolerance or sensitivity due to different concentrations of ions in the genotypes could be attributed to differences in their genetic constitution (Qureshi *et al*., 1990).

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