Pak. J. Agri. Sci. Vol. 32 (4), 1995

EFFECT OF SALINITY AND WATERLOGGING INTERACTION ON GROWTH AND IONIC DISTRIBUTION IN LEAVES OF WHEAT GENOTYPES

M. Aslam, H.R.. Ahmad, R.H. Qureshi, S.Nawaz & S. Parveen
Department of Soil Science, University of Agriculture, Faisalabad

The interactive effect of salinity and hypoxia was studied on the distribution of ions in leaves of four wheat genotypes grown with (75, 150 mol m⁻³) and without NaCl salinity under aerated and hypoxic conditions. Number of tillers, shoot fresh weight and shoot length were negatively affected by salinity. The combined effect of salinity and hypoxia was more injurious to the number of tillers, shoot fresh weight and shoot length. Ionic concentrations (Na", K+ and Cl") in different leaves indicated that the concentration of Na" and Cl- increased in leaves due to salinity and hypoxia and was higher in older leaves, whereas the order was reverse in case of K+

Key words: growth, ionic distribution, salinity, waterlogging, wheat genotypes

INTRODUCTION

Soil salinity is inimical to plant growth due to specific ion toxicity, osmotic effect, induced nutrient deficiency, etc. (Flowers *et al.,* 1991). A major part of the problem soils (over lm ha out of 6.3m ha salt-affected land) are presently under rice cultivation and dense in nature with poor drainage (Chaudhry, 1978). Surface ponding (waterlogging) is a common feature of these soils; rainfall or heavy irrigation causes temporary oxygen stress to plant roots. Since wheat, unlike rice is sensitive to hypoxia (low oxygen conditions), its production is seriously affected (Parveen *et al.,* 1991). Two approaches could increase wheat yield from these soils facing twin problem of waterlogging and salinity. One is the planting of wheat with such a technique which may facilitate oxygen supply to roots, the other is cultivation of a variety/line capable to grow under dual stress of waterlogging and salinity. However, both the approaches in combination could enhance wheat production manifold. Further, it is important to understand that how does a plant regulate toxic ions and essential plant nutrients under such adverse conditions since this information is essential in the development/selection of a cultivar. The aim of the present study is to understand the interactive effects of salinity and waterlogging on the distribution of ions in leaves of some selected wheat genotypes.

MATERIALS AND METHODS

Fibre glass pots filled with gravels and foam were used to grow wheat genotypes viz. SARC-I, SARC-III, Pb-85 and 7-Cerros. Prior to sowing, sufficient number of healthy seeds of all wheat genotypes were soaked in aerated distilled water for twenty-four hours. Then ten seeds of each genotype were placed in respective pots at a depth of 2 cm. During 'germination, 2mM $Ca(NO_3)_2.4H_2O$ and 1m $MgSO_4.7H_2O$ solution was sprinkled. After germination, half strength Hoagland nutrient solution (Hoagland and Arnon, 1950) prepared in canal water was applied to the pots. Ten days after germination (at 2-3 leaf stage) thinning was done and salinity levels of 75 and 150 mol m" were developed in three equal increments (each increment applied after 24 hours) followed by a hypoxic stress. Nutrient solutions were changed at a week's interval.. Plants were harvested forty days after the imposition of salt and hypoxic stress and growth data recorded. Leaf sap was analyzed for Na" ,K+, and Cl- concentrations using flame photometer and chloride analyzer..

RESULTS AND DISCUSSION

Growth: Tillering decreased due to increase in salinity under aerobic as well as hypoxic conditions (Table 1). Greater number of tillers ensure better crop stand and ultimately better yield. Hypoxia, however, increased the tillering under control and moderate salinity; these results are contradictory to the initial findings which showed that introduction of hypoxia decreased tillering in wheat (Parveen et al., 1991).Probably the reason is the difference in growth medium as well as matrix culture as was used in this experiment.. Among the four wheat genotypes, the maximum tillering was in the

Table 1. Growth parameters of four wheat genotypes as affected by salinity and hypoxia

Varieties	NaCl salinity ($molm^{-3}$) Control		75		150		Mean
	Aerobic	Hypoxic	Aerobic	Hypoxic	Aerobic	Hypoxic	
			Tillers ($plant^{-1}$)				
SARC-I	5.42 ef	7.67ab	3.75gi	4.42fg	2.67jk	2.67jk	4.43B
SARC-III	5.42ef	6.67bd	4.25fh	4.42fg	3.08hk	2.67jk	4.42B
Pb-85	6.08de	5.25a	4.33fg	5.83de	2.92ik	3.67gj	5.18A
7-Cerros	6.42	7.33ab	4.08gi	4.00gi	2.08k	2.17k	4.35B
Mean	5.83B	7.50A	4.10D	4.67C	2.67E	2.79E	
			Shoot fresh weight (g) $plant^{-1}$)				
SARC-1	26.27b	28.88a	15.09df	12.91eg	6.60ij	4.69ij	15.74B
SARC-III	31.31a	31.28a	16.69d	15.40de	6.92i	5.49ij	17.85A
Pb-85	25.53b	25.05b	13.62e	12.55fh	5.25ij	5.55ij	14.59C
7-Cerros	22.48c	23.69bc	10.69gh	10.69h	3.85j	2.99j	12.33D
Mean	26.39A	27.22A	14.03B	12.78C	5.65D	4.68D	
			Shoot length (cm)				
SARC-I	66.62b	63.29bc	59.21df	53.20g	51.59g	44.58ij	56.42B
SARC-III	72.04a	63.63bc	61.29ce	56.73f	49.88gh	42.74jk	57.72AB
Pb-85	73.81a	61.87cd	61.18ce	57.49ef	47.94hi	45.20ij	57.91A
7-Cerros	73.53a	60.55ce	66.93b	58.26df	50.05gh	40.27k	58.27A
Mean	71.50A	62.33B	62.15B	56.42C	49.87D	43.20E	

Means followed by the same letter(s) are statistically similar at P=0.05.

case of Pb-85 and the minimum in 7-Cerros. Shoot length and shoot fresh weight decreased with increasing salinity in the rooting medium (Table 1). Imposition of hypoxia over salinity further affected these parameters. Similar results were obtained by Drew (1988). Among the varieties, Pb-85 was affected the least while 7-Cerros the maximum due to combined stress of high salinity and hypoxia. Maximum shoot fresh weight was recorded in the case of control treatment. However, shoot fresh weight decreased with increasing salinity levels (Table 1). The reduction in shoot fresh weight might be due to the reduced crop growth because of salinity and hypoxia (Barrett-Lennard, 1986). Among the genotypes, SARC-III produced the higher shoot fresh weight under all sets of treatments Le. salinity and hypoxia, whereas the performance of 7-Cerros was found poor.

Leaf Ionic Concentration: Salinity significantly increased the accumulation of sodium in the leaves compared with control (Table 2). Concentration of sodium in leaf sap of plant at all salinity levels was related to the relative concentration of salt in the rooting medium. This could be due to high transport of salts from the root zone to the shoot and reduced growth of plants (Rashid, 1986; Gorham, 1990; Aslam *et al.,* 1991). Under hypoxic conditions efflux of Na" is not possible due to lack of energy. It was observed that Pb-85 had the minimum Na" concentration while 7-Cerros retained the maximum Na" concentration in their leaf saps, respectively. This indicated that Pb-85

Table 2. Concentration of Na. K. K:Na ratio and Cl in various leaves of four wheat genotypes as afffected by salinity and hypoxia

	NaCl salinity mol m-2																		
	Control						75						[illegible]						
	[illegible]			Hypoxic			Aerobic			Hypoxic			Aerobic			Hypoxic			
Varieties	L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	L3	L1	L2	[illegible]	[illegible]
[illegible]	[illegible]	38.5 z	46.4 u-z	[illegible]	[illegible]	34.9 z	[illegible]	[illegible]	[illegible]	49.4 s-z	55.9 m-w	[illegible]	56.1 m-w	62.4 j-t	69.8 h-n	67.1 l-o	[illegible]	102.8 ab	[illegible]
SARC-III	[illegible]	41.9 w-z	49.4 s-z	[illegible]	[illegible]	34.6 u-z	[illegible]	[illegible]	[illegible]	42.6 v-z	48.4 t-z	[illegible]	58.7 l-u	66.5 l-p	83.4 d-h	63.6 j-s	[illegible]	97.3 bc	[illegible]
Pb-85	[illegible]	48.5 t-z	54.0 o-y	[illegible]	[illegible]	37.2 z	[illegible]	[illegible]	[illegible]	47.8 t-z	52.2 p-z	[illegible]	47.8 t-z	61.2 k-u	71.2 g-l	53.2 o-y	[illegible]	92.2 b-d	[illegible]
7-Cerros	[illegible]	46.9 u-z	54.5 o-x	[illegible]	[illegible]	42.3 v-z	[illegible]	[illegible]	[illegible]	48.7 t-z	53.4 o-y	[illegible]	58.8 l-u	70.1 h-m	87.8 c-e	80.4 d-l	[illegible]	112.7 a	[illegible]
Average	[illegible]	43.9 HI	51.1 FG	[illegible]	[illegible]	37.3 JK	[illegible]	[illegible]	[illegible]	47.1 GH	52.5 FG	[illegible]	55.3 EF	65.1 D	78.0 C	66.1 D	[illegible]	101.3 A	[illegible]
[illegible]	191.3 b-d	[illegible]	127.5 j-v	[illegible]	152.4 e-n	[illegible]	178.3 c-g	[illegible]	[illegible]	[illegible]	69.7 z	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	90.8 v-z	[illegible]	[illegible]
SARC-III	224.4 a	[illegible]	142.6 g-r	[illegible]	148.7 e-p	[illegible]	155.4 d-m	[illegible]	[illegible]	[illegible]	94.1 n-y	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	110.0 t-z	[illegible]	[illegible]
Pb-85	232.3 a	[illegible]	161.6 d-k	[illegible]	146.5 f-g	[illegible]	150.4 e-o	[illegible]	[illegible]	[illegible]	77.6 yz	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.3 y-z	[illegible]	[illegible]
7-Cerros	216.2 ab	[illegible]	140.2 h-s	[illegible]	155.7 d-m	[illegible]	177.5 c-g	[illegible]	[illegible]	[illegible]	82.9 yz	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.9 yz	[illegible]	[illegible]
[illegible]	216.0 A	[illegible]	142.9 EF	[illegible]	150.8 DE	[illegible]	165.4 CD	[illegible]	[illegible]	[illegible]	81.1 H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88.5 H	[illegible]	[illegible]
								K:Na ratio											
SARC-I	5.49 ab	4.39 c-g	3.28 i-m	5.06 a-d	4.60 c-f	4.01 e-l	3.64 g-j	1.93 q-z	1.21 x-z	2.15 p-w	1.27 vw	0.89 z	2.74 k-q	[illegible]	[illegible]	1.75 s-z	[illegible]	[illegible]	2.63 AB
SARC-III	5.91 a	4.29 d-h	3.00 j-p	5.28 ab	4.75 b-e	3.61 g-k	2.96 j-p	2.25 n-u	1.49 s-z	2.78 k-q	1.95 q-z	1.19 x-z	3.04 j-p	[illegible]	[illegible]	2.16 o-v	[illegible]	[illegible]	2.82 A
Pb-85	5.69 a	4.31 c-h	3.07 j-o	5.53 ab	4.39 c-g	3.45 h-l	3.01 j-p	2.34 n-t	1.43 t-z	2.27 n-t	1.48 s-z	1.05 yz	4.48 c-g	[illegible]	[illegible]	2.05 q-x	[illegible]	[illegible]	2.73 A
7-Cerros	5.53 ab	3.77 f-j	2.66 l-r	5.17 a-c	4.05 e-l	3.09 j-n	3.12 j-n	1.77 r-z	1.16 x-z	2.81 x-y	1.58 s-z	1.11 yz	3.06 j-o	[illegible]	[illegible]	1.49 s-z	[illegible]	[illegible]	2.46 B
[illegible]	5.66 A	4.19 B	3.00 D	5.34 A	4.45 B	3.54 C	3.18 CD	2.07 F	1.32 HI	2.50 E	1.57 GH	1.06 L	3.33 CD	[illegible]	[illegible]	1.86 FG	[illegible]	[illegible]	

Cl^- (mmol kg^{-1})																			
SARC-I	[illegible]	49.6 z	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	95.2 l-u	10.5 j-s	[illegible]	90.7 n-w	110.8 j-r	90.5 n-w	105.4 j-t	[illegible]	123.1 h-n	150.5 e-h	222.2 b	91.6 B
SARC-III	[illegible]	59.6 w-z	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	117.9 j-o	146.6 e-l	[illegible]	83.9 p-z	100.5 ku	104.7 j-t	124.7 nm	[illegible]	136.6 f-j	173.1 de	207.5 bc	100.8 A
Pb-85	[illegible]	61.5 v-z	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85.4 o-z	100.8 k-u	[illegible]	77.3 r-z	93.7 m-v	82.5 q-z	113.1 j-q	[illegible]	97.4 l-u	151..3 e-h	192.4 cd	89.8 B
7-Cerros	[illegible]	70.2 u-z	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99.7 k-u	116.4 j-p	[illegible]	88.4 o-y	83.9 m-v	87.6 o-x	98.4 l-u	[illegible]	152.0 e-h	213.9 bc	261.4 a	102.9 A
Average	[illegible]	60.2 IJ	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99.6 FG	118.32 DE	[illegible]	85.2 GI	99.7 FG	91.3 GH	110.4 EF	[illegible]	127.3 D	172.2 B	220.9 A	

had a better mechanism to exclude sodium at the root level therefore it seemed to be a better tolerant to combined stress of salinity and hypoxia.' Concentration of Na" was the highest in older leaf (L-3 from the top) and the lowest in the youngest.. Concentration of chloride in the leaf sap followed the same pattern as that of sodium.

Distribution of KT in various leaves was opposite to that of Na" and Cl (Table 2). Maximum Kt concentration was observed in a fully expanded young leaf. Salinity had a significant effect on K' concentration which decreased with increasing salinity. However, under hypoxic condition it also decreased due to oxygen stress. Barrett-Lennard *et al.(* 1988) reported that K+ concentration was reduced by anaerobiosis, which might be due to the K+ selectivity in plants (energy demanding process). It required the utilization of oxygen for the production of ATP which in turn was required for selective absorption of K'. Salt tolerant wheat genotypes SARC-III and Pb-85 had the maximum K+ concentration in their leaf saps due to poor selectivity of K+ over Na".

K:Na ratio decreased with the age of the leaf, the younger leaves had the higher K:Na ratio (Table 2). The higher K:Na ratio in younger leaves may be due to the reason that in the vacuoles of mature leaves, K could be exchanged for Na imported into leaf by xylem. The phloem could take up K directly from xylem. The higher K:Na ratio in the younger leaves is presumably critical for maintenance of metabolism in the cytoplasm of these young cells (Aslam *et al.,* 1989). This ratio also decreased markedly due to salt as well as oxygen stress. The higher K:Na ratio was observed in the case of SARC-III followed by Pb-85 which were statistically equal but different from 7-Cerros. Though tolerant wheat genotypes (SARC-III and Pb-85) have the same K+ concentration and statistically at par with 7-Cerros (salt sensitive) but marked difference for K:Na ratio in these three genotypes was recorded. This clearly indicates that it is not the concentration of K but K:Na ratio which provides stress tolerance. Thus K:Na ratio can be used as a criterion to screen the wheat genotypes against the combined stress of salinity and hypoxia.

REFERENCES

Aslam, M., R.H. Qureshi and N.Ahmad. 1989. Effect of external sodium chloride on ionic variation in the leaves of rice varieties. J. Agri. Res. 27(4): 327-332.

Aslam, M., R.H. Qureshi, N.Ahmad and M.A.Kausar. 1991. Relative growth rate and ion transport in rice under saline environment. Pak. J. Bot. 23:1-10.

Barren-Lennard, E. G. 1986. Effect of waterlogging on the growth and NaCI uptake by vascular plants under saline conditions. Reclam. Reveg. Res. 5:245-261.

Barrett-Lennard, E.G., P.D. Leighton, F. Buwalda, J. Gibbs, W. Arrnstrong, C.J. Thomson and H. Greenway. 1988. Effect of spring wheat in hypoxic nutrient solutions and subsequent transfer to aerated solution: Status of shoots and roots. Amer. J. Plant Physiol.. 15:585-598.

Chaudhry, M.A. 1978. Rice soils of Pakistan. In Soils and Rice. pp. 147-161.. IRRI, Manila, Philippines.

Drew, M.C. 1988. Effect of flooding and oxygen deficiency on plant nutrition. Adv. Plant Nutr. 3: 115-159.

Flowers, T.J.• M.A. Hajibagheri and A.R. Yeo. 1991. Ion accumulation in the cell walls of rice plants growing under saline conditions: Evidence for Oertli hypothesis. Plant Cell Environ. 14: 319-325.

Gorham, J. 1990. Salt tolerance in triticeae: Ion distribution in rye and triticale. J. Exp. Bot. 41: 609-614.

Hoagland, D.R.and D.L.. Arnon. 1950. The water culture method for growing plants without soil. Calif.. Agri.. Exp. Sta. Circ. No. 247. p.359.

Parveen, S., R.H. Qureshi and M. Aslam. 1991. Growth response of wheat to salinity and hypoxia. Pak. J; Agri.. Sci. 28 (2): 195-198.

Rashid, A. 1986. Mechanisms of salt tolerance in wheat *(Triticum aestivum)*. Ph.D. Thesis, Univ. Agri., Paisalabad, Pakistan.