http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Science, 1 (3): 167-169, 1998 *Research Article*

Combined Effect of Salinity andllypoxia on Growth, Ionic Composition and Yield of Wheat Line 234-1

M. Saqib and R. H. Qureshi
Department of Soil Science, University of Agriculture, Faisalabad-38040, Pakistan

Abstract
The present experiment was designed to study the response of wheat line 234-1 to the combined stress of NaCl salinity and hypoxia in soil culture in pots. All the growth parameters (shoot fresh and dry weights, shoot length, number of tillers, CO. assimilation and transpiration rates) and yield components (number of tillers, total biomass, number of spikes, 100 grain weight and grain yield) except number of spikelets were significantly affected under saline hypoxic conditions. This combined effect of salinity and hypoxia was more negative than any of the individual stresses. The ionic composition of leaves was also disturbed. The concentration of Na^+ and Cl^- was generally increased while K^+ concentration decreased. Hypoxia increased the grain yield significantly, however, salinity alone caused a non significant reduction while a significant reduction was observed under saline hypoxic conditions. Grain yield was 5.15 g, 4.24 g, 3.52 g and 1.45 g under hypoxic, controlled saline and saline hypoxic conditions, respectively.

Key words: Salinity, Hypoxia, Wheat

Introduction
In dense saline and saline sodic soils with low water permeability, crops face surface ponding or temporary water logging at the time of flood irrigation or after heavy rainfall. The incidence of salinity and hypoxia (water logging induced oxygen deficiency) in top soil is a common feature of irrigated agriculture. In Pakistan, salinity and waterlogging co-exist in an area of 1.16 x 10^6 ha (Qureshi *et al*., 1993). Wheat is the most important staple food of Pakistan and is grown extensively in rotation with rice. In many instances moderate salinity and sodicity is present in rice tract and land is usually low lying. Here, the wheat crop typically faces a dual stress of hypoxia and moderate salinity with devastating effects on yield. Despite their usual common occurrence, very little work has been directed to study the consequences of these joint stresses. Low oxygen tension in root zone inhibits oxidative phosphorylation which, inturn, restricts the energy available for the ion pumps involved in exclusion of salts from roots (Barrett-Lennard, 1986). In wheat, differences in varietal response to salt stress and hypoxia and various physiological parameters related to such differences have been studied earlier by Akhtar *et al*. (1994). The present study was designed to obtain information on response of wheat line 234-I to the interactive effects of salinity and hypoxia.

Materials and Methods
Wheat line 234-I was sown in pots each containing 10 kg soil, collected from a normal field and sieved through a 2 mm sieve. Four treatments viz. control, hypoxia, saline and saline- hypokia were employed and replicated, thrice in Completely Randomized Design. The saline treatment had EC_e = 12 dS m^{-1} which was developed by mixing required amount of NaCI in soil. For non saline treatments soil was Used as such. Pots were filled with soil and irrigated with canal water. Ten seeds were sown per pot at "wattar" condition. Plants were thinned out to 6 per pot at two leaf stage. Hypoxic conditions were created twice for about 15 days each time, i.e. at tillering stage and later at booting stage by maintaining a water level of 5-7 cm above the soil surface. Non hypoxic pots were given irrigation as and when required. Recommended doses of fertilizer (NPK) were also uniformly applied to all pots.
Photosynthetic and transpiration rates of standing plants were recorded during sixth week of salt stress by Infra Red Gas Analyser (IRGA). Three plants from each pot were uprooted at the age of about 8 weeks and data regarding the shoot fresh weight, shoot dry weight, shoot length and number of tillers were recorded. Young and old leaves were washed with distilled water and stored in separate eppendorf tubes in the refrigerator. Leaf sap was collected by crushing with steel rod after thawing the frozen leaves. After centrifuging the sap at 6500 rpm for about 10 minutes the supernatant sap was collected. This tissue sap was diluted as required and sodium and potassium were determined using Jenway PFP 7 Flame Photometer (Richards, 1954). Chloride in the tissue sap was determined by titrating the sap against 0.005 N $AgNO_3$ in the presence of K_2CrO_4 as an indicator (Richards, 1954). At maturity data regarding number of tillers, number of spikes, number of spikelets, grain yield and total above ground biomass were also recorded. Data were subjected to statistical analysis using Completely Randomized Design in factorial classification (Steel and Torrie, 1980).

Results
Plant growth: Salinity and hypoxia alone as well as in combination caused a significant reduction in all the growth parameters, viz. shoot fresh weight, shoot dry weight, shoot length, number of tillers, CO_2, assimilation rate and transpiration rate (Table 1). Hypoxia alone and in

combination with salinity caused a significantly higher reduction ($p<0.05$) in growth parameters than salinity alone. However, difference between the effects of hypoxia alone and that of saline hypoxia could reach the level of significance only in the case of transpiration rate. The maximum growth was observed in the case of control, followed by saline, hypoxic and saline hypoxic treatments in a descending order.

Ionic composition: Salinity and hypoxia disturbed the uptake and accumulation of Na^+, K^+ and Cl^- in wheat leaves. The disturbance was observed both under individual and combined stresses, However, the effects of combined stress were significantly more pronounced than that of the individual stresses (Table 2). These effects were true for the young as well as older leaves. The concentration of Na^+ was increased significantly under increased salt concentrations and decreased supply of oxygen in the rooting media. The increse due to the combined stress of salinity and hypoxia was more than that of the individual stresses. In contrast to Na^+, the concentration of K^+ was significantly decreased under saline and saline hypoxic conditions. However, hypoxia alone produced a very interesting trend. It caused a significant increase in K^+ concentration in old leaves while decreased it non-significantly in younger leaves. The ratio of K^+/Na^+ was also reduced significantly both by salinity and hypoxia. Saline hypoxic conditions also decreased this ratio but varied non-significantly from salinity treatment. The Cl^- content of leaves was also increased significantly under saline and saline hypoxic conditions while hypoxia alone produced a non-significant effect.

Table 1: Effect of salinity and hypoxia on growth of wheat line 234-1 (at seedling stage)

Parameters	Control	Hypoxic	Saline	Saline Hypoxic
Shoot fresh weight (g plant^{-1})	8.04a	3.17c	5.46b	3.12c
Shoot dry weight (g plant^{-1})	1.11a	0.69c	0.89b	0.62c
Shoot length (cm)	13.36a	8.96c	12.47b	8.21c
No. of tillers (plant^{-1})	7.78a	4.67c	6.33b	4.33c
00_2 assimilation rate (mmol m^{-2} 5^{-1})	85.75a	49.89c	66.50b	38.44c
Transpiration rate (mmol m^{-2} S^{-1})	91.70a	25.63c	40.23b	13.50d

Means with different letter(s) in a row differ significantly according to least significant difference test ($p<0.05$)

Table 2: Effect of slinity and hypoxia on ionic composition (mol m^{-3}) in leaf sap of wheat line 234-1

Parameters	Control	Hypoxic	Saline	Saline Hypoxic
Na^+ (youngest leaf)	5.18d	15.58c	29.32b	68.17a
Na^+ (Oldest leaf)	6.76d	17.46c	40.86b	73.57a
K^+ (youngest leaf)	206.50a	203.89a	106.87b	69.56c
K^+ (Oldest leaf)	132.87b	163.18a	71.61c	56.85d
K^+:Na^+ (Youngest leaf)	41.15a	13.42b	3.78be	1.03c
K^+:Na^+ (Oldest leaf)	19.81a	9.47b	1.76c	0.79c
Cl^- (youngest leaf)	26.00c	25.50c	46.87b	59.90a
Cl^- (Oldest leaf)	38.21c	34.22c	65.85b	84.67a

Means with different letter(s) in a row differ significantly according to least significant difference test ($p<0.05$)

Table 3 Effect of slinity and hypoxia on yield components of wheat line 234-1

Parameters	Control	Hypoxic	Saline	Saline Hypoxic
No. of tillers (plant^{-1})	7.33b	10.00a	5.33c	5.00c
Total biomass (g plant^{-1})	12.19b	17.59a	8.93c	5.79d
No. of spikes (plant^{-1})	5.33b	7.67a	4.67be	3.67c
No. of spikelets (spike^{-1})	16.33a	16.67a	14.47a	16.00a
100 grain weight (g)	4.45a	2.87c	3.69b	1.39d
Grain yield (g plant^{-1})	4.24b	5.15a	3.52b	1.45c

Means with different letter(s) in a row differ significantly according to least significant difference test ($p<0.05$)

Table 4: Correlation between yield components and ionic composition (young leaves) as affected by salinity and hypoxia

Ions	Biomass	Tillers	Spikes	Spikelets	100 grain weight	Grain yield
Na^+	-0.77*	-0.67^{NS}	-0.68^{NS}	-0.23^{NS}	-0.88**	-0.92**
K^+	0.89**	0.86**	0.82*	0.61^{NS}	0.65^{NS}	0.90**
Cl^-	-0.90**	-0.86**	-0.83*	-0.53^{NS}	-0.69^{NS}	-0.94**
K^+/Na^+	0.42^{NS}	0.46^{NS}	0.29^{NS}	0.47^{NS}	0.57^{NS}	0.52^{NS}

*Significant **Highly significant ^{NS}Non-significant

Yield performance: A severe effect of salinity and hypoxia is obvious on all the yield components except number of spikelets (Table 3). Salinity caused a significant reduction in all the yield components except number of spikes and spikelets and grain yield where this reduction was non-significant. Hypoxia increased the number of tillers, total biomass, number of spikes and total grain weight. However, number of spikelets were increased non-significantly while 100 grain weight was decreased significantly. Salinity and hypoxia in combination caused a severe decrease in all the yield components except number of spikelets compared with salinity alone. However, this decrease was significant only in the cases of total biomass, 100 grain weight and total grain yield/weight.

The concentration of Na^+ and Cl^- in younger leaves showed a negative correlation while K^+ and K^+/ Na^+ ratio showed a positive correlation with all the yield components (Table 4). In particular, the negative correlation of total grain yield was highly significant with Na^+ as well as Cl^- while that of 100 grain weight was only significant with Na^+ and non significant with Cl^-. Similarly, 100 grain weight exhibited a nonsignificant correlation with K^+ and K^+/Na^+ ratio but total grain yield exhibited highly significant correlation only with K^+ while non-significant correlation with K^+/Na^+ ratio.

Discussion

The sensitivity of crop plants to abiotic stresses is usually manifested in reduced plant growth. In this study salinity and hypoxia both individually and in combination decreased the wheat growth compared with the control. Salinity might have reduced the shoot growth and tillering by causing water stress, salt ion toxicity or by disturbing the nutrient balance of plants. A decrease in these parameters have also been reported earlier by Nasim *et al*. (1993). Hypoxia might have reduced the growth mainly due to oxygen deficit for root respiration (Barrett-Lennard, 1986) and decreased nutrient uptake (Morard and Silvestre, 1996). The changed soil chemistry might also have contributed to damaged plant growth and development. Similar results have also been reported earlier by Shafqat (1994). Yeo *et al*. (1985) reported that high salt concentration in leaves reduce the photosynthesis and transpiration by causing damage to leaf tissues. However, hypoxia might have reduced the transpiration by reducing stomatal conductance (Bradford and Hsiao, 1982). The decreased transpiration will lead to decreased photosynthesis.

The increased Na^+ concentration and decreased K^+ concentration in leaves under hypoxic conditions can be attributed to the increased permeability for Na^+ intake and decreased selectivity of K^+ against Na^+ at root membrane level due to decreased energy available because of depressed aerobic; respiration. The increased K^+ concentration in older leaves under hypoxic conditions might be due to the improved K^+ uptake during relief period after flooding as reported by Buwalda *et al*. (1988). Salinity might have increased the Na^+ and Cl^- concentration and decreased the K^+ concentration because of the increased salt concentration in rooting media, damaged membrane permeability and selectivity as well as disrupted exclusion mechanisms. The increased Na^+ concentration and decreased K^+ concentration under stressed conditions lead to decreased K^+/Na^+ ratio in leaves. Similar effects of salinity and hypoxia on leaf ionic composition of wheat has also been reported earlier by Akhtar *et al*. (1994). The higher concentration of Na^+ in older leaves and that of K^+ in younger leaves may be considered a resistive mechanism developed by these plants.

The reduced grain yield under saline and saline hypoxic conditions has earlier been reported by Akhtar *et al*. (1994). The reduced 100 grain weight under saline and hypoxic conditions may be attributed to impaired grain filling and development because of reduced photosynthesis and transpiration as well as imbalanced nutrition and reduced water uptake under saline and hypoxic conditions. However, the increased grain yield reported here in this study may be attributed to improved growth because of increased nutrient uptake by plants during relief period as reported by Buwalda *et al*. (1988).

References

Akhtar, J., J. Gorham and R.H. Qureshi, 1994. Combined effect of salinity and hypoxia in wheat (*Triticum aestivum* L.) and wheat-*Thinopyrum amphiploids*. Plant Soil, 166: 47-54.

Barrett-Lennard, E.G., 1986. Effects of waterlogging on the growth and NaCl uptake by vascular plants under saline conditions. Reclamat. Revegetat. Res., 5: 245-261.

Bradford, K.J. and T.C. Hsiao, 1982. Stomatal behavior and water relations of waterlogged Tomato plants. Plant Physiol., 70: 1508-1513.

Buwalda, F., E.G. Barrett-Lennard, H. Greenway and B.A. Davies, 1988. Effects of growing wheat in hypoxic nutrient solutions and of subsequent transfer to aerated solutions. II. Concentrations and uptake of nutrients and sodium in shoots and roots. Aust. J. Plant Physiol., 15: 599-612.

Morard, P. and J. Silvestre, 1996. Plant injury due to oxygen deficiency in the root environment of soilless culture: A review. Plant Soil, 184: 243-254.

Nasim, M., R.H. Qureshi and M. Aslam, 1993. Screening of different wheat strains for salt tolerance. Pak. J. Agric. Sci., 30: 221-223.

Qureshi, R.H., S. Nawaz and T. Mahmoud, 1993. Performance of Selected Tree Species under Saline-Sodic Field Conditions. In: Towards the Rational Use of High Salinity Tolerant Plants: Agriculture and Forestry under Marginal Soil Water Conditions, Lieth, H. and A.A Al Masoom (Eds.). Vol. 2, Kluwer Academic, Netherlands, pp: 259-269.

Richards, L.A., 1954. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Department of Agriculture, Washington, DC., USA.

Shafqat, M.N., 1994. Effect of salinity and waterlogging interaction on enzyme activity in wheat root. M.Sc. Thesis, University of Agriculture, Faisalabad, Pakistan.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.

Yeo, A.R., S.J.M. Caporn and T.J. Flowers, 1985. The effect of salinity upon photosynthesis in rice (*Oryza sativa* L.): Gas exchange by individual leaves in relation to their salt content. J. Exp. Bot., 36: 1240-1248.