OnLine Journal of Biological Sciences 2 (9): 608-611, 2002
ISSN 1608-4127

Effect of NaCl Salinity on Growth and Ion Partitioning in Some Barley Varieties

Muhammad Hussain, [1]Muhammad Naeem, [2]M. Yasin Ashraf and [2]Zafar Iqbal
University of Agriculture, Faisalabad, Pakistan
[1]Government College, Jaranwala, Pakistan
[2]Nuclear Institute for Agriculture and Biology, P.O. Box No. 128, Jhang Road, Faisalabad, Pakistan

Abstract: Effect of salinity on yield of three barley cultivars Jou-83, Jou-87 and Haider-93 were investigated. It was noted that the number of fertile tillers, spike length, 100 seed weight, yield per plant were higher in Jou-83 followed by Jou-87 and Haider-93. Jou-87 produced highest number of grain per ear followed by Jou-83 and Haider-93. Grain yield production was highest in Jou-83. Reduction in yield per plant in highest salinity level compared to control was 77.22 % in Jou-83 while the corresponding value was 91.78 % for Jou-87 and 86.35 % for Haider-93. Accumulation of Na^+ and Cl^- ions increased with increase in salinity levels in all plant parts (root, stem and leaf). Jou-83 maintained lowest Cl^- ion concentration than other varieties while Na^+ ion accumulation was slightly higher than Jou-87.

Key words: Salinity, growth, ion partitioning, barley

Introduction

Salts have been reported to disturb integrity of cell membranes by inducing changes in the structure, lipid composition and membrane proteins. Salinity is a wide spread phenomenon on earth and is dominant constraint to successful agriculture in arid and semi-arid regions of the world. Soil salinity reduces the land capability to produce optimum crop yield and can even lead to complete failure of agricultural production.

Total geographical area of Pakistan is 80.5 mha and of which 20.36 mha is under cultivation. An area of 16.23 mha is irrigated by canal or tubewell water while the remaining 4.13 mha is rain dependent (Rafiq, 1990). Pakistan is predominantly situated in the arid/semi-arid region; evapotranspiration is high as compared with precipitation. Salinity is a major constraint to irrigated agriculture. In Pakistan 6.61 mha area has been affected by various degrees of salinity (Anonymous, 2001). The harmful salts which predominate in the Pakistan soils are NaCl and Na_2SO_4 (Khan *et al.*, 1995).

Barley is one of the important food crop. It has eminent place because of its malting properties, use in manufacture of bear and as livestock feed. Barley has proved very useful diet in many diseases like painful dyspepsia, hepatic cirrhosis, dementia and Alzheimer's disease. It is principal crop in mountainous and sub-mountainous regions of Pakistan, where wheat cannot grow at high altude. In Pakistan barley is grown over an area of 152.1 thousand hectares with an average yield of 986 kg ha^{-1} (Anonymous, 2001).

Problem of soil salinity can be combated through two approaches, one is to make use of available technology for reclaiming these soils, while other is based on biological exploitation of such soils through cultivation of salt tolerant plant species. In the former approach due to certain limitations such as insufficient supply of irrigation water and high reclamation and drainage cost, the poor farmer is not in a position to exercise this option. While the latter approach does not involve so such investment and is feasible under same situation.

Barley can tolerate extreme environmental and edaphic conditions (Karim *et al.*, 1994), thus in order to have effective utilization of salt affected soils, it is important to select barley genotypes, which may tolerate salinity and produce substantial yields under adverse soil environment. With this objective in view, this experiment was designed to screen three barley genotypes for tolerance to salinity with respect to growth and ion partitioning.

Materials and Methods

Seeds of the barley varieties Jou-83, Jou-87 and Haider-93 were obtained from Ayub Agriculture Research Institute, Faisalabad, Pakistan and sown in earthen pots measuring 30 cm in diameter lined with polythene bags. The soil used for the experimental studies was loamy with pH 8.0, EC 2.8 dS m^{-1} and saturation percentage 32. Each pot was filled with 10 kg of dried and sieved soil, eight seeds were sown in each pot and tap water was used for irrigation as and when needed adding equal amount on every occasion. Germination took place one week after sowing. Five salinity levels i.e., 2.8 (normal), 5, 10, 15 and 20 dS m^{-1} were developed by using NaCl and salinization was started 30 days after germination with an increment of 2 dS m^{-1} per day in order to prevent the osmotic shock.

Three plants from each treatment of a variety were randomly selected and tagged in the beginning of the experiment. Number of fertile tillers of the selected plants were counted and the average number of fertile tillers per plant was calculated. Spike length, number of grains per ear, 100 seeds weight and yield per plant were estimated and mean was calculated.

Root, stem and leaf were separated dried and analyzed for Na and Cl^- to study the transport and partitioning of these ions in roots, stems and leaves in three cultivars. Na^+ ion was determined using flame photometer (Jenway PFP7) after digestion in acid mixture (HNO_3 and $HClO_4$ in the ratio of 9:4) as described by Jackson (1962). Chloride was determined according to Rashid (1986). For this purpose 200 mg oven dried ground tissues were taken in a test tube, digested with 1 ml of 1 mol HNO_3 over night, boiled in water bath added 10 ml distilled water reboiled for 10 min. Supernatent was transferred to a 50 ml volume flask, followed by two more extractions with boiling distilled water. Chloride was determined using Sherwood 926 chloride analyzer directly calibrated in mg L^{-1}.

Results and Discussion

Grain yield is highly dependent upon the number of spike-bearing tillers produced by each plant. Comparison among treatment means showed that salinity reduced the number of fertile tillers significantly. The maximum number of fertile tillers (5.67) was observed in 2.8 dS m^{-1} and the minimum in 20 dS m^{-1} (Table 1). Percent decrease ranged from 8.09 to 64.03 % in 5.0 to 20 dS m^{-1} as compared. The three varieties differed non-significantly. The maximum number of tillers (6.00) was produced by Jou-87 in control and the minimum also by it in 20 dS m^{-1}. At highest salinity level the percentage decrease compared to respective control was 47.0, 77.8 and 66.8 % in Jou-83, Jou-87 and Haider respectively. Similar results have also been reported by many

Corresponding Author: Dr. M. Yasin Ashraf, Nuclear Institute for Agriculture and Biology, P.O. Box No. 128, Jhang Road, Faisalabad, Pakistan

Table 1: Effect of different levels of NaCl salinity on number of fertile tillers per plant and grain yield in barley

	Treatments (dS m^{-1})					
Varieties	2.8	5.0	10.0	15.0	20.0	Mean
Fertile tillers per plant						
Jou-83	5.67	5.00 (11.82)	4.00 (29.45)	3.66 (35.45)	3.00 (47.09)	4.27^{NS}
Jou-87	6.00	5.67 (5.50)	2.66 (55.66)	1.66 (72.33)	1.33 (77.83)	3.73
Haider-93	5.00	4.67 (6.60)	4.00 (20.00)	3.33 (33.4)	1.66 (66.80)	3.47
Mean	5.56a	5.11a (8.10)	3.56b (35.97)	2.89c (48.02)	2.00d (64.02)	
Grain yield						
Jou-83	10.14	8.40 (17.16)	5.90 (41.81)	4.23 (58.28)	2.31 (80.00)	6.20a
Jou-87	8.76	6.90 (21.23)	3.40 (61.19)	1.60 (81.73)	0.72 (91.78)	4.28b
Haider-93	6.89	5.40 (20.32)	4.88 (29.17)	2.74 (60.23)	0.94 (86.36)	4.17b
Mean	8.60a	6.90b (19.76)	4.72c (45.12)	2.86d (66.74)	1.32d (84.65)	

Means with different letters differ significantly according to Duncan's multiple range test (P = 0.05),
The values in the parenthesis show % decrease over control

workers (Ashraf *et al.*, 1998, 1999; Khan and Ashraf, 1988). Maas *et al.* (1994) reported that in wheat production of secondary tillers and spikes were nearly eliminated by low and high salinity levels due to which heavy yield losses were recorded.

The maximum yield was noted (6.20 g) in Jou-83 which was highly significant with other two varieties (Table 1). The minimum yield (4.17g) was recorded in Haider-93 which was non-significant with Jou-87 but highly significant with Jou-83. A decrease of 30.97 and 32.74 % in yield was observed for Jou-87 and Haider-93 respectively as compared to Jou-83. Yield was significantly influenced by salinity. Maximum yield (8.60 g) was found in control and the minimum (1.32 g) in 20 dS m^{-1}.

Treatment 15 and 20 dS m^{-1} were nonsignificant with each other but significant with control, 5 and 10 dS m^{-1} which were also significant with one another. Treatment 5, 10, 15 and 20 dS m^{-1} showed 19.78, 48.50, 66.74 and 84.65 % reduction in yield respectively as compared to control. Interaction between variety and treatment was non-significant. The maximum yield (10.14 g) was recorded in Jou-83 in control and the minimum (0.72 g) in Haider-93 in 20 dS m^{-1}. Reduction in yield per plant with increased salinity may be due to decrease in number of spikes per plant, number of spikelet per spike and number of seeds per spike. In these studies all these parameters were almost equally responsible for reduction in yield. Reduction in yield with significant inter-varietal differences due to rise in salinity have also been reported for barley (Slavish *et al.*, 1990; Aloy *et al.*, 1992). Data regarding 100 seed weight showed that the interaction between variety and treatments was non-significant. Maximum hundred seed weight (5.83 g) was produced by Jou-83 in control and the minimum (3.37 g) in Jou-87 and Haider-93. At highest salinity level (20 dS m^{-1}) varieties Jou-83, Jou-87 and Haider-93 showed 19.38, 31.61 and 26.40 % decrease in 100 seed weight respectively as compared to respective control. Khan *et al.* (1992) also reported a significant decrease in 1000 seed weight with increase in salinity for wheat.

Minimum Na^+ concentration (53.0 mmol Kg^{-1}) was recorded in control while maximum (161.8 m mol Kg^{-1}) was found in 20 dS m^{-1} (Table 2). Treatments 5, 10, 15 and 20 dS m^{-1} had an increasing value of 34.79, 108.11, 174.15 and 205.77 % respectively over control. Varietal means also showed significant differences. Maximum Na^+ concentration (133.3 mmol Kg^{-1}) was found in Haider-93 and minimum in Jou-87. Percent decrease of 25.68 and 30.38 % as compared to Haider-93 was found in Jou-83 and Jou-87 respectively. On overall basis Na^+ concentration increased with salinity in all the varieties. Minimum Na^+ concentration was noted in Jou-83 in control and maximum in Haider-93 at 20 dS m^{-1}.

Significant differences in Na^+ accumulation in stem tissue of all the varieties (Table 2) were recorded. Maximum Na^+ accumulation (265.60 mmol Kg^{-1}) was noted in Haider-93 and the minimum (201.00 mmol Kg^{-1}) in Jou-83. Varieties Jou-87 and Jou-83 showed 20.33 and 24.32 % decrease in Na^+ accumulation respectively as compared with Haider-93. Salinity significantly affected the Na^+ ion accumulation in various treatments. Minimum Na^+(134.0 mmol Kg^{-1}) was found in control and the maximum (293.7 mmol Kg^{-1}) in 20 dS m^{-1}. Percent increase in Na^+ accumulation was 50, 76.12, 97.76 and 119.18 % in 5, 10, 15 and 20 dS m^{-1} respectively as compared to control. Variety x treatment interaction was highly significant. Maximum Na^+ accumulation was noted in 20 dS m^{-1} and the minimum in control. All varieties had minimum Na^+ in control and maximum in 20 dS m^{-1}.

Similarly in leaves minimum Na^+ concentration (143.0 mmol Kg^{-1}) was noted in control while maximum (306.7 mmol Kg^{-1}) was found in 20 dS m^{-1}. Treatments 5, 10, 15 and 20 dS m^{-1} had an increasing value of 27.48, 39.86, 48.95 and 114.448 % respectively as compared to control. Varietal means were also significant. Maximum Na^+ accumulation (220.8 mmol Kg^{-1}) in leaves was recorded in Jou-87 and the minimum in Haider-93. Percent decrease in Jou-83 and Haider-93 was 5.46 and 10.00 % respectively as compared to Jou-87. Variety x treatment interaction was highly significant. All the varieties accumulated minimum Na^+ in control and maximum in 20 dS m^{-} .[1] Overall, minimum (108.0 mmol Kg^{-1}) Na^+ as accumulated in Jou-87 in control and maximum (375.0 mmol Kg^{-1}) also in Jou-87 in 20 dS m^{-1}. Increase in Na^+ concentration with increased salinity has also been reported in rice (Iram *et al.*, 1998) and wheat (Qureshi *et al.*, 1991; Akhtar *et al.*, 1998). Boursier and Lauchli (1990) reported that in *Sorghum bicolour* increase in salinity remarkably increased Na^+ accumulation in stem, leaf sheath and leaf blade.

Comparison among treatment means showed significant differences in Cl^- concentrations. Minimum Cl^- accumulation (132.2 mmol Kg^{-1}) was noted in control and maximum (543.3 mmol Kg^{-1}) in 20 dS m^{-1} (Table 2). Varietal means also showed significant results. Variety Haider-93 accumulated maximum (439.6 mmol Kg^{-1}) Cl^- and was significant with Jou-87 and Jou-83 which were non-significant with each other regarding Cl^- accumulation in root. Jou-87 and Jou-83 showed a decreasing value of 34.94 and 30.60 % respectively over Haider-93. Interaction between variety and salinity was significant. Maximum Cl^- (690.0 mmol Kg^{-1}) was accumulated in Haider-93 in 20 dS m^{-1} and the minimum (84.5 mmol Kg^{-1}) in Jou-83 in control.

Similarly an increase in salinity was associated with increased Cl^- concentration in stem (Table 2). A significant increase in Cl^- accumulation was recorded with rise in salinity level. Minimum Cl^- concentration (274.7 mmol Kg^{-1}) was noted in control and maximum value (1025.0 mmol Kg^{-1}) in 20 dS m^{-1}. Varietal means showed significant differences. Haider-93 had maximum (760.4 mmol Kg^{-1}) Cl^- followed by Jou-87 and Jou-83. Varieties Jou-87 and Jou-83 showed 18.99 and 32.67 % decrease in chloride accumulation over Haider. Interaction between variety and salinity was significant. Maximum chloride accumulation (1217.0 mmol Kg^{-1}) was noted in 20 dS m^{-1} in Haider-93 and the minimum (148.0 mmol Kg^{-1}) in control in Jou-83.

Table 2: Effect of salinity levels on Na^+ and Cl^- concentration in root, stem and leaves (mmol per Kg) in barley

	Treatments (dS m^{-1})					
Varieties	2.8	5.0	10.0	15.0	20.0	Mean
Na^+ concentration						
Root						
Jou-83	24.00	62.33	100.00	145.30	161.08	99.07b
Jou-87	63.00	80.00	96.00	100.00	125.00	92.80b
Haider-93	72.00	72.00	135.00	192.00	195.30	133.30a
Mean	53.00e	71.44d (34.79)	110.30c (108.11)	145.30b (174.15)	161.80a (205.28)	
Stem						
Jou-83	102.0	210.0	216.0	234.0	243.0	201.0b
Jou-87	150.0	153.0	200.0	261.0	294.0	211.6b
Haider-93	150.0	240.0	294.0	300.0	344.0	265.6a
Mean	134.0	201.0 (50.00)	236.0b (76.12)	265.0b (97.76)	293.7a (119.18)	
Leaves						
Jou-83	186.0	187.0	198.0	204.0	265.0	208.0b
Jou-87	108.0	174.0	210.0	237.0	375.0	220.8a
Haider-93	135.0	186.0	192.0	198.0	280.0	198.2c
Mean	143.0d	182.3c (27.48)	200.0b (39.86)	213.0b (48.95)	306.7a (114.48)	
Cl^- concentration						
Root						
Jou-83	84.5	219.0	222.0	334.0	532.0	278.3b
Jou-87	127.0	236.0	305.0	352.0	408.0	285.6b
Haider-93	185.0	228.0	532.0	563.0	690.0	439.6a
Mean	132.2e	227.7d (72.23)	353.0c (167.09)	416.3b (214.67)	543.3a (310.97)	
Stem						
Jou-83	148.0	524.0	519.0	596.0	769.0	511.3c
Jou-87	338.0	370.0	422.0	862.0	1090.0	616.4b
Haider-93	338.0	642.0	718.0	887.0	1217.0	760.4a
Mean	274.7d	512.0c (86.38)	553.0c (101.31)	781.9b (184.64)	1025.0a (273.13)	
Leaves						
Jou-83	204.7	285.0	565.0	608.0	709.0	430.4c
Jou-87	447.5	473.0	481.0	591.0	750.0	474.3b
Haider-93	262.0	270.0	346.0	458.0	816.0	548.6a
Mean	307.4e	342.7d (13.76)	464.0c (50.94)	552.3b (79.67)	758.4a (146.71)	

Means with different letters differ significantly according to Duncan's multiple range test ($P=0.05$); The values in the parenthesis show % increase over control

Data regarding Cl^- concentration in leaves showed that its concentration increased significantly with increase in salinity (Table 2). Minimum Cl^- (307.4 mmol Kg^{-1}) was observed in control and maximum (758.4 mmol Kg^{-1}) in 20 dS m^{-1}. Treatments 5, 10, 15 and 20 showed an increase of 11.48, 50.94, 79.66 and 146.71 % respectively as compared to control. Differences in varietal means were also significant. Jou-87 accumulated maximum (548.6 mmol Kg^{-1}) Cl^- followed by Jou-83 and Haider-93. Interaction between variety and treatment was significant. Increase in salinity was associated with increased Cl^- ion accumulation. Overall minimum Cl^- concentration (204.7 mmol Kg^{-1}) was noted in Jou-83 in control and maximum (816.0 mmol Kg^{-1}) in Haider-93 in 20 dS m^{-1}. Increase in Cl^- ion concentration with NaCl addition to growth medium was also reported by Aslam *et al.* (1990) in rice and Ashraf *et al.* (1998) in wheat. Rashid *et al.* (1999) reported Jou-83 and Haider-93. Interaction between variety and treatment was significant. Increase in salinity was associated with increased Cl^- ion accumulation. Overall minimum Cl^- concentration (204.7 mmol Kg^{-1}) was noted in Jou-83 in control and maximum (816.0 mmol Kg^{-1}) in Haider-93 in 20 dS m^{-1}. Increase in Cl^- ion concentration with NaCl addition to growth medium was also reported by Aslam *et al.* (1990) in rice and Ashraf *et al.* (1998) in wheat. Rashid *et al.* (1999) reported

that Na^+ and Cl^- contents of shoot increased with increase in salinity. Higher accumulation of Cl^- in stem as compared to leaf probably allowed the plants to maintain relatively low Cl^- level in leaf tissue, thus protecting the primary sites of carbon assimilation in leaves from potential toxic levels of Cl^-. The results of this study showed that more than one factor is responsible for these differences in salt tolerance expressed in growth depression. The varieties differ in Na^+ and Cl^- contents in shoot, root and leaves. In all varieties, Cl^-content was higher than Na^+. Relatively higher uptake of Cl^- could be directly or indirectly responsible for growth depression, either by depressing the uptake of other anions (Ashraf *et al.*, 1998) or by direct osmotic effects of high local concentrations (Khan and Ashraf, 1988). However, high Cl^- concentration are not always damging for crop plants, as has been reported for tomato varieties (Tal, 1971). High tolerance of the cell for Cl^- and Na^+ is caused by particular compartmentation within the cells (Flowers, 1972). The Na^+ was mainly retained in the roots of Jou-83 and Jou-87 varieties and translocated in limited amount to stem and leaves, although it was higher in leaves and stem than root but was low than Haider-93. It can concluded that Jou-87 performed better and can be categorized as tolerant and Haider as non-tolerant.

References

Akhtar, J., R.H. Qureshi, M. Aslam and S. Nawaz, 1998. Performance of selected wheat genotypes grown under saline and hypoxic environment. Pak. J. Soil Sci.,15:146-153.

Aloy, M., A. Royo and R. Aragues, 1992. Effect of different levels of salinity on yield and yield components of six varieties of barley. Proc. Sec. Congress. European Soc. Agron. Warwick Univ., 23-28.

Anonymous, 2001. Agricultural Statistics of Pakistan. Govt. of Pakistan Ministry of Food, Agriculture and Livestock Division, Economic Wing, Islamabad, Pakistan.

Ashraf, M., R.A. Wahed, A.S. Bhatti, G. Sarwar and Z. Aslam, 1999. Salt tolerance potential in different Brassica species, Growth studies. In: Halophytes Uses in Different Climates - II (eds. Hamdy, H., H. Lieth, M. Todorovic and M. Moschenko), Backhuys Publishers, Leiden, The Netherland, pp: 119-125.

Ashraf, M.Y., Y. Ali and T.M. Qureshi, 1998. Effect of salinity on photosynthetic efficiency and yield of rice genotypes. Pak. J. Biol. Sci., 1: 72-74.

Aslam, M., R.H. Qureshi, N.M. Nasir and T. Hussain, 1990. Intravarietal variability in rice for salt tolerance. Pak. Soil Sci., 5: 7-11.

Boursier, P. and A. Lauchli, 1990. Growth responses and mineral nutrient relations of salt stressed sorghum. Crop Sci., 30: 1226-1233.

Flowers, T.J., 1972. Salt tolerance in *Sueda* m*aritim*e (L.) Dumm: The effect of sodium chloride on growth, respiration and soluble enzymes in a comparative study with *Pisu*m *sativu*m L. J. Exp. Bot., 23: 310-321.

Iram, S., M. Ashraf and S. Masood, 1998. Screening of rice germplasm for NaCl tolerance. Pak. Soil Sci.,15: 78-83.

Jackson, M.L., 1962. Soil Chemical Analysis. Published by Constable and Company Ltd., England.

Karim, M.A., E. Nawata and S. Shigenaga, 1994. Response of hexaploid triticale, wheat, rye and barley to salinity in relation to grain yield. Japanese J. Trop. Agric., 38: 16-25.

Khan, A.H., M.Y. Ashraf, S.S.M. Naqvi, B. Khanzada and M. Ali, 1995. Growth, ion and solute contents of sorghum grown under NaCl and Na_2SO_4 salinity stress. Acta Physiol. Plant, 7: 261-268.

Khan, A.H., M.Y. Ashraf and A.R. Azmi, 1992. Osmotic adjustment in sorghum under sodium chloride stress. Acta Physiol. Plant, 14:159-162.

Khan, A.H. and M.Y. Ashraf, 1988. Effect of sodium chloride on growth and mineral composition of sorghum. Acta Physiol. Plant, 10: 259-264.

Maas, E.V., S.M. Lesch, L.E. Francois and C.M. Grieve, 1994. Tiller development in salt-stressed wheat. Crop Sci., 34: 1594-1603.

Qureshi, R.H., A. Aslam, G. Mustafa and J. Akhtar, 1991. Some aspects of physiology of salt tolerance in wheat. Pak. J. Agric. Sci., 28: 199-206.

Rafiq, A., 1990. Soil Resources and Soil Related Problems in Pakistan. In: M. Ahmad, M.E. Akhtar and M.I. Nizami (Eds.), Soil Physics Application Under Stress Environments. BARD, PARC, Islamabad, Pakistan, pp: 16-23.

Rashid, A.,1986. Mechanisms of salt tolerance in wheat. Ph.D. Thesis, Univ. Agric. Faisalabad, Pakistan.

Rashid, A., R.H. Qureshi, P.A. Holington and R.G. Wyn Jones, 1999. Comparative response of wheat cultivars to salinity at seedling stage. J. Agron. Crop Sci., 182: 199-207.

Slavish, P.G., B.J. Read and B.R. Cullis, 1990. Yield response of barley germplasm to field variation in salinity quantified using the EM-38. Aust. J. Exptl. Agric., 30: 551-556.

Tal, M., 1971. Salt tolerance in the wild relatives of the cultivated tomato: Responses of *Lycopersicon exculentu*m L. *peruvianu*m and *L. esculentu*m minor to sodium chloride solutions. Aust. J. Agric. Res., 22: 631-638.