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Effect of Hydroponic Salinity (120 Molm^{-3} NaCl) on the Ion Uptake and Growth of Different Wheat Varieties

Rajpar and N.B. Sial
Faculty of Crop Production, Department of Soil Science
Sindh Agriculture University, Tando jam, Pakistan

Abstract: Ten hexaploid (Triticum aestivum L.) wheat varieties (Tonic, LU-26S, Q-19, KRL1-4, Kharchia-65, SARC-1, PAK-18, KTDH-19, Cadenza and NIAB-20) were grown up to flag leaf stage in 120 molm^{-3} NaCl salt solution. The plants of variety Q-19 were smaller, without tillers and had lower shoot dry weight than other varieties. The plants of variety Kharchia-65, KTDH-19 and Cadenza were taller, with higher shoot dry weight and had more tillers and mainstem leaves than most of the varieties. Compared to other varieties tested in this experiment, poor performance of Q-19 was associated with higher Na^+ and lower K^+/Na^+ ratio. The better performance of Kharchia-65 was associated with less Na^+ and Cl^- accumulation and higher K^+/Na^+ ratio content in the flag leaf sap, however, this trend was not found in KTDH-19 and Cadenza,

Key words: Flag Leaf, K^+/na^+ Ratio, Salinity, Salt-tolerant, Sap, Wheat

Introduction

The addition of NaCl to the growth medium leads to a decrease in the accumulation of $K^+$and increase in the accumulation of Na^+ and Cl^- in germinating seeds (Begum *et al.*, 1992) and in stems and leaves of various crop plants including barley (Yeo and Flowers, 1982; Gorham, 1994); corn (Shone *et al.*, 1969; Julie *et al.*, 1983). Evidence for this in wheat has also been given by many workers including (Joshi *et al.*, 1985); (Khan *et al.*, 1992); (Chhipa and Lal, 1983); (Sastry and Parkash, 1993); (Leland *et al.*, 1994); (Barkat and Abdullatif, 1996); (Hamada, 1996); (Sharma, 1996) and (Gorham *et al.*, 1997). Like seedling emergence, growth and development, different plant species and varieties show large differences in Na^+, K^+ and Cl^- accumulation and K^+/Na^+ ratio content in presence of equal salinity (Baykal, 1983), some species and varieties accumulate more Na^+ and Cl^- but less K^+, while others show an opposite trend of less Na^+ but more K^+ accumulation. Differences between wheat species and varieties in ion uptake have also been reported by many workers (Shah *et al.*, 1987; Azmi and Alam, 1990; Sastry and Parkash, 1993; Dvorak *et al.*, 1994; Ashraf and O' Leary, 1996 and Gorham *et al.*, 1997).

It has been considered by several researchers that the discrimination between plants in $Na^+$and K^+ accumulation determines the ability of plants to respond under saline conditions as salt-tolerant or sensitive. Hence the use of K^+/Na^+ ratio as one of the criteria for selecting salt tolerant and salt-sensitive plants including wheat has been adopted by several workers (Greenway and Munns, 1980). The recommendations of wheat varieties as resistant to salinity may provide the best possible opportunity to farmers for achieving the highest returns from saline soils. Therefore this comparative study was started so that some salt-tolerant wheat varieties could be selected for cultivation on saline soils.

Materials and Methods

Preparation of pots: Four pots (52 x 35 surface x 15 cm depth) with 4 holes (two in front, 1 in the right side and 1 in the left side) of 7mm for air supply and one 9 mm hole (in front of each pot) for solution change were used in this study. Rubber bungs were used to plug the holes for facilitating both the easy change of nutrient solutions and to fix air supply needles. All pots were placed on a trolley standing in a growth-room. Silicon tubing (Scientific Service, Chester, UK) which automatically seals the holes made by needles was used. A silicon tube with 5mm internal diameter and 8mm external diameter was fixed along the trolley and was connected to the air regulator. Narrow polyethylene capillary tubes with 0.58mm internal diameter and 0.96 mm external diameter were used to supply air from silicon tubes to the pots. The capillary tubes were cut into appropriate lengths and then fixed with needle at both ends, one end inserted into the silicon tube and the other end into the bung fitted into the pots.

Raising and Transplanting of Seedlings: The experiment tested 10 hexaploid wheat varieties. Seeds of all wheat varieties were pre-germinated in perlite using black painted plastic pots (10cm x 10 cm surface x 16 cm deep). Ten days after sowing, seedlings of each variety were transferred into the solution culture pots (52 cm x23 cm surface x 16 cm deep). There were 4 pots and each pot of solution culture was considered as a replication. In total seven seedlings of each variety per pot were transferred. The seedlings were fixed in plastic lids (Plantpak trays, Maldon, UK) at a distance of 7 cm plant to plant and 6 cm row to row, using a completely randomized block design. A foam collar around the stem base of individual seedling was used to hold the plants with their roots immersed in 25 liters aerated nutrient solution.

Growth Conditions: The seedlings were raised and the experiment was performed in a walk-in growth chamber set at 18 ^{0}C day and 9 ^{0}C night temperature, 65 % RH with photoperiod of 16 hours.

Salt Stress and Fertilizer: Salt stress of 120 mol m^{-3} NaCl and 6 mol m^{-3} of $CaCl_2.H_2O$ was commenced seven days after transplanting the seedlings. Salt stress was introduced in three equal increments over a period of 5 days. Phostrogen fertilizer @ 0.5 g/l (Phostrogen LTD, Deeside Industrial Park, Deeside, Flintshire CH5 2NS) was applied to each pot. In addition the Long Ashton Nutrient Solution to supply micro-nutrients (Hewitt, 1996) was also applied to each pot. The solution in the pots was initially changed after 10 days and later after every fifth day.

Harvesting, Leaf Sampling, Sap Extraction and Chemical Analysis: All plants of each variety were harvested when they achieved fully expanded flag leaf stage. The fully expanded flag leaf of harvested plants was detached, placed in eppendorf tubes and stored in a freezer set at -10 °C. The lamina of leaves were removed and the sap was extracted and analysed for Na^+, K^+ (by atomic absorption spectrophotomtery using 151aa/a Spectrophotometer. Instrumentation Laboratories, Lexington, Mass 02173) and Cl^- (by chloride electrode, using Microprocessor Ionalzer/901. Orion Research Incorporated. 380 Putman Avenue, Cambridge). The harvested plants were used to measure height (from base of the plant to the tip of the longest leaf), number of leaves on the mainstem and number of tillers per plant. Shoot dry weight (mg/plant) of plants was recorded after oven drying the green plant matter at 80 °C for 48 hours.

Statistical Analysis: All data were analysed by the analysis of variance (ANOVA) method, using one way ANOVA in MINITAB statistical package, version 10.51. Significant levels are shown in the tables by *, **, *** for 5%, 1% and 0.1% probability levels, respectively. The non-significant differences are denoted by N.S. The standard error of the difference between means (S. E. D) and the least significant differences (L. S. D) were calculated.

Results and Discussion

The number of days after transplanting at which the flag leaf fully expanded stage was reached varied from 39 to 61 (Table 1). Some varieties (Q-19, SARC-1and NIAB-20) generally took fewer days and some (KTDH-19 and Cadenza) took many more days to expand their flag leaves than others.

There were significant ($P < 0.005$) differences between varieties for all growth and development parameters measured during this study (Table 1). Plants of variety Q-19 were significantly shorter without tillers and had significantly ($p < 0.005$) lower shoot dry weight than other varieties. However the plants of variety Kharchia-65 grown taller, plants of KTDH-19 and Cadenza had more tillers and mainstem leaves and showed higher shoot dry weight than other varieties.

The results obtained from this study provided evidence that out of ten varieties tested, Q-19 showed poor performance in terms of growth and development under saline conditions while the response of three varieties viz. KTDH-19, Cadenza and Kharchia-65 was considerably better than that of six varieties which was intermediate. The poor performance of Q-19 was clearly associated with higher flag leaf Na^+ and lower K^+/Na^+ ratio. It has been well documented by several workers including Larcher, (1995) that under saline conditions either due to ion imbalance (K^+/Na^+ imbalance), or due to water deficit, disturbances in protein metabolism and hence plant growth is decreased. Better performance of Kharchia-65 was associated with lower flag leaf Na^+, Cl^- and higher K^+/Na^+ ratio. There have been several reports including Joshi *et al.*, (1982) and Sharma, (1991) showing that Kharchia-65 is a salt-tolerant variety and it accumulates less Na^+ and shows higher K^+/Na^+ ratio under saline condition. Although the seedling dry weight and number of tillers of KTDH-19 and Cadenza was higher compared to other varieties, the ion concentrations did not show clear association with this, because the concentrations of Na^+ and Cl^- were not markedly different from those of some other varieties which showed intermediate growth. This suggests that possibly when these two varieties achieved the flag leaf stage they were still growing, so that they had more shoot dry weight. These results suggest that K^+/Na^+ ratio should not be considered as the only criteria for salt-tolerance, but the concentration of Cl^- and more important growth and development parameters must be taken in to account while selecting salt-tolerant wheat varieties.

Ion Concentrations: Significant ($P < 0.005$) differences were found between the varieties for Na^+, K^+ and Cl^- accumulation and K^+/Na^+ ratio calculated in the flag leaf sap (Table 2). The variety Kharchia-65 accumulated (significantly ($p < 0.005$)) less Na^+ and (non-significantly ($p > 0.005$)) and Cl^- hence they showed significantly ($P < 0.005$) higher K^+/Na^+ ratio than other varieties. The variety Q-19 accumulated significantly ($P < 0.005$) higher Na^+ and showed significantly ($P < 0.005$) lower K^+/Na^+ ratio than other varieties. The concentration of K^+ remained higher in the leaves of KTDH-19 and NIAB-20 and lower in the leaves of LU26S showed more K^+ than other varieties.

Table1: Effect of 120 Molm^{-3} NaCl Solution on the Height (cm), Number of Leaves on the Mainstem, Number of Tillers/plant and Shoot Dry Weight (mg/plant) of 10 Wheat Varieties Grown in Hydroponic Culture

Varieties	Flag leaf fully expanded at (DAT)	Height (cm)	Number of leaves on the mainstem	Number of. tillers/plant	Dry wt. (mg/plant)
Tonic	53	55	7.8	1.10	692
LU26S	46	57	8.5	0.63	619
Q-19	43	33	7.3	0.00	249
KRL1-4	43	53	6.8	0.00	466
KHARCHIA-65	39	72	7.2	1.13	777
SARC-1	43	46	7.7	0.30	0413
PAK-81	53	50	8.5	1.13	592
KTDH-19	61	61	8.7	3.00	944
CADENZA	61	64	8.4	2.00	856
NIAB-20	43	52	7.8	1.00	685
S. E. D.	-	2.2	0.16	0.27	108.0
L. S. D.	-	6.4***	0.48***	0.79***	220.0***

Table 2: Na^+, K^+ Concentrations and K^+/Na^+ Ratio Content in the Flag Leaf Sap of 10 Wheat Varieties Grown in 120 Molm^{-3} NaCl Solution

Varieties	Na^+	K^+	K^+/Na^+	Cl^-
Tonic	76	150	2.0	243
LU26S	71	378	4.6	144
Q-19	144	211	1.5	214
KRL1-4	40	179	4.7	171
KHARCHIA-65	19	152	8.2	170
SARC-1	72	176	2.5	251
PAK-81	78	179	2.5	244
KTDH-19	40	74	2.5	200
CADENZA	42	126	3.1	385
NIAB-20	41	75	2.0	253
S. E. D.	8.0	27.0	0.60	20.0
L. S. D.	15.0***	56.0***	1.19***	43.0***

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