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Sodium and Potassium Accumulation in Different Parts of Wheat Under Salinity Levels

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Abstract: Water and soil salinity concentration are important for decreases in the yield of a wide variety of crops in many parts of the word. In addition to evaluation of plant tolerant and toxic ion effects in saline condition, concentration of Na^+ and K^+ ions in different part of plant (e.g., wheat) is very important. Results showed that, biological yield or dry matter accumulation in Leaves, stem, root, spike, number of fertile tiller and grain yield per tiller seed decreased with increasing salinity. Also, by increasing salinity, Sodium content of Leaf, stem, root, spike and seed increased but potassium content decreased. In high salinity Level, Kharchia and Bangor cultivars showed minimum sodium and maximum potassium accumulation, while in different parts of Chamran Cultivar potassium and sodium were minimum and maximum respectively. In Chamran cv. Sodium content decreased in root, against the increased sodium content in shoot. High Na^+ concentration strongly inhibited uptake and accumulation of K^+ by root and induced a reduction in K^+ grain. Yield analysis showed that there was significant difference between all salinity treatments. Seed weight had significant reduction with increasing salinity. Results indicated that Kharchia and Bangor cultivars were more tolerant to salinity than Chamran cultivar.

Key words: Salinity, wheat, sodium, potassium, seed weight, partitioning

INTRODUCTION

Data collection at CIMMYT suggested that 8-10% of the area planted to wheat in Iran is affected by salinity (Timothy and Timothy, 2006). Also a rapid increase in the population of Iran during the past two decades has significantly increased the country's need for food and fiber and has put its Land and water resources under sever stress. Freshwater resources of the country, both surface and ground water has been over-exploited, often at the expense of deteriorating water and Land quality (Dordipour *et al*., 2004). Use of saline water for irrigation is a subject of increasing interest because of the increasing water requirements for irrigation and the competition between human, industrial and agricultural. Moreover there is the pressure for safe the disposal of drainage water through reuse. Saline water earlier on, considered to be unusable for irrigation but research efforts during the past two decades have brought into practice some large irrigation schemes which depend on saline water (Hamdy *et al*., 1993). However, increasing land and ground-water salinity as well as possible deterioration of soil physical, chemical and biological characteristics causes, this issue to be thoroughly researched. The sustainability of irrigated agriculture in arid and semi-arid areas (like Iran) depends on maintenance of salt balance within the soil profile and disposal of shallow groundwater. Saline drainage water can be used for irrigation of certain crops and their use Lessens drainage disposal requirements and water pollution (Rhoades *et al*., 1980). Soil Salinity is an important growth Limiting Factor for most non-halophytic plants (e.g., wheat).

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Salt inhibit plant growth by osmotic stress, nutritional imbalance and specific ion toxicity (Alam, 1994; Cornill and Palloix, 1997; Gunes *et al*., 1996; Jacoby, 1994). Soil salinity is being progressively exacerbated by agronomic practice such as irrigation and fertilization, especially in arid regions. Salinity generally affects the growth of plants by water deficits in the expanded leaves (Cramer *et al*., 2001; Greenway and Munns, 1980), decreases germination (Bernardo *et al*., 2000a), leaf area and dry matter accumulation, the rate of net CO_2 assimilation and relative growth (Bernardo *et al*., 2000b). Wheat is one of the major threats to crop production in tropical regions (like Iran). Although there are many factors which are responsible for grain yield like the number of tillers, seed numbers, leaf area, photosynthesis and availability of carbohydrates in floret and vegetative parts, mainly by flag leaf, stem and ear (Carr and Wardlaw, 1995). It is of vital interest to try to overcome the problem of salinity and expand wheat production in many saline regions in Iran and to be able to predict the wheat crop growth, development and yield potential with varying salinity of irrigation water.

So this study examines growth, yield, sodium, potassium partitioning, ear wheat dry weight in main-stem and tiller in irrigated pot experiment using fresh water as control (well water) and saline water with different levels of salinity.

MATERIALS AND METHODS

The study was pot experiment carried out at the experimental farm of the Department of Agronomy and Crop Breeding, Faculty of Agriculture in Shahid Chamran University of Ahvaz (Iran) in 2004-2005. The climatic data of the region is represented in Table 1. The soil had a clay-loam texture with low organic matter (Table 2).

The study was established using a split plot under randomized block, designed with four replications. The cultivars were placed in the main plots (one Iranian cultivar, Chamran and two introduce variety kharchia and Bangor). Water salinity levels, S_1 or freshwater as control (EC was less than 2 dS m^{-1}), S_2: EC=6 dS m^{-1}, S_3: EC=12 dS m^{-1} and S_4: EC=18 dS m^{-1} were used in this study as sub plots. Wheat (*Triticum aestivum* L.) was grown on a clay-loam in pots, made of PVC tubing, 10 cm in diameter and 60 cm in height. Pots bottom were covered by unolite sheet. Three holes where drilled in each pot bottom to drain the pot. Also under each pot a tray was put to accumulate drain water. After irrigation, drain water which accumulated in tray, to constant the soil nutrients was converted to its pot. Owing the leaching at each water application, soil salinity remained almost constant from the start till the end of the growing period.

Table 1: Climatic data of experimental farm of Ahvaz University in 2004-2005 (in growth period)*

	Temperature (°C)			Transpiration
	------------------------------------		Rain	average
Months	Min	Max	(mm)	(mm)
September	20.4	37.6	0.0	171.4
October	13.6	27.7	82.4	70.2
November	10.8	18.1	15.7	55.0
December	10.9	17.2	15.6	86.7
January	9.3	20.5	10.1	142.6
February	14.4	28.6	0.4	185.4

* Source: Department of irrigation, Agriculture Faculty, Ahvaz University

Table 2: Some chemical and physical result of pot experimental soil*

EC dS m^{-1}	pH	Organic matter (%)	K (mg kg^{-1} soil)	P (mg kg^{-1} soil)	N (%)	Soil texture
2.8	7.25	0.552	172.5	16.25	0.039	Clay-loam

* Soil analysis was done at the laboratories of the soil Science Department, Ahvaz University

Table 3: Some physico-chemical properties of the water, used for irrigation

	Anions (meq L^{-1})				Cations (meq L^{-1})						
Water	HCO_3	Cl	SO_4	Total anions	Ca	Mg	Na	Total cations	SAR	pH	EC (dS m^{-1})
S_1	3.0	6.4	4	13.4	2.5	5.7	4.6	12.8	2.5	1.34	8.0
S_2	3.2	45.0	16	64.2	9.2	20.0	37.4	66.6	13.3	6.02	7.8
S_3	3.3	100.0	27	130.3	17.0	27.0	85.0	129.0	21.2	11.97	7.9
S_4	3.4	175.0	50	228.4	19.0	38.4	147.0	204.4	29.6	18.01	8.1

Fertilizer applications were made according to recommendation based on soil chemical analysis and seed production (5 t ha^{-1}). Nitrogen was applied to all pots (0.275 g urea pot^{-1}: half before planting, one fourth at the tillering and one fourth at the heading stage). Each treatment also received 1 g P_2O_5 per pot, P_2O_5 as super phosphate and 1 g K pot^{-1}, as K_2SO_4 before planting. PVC pots were filled the soil which was passed through a 2 mm sieve. In each pot, 5 seeds were sown on middle of December, 2004. They were thinned to three plants after germination and Full establishment of seedling (20 days after planting). Three plants in each pot were used for measurement and sampling in the four stages which consisted of 1: late of tillering stage (50 days after planting), 2: Late elongation stage (65 days after planting), 3: Early of flowering stage (95 days after planting), 4: At maturity stage (125 days after planting) to determine quantity of yield, dry matter, sodium, potassium partitioning in different parts of plant and so on.

Irrigation water to make different water salinity Levels (S_2, S_3 and S_4 was made by adding well water to drainage water) was provided from the drainage water-Farm of Amir-kabir Agriculture Company. The basic physico-chemical properties of water were determined with standard techniques (Sparks *et al*., 1996). Some chemical data for the irrigation waters are presented in Table 3.

The pots were irrigated with well water for germination and establishment of seedling until the respective irrigation treatments were applied (starting at tillering stage 40 days after planting). The irrigation then continued with different water salinity levels (S_1, S_2, S_3 and S_4) according to water requirement. The pots were covered by plastic sheets to prevent the excess of water to them during rainy climate condition. At harvest, plants were cut at the soil surface and divided into tops (head, leaf and shoot) and roots (roots were separated from the soil with a gentle spray of tap water) and their fresh oven-dry weights (60°C for 48 h) were determined. Dried plant samples were ground to pass through 40 mesh using digested for Na and k analyses by Flame photometry (Anonymous, 1954).

RESULTS AND DISCUSSION

Total Dry Weight

Salinity affected total dry matter (TDM) accumulation and it was observed that all salinity levels treatment (S_2, S_3 and S_4) reduced TDM (Table 7). TDM reduction caused by S_4 was higher than that in other (S_2 and S_3). With an increasing salinity level, the TDM decreased drastically. This decline was more prominent in S_4. Excess of salt creates osmotic stress by a decline in water potential producing negative effects on physiological processes (Shereen *et al*., 2001). One Factor that might have caused the lower growth in plants that were exposed to salinity is different balancing pressure. Balancing pressure prevented a fall in leaf elongation rate as the soil was made saline (Passioura and Munns, 2000). Different Leaf elongation made up different area to get irradiances and assimilate production (Iybal, 2003). While leaf area affected by salinity treatment, assimilation area would be reduced and TDM reduction tends to lower than that in control condition.

Leaf Area Index (LAI)

Change in salinity level treatment produced significant differences in Leaf Area Index (LAI). In all cultivars the change in LAI was not significant.

Also interaction, cultivar × salinity effect on LAI was not significant (data not shown). Among the cultivars Kharchia with LAI 3.56 produced the greatest LAI and the lowest observed in Chamran co. (LAI=3.13), respectively. Also in S_1 the highest LAI obtained in Chamran cv. but due to sensitivity of this cultivar to salinity (in S_2, S_3 and S_4) the LAI was reduction was more than others. In salinity level treatments the highest LAI indicated in S_1 (LAI=4.8), while the Lowest observed in S_4 (LAI=1.3). Moreover, the higher LAI in S_1 comparison to other salinity Level may be due to increase in osmotic pressure in S_2, S_3 and S_4, which caused a significant reduction in leaf extension growth. This Finding is in line with the work of other researcher (Matsuda and Riazi, 1981), who concluded that Leaves grow more slowly after exposure to salinity because of water deficit.

Salinity Levels and Number of Tiller per Plant

Field-grown wheat plants may produce up to 11 tillers under moderation to high levels of nutrition (Beech and Norman, 1966), but a proportion of tillers die at or before emergence of the main ear and contribute nothing directly to grain yield. Each tiller's die is associated with the time of appearance in relation to the main shoot, with late tillers being less productive (Bunting and Drennan, 1965). While the extent of tiller survival and yield differs with variety, soil properties (Fertility, salinity etc.), (Barley and Noidu, 1964; Syme, 1967) and the water statues of the plant. The primary tiller at the coleoptiles node is particularly sensitive to environmental conditions (Cannell, 1969a, b). The result showed that tiller number per cultivar was affected by increasing salinity ($p \leq 0.05$). Also salinity levels had significant difference on tiller production ($p \leq 0.01$). While cultivar×salinity level reaction was not significant (Table 5). Among the cultivars, Chamran and Bangor cv. had the highest and lowest tiller per plant respectively. In salinity levels treatment, S_1 and S_4 had the highest and lowest tiller per plant (Table 6). The number of tiller per plant in Chamran cv. in S_1 and S_2 was more than other cvs, but this attention in S_3 and S_4 had vice versa.

Table 4: Mean comparison for biomass in plant, grain yield in plant and harvest index (HI), in different cultivars and salinity levels (S_1, S_2, S_3 and S_4)

Treatments	Grain yield (g)	Biomass (g)	Harvest Index (HI %)
Salinity level			
S_1	6.6a	15.4a	43.0a
S_2	5.2b	12.9b	40.3b
S_3	3.0c	8.3c	35.7c
S_4	0.9d	4.5d	15.5d
Cultivars			
Bangor	3.95b	9.91b	36.8a
Kharchia	4.61a	12.13a	35.0b
Chamran	3.25c	8.82c	28.1c

Means with the same letter(s) in each column are not significantly different (Duncan 0.05)

Table 5: Interaction cultivar×salinity levels treatment effect in grain sodium, potassium and mean No. of Fertile tiller per plant

Salinity	Cultivar	Sodium in grain (%)	Potassium in grain (%)	Mean No. of fertile tiller per plant
S_1	Chamran	0.0032e	0.062c	4.0ns
S_2	Chamran	0.0043c	0.06d	2.9ns
S_3	Chamran	0.0052b	0.052f	1.0ns
S_4	Chamran	0.0065a	0.01g	0.1ns
S_1	Kharchia	0.0031e	0.068a	3.1ns
S_2	Kharchia	0.004de	0.064b	2.1ns
S_3	Kharchia	0.0046cd	0.063c	1.1ns
S_4	Kharchia	0.006a	0.06d	0.9ns
S_1	Bangor	0.0033e	0.066b	2.9ns
S_2	Bangor	0.0042de	0.062c	2.0ns
S_3	Bangor	0.0052b	0.055e	1.3ns
S_4	Bangor	0.0063a	0.05f	0.2ns

Means with the same letter(s) in each column are not significantly different (Duncan 0.05), ns: Non significant

Table 6: Mean root dry weight, mean fertile tiller production, grain yield per main stem and tillers in salinity levels and different varieties (Each number is meaning of 3 plants per pot)

Treatments	Root dry weight (g)	No. of fertile tiller production	Grain yield per main stem (g)	Grain yield per tillers (g)
Salinity levels				
S_1	0.77a	3.2a	1.83a	4.8a
S_2	0.64b	2.25b	1.53b	3.7b
S_3	0.41c	1.25c	1.06c	1.95c
S_4	0.24d	0.6d	0.53d	0.38d
Cultivars				
Bangor	0.51b	1.7c	1.31b	2.65b
Kharchia	0.64a	1.9b	1.37a	3.25a
Chamran	0.38c	2.1a	1.02c	2.22c

Means with the same letter(s) in each column are not significantly different (Duncan 0.05)

Generally, the values of tiller number decreased with increasing salinity (Table 6). However, salt sensitive cultivar showed a greater reduction in tiller number. This may indicate that tiller number and their behavior under salinity can be used as simple and non-destructive measurement to evaluate wheat genotypes in breeding programs. Nicolas *et al*. (1994) found that salt stress during tiller emergence can inhibit their formation and can cause their abortion at later stages. When salinity levels are greater than 7.5 dS m^{-1} NaCl, most of the secondary tillers of moderately tolerant genotypes were eliminated and the number of primary tillers for salt sensitive wheat genotypes was greatly reduced (Eugene *et al*., 1994). High-tillering varieties of wheat have greater grain yield on poor soil than low-tillering ones, whereas low-tillering varieties on rich soil produce as much as or more than the high-tillering ones (EL-Hendawy *et al*., 2004). Therefore, increasing the salinity tolerance in wheat may require an increasing in the capacity of tillering (Islam and Sedgley, 1981).

Root Dry Weight

Root dry weight diminished drastically with increasing salinity levels (Table 6), while the effects of salinity varied with concentration. Among the varieties there was a difference significant ($p \leq 0.01$), also root weight in salinity levels, the differences observed significant ($p \leq 0.01$) but reaction effect of salinity levels×variety had not differences significant. The affect of salinity of shoot dry weight was more than that in root. In all salinity levels, S_1 (0.77 g pot^{-1} $plant^{-1}$) gave the highest root dry weight while the lowest values determined on S_4 (0.24 g pot^{-1} $plant^{-1}$). The decline in root dry weight between the control (S_1) and S_4 salinity levels was the Lowest in Kharchia while the highest reduction was determined on Chamran cultivar (Table 6). The variety could tolerate soil salinity levels up to 12 dS m^{-1} in terms of root dry weight, because a decreasing rate occurring between S_1, S_2 and S_3 was considered negligible.

In this study, the roots dry weight of Kharchia, which gave the highest value in respect of root dry weight, grew better under saline conditions. In pot study, generally, shoot dry weight ratio declined with increasing salinity Levels, showed that a greater reduction occurred than that in root dry weight ratio. On the other hand, it means that the shoots were more adversely affected than root by soil salinity (Francois *et al*., 1986; Gaballah and Moursy, 2004).

Grain Yield

Among the salinity Levels the highest grain yield in main-stem indicated in S_1 (1.83 g $plant^{-1}$ pot^{-1}) and due to grain-number reduction in main-stem the Lowest observed in S_4 (0.53 g $plant^{-1}$ pot^{-1}). Between cultivars, grain yield production in main-stem in Kharchia cv. obtained the greatest (1.37 g $plant^{-1}$ pot^{-1}) and in Chamran cultivar was the lowest (1.02 g $plant^{-1}$ pot^{-1}). The differences in sensitivity to salinity between cultivars may be caused by grain yield production due to LAI, chlorophyll content reduction and less assimilation could be effective to reduce grain yield production. In salinity levels treatment the highest grain yield per tiller was obtained in S_1 (4.8 g $plant^{-1}$ pot^{-1}) and

Table 7: Comparison of sodium content in leaves, stem and root in differences cultivar in each salinity level (each number is meaning of 3 plant per pot)

	Sodium (%) in each section of plant											
	S_1			S_2			S_3			S_4		
Varieties	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Bangor	0.013	0.017	0.045	0.13	0.21	0.081	0.21	0.29	0.09	2.47	3.5	0.103
Kharchia	0.012	0.010	0.056	0.07	0.12	0.085	0.14	0.15	0.10	1.98	2.2	0.108
Chamran	0.015	0.023	0.057	0.17	0.23	0.059	0.25	0.33	0.08	2.74	3.9	0.100

Table 8: Comparison of sodium content in dry weight (each number is meaning of three plant per pot)

	Sodium (mg g^{-1}) in plant dry matter per salinity levels			
Varieties	S_1	S_2	S_3	S_4
Bangor	7.9	43.3	59.2	70.7
Kharchia	8.2	28.1	40.9	53.3
Chamran	9.8	47.2	67.9	77.3

there was the Lowest in S_4 (0.38 g plant^{-1} pot^{-1}). The main reason to reduce grain yield, may be to produce, small and thin grain, also grain number reduction per plant (Table 6).

The highest grain yield per tillers was in S_1 (4.8 g plant^{-1} pot^{-1}) and the lowest related to S_4 (0.38 g plant^{-1} pot^{-1}). This reduction may be due to small and thin grain production and reduction in grain number with increasing salinity. Among the cultivars, grain yield per tillers in salinity levels treatment, Kharchia cv. (3.25 g plant^{-1} pot^{-1}) by production of more fertile tiller was greatest and the lowest was observed in Chamran cv. (2.22 g plant^{-1} pot^{-1}). Also the highest grain yield per plant (main-stem + tillers) indicated in Kharchia (4.6 g plant^{-1} pot^{-1}) and the lowest obtained in Chamran (3.25 g plant^{-1} pot^{-1}) (Table 4).

Sodium and Potassium Accumulation in Grain

There was relatively higher grain sodium (%) when plants were fed with more water salinity (Table 5). In this relation, grain sodium content in S_1 treatment was the lowest and S_4 had the highest. Among the cultivars, Chamran cv. in all salinity levels treatment had the highest sodium content in grain and interaction cultivar×salinity Levels treatment effect was significant (Table 5).

On the other hand, in Chamran cv. sodium contents decreased in root, against the increased sodium content in shoot especially in grain (Table 7). This shows retention of sodium ion in tissues in cultivar by more salinity tolerant (Kharchia and Bangor cvs), because the salt tolerant plants accumulated less Na^+ in the shoot and also accumulated the major proportion of shoot Na^+ in leaf sheaths.

Different cultivars may differ in the ability of the sheath cells to extract Na^+ from the xylem stream. This possibility was supported by cultivar differences in the proportion of total of leaf Na^+ content that was stored in the sheath. The cultivar varied in net uptake into the whole plant and this must result from differences in net uptake via the roots (i.e. the sum of unidirectional influx and efflux across the plasma membrane of root cells). However, the differences of Na^+ accumulation in root may be due to differences of root influx and relative efflux (efflux capacity). A cultivar difference in influx or efflux could reflect cultivar differences in abundance, selectivity, or control of plasma membrane cation transports. However, it is more likely that the difference in net uptake arises mainly from a difference in the net rate of xylem loading of Na^+ for transfer to the shoot (Davenport *et al*., 2005) (Table 7 and 8).

The higher K^+ content was in S_1 and the Lower obtained in S_4 (Table 5, 9 and 10). Among the cultivars, Kharchia had the highest k^+ and there was the lowest in Chamran. The interaction salinity levels treatment×cultivar effect was significant.

Table 9: Comparison of potassium content in leaves, stem, root and grain in differences cultivar in each salinity level (each number is meaning of 3 plant per pot)

	Potassium (%) in each section of plant											
	S_1			S_2			S_3			S_4		
Varieties	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Bangor	0.45	0.33	0.07	0.37	0.32	0.036	0.35	0.30	0.033	0.24	0.24	0.028
Kharchia	0.41	0.36	0.05	0.36	0.35	0.033	0.36	0.32	0.029	0.25	0.27	0.022
Chamran	0.36	0.32	0.09	0.34	0.31	0.041	0.27	0.26	0.037	0.18	0.20	0.031

Table 10: Comparison of potassium content in dry weight (each number is meaning of 3 plant per pot)

	Potassium (mg g^{-1}) in plant dry matter per salinity levels			
Varieties	S_1	S_2	S_3	S_4
Bangor	93.5	79.7	75.0	57.2
Kharchia	90.3	81.3	78.4	61.5
Chamran	83.7	75.4	63.4	43.8

Considering the whole plant, leaves and stem (except in $S_{1)}$ contained much higher K^+ concentration than roots and grains. High Na^+ concentration strongly inhibited uptake and accumulation of K^+ by root (Netondo *et al*., 2004a, b) and induced a reduction in K^+ grain (Table 8). Because K^+ is a macronutrient involved in turgor control, inhibition of K^+ uptake should stunt growth (Renault *et al*., 2001).

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