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Effects of Saline Water on Shoot and Nutrient Accumulation of Four Wheat Cultivars

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ABSTRACT

The effect of salinity (0, 4, 8 or 12 dSm^{-1}) induced by NaCl in irrigated water was studied on the shoots of wheat cultivars. After 80 days from sowing, fresh and dry weight of shoot and shoot content of N_{tot}, P, K, Ca, Mg and Cu were significantly decreased as salinity level increased, whereas Na, Cl, Mn and Zn were increased in the shoots of wheat. The highest fresh and shoot dry weight was recorded with Abo-Graib followed by Sham 4 in which both was significantly higher as compared to Rizgary and Semeto. The concentration of N_{tot}, P, K, Ca, Mg, Na, Cl and Zn showed that there were significant differences among the cultivars. The highest content of N_{tot}, P, K, Ca and Mg were found in Abo-Graib and Sham 4 and the lowest concentration in Semeto and Rizgary, and opposite was true with Na, Cl and Zn. Indeed, Abo-Graib and Sham 4 cultivar showed significant higher K/Na than Semeto and Rizgary. However, non-significant differences were noticed between Semeto and Rizgary cultivars as well as between Abo-Graib and Sham 4 with regarding to the content of studied nutrients. The results shows that Abo-Graib and Sham 4 cultivars are moderately salt-tolerant compare to the other sensitive salt tolerant Rizgary and Semeto cultivars.

Keywords: Salinity, Wheat, Abo-Graib, Rizgary, Semeto, Sham 4, K/Na

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تأثير ملوحة الماء في النمو الخضري وتجمع المغذيات لأربعة أصناف من الحنطة

الملخص

درس تاثير الملوحة عن طريق اضافة NaCl الى ماء الري بمستويات صفر و 4 و 8 و 12 ديسيسيمنز/م في النمو الخضري لأربعة أصناف من الحنطة. بعد 80 يوماً من البذار وجد انخفاض معنوي في الوزن الطري والوزن الجاف للمجموع الخضري للنبات ونقص محتواها من النيتروجين والفسفور والبوتاسيوم والكالسيوم والمغنيسيوم والنحاس مع ازدياد مستوى الملوحة، في حين ازداد محتوى الصوديوم والكلور والمنغنيز والخارصين مع ازدياد مستوى الملوحة، وأن أعلى قيمة للوزن الطري والجاف للمجموع الخضري سجلت لنبات صنف ابي غريب ويليه شام 4، وتفوق الصنفان معنوياً على الصنفين رزكاري وسميتو. واختلفت الاصناف فيما بينها معنويا من حيث تركيز النيتروجين والفسفور والبوتاسيوم والكالسيوم والمغنيسيوم و الصوديوم والكلور والخارصين وان أعلى قيمة للنيتروجين والفسفور والبوتاسيوم والكالسيوم والمغنيسيوم وجدت في صنفي ابي غريب وشام4 واوطأ قيمة في صنفي رزكاري وسميتو والعكس صحيح بالنسبة للصوديوم والكلور والخارصين. وتفوق الصنفان ابي غريب و شام4 معنويا على صنفي رزكاري وسميتو من حيث نسبة Na/K. ولوحظت اختلافات غير معنوية بين صنف رزكاري وصنف سميتو وكذلك بين صنف ابي غريب وصنف شام4 بالنسبة الى محتوى العناصر المدروسة. وتوصلت هذه الدراسة الى أن صنفي ابي غريب وشام4 متوسطة في درجة تحملها للملوحة مقارنة بصنفي رزكاري وسميتو والتي كانت حساسة للملوحة.

INTRODUCTION

Wheat *(Triticum aestivum* L.) is considered as the major cereal crop in the world in respect of the cultivated area and total production, it cultivated over a wide range of environments because of wide adaptation to diverse environmental conditions. It is a sensitive to moderately salt-tolerant crop (Saboora and Kiarostami, 2006). The earliest written account of salt lands dates back to 2400 BC and was recorded in the Tigris-Euphrates alluvial plains of Iraq (Russel *et al*., 1965). Mediterranean regions are currently experiencing increasing salt stress problems resulting from seawater intrusion into aquifers and irrigation with brackish water (Rana and Katerji, 2000). Saline soil can be defined as soil having an electrical conductivity of solution extracted from the water-saturated soil paste ECe of 4 dS $m^{-1} \approx 40$ mM NaCl or more (Chinnusamy *et al*., 2005). Salinity is one of the most important abiotic stress and limiting factor for worldwide plant production. Up to 20% of the irrigated arable land in arid and semiarid regions is already salt affected and is still expanding (Muhling and Lauchli, 2003). The harmful effects of salt on plants are the consequence of both a water deficit that results from the relatively high solute concentrations in the soil as well as a stress specific to Cl and Na, resulting in a wide variety of physiological and biochemical changes that inhibit plant growth and development (Chinnusamy *et al*., 2005; Shaddad *et al*., 2005). Salinity can inhibit plant growth by a range of mechanisms; including low external water potential, ion toxicity and interference with the uptake of nutrients, particulary K, the uptake of water, growth limiting nutrients (such as P, Fe or Zn) and the growth of soil microorganisms such as mycorrhizal fungi can be inhibited. Leaves are more sensitive than roots to Na because Na and Cl accumulate to higher levels in shoots than in roots (Tester and Davenport, 2003). The degree to which salinity affect growth depends on the plant genotype and environmental conditions (Poustini and Siosemardeh, 2004) and the time scale over which specific damage is manifested depends on the rate of accumulation of Na in leaves, and on the effectiveness of Na compartmentation within leaf tissues and cells (Bohnert, 2007).

The objective of the present research is to investigate the effects of saline irrigation water representing by sodium chloride solutions graduated in concentration on shoot biomass, shoot nutrient concentrations, uptake and balance in four wheat cultivars and to assign the most tolerant cultivars.

MATERIALS AND METHODS

Pot experiment was carried out at the greenhouse of Biology department, College of Education, University of Salahaddin during the period from December 20, 2011 to March 10, 2012. Seeds of wheat cultivars including Rizgary, Abo-Graib, Sham-4 and Semeto were obtained from the Agricultural Research Center of Erbil. The first three cultivars are bread wheat and the fourth one is durum wheat. Germination tests before sowing were performed in petri dishes on two layer of filter paper moistened with water. Forty seeds where placed on each petri dish. Germination percentage was measured at 12h intervals and continued until fixed state. Germination percentages were %87, 90%, %84 and % 86 for Semeto, Rizgary, Abo-Graib and Sham-4, respectively. 8 kg soil was put in plastic pots. Some chemical and physical properties of the soil were analyzed using different methods as described by (Ryan *et al.*, 2001) were shown in Table (1).

Seven wheat grains were sown in each pot; two week after seed germination the seedling were thinned to two per pot. All pots received 1.0g P/kg soil (as Ca-superphosphate, 15.5 % P_2O_5), 1.5g N/kg soil (as NH_4NO_3, 33.5 % N) and 1.0g K / kg soil (as K_2SO_4, 48.5 % K_2O). Application of K and P fertilizer nutrients was done in a form of water solution added in the first irrigation. Nitrogen fertilizer was added in three equal doses, at 1st, 3rd and within the 5th irrigation, respectively. Five solutions of electrical conductivity (EC) accounted for 0 (only tap water: control), 4, 8 or 12 dSm^{-1} were prepared based on methods by Rhoades *et al*., (1992). Irrigation with chloride solutions started at 30days after sowing with 4 days intervals to maintain the soil moisture content at the field capacity of the used soils during plant growth. Average temperature in the greenhouse varied from

11 to 22 ºC during night and day, respectively. Relative humidity in greenhouse ranged from 40% to 75% at day and night, respectively.

The plant shoots were collected after 80 days (at stem elongation stage) from sowing, washed with tap water then by distilled water, dried in an oven at 70°C for 48 hrs and the fresh and dry weights were recorded. Water percent obtained by subtracting shoot dry weight from shoot fresh weight multiplying by 100. Sub-samples of plants were ground using stainless steal mill. Powdered dried shoots sample of 0.3g were taken in digestion tubes, and digested by adding 10ml of concentrated sulfuric acid and 10ml of H_2O_2 with heating for digestion as described by Ryan *et al.,* (2001). Total nitrogen (N_{tot}) was estimated from the digested plant by Kjeldahl method (Ryan *et al.*, 2001) according to the equation: $\%N_{tot}$= (T-B) x Nx1.4/g sample) where, T=ml of sample titrated, B= ml of blank titrated and N = acid normality. Sodium, K and Ca were estimated by flame emission photometer technique as adopted by (Temminghoff and Houba, 2004). Chloride was estimated according to Mohr method which was described by Pandey *et al*., (2000). Mg, Mn, Cu and Zn content were determined simultaneously from the plant digestion by using atomic absorbance spectrophotometer as described by Hanlon (1992). The experiment was factorial laid in randomized design, included (16) treatments with 3 replicates. The statistical analyses were performed using SPSS for windows, version 18 (Levesque, 2007). Data were subjected to statistical analysis of variance (ANOVA). When ANOVA showed a significant (P < 0.05) effect, the least significant differences (L.S.D) where used to compare treatments.

Table 1: Soil chemical and physical characteristics

Properties		Values	Properties	Values
Particle Size Distribution (g kg^{-1})	Sand	157.5	Total- N (g kg^{-1})	7.74
	Silt	276.1	Available - P(ppm)	3.49
	Clay	566.4	Soluble - K(ppm)	170.67
Soil Texture		Clay Loam	Exchangeable -K (meq/L)	2.41
Organic matter (g kg^{-1})		2.8	Exchangeable -Ca (meq/L)	2.69
Lime (g kg^{-1})		301.4	Exchangeable -Mg (meq/L)	2.03
EC (dsm^{-1}at 25 °C)		0.31	Exchangeable -Na (meq/L)	0.74
pH		8.20	Available - Cu(ppm)	2.43
Water Content at field capacity(g kg^{-1})		26.95	Available - Mn(ppm)	2.12
Soluble Chloride(mg kg^{-1} soil)		23.11	Available - Zn(ppm)	1.01

RESULTS AND DISCUSSION

Data (Table 2) showed that salt stress (EC = 4, 8 and 10 dSm^{-1}) significantly ($p \leq 0.05$) reduced the shoot fresh and dry weights as well as water content compared with non-saline conditions. These results are partially agreed with those obtained by (Shaddad *et al*., 2005; Rajpar *et al*., 2006; Tammam *et al*., 2008; Ahmadi *et al*., 2009, Addai and Abdul-Kareem, 2010; Mohammed, 2013) on wheat. Reduction in water content of seedlings grown in saline soils might have resulted internal water deficit to plants, which in turn, reduced the growth of shoots and roots. The reduction of most biomass changes of wheat by the salinity levels can be interpreted that the high concentration of NaCl causes negative effect on ionic balance and reduction of the content of K in the flag leaf sap led to stomatal closure subsequently reducing CO_2 uptake and limiting photosynthesis and water content of plant decreases and plant lose turgor causing growth inhibition (Grewal *et al*., 2006). Fresh and shoot dry weight and water content percent of different cultivars differed significantly due to the mean effect of salinity levels (Table 3). The highest fresh and shoot dry weight was recorded in Abo-Graib followed by Sham 4 in which both significantly higher as compared to Rizgary and Semeto. A significant variation was obtained in percent water content of four selected wheat cultivars due to the mean effect of salinity levels. The highest percent water content was found in Sham 4 followed by Abo-Graib both were significantly higher than those of Rizgary and Semeto. The reduction in shoot biomass due to salt stress was more pronounced in

Rizgary and Semeto than in Abo-Graib and Sham 4. In other means salt stress had a significant inhibitory effect on fresh and dry weight of shoots in Rizgary and Semeto, whears there was no significant variation among Rizgary and Semeto cultivars as well as among Abo-Graib and Sham 4 cultivars, hence according to Munns (2002) can be this two cultivar demonstrates sensitive tolerant to salinity with respect to others Abo-Graib and Sham 4 moderate to salt tolerant cultivars. These results are similar to those reported by (Shaddad *et al*., 2005; Saboora and Kiarostami, 2006; Goudarzi and Pakniyat, 2008; Tammam *et al*., 2008; Ahmadi *et al*., 2009) on different wheat cultivars. Addai and Abdul-Kareem (2010) showed significant differences among the three genotypes in all growth characters studied. 3.37 Maxback was superior compare to the others; genotypes differ in their salt tolerance ability, 3.37 Maxback and ACTED were more tolerant at compare to 3.41 Abu- Grab -3. Akbarimoghaddam *et al*., (2011) observed that increasing NaCl concentrations adversely affected shoot dry weight in studied each wheat cultivar; shoot dry weight fluctuated by varying NaCl concentrations. The lowest value found in Chamran cultivar and the higher value found in Sorkhtokhm and Kavir cultivars, maximum water uptake was recorded in Hamoon and Kavir cultivars and lowest was obtained with Hirmand and Sorkhtokhm. Mohammed (2013) reported a significant decrease in water uptake, shoot length and plant dry weight with the increasing of salinity level. Dor-29 cultivar showed the highest values in all characters.

Data presented in Table (4) shows significant decrease in N_{tot}, P, K, Mg and Ca content as well as Fe and Cu in shoots of wheat plants as a result of irrigation with saline water compared to tap water irrigation. Salinity level caused significant increases in the rate of Na, Cl, Mn and Zn in shoots of wheat plants as compared to control. These results are confirmed those obtained by Murat *et al*., (2007) who reported that application of NaCl caused decreases in N, K, Fe and Cu concentrations. Hirpara *et al*., (2005) on *Butea monosperma* seedlings when grown under salinity NaCl at 0.3, 1.9, 3.9, 6.2, 8.2, 10.2, 12.2 and 13.8 dSm^{-1}. They found that K, N_{tot}, Ca, Mg, Fe, and K/Na exhibited significant decreases in shoots while there were significant increases in the concentration of Na, Cl, Zn, Cu and Mn and accumulation of Mn has been recorded by (Hu *et al*., 2000) in wheat. Solutions of NaCl (0, 2, 4, 8, and 10 dSm^{-1}) was examined by Rajpar *et al*., (2006), they showed that the Na and Cl content was increased and that of K decreased which led to lower down the K/Na ratio of the flag leaf sap in wheat (cv. Inqlab). Sodium content increased significantly in root, shoot and spikes of wheat cv. Banysoif 1 grown in clay soil and irrigated by different saline waters (0, 60, 120, 180, 240 and 320 mM NaCl). In general, salinity reduces N accumulation in plants; this is due to the fact that an increase in chloride uptake and accumulation is mostly accompanied by a decrease in shoot nitrate concentration and the uptake of Ca from the soil solution may decrease because of ion interactions, precipitation and increases in ionic strength that reduce the activity of Ca (Garg and Gupta, 1997). The low P-uptake by plants under the conditions of saline soil, in particular, resulted in the low growth obtained under such conditions (Turan *et al*., 2010). The observed decrease in K content might be related to the competition between the uptake of cations Na and K. Such competition might be due to the existence of general carrier for their absorption by the roots (De- Lacerda *et al*., 2003). Hu and Schmidhalter (2001) also suggested that ions Na or Cl in high concentration in the external solution are taken up at high rates, which may lead to their excessive accumulation in the tissue. These ions may inhibit the uptake of other ions into the root and their transport to the shoot through the xylem, finally leading to a deficiency in the tissue. Flowers *et al*., (1977) reported that high K at higher salinity level is a good selection criterion for salt tolerance. The selective uptake of K as opposed to Na is considered to be one of the important physiological mechanisms contributing to salt tolerance in many plant species (Dashti *et al*., 2009). Under salt stress, plants maintain high concentrations of K and low concentrations of Na in the cytosol. There is a negative relationship between Na and K concentration in roots and leaves of many plants (Goudarzi and Pakniyat, 2008). Significantly higher concentrations of Na in plants in relation to more tolerance might explain the differences found between the responses, whether due to the toxic effect that the ion can produce. The data have shown that K uptake in the aerial part of the plant was significantly reduced with increased salinity in all cultivars.

Rate of shoot mineral content was varied considerably among the four wheat cultivars. The concentration of N_{tot}, P, K, Ca, Mg, Na, Cl and Zn showed that there were significant differences ($p > 0.05$) among the cultivars. The highest concentration of N_{tot}, P, K, Ca and Mg were found in Abo-Graib and Sham 4 and the lowest concentration in Semeto and Rizgary, whereas the highest concentration of Na, Cl and Zn were found in Semeto and Rizgary and the lowest in Abo-Graib and Sham 4 (Table 5). However, non-significant differences were noticed between Semeto and Rizgary cultivars as well as between Abo-Graib and Sham 4 with regarding to all of the nutrient content. Both Abo-Graib and Sham 4 cultivar showed low Na concentrations and high K concentrations in their shoots, while the opposite was true with Semeto and Rizgary. Indeed, Abo-Graib and Sham 4 cultivar showed significant higher K/Na than Semeto and Rizgary (Table 5). A significant decrease in K/Na indicates that Na was transferred to these tissues in greater proportion than K. The increasing salinity stress decreased K and K/Na ratio and increased Na in both genotypes of wheat and maize under two salinity levels, the higher amounts of K and K/Na ratios in wheat compared to maize resulted in better ion homeostasis in wheat that caused this species to have a higher tolerance than maize (Ahmadi *et al*., 2009). Cuin *et al*., (2003) recorded that high K/Na ratio is more important for many species than simply maintaining a low concentration of Na, which makes sense given that much of the basis for Na toxicity is due to competition with K for K binding sites. Wyn Jones and Gorham (1986) suggested a minimum value of 1 for K/Na ratio for normal growth of plants subjected to saline conditions. Maintenance of higher K/Na ratios in salt tolerant lines may have been attributable to K/Na exchange across the plasmalemma of root cortex cells and selective uptake of K (Dashti *et al*., 2009). The higher K/Na ratio in salt tolerant accessions may be one of reasons for their superior growth under saline conditions (Ashraf and Ahmad, 2000). Thus the difference in salt tolerance among the four wheat cultivars might be closely related to its ability to enhance K/Na discrimination traits which enhanced the machinery of water flow. This was supported by the relative highest water content in shoots. In sever salinity plant tissues are able to maintain their water content much, for more tolerance to dehydration (Flowers *et al*., 1977). It is well established that the genotypes of plants vary widely in their ability to metabolize micronutrients efficiently and also, different varieties of the same species may differ in uptake efficiency of micronutrients as well (Marschner, 1995). Azooz (2004) observed differences in tolerance to chloride ions at high salinity levels among sorghum cultivars. Thus, the composition of macroelements and microelements alters greatly under varying levels of salinity and depends on plant species. It is well known that the micronutrients are generally less affected by salt stress than macronutrients (Iqbal *et al*., 2006). Nevertheless, plant species and their genotypes differ genetically in their ability to adapt to salt stress environment (Shahzad *et al*., 2012). Yousufinia *et al*., (2013) found that ion content of barley cultivars changed in salinity conditions and significant differences were observed between barley cultivars for various salt tolerance-associated traits under salinity stress.

Finally, the results shows that Abo-Graib and Sham 4 cultivars are moderately salt-tolerant compare to the other sensitive salt tolerant Rizgary and Semeto cultivars.

Table 2: Effect of salinity treatment on fresh weight, dry weight and water content of shoot of different wheat cultivars

Salinity (dSm^{-1})	Shoot fresh weight (g $plant^{-1}$)	Shoot dry weight (g $plant^{-1}$)	Water content (%)
0	13.01	7.58	71.63
4	10.16	6.27	62.04
8	7.80	5.01	55.68
12	5.76	3.83	50.39
L.S.D (0.05)	2.77	1.21	8.03

Table 3: Fresh weight, dry weight and water content of shoot of wheat cultivars grown under different salinity levels in the irrigation water.

Cultivars	Shoot fresh weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Water content (%)
Semeto	7.32	4.87	50.30
Abo-Graib	11.68	6.93	68.54
Sham-4	11.04	6.42	71.96
Rizgary	6.69	4.47	49.66
L.S.D (0.05)	2.77	1.21	8.03

Table 4: Nutrients content in wheat shoots as affected by different salinity levels in the irrigation water.

Salinity (dSm^{-1})	Macronutrients (mg g^{-1} shoot)							Micronutrients (µg g^{-1} shoot)			
	N	P	K	Ca	Mg	Na	Cl	Fe	Mn	Cu	Zn
0	31.31	5.84	37.22	25.50	9.14	21.91	35.06	504	54.24	16.50	7.35
4	29.45	4.47	34.83	26.04	8.71	32.39	40.78	468	57.18	14.84	7.57
8	21.62	2.73	26.27	14.76	6.55	50.89	74.26	272	64.75	14.16	9.02
12	12.41	1.05	19.14	14.25	5.37	82.67	112.54	159	70.25	12.25	12.60
L.S.D (0.05)	5.90	1.21	7.23	6.11	1.02	9.44	27.57	078	8.25	2.10	1.28

Table 5: Nutrients content and K/Na ratio in wheat shoots as affected by different salinity levels in the irrigation water.

Cultivars	Macronutrients (mg g^{-1} shoot)							K/Na ratio	Micronutrients (µg g^{-1} shoot)			
	N	P	K	Ca	Mg	Na	Cl		Fe	Mn	Cu	Zn
Semeto	20.05	2.92	24.41	16.83	6.05	58.10	79.35	0.42	333	59.95	15.01	9.93
Abo-Graib	27.40	4.20	37.00	23.11	8.73	34.99	48.01	1.05	368	57.29	14.63	7.85
Sham-4	25.91	4.41	33.80	25.43	9.01	30.15	45.83	1.12	380	64.06	14.34	8.31
Rizgary	19.41	2.56	22.25	15.18	5.98	64.64	89.48	0.34	320	65.12	13.77	10.41
L.S.D (0.05)	5.90	1.21	7.23	6.11	1.02	9.44	27.57	0.26	n.s.	n.s.	n.s.	1.28

CONCLUSIONS

Salinity disturb the mineral-nutrient relations in plants through their effects on nutrient availability, transport, partitioning in plants and induces ion deficiency or imbalance due to the competition of nutrients such as K, Ca, and NO^{-3} with the toxic ions Na and Cl. Mineral nutrients play a vital role in determining plant resistance to salinity. K is equally important to maintain the turgor pressure of the plant under either stress. High K: Na ratios will also improve the resistance of the plant to salinity. The competition between Cl and NO^{-3} under saline conditions means that the form of N plays a critical role in determining the growth of salinized plants. Compared to N_{tot}, P, K, and Ca, however, micronutrients might be less important with respect to plant resistance to salinity.

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