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Assessment of Tolerance to NaCl Salinity of Fourteen Wheat and Broad Bean Cultivars

By

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With 3 Figures

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Summary

RADI A. A., FARGHLY F. A. & HAMADA A. M. 2012. Assessment of tolerance to NaCl salinity of fourteen wheat and broad bean cultivars. – Phyton (Horn, Austria) 52 (1): 145–162, with 3 figures.

The development and identification of salt-tolerant crop cultivars would complement salt management programs. The present investigation provides differential responses to salt stress in seven wheat and seven broad bean cultivars to select the most salt tolerant cultivars versus the most sensitive ones. Two cultivars have been shown to have a certain affinity to tolerate NaCl-stress (wheat Sakha93 and broad bean Sakha1), while wheat Gemmeza10 and bean Giza716 exhibited notable sensitivity. Wheat Sakha93 and broad bean Sakha1 was recorded lower growth depression compared with wheat Gemmeza10 and bean Giza716 which recorded the highest growth depression. The lowest Na^+ content in roots and shoots was consistently found in Sakha93 and Giza716, while the highest Na^+ content was manifested in Gemmeza10 and Sakha1 at the highest salt level. The high Na^+ content in the different organs of Sakha1 was associated with a marked increase in water content as compared to Giza716. Potassium content of roots and shoots of wheat cultivars was profoundly reduced with the increase of NaCl supply. While K^+ content of roots and shoots of bean cultivars fluctuated between significant and non-significant reduction. On the other hand, NaCl treatments had generally a depressive effect on K^+/Na^+ selectivity in shoot and root of wheat and broad bean cultivars.

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Zusammenfassung

RADI A. A., FARGHLY F. A. & HAMADA A. M. 2012. Assessment of tolerance to NaCl salinity of fourteen wheat and broad bean cultivars. [Die Kochsalztoleranz von vierzehn Weizen- und Ackerbohnensorten]. – Phyton (Horn, Austria) 52 (1): 145–162, mit 3 Abbildungen.

Das Wissen, welche Kulturpflanzen salztolerant sind und deren Weiterentwicklung würden Salzmanagement-Programme sinnvoll ergänzen. Die vorliegenden Untersuchungen dienten dazu, von sieben Weizen- und sieben Ackerbohnensorten die kochsalzresistentesten Sorten zu ermitteln und gleichzeitig die salzempfindlichsten Sorten zu erkennen. Die Weizensorte Sakha93 und die Ackerbohnensorte Sakha1 scheinen Salzstress relativ gut zu ertragen, während die Weizensorte Gemmeza10 und die Ackerbohnensorte Giza716 sehr empfindlich waren. Das verringerte Wachstum unter Salzstress war bei Weizen Sakha93 und Ackerbohne Sakha1 nicht so ausgeprägt wie beim Weizen Gemmeza10 und bei der Ackerbohne Giza716, mit dem geringsten Wachstum. Beim Versuch mit der höchsten Salzkonzentration hatten die Wurzeln und Sprosse von Sakha93 und Giza716 den geringsten Na^+ Gehalt, während die höchsten Na^+-Konzentrationen in Gemmeza10 und Sakha1 gemessen wurden. Bei einem hohen Na^+-Gehalt in den verschiedenen Organen von Sakha1 war auch der Wassergehalt wesentlich höher, verglichen mit dem Wassergehalt von Giza716. Bei den Weizenkulturen war ein höherer NaCl Gehalt der Wurzeln und Sprosse stets mit einem geringeren Kaliumgehalt verbunden. Hingegen in den Wurzeln und Sprossen der Ackerbohnensorten war der K^+ Gehalt teilweise signifikant, teilweise nicht signifikant geringer. Insgesamt führte, bei allen untersuchten Weizen- und Ackerbohnensorten, eine Behandlung mit erhöhten NaCl Konzentrationen zu einem verringerten K^+/Na^+ Trennvermögen in den Sprossen und Wurzeln.

Introduction

Excess sodium in soil is a widespread and common stress in natural and agricultural ecosystems (FAO 2008). Egypt is one of the countries that suffer from severe salinity problems. For example, 33% of the cultivated land, which comprises only 3% of total land area in Egypt, is already salinized due to low precipitation and irrigation with saline water (GHASSEMI & al. 1995). Plant responses to these stresses are complex but can be grouped into three general categories: homeostasis, detoxification of free radicals and growth control (ZHU 2000). Growth control refers to the coordination of stress adaptation and the rate of cell division and expansion. Plants differ greatly in their tolerance of salinity, as reflected in their different growth responses. Plant growth is inhibited by moderate and high salinity (MARIN & al. 1995, TATTINI & al. 1995, CHARTZOULAKIS & al. 2002, VIGO & al. 2005). The extent of reduction showed, however, significant variation according to the cultivar type and the duration of salt exposure (CHARTZOULAKIS 2005, VIGO & al. 2005).

Nutrient uptake by plants can be reduced by excessive salts in the soil solution, either by direct competition between ions or by increased osmotic potential of the solution reducing the mass flow of mineral nutrients to the root surface (GRATTAN & GRIEVE 1999). Salinity can directly affect nutrient uptake, such as sodium reducing potassium uptake or by chloride reducing nitrate uptake (GRATTAN & GRIEVE 1999). Salinity can also cause a combination of complex interactions that affect plant metabolism, susceptibility to injury or internal nutrient requirement (GRATTAN & GRIEVE 1999). Salt-tolerant plants differ from salt-sensitive ones in having a low rate of sodium and chloride transport to leaves, and the ability to compartmentalize these ions into vacuoles in order to prevent their build up in cytoplasm or cell walls and thus avoid salt toxicity (MUNNS 2002).

Ion exclusion and compartmentation at the root level regulates ion concentration in the xylem sap preventing accumulation of potentially toxic ions in the aerial part (FLOWER & YEO 1989, DREW & al. 1990). The effectiveness of exclusion mechanism depends on the salinity level. CHARTZOULAKIS & al. 2002 reported that the exclusion mechanism works effectively at low and moderate levels of salinity (up to 50 mM NaCl), while at high salinities, sodium was transported and accumulated in the aerial parts, resulting in toxicity symptoms.

Wheat is one of the oldest and most important cereal crops in Egypt EL-HENDAWY 2004. Most importantly, Egypt still one of the largest countries that import wheat. Therefore, the Egyptian Government needs to make a great effort to increase wheat productivity. Extending wheat growing outside the Nile Valley is the first effort toward overcoming wheat problems. However, most of the area outside the Nile Valley suffers from salinity or depends on water sources that are affected by salinity.

Vicia faba beans are considered the main legume of Middle Eastern countries (SHETTY & al. 2003). The importance of beans in Egypt is as an essential and relatively inexpensive dietary source of protein for both humans and animals. CORDOVILLA & al. 1999 reported that faba bean is often grown on saline soils in the Middle East and Mediterranean regions.

Therefore, increasing salt tolerance for wheat and broad bean genotypes is one of the cheap methods to spread growing wheat and bean in salinized areas.

The aim of this work was to investigate and compare the effect of salinity on growth parameters and ions accumulation of seven wheat and seven broad bean cultivars grown under controlled conditions, in order to assess NaCl salinity tolerance, to order cultivars with respect to their response to the salt stress.

Materials and Methods

Grains of seven wheat (*Triticum aesativum* L.) cultivars: Gemmeza7, Gemmeza9, Gemmeza10, Giza168, Sakha93, Sakha94 and Sohag3 and the seeds of seven broad bean (*Vicia faba* L.) cultivars: Assiut110, Assiut111, Giza3, Giza716, Nobarya, Sakha1 and Sakha2 were grown hydroponically in aerated Hoagland's solution (HOAGLAND & ARNON 1950) in a green house under natural light. Salt treatment (16-d-old) was performed by supplementing the nutrient solution with NaCl (80, 120, 160, 200 and 240 mM). Control plants were kept in Hoagland's solution without NaCl. After treatment (7 days) fresh and dry matter yields of shoots and roots were determined by drying in an aerated oven at 70 °C until constant dry mass. Total water content was calculated as dry weight subtracted from fresh weight. Sodium and potassium were determined by flame photometer method (WILLIAMS & TWINE 1960).

Statistical Analysis

Data were subjected to statistical analysis using statistical programme package SPSS (version 16). The one-way analysis of variance (ANOVA) followed by Duncan multiple range test were employed and the differences between individual means were deemed to be significant at $p < 0.05$.

Results

Percent of Depression in Plant Growth

Percent of depression or dose response was determined as percent of differences of control. The data presented in Fig. 1 show that increasing salinity level from 80 to 240 mM reduced growth of roots and shoots of all the test cultivars. The adverse concentration effects of salinity stress were clearly demonstrated by wheat and bean cultivars treated with 200 and 240 mM NaCl. Moreover, injurious effects followed by the death of the test plants at the end of the experimental period were exhibited by two bean cultivars (Assiut110 and Giza 716). In addition, it could be noticed that the successive increases in salinization level did not attenuate the growth of wheat cv. Sakha93 and bean cv. Sakha1 as severely as wheat cv. Gemmeza10 and bean cv. Giza716. The effective concentration 50 (EC50) value for wheat cultivar Gemmeza10 root is around 80 mM, while this value (EC50) was not reached in case of Sakha93 at 240 mM NaCl. On the other hand, EC50 was reached in case of Gemmeza10 shoot at the 160 mM NaCl. With respect to bean plants, EC50 is around 160 mM NaCl for roots and shoots of Giza716; however, Sakha1 was tolerant and did not reach this value (EC50). These results indicate that wheat roots were more sensitive to salt stress compared to bean shoots at the high concentration of salt stress. The other cultivars were intermediate between the most and least tolerant cultivars. The results also show a wide variation among cultivars.

Sodium Content

Sodium accumulation in roots and shoots of the various wheat and bean cultivars was stimulated by all the NaCl levels (Table 1). In addition, Na^+ accumulation increased gradually with the rise of salt level. The

Table 1. Effect of different NaCl concentrations on sodium content of shoots and roots of wheat and broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters within each cultivar are significantly different at P <0.05.

	Wheat cultivars							
	Treatment	Gemmeza7	Gemmeza9	Gemmeza10	Giza168	Sakha93	Sakha94	Sohag3
Shoot Na^+ content	0 mM	0.067±0.003 a	0.079±0.001 a	0.036±0.004 a	0.040±0.002 a	0.068±0.024 a	0.049±0.002 a	0.310±0.022 a
	80 mM	0.915±0.024 b	1.085±0.021 b	1.142±0.061 b	1.136±0.002 b	0.532±0.054 b	0.973±0.016 b	0.925±0.031 b
	120 mM	1.011±0.167 b	1.185±0.078 b	1.342±0.014 c	1.176±0.171 b	0.552±0.023 b	1.130±0.283 b	0.933±0.041 b
	160 mM	1.048±0.090 b	1.018±0.240 b	1.492±0.008 c	1.181±0.029 b	0.791±0.042 b	1.387±0.063 bc	1.287±0.123 b
	200 mM	1.548±0.061 c	1.687±0.036 c	2.036±0.053 d	1.237±0.014 b	0.619±0.084 b	1.629±0.182 cd	1.872±0.062 c
	240 mM	1.778±0.030 c	2.065±0.017 c	2.220±0.001 e	1.371±0.001 b	0.869±0.143 b	1.919±0.041 d	1.939±0.157 c
Root Na^+ content	0 mM	0.177±0.004 a	0.112±0.015 a	0.054±0.011 a	0.181±0.001 a	0.040±0.001 a	0.065±0.003 a	0.159±0.017 a
	80 mM	0.579±0.001 b	0.531±0.016 b	0.645±0.034 b	0.479±0.011 b	0.249±0.013 b	0.386±0.007 b	0.483±0.019 ab
	120 mM	0.590±0.007 b	0.565±0.015 b	0.670±0.004 b	0.432±0.018 b	0.249±0.006 b	0.457±0.037 c	0.504±0.013 ab
	160 mM	0.698±0.012 c	0.662±0.028 b	0.713±0.006 b	0.397±0.007 b	0.274±0.001 b	0.464±0.008 c	0.549±0.009 ab
	200 mM	0.712±0.012 c	0.746±0.002 b	0.793±0.001 bc	0.432±0.021 b	0.309±0.027 bc	0.606±0.024 d	0.636±0.012 b
	240 mM	0.723±0.018 c	0.804±0.015 b	0.888±0.001 c	0.467±0.001 b	0.389±0.009 c	0.626±0.028 d	0.623±0.018 b

	Broad bean cultivars							
	Treatment	Assiut110	Assiut111	Giza3	Giza716	Nobarya	Sakha1	Sakha2
Shoot Na^+ content	0 mM	0.314±0.012 a	0.614±0.108 a	0.432±0.051 a	0.345±0.027 a	0.394±0.050 a	2.141±0.282 a	0.477±0.041 a
	80 mM	4.987±0.511 b	5.172±0.435 b	4.548±0.246 b	3.112±0.454 b	2.848±0.303 b	3.649±0.431 b	3.997±0.098 b
	120 mM	4.984±0.178 b	6.236±0.404 b	5.315±0.239 bc	4.161±0.595 b	4.760±0.209 c	7.777±0.428 c	4.377±0.281 b
	160 mM	6.624±0.183 c	7.789±0.216 bc	6.539±0.500 c	6.154±0.551c	6.914±0.515 d	11.607±0.657 d	5.923±0.234 b
	200 mM	8.029±0.148 c	10.790±0.581 c	8.698±0.529 d	7.423±0.717 c	6.939±0.439 d	12.320±0.113 d	8.470±0.446 c
	240 mM		16.517±0.758 d	9.971±0.286 d		7.404±0.254 d	17.923±0.369 e	9.177±0.685 c
Root Na^+ content	0 mM	0.936±0.016 a	1.385±0.148 a	0.323±0.012 a	0.678±0.151 a	0.483±0.013 a	1.282±0.006 a	0.842±0.006 a
	80 mM	3.716±0.159 b	3.716±0.258 b	3.811±0.391 b	3.001±0.116 b	2.747±0.117 b	4.033±0.101 b	2.496±0.102 b
	120 mM	3.906±0.293 b	3.669±0.104 b	4.399±0.391 b	3.051±0.242 b	3.656±0.088 c	6.153±0.093 c	2.612±0.218 b
	160 mM	4.851±0.31 bc	3.797±0.177 b	4.674±0.105 bc	3.021±0.053 b	3.901±0.356 c	6.373±0.273 c	3.052±0.265 b
	200 mM	5.062±0.188 c	4.475±0.210 c	4.692±0.360 bc	3.294±0.017 b	3.953±0.368 c	6.109±0.388 c	3.303±0.115 b
	240 mM		5.502±0.307 d	4.973±0.265 c		4.039±0.179 c	6.928±0.361 cd	5.445±0.277 c

Table 2. Effect of different NaCl concentrations on sodium translocation and sodium uptake of wheat and broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters within each cultivar are significantly different at $P < 0.05$.

		Wheat cultivars						
	Treatment	Gemmeza7	Gemmeza9	Gemmeza10	Giza168	Sakha93	Sakha94	Sohag3
Na^+ translocation	0 mM	0.379 ± 0.005 a	0.738 ± 0.075 a	0.848 ± 0.167 a	0.221 ± 0.012 a	1.689 ± 0.059 a	0.772 ± 0.046 a	1.981 ± 0.115 a
	80 mM	1.580 ± 0.028 bc	2.551 ± 0.082 b	1.891 ± 0.220 b	2.369 ± 0.039 b	2.128 ± 0.144 a	2.523 ± 0.049 b	1.926 ± 0.141 a
	120 mM	1.706 ± 0.086 bc	2.107 ± 0.118 b	2.003 ± 0.021 b	2.746 ± 0.051 bc	2.224 ± 0.149 a	2.452 ± 0.194 b	1.858 ± 0.133 a
	160 mM	1.499 ± 0.072 b	1.539 ± 0.012 ab	2.094 ± 0.021 b	2.979 ± 0.091 c	2.891 ± 0.161 a	2.985 ± 0.072 b	2.402 ± 0.175 a
	200 mM	2.173 ± 0.034 cd	2.262 ± 0.041 b	2.567 ± 0.022 b	2.883 ± 0.127 c	2.240 ± 0.067 a	2.721 ± 0.289 b	3.249 ± 0.047 ab
	240 mM	2.462 ± 0.015 d	2.569 ± 0.051 b	2.500 ± 0.051 b	2.936 ± 0.001 c	2.201 ± 0.067 a	3.072 ± 0.050 b	3.970 ± 0.023 b
Na^+ uptake	0 mM	5.85 ± 0.209 a	4.26 ± 0.347 a	2.87 ± 0.219 a	9.145 ± 0.308 a	2.688 ± 0.596 a	4.07 ± 0.249 a	19.76 ± 0.167 a
	80 mM	50.65 ± 1.472 b	54.35 ± 5.083 b	107.13 ± 6.64 b	80.91 ± 2.579 b	29.12 ± 1.35 b	84.71 ± 3.70 b	80.72 ± 7.91 ab
	120 mM	74.99 ± 12.28 bc	67.13 ± 3.93 bc	143.77 ± 0.958 c	129.21 ± 17.06 b	33.53 ± 2.08 bc	110.97 ± 5.71 b	91.49 ± 1.57 ab
	160 mM	103.71 ± 6.78 c	79.05 ± 2.11 c	233.35 ± 9.34 d	182.66 ± 1.17 c	58.37 ± 1.56 d	159.36 ± 8.81 c	133.81 ± 2.95 ab
	200 mM	153.14 ± 3.15 d	140.35 ± 0.047 d	288.66 ± 1.19 e	196.26 ± 18.52 c	50.8 ± 10.79 bcd	194.67 ± 20.45 c	192.9 ± 20.12 bc
	240 mM	217.59 ± 2.44 e	214.72 ± 4.43 e	408.925 ± 0.01 f	257.08 ± 0.527 d	53.47 ± 9.53 cd	272.33 ± 1.85 d	302.35 ± 11.64 c

		Broad bean cultivars						
	Treatment	Assiut110	Assiut111	Giza3	Giza716	Nobarya	Sakha1	Sakha2
Na^+ translocation	0 mM	0.335 ± 0.014 a	0.444 ± 0.012 a	1.336 ± 0.063 a	0.544 ± 0.106 a	0.814 ± 0.082 a	1.326 ± 0.106 a	0.566 ± 0.053 a
	80 mM	1.330 ± 0.047 b	1.382 ± 0.119 b	1.193 ± 0.057 a	1.04 ± 0.103 b	1.043 ± 0.054 ab	0.883 ± 0.107 a	1.602 ± 0.132 b
	120 mM	1.335 ± 0.045 b	1.700 ± 0.026 bc	1.069 ± 0.165 a	1.371 ± 0.102 b	1.302 ± 0.025 b	1.263 ± 0.018 ab	1.697 ± 0.151 b
	160 mM	1.370 ± 0.142 b	2.158 ± 0.163 cd	1.603 ± 0.102 bc	2.041 ± 0.223 c	2.003 ± 0.171 c	1.851 ± 0.095 bc	1.96 ± 0.157 b
	200 mM	1.589 ± 0.124 b	2.402 ± 0.131 d	1.861 ± 0.128 c	2.254 ± 0.227 c	1.76 ± 0.182 c	2.057 ± 0.087 c	2.573 ± 0.141 bc
	240 mM		2.994 ± 0.207 e	2.006 ± 0.154 c		1.833 ± 0.044 c	2.587 ± 0.058 cd	2.751 ± 0.250 c
Na^+ uptake	0 mM	8.46 ± 0.248 a	14.91 ± 1.82 a	5.23 ± 0.34 a	6.10 ± 0.136 a	5.87 ± 0.186 a	19.15 ± 2.11 a	8.61 ± 0.29 a
	80 mM	80.04 ± 2.87 b	76.92 ± 2.06 b	63.17 ± 4.12 b	55.29 ± 0.723 b	52.74 ± 6.83 b	82.33 ± 7.85 b	54.04 ± 2.93 b
	120 mM	84.35 ± 5.11 b	85.57 ± 1.01 b	80.88 ± 2.20 b	68.47 ± 0.639 b	66.89 ± 1.145 b	105.15 ± 1.32 b	70.64 ± 1.82 b
	160 mM	97.00 ± 7.22 b	126.94 ± 9.41 c	127.27 ± 6.87 c	103.94 ± 4.62 c	92.28 ± 4.37 c	147.19 ± 9.84 c	94.45 ± 4.22 bc
	200 mM	143.35 ± 3.57 c	165.01 ± 9.89 d	136.36 ± 9.13 c	119.37 ± 1.746 c	130.35 ± 7.69 d	167.19 ± 10.93 c	132.63 ± 3.37 c
	240 mM		273.46 ± 13.61 e	233.46 ± 15.84 d		106.71 ± 6.92 cd	314.38 ± 22.10 d	152.99 ± 9.37 c

highest Na^+ content in roots and shoots was consistently found in plants grown at the highest salt level (240 mM). It is worth to mention that wheat cultivars accumulated less Na^+ in its different organs than bean ones. In addition, wheat cultivar susceptible to NaCl stress (Gemmeza10) accumulated higher content of Na^+ in shoots and roots than do the tolerant one (Sakha93). The opposite trend was detected in bean cultivars, where Sakha1 (less susceptible to NaCl) accumulated more Na^+ in its shoots and roots than Giza716, the NaCl sensitive one.

Sodium Translocation

Sodium translocation from roots to shoots (expressed as Na^+ exclusion at the level of xylem parenchyma cells) was determined as the ratio between Na^+ content of the shoots and roots. In this respect, considerable variations in Na+ translocation were induced by the various salt levels in both wheat and bean cultivars (Table 2).

Sodium Uptake

Sodium uptake by the roots of the test wheat and bean cultivars (Table 2) is expressed as mg taken up by whole plant/g DW root. The data herein obtained revealed that, in the range studied, the increase in NaCl supply generally had a considerable stimulatory effect on Na^+ uptake by roots of both wheat and bean cultivars. The highest Na^+ uptake was consistently found in plants grown in the highest NaCl cultures. The presence of NaCl in the culture medium at a concentration of 240 mM greatly stimulated Na^+ uptake in wheat cv. Gemmeza10 and bean cv. Sakha1 compared to wheat cv. Sakha93 and bean cv. Giza716.

Potassium Content

Potassium content of roots and shoots of both wheat and bean cultivars was profoundly reduced with the increase of NaCl supply (Table 3). The adverse effects of salinization treatments on potassium accumulation were more pronounced in wheat than bean cultivars.

Potassium Translocation

Translocation of K^+ from root to shoot of salt-stressed wheat and bean cultivars are presented in Table 4. The data revealed that the increase in NaCl level in the culture medium had a stimulatory effect on the translocation of K^+ in most wheat and bean cultivars.

Potassium Uptake

The effect of NaCl supply on K^+ uptake by the roots of wheat and bean cultivars is shown in Table 4. Most of the test wheat cultivars exhibited a significant reduction in K^+ uptake by increasing NaCl concentration in the culture media, while the K^+ uptake by roots of bean cultivars fluctuated between significant and non-significant reduction.

Potassium Sodium Selectivity

Potassium sodium selectivity is critical for salt tolerance. To investigate K^+ and Na^+ homeostasis in wheat and bean plants, K^+/Na^+ selectivity was determined in the root and shoot of different cultivars (Table 5). In both wheat and bean cultivars, the investigated salinization treatments had generally a depressive effect on K^+/Na^+ selectivity in shoot and root.

Vacuolar Compartmentation

The data in Figs. 2 and 3, correlating root and shoot water content with its Na^+ content, show that the presence of salt in the medium provoked a sodium accumulation in roots and shoots of wheat and bean cultivars [Gemmeza 10 and Giza 716 (NaCl-sensitive cultivars) and Sakha 93 and Sakha 1 (NaCl-tolerant cultivars)]. This accumulation was associated with a decrease of water content at all salinity levels in the test wheat and bean cultivars. The lowest water content in roots and shoots was consistently found in plants grown in the highest salt cultures of wheat cv. Gemmeza10 and bean cv. Giza716. It is noteworthy that the high Na^+ content in the different organs of bean cv. Sakha1 (tolerant cv.) was associated with a marked increase in water content as compared to Giza716 (sensitive cv). Opposite trend was exhibited by wheat cultivars, where salt stress which activated Na^+ accumulation in roots and shoots of Gemmeza10 (sensitive cv.) induced a sharp reduction in water content as compared to Sakha93 (tolerant cv.).

Discussion

Natural phenomena and human practices such as irrigation can cause salts to accumulate in soil (WIEBE & al. 2007). To verify the relative salt resistance of the test plants, fourteen cultivars of wheat and bean were chosen to grow over a range of salt stress for 7-day-period. Percent of depression or dose response in plant growth is considered as marker for the response of different plant organs to salt stress. The present study revealed that increasing salinity level from 80 to 240 mM reduced growth of roots and shoots of all the test cultivars. The adverse concentration effects of salinity stress were clearly demonstrated by wheat and bean cultivars treated with 200 and 240 mM NaCl. In addition, two cultivars have been shown to have a certain affinity to tolerate NaCl-stress (wheat cv. Sakha93 and bean cv. Sakha1), while wheat cv. Gemmeza10 and bean cv. Giza716 exhibited notable sensitivity. Wheat cv. Sakha93 and bean cv. Sakha1 (re-

Table 3. Effect of different NaCl concentrations on potassium content of shoots and roots of wheat and broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters within each cultivar are significantly different at P <0.05.

	Wheat cultivars							
	Treatment	Gemmeza7	Gemmeza9	Gemmeza10	Giza168	Sakha93	Sakha94	Sohag3
Shoot K^+ content	0 mM	2.869 ± 0.135 c	2.417 ± 0.049 c	1.471 ± 0.211 b	1.436 ± 0.084 c	0.722 ± 0.012 b	1.592 ± 0.115 b	2.229 ± 0.138 b
	80 mM	0.980 ± 0.018 b	0.734 ± 0.038 ab	0.326 ± 0.072 a	0.498 ± 0.022 b	0.353 ± 0.037 a	0.431 ± 0.024 a	0.553 ± 0.052 a
	120 mM	0.553 ± 0.083 a	0.847 ± 0.07 b	0.281 ± 0.008 a	0.253 ± 0.014 a	0.302 ± 0.015 a	0.427 ± 0.077 a	0.308 ± 0.023 a
	160 mM	0.622 ± 0.091 ab	0.639 ± 0.061 ab	0.327 ± 0.002 a	0.214 ± 0.036 a	0.300 ± 0.025 a	0.436 ± 0.011 a	0.415 ± 0.025 a
	200 mM	0.484 ± 0.029 a	0.485 ± 0.014 a	0.347 ± 0.055 a	0.140 ± 0.026 a	0.226 ± 0.010 a	0.527 ± 0.053 a	0.727 ± 0.078 a
	240 mM	0.376 ± 0.041 a	0.508 ± 0.033 a	0.273 ± 0.001 a	0.097 ± 0.001 a	0.216 ± 0.081 a	0.465 ± 0.004 a	0.462 ± 0.005 a
Root K^+ content	0 mM	1.384 ± 0.021 b	1.546 ± 0.065 b	1.187 ± 0.095 b	0.775 ± 0.083 b	0.475 ± 0.003 d	0.938 ± 0.055 b	0.646 ± 0.074 b
	80 mM	0.373 ± 0.006 a	0.085 ± 0.010 a	0.117 ± 0.012 a	0.185 ± 0.022 a	0.121 ± 0.002 c	0.139 ± 0.003 a	0.178 ± 0.024 a
	120 mM	0.177 ± 0.006 a	0.085 ± 0.008 a	0.087 ± 0.009 a	0.068 ± 0.012 a	0.070 ± 0.008 b	0.082 ± 0.008 a	0.098 ± 0.015 a
	160 mM	0.109 ± 0.001 a	0.0473 ± 0.004 a	0.068 ± 0.008 a	0.044 ± 0.001 a	0.043 ± 0.0015 a	0.065 ± 0.002 a	0.092 ± 0.018 a
	200 mM	0.103 ± 0.008 a	0.029 ± 0.003 a	0.070 ± 0.006 a	0.025 ± 0.009 a	0.033 ± 0.004 a	0.053 ± 0.002 a	0.094 ± 0.012 a
	240 mM	0.061 ± 0.010 a	0.024 ± 0.001 a	0.028 ± 0.001 a	0.012 ± 0.001 a	0.033 ± 0.001 a	0.045 ± 0.002 a	0.057 ± 0.005 a
	Broad bean cultivars							
	Treatment	Assiut110	Assiut111	Giza3	Giza716	Nobarya	Sakha1	Sakha2
Shoot K^+ content	0 mM	3.528 ± 0.321 b	3.1481 ± 0.264 b	2.773 ± 0.006 c	3.132 ± 0.284 b	3.122 ± 0.356 b	6.415 ± 0.289 b	2.800 ± 0.160 b
	80 mM	2.616 ± 0.313 ab	2.507 ± 0.168 ab	2.678 ± 0.107 c	2.163 ± 0.278 a	2.427 ± 0.103 ab	3.580 ± 0.180 a	2.825 ± 0.156 b
	120 mM	2.198 ± 0.156 ab	2.805 ± 0.030 b	2.037 ± 0.163 ab	1.954 ± 0.124 a	2.750 ± 0.254 ab	3.093 ± 0.159 a	2.158 ± 0.006 a
	160 mM	2.301 ± 0.147 ab	2.499 ± 0.207 ab	1.942 ± 0.030 ab	1.915 ± 0.108 a	2.846 ± 0.277 b	3.201 ± 0.082 a	2.079 ± 0.093
	200 mM	1.936 ± 0.104 ab	2.289 ± 0.208 ab	2.334 ± 0.160 bc	1.592 ± 0.002 a	2.208 ± 0.106 ab	3.101 ± 0.258 a	2.033 ± 0.034 a
	240 mM		1.712 ± 0.002 a	1.607 ± 0.034 a		1.762 ± 0.001 a	2.424 ± 0.170 a	1.908 ± 0.187 a
Root K^+ content	0 mM	1.955 ± 0.046 c	1.548 ± 0.028 c	1.657 ± 0.065 d	1.940 ± 0.028 c	1.890 ± 0.172 c	3.547 ± 0.167 d	1.895 ± 0.026 b
	80 mM	1.049 ± 0.118 b	1.111 ± 0.023 b	1.401 ± 0.01 c	1.037 ± 0.010 b	1.011 ± 0.041 b	1.518 ± 0.117 c	1.234 ± 0.089 a
	120 mM	1.092 ± 0.134 b	1.074 ± 0.041 b	1.306 ± 0.042 c	0.964 ± 0.046 b	1.206 ± 0.066 b	1.569 ± 0.153 c	0.925 ± 0.034 a
	160 mM	1.012 ± 0.155 b	0.899 ± 0.025 b	0.833 ± 0.009 b	0.768 ± 0.002 a	1.066 ± 0.162 b	1.137 ± 0.072 b	0.882 ± 0.088 a
	200 mM	0.772 ± 0.070 ab	1.068 ± 0.008 b	0.920 ± 0.092 b	0.752 ± 0.005 a	0.730 ± 0.041 a	0.963 ± 0.081 b	0.704 ± 0.081 a
	240 mM		0.581 ± 0.001 a			0.668 ± 0.001 a	0.538 ± 0.014 a	0.684 ± 0.135 a

Table 4. Effect of different NaCl concentrations on potassium translocation and potassium uptake of wheat and broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters within each cultivar are significantly different at P < 0.05.

	Wheat cultivars							
	Treatment	Gemmeza7	Gemmeza9	Gemmeza10	Giza168	Sakha93	Sakha94	Sohag3
K^+ translocation	0 mM	2.144 ± 0.232 a	1.571 ± 0.098 a	1.294 ± 0.223 a	1.872 ± 0.092 a	1.521 ± 0.033 a	1.694 ± 0.023 a	3.544 ± 0.246 a
	80 mM	2.626 ± 0.009 ab	8.796 ± 0.572 b	2.859 ± 0.615 ab	2.740 ± 0.203 a	2.892 ± 0.247 ab	3.107 ± 0.191 ab	3.147 ± 0.135 a
	120 mM	3.169 ± 0.569 ab	10.348 ± 0.791 b	3.369 ± 0.304 b	3.855 ± 0.456 ab	4.442 ± 0.255 ab	5.128 ± 0.466 bc	3.212 ± 0.239 a
	160 mM	5.676 ± 0.785 c	13.46 ± 0.196 bc	4.929 ± 0.579 b	4.94 ± 0.997 abc	6.894 ± 0.340 b	6.774 ± 0.357 c	4.777 ± 0.667 ab
	200 mM	4.689 ± 0.063 bc	17.22 ± 1.348 cd	4.904 ± 0.375 b	6.417 ± 1.191 bc	7.107 ± 1.168 b	10.070 ± 1.413 d	8.230 ± 1.182 b
	240 mM	6.330 ± 0.382 c	21.619 ± 1.267 d	1.097 ± 0.001 a	8.054 ± 0.001 c	6.605 ± 0.466 b	10.335 ± 0.585 d	8.247 ± 0.635 b
K^+ uptake	0 mM	101.09 ± 1.517 b	88.39 ± 0.564 c	87.69 ± 8.011 b	90.89 ± 2.927 d	29.98 ± 0.741 c	92.96 ± 12.671 b	121.79 ± 5.414 c
	80 mM	45.86 ± 0.248 a	27.52 ± 1.766 a	26.48 ± 4.255 a	34.06 ± 1.303 c	17.19 ± 0.335 ab	35.54 ± 2.101 a	41.09 ± 0.594 ab
	120 mM	34.16 ± 5.488 a	35.87 ± 3.220 ab	26.26 ± 1.192 a	25.86 ± 1.56 abc	15.35 ± 0.303 ab	35.29 ± 3.691 a	25.67 ± 1.488 a
	160 mM	43.446 ± 5.726 a	30.05 ± 1.806 ab	41.78 ± 1.066 a	29.79 ± 3.839 bc	18.72 ± 0.221 ab	43.15 ± 1.124 a	37.28 ± 2.054 ab
	200 mM	39.73 ± 2.032 a	29.62 ± 0.265 b	42.33 ± 5.626 a	18.64 ± 2.306 ab	14.15 ± 2.931 ab	50.57 ± 6.191 a	65.93 ± 5.987 ab
	240 mM	37.79 ± 3.238 a	39.88 ± 3.244 b	68.58 ± 0.001 b	15.30 ± 0.001 a	10.45 ± 2.872 a	54.66 ± 2.025 a	72.13 ± 6.203 b

	Broad bean cultivars							
	Treatment	Assiut110	Assiut111	Giza3	Giza716	Nobarya	Sakha1	Sakha2
K^+ translocation	0 mM	1.811 ± 0.194 a	2.031 ± 0.133 a	1.676 ± 0.069 a	1.618 ± 0.244 a	1.639 ± 0.145 a	1.823 ± 0.165 a	1.477 ± 0.064 a
	80 mM	2.502 ± 0.144 a	2.325 ± 0.335 a	1.912 ± 0.090 a	2.084 ± 0.248 ab	2.400 ± 0.004 b	2.417 ± 0.467 a	2.525 ± 0.271 b
	120 mM	2.060 ± 0.220 a	2.618 ± 0.128 a	1.554 ± 0.192 a	1.933 ± 0.034 ab	2.276 ± 0.085 b	1.990 ± 0.096 ab	2.336 ± 0.080 b
	160 mM	2.422 ± 0.107 a	2.798 ± 0.281 a	2.332 ± 0.012 b	2.494 ± 0.133 b	2.693 ± 0.149 bc	2.830 ± 0.118 b	2.369 ± 0.133 b
	200 mM	2.516 ± 0.095 a	2.142 ± 0.178 a	2.545 ± 0.082 b	2.118 ± 0.016 ab	3.026 ± 0.023 c	3.263 ± 0.383 b	2.933 ± 0.387 b
	240 mM		2.927 ± 0.399 a	2.908 ± 0.329 b		2.640 ± 0.001 bc	4.528 ± 0.189 c	4.612 ± 0.271 c
K^+ uptake	0 mM	37.14 ± 2.544 a	35.25 ± 0.189 a	31.16 ± 5.076 a	35.31 ± 4.336 a	33.29 ± 1.372 a	56.19 ± 3.378 b	30.66 ± 0.980 a
	80 mM	34.062 ± 0.498 a	31.42 ± 1.519 a	30.82 ± 1.755 a	28.89 ± 2.095 a	32.39 ± 0.723 a	38.38 ± 5.149 a	31.98 ± 5.940 a
	120 mM	30.95 ± 1.268 a	33.56 ± 1.456 a	27.62 ± 0.110 a	29.02 ± 1.273 a	31.37 ± 0.896 a	33.26 ± 0.297 a	31.12 ± 1.162 a
	160 mM	30.36 ± 2.249 a	38.13 ± 3.413 a	31.49 ± 0.445 a	30.42 ± 1.510 a	34.61 ± 1.314 a	35.09 ± 1.315 a	31.18 ± 1.569 a
	200 mM	29.64 ± 1.660 a	36.35 ± 0.489 a	32.65 ± 2.347 a	28.45 ± 0.073 a	35.05 ± 3.627 a	38.99 ± 3.222 a	30.89 ± 1.728 a
	240 mM		28.40 ± 3.183 a	33.99 ± 2.867 a		33.67 ± 0.001 a	36.79 ± 0.491 a	28.02 ± 4.405 a

Table 5. Effect of different NaCl concentrations on potassium sodium selectivity of shoots and roots of wheat and broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters within each cultivar are significantly different at $P < 0.05$.

		Wheat cultivars						
	Treatment	Gemmeza7	Gemmeza9	Gemmeza10	Giza168	Sakha93	Sakha94	Sohag3
Root K^+/Na^+ selectivity	0 mM	0.977 ± 0.0001 e	0.968 ± 0.0006 d	0.977 ± 0.0006 b	0.973 ± 0.0005 e	0.896 ± 0.059 d	0.969 ± 0.006 d	0.878 ± 0.005 d
	80 mM	0.517 ± 0.016 d	0.403 ± 0.024 c	0.212 ± 0.051 a	0.304 ± 0.013 d	0.403 ± 0.025 c	0.313 ± 0.016 c	0.374 ± 0.042 c
	120 mM	0.355 ± 0.006 c	0.416 ± 0.010 c	0.173 ± 0.005 a	0.180 ± 0.019 c	0.354 ± 0.025 bc	0.272 ± 0.010 b	0.247 ± 0.008 ab
	160 mM	0.369 ± 0.020 c	0.353 ± 0.015 b	0.180 ± 0.0002 a	0.152 ± 0.027 bc	0.274 ± 0.008 ab	0.240 ± 0.008 b	0.245 ± 0.009 ab
	200 mM	0.238 ± 0.005 b	0.223 ± 0.002 a	0.144 ± 0.023 a	0.101 ± 0.022 ab	0.272 ± 0.025 ab	0.245 ± 0.003 b	0.278 ± 0.021 b
	240 mM	0.174 ± 0.019 a	0.197 ± 0.0128 a	0.109 ± 0.0001 a	0.066 ± 0.0001 a	0.192 ± 0.014 a	0.195 ± 0.007 a	0.194 ± 0.020 a
Shoot K^+/Na^+ selectivity	0 mM	0.883 ± 0.0189 e	0.933 ± 0.0569 c	0.949 ± 0.0129 c	0.808 ± 0.0244 d	0.920 ± 0.030 e	0.933 ± 0.0124 e	0.801 ± 0.0102 c
	80 mM	0.392 ± 0.0055 d	0.153 ± 0.038 b	0.154 ± 0.0050 b	0.277 ± 0.040 c	0.319 ± 0.0164 d	0.263 ± 0.0005 d	0.267 ± 0.0268 b
	120 mM	0.230 ± 0.0109 c	0.130 ± 0.0107 b	0.114 ± 0.019 ab	0.136 ± 0.0003 b	0.216 ± 0.0229 c	0.151 ± 0.010 c	0.1626 ± 0.034 a
	160 mM	0.135 ± 0.0015 b	0.060 ± 0.0035 a	0.087 ± 0.012 ab	0.099 ± 0.002 ab	0.137 ± 0.0062 b	0.123 ± 0.007 b	0.142 ± 0.0054 a
	200 mM	0.126 ± 0.0089 b	0.037 ± 0.0044 a	0.081 ± 0.009 ab	0.056 ± 0.029 ab	0.099 ± 0.008 ab	0.080 ± 0.0036 a	0.132 ± 0.0125 a
	240 mM	0.077 ± 0.0142 a	0.029 ± 0.0003 a	0.031 ± 0.0001 a	0.025 ± 0.0001 a	0.079 ± 0.0046 a	0.067 ± 0.0036 a	0.094 ± 0.0271 a

		Broad bean cultivars						
	Treatment	Assiut110	Assiut111	Giza3	Giza716	Nobarya	Sakha1	Sakha2
Root K^+/Na^+ selectivity	0 mM	0.917 ± 0.0054 c	0.838 ± 0.0127 e	0.865 ± 0.0136 d	0.899 ± 0.0195 c	0.887 ± 0.0051 f	0.750 ± 0.033 c	0.854 ± 0.178 e
	80 mM	0.348 ± 0.0143 b	0.330 ± 0.0259 d	0.371 ± 0.0033 c	0.370 ± 0.0012 b	0.461 ± 0.0159 e	0.402 ± 0.0183 b	0.392 ± 0.0022 d
	120 mM	0.310 ± 0.0157 b	0.311 ± 0.0162 d	0.259 ± 0.0059 b	0.355 ± 0.0237 b	0.366 ± 0.0112 c	0.28 ± 0.0003 ab	0.361 ± 0.0051 c
	160 mM	0.235 ± 0.0222 a	0.241 ± 0.0282 c	0.244 ± 0.0181 b	0.208 ± 0.0216 a	0.291 ± 0.0047 b	0.216 ± 0.0083 a	0.260 ± 0.001 b
	200 mM	0.194 ± 0.0055 a	0.176 ± 0.0051 b	0.165 ± 0.0016 a	0.205 ± 0.0190 a	0.242 ± 0.0028 a	0.163 ± 0.0049 a	0.194 ± 0.0056 a
	240 mM		0.093 ± 0.0066 a	0.153 ± 0.0002 a		0.422 ± 0.0001 d	0.178 ± 0.0369 a	0.177 ± 0.0094 a
Shoot K^+/Na^+ selectivity	0 mM	0.676 ± 0.0051 b	0.532 ± 0.0404 c	0.837 ± 0.0107 d	0.743 ± 0.0455 b	0.796 ± 0.0102 d	0.739 ± 0.033 d	0.692 ± 0.0013 d
	80 mM	0.221 ± 0.0086 a	0.228 ± 0.0263 b	0.269 ± 0.0025 c	0.257 ± 0.0055 a	0.269 ± 0.0164 c	0.250 ± 0.024 c	0.242 ± 0.001 bc
	120 mM	0.221 ± 0.031 a	0.194 ± 0.0012 b	0.231 ± 0.0182 b	0.249 ± 0.0063 a	0.248 ± 0.0057 c	0.196 ± 0.009 bc	0.262 ± 0.009 c
	160 mM	0.179 ± 0.0201 a	0.199 ± 0.0032 b	0.218 ± 0.0078 b	0.203 ± 0.0023 a	0.234 ± 0.0012 c	0.171 ± 0.0121 b	0.225 ± 0.003 bc
	200 mM	0.158 ± 0.0181 a	0.213 ± 0.0117 b	0.174 ± 0.0039 a	0.186 ± 0.0017 a	0.187 ± 0.0138 b	0.144 ± 0.006 ab	0.198 ± 0.034 b
	240 mM		0.095 ± 0.0015 a	0.163 ± 0.0001 a		0.142 ± 0.0001 a	0.103 ± 0.0173 a	0.110 ± 0.0022 a

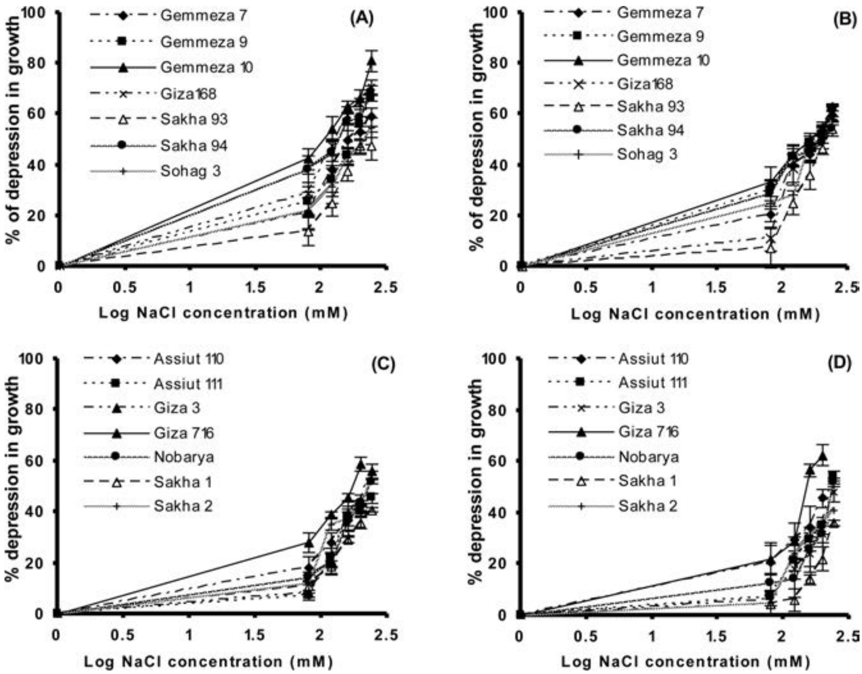

Fig. 1. Effect of different NaCl concentrations on percent of depression in dry matter yield of roots and shoots wheat (A and B) and broad bean (C and D) cultivars. [The data are given as average of three replicates ± standard error].

latively-salt-tolerant) was recorded lower growth depression, compared with wheat cv. Gemmeza10 and bean cv. Giza716 (relatively-salt-sensitive) which recorded the highest growth depression. The other cultivars were intermediate between the most and least tolerant cultivars. The results also show a wide variation among cultivars. These results indicate that wheat roots were more sensitive to salt stress compared to bean shoots at the high concentration of salt stress. Moreover, injurious effects followed by the death of the test plants at the end of the experimental period were exhibited by two bean cultivars (Assiut110 and Giza 716). Salinity is known to inhibit cell division and cell expansion as a likely consequence of physiological and nutritional disorders (MANIVANNAN & al. 2008). Reduced rates of new cell production may show additional contribution to the inhibition of growth as reported by SHABALA & al. 2000.

For most species, Na^+ appears to reach a toxic concentration before Cl^- does, and so most studies have concentrated on Na^+ exclusion and the control of Na^+ transport within the plant. The applied salt was effective in producing Na^+ accumulation in the test wheat and bean cultivars, and the highest Na^+ concentration in roots and shoots was consistently found in

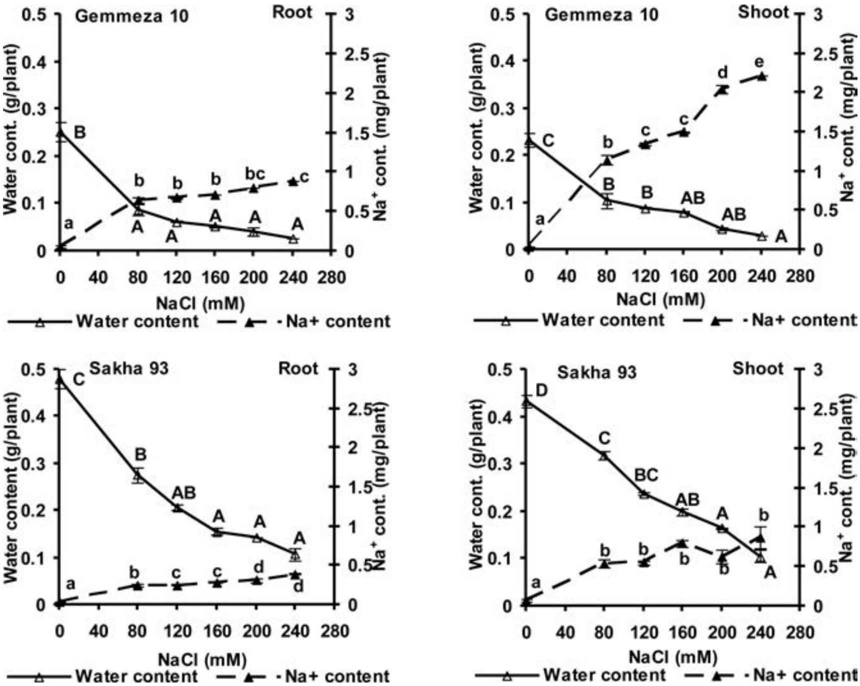

Fig. 2. Effect of different NaCl concentrations on correlations between water content and its sodium content in roots and shoots of Gemmeza 10 (NaCl-sensitive cultivar) and Sakha 93 (NaCl-tolerant cultivar) wheat cultivars. [The data are given as average of three replicates ± standard error]. Different litters are significantly different at $P < 0.05$.

plants subjected to the highest salt level. It is worth to mention that wheat cultivars accumulate less Na^+ than that of bean. In addition, wheat cultivar susceptible to NaCl stress (Gemmeza10) accumulated higher content of Na^+ in shoots and roots than do the tolerant one (Sakha93). The opposite trend was detected in bean cultivars, where Sakha1 (less susceptible to NaCl) accumulated more Na^+ in its shoots and roots than Giza716, the NaCl sensitive one.

Sodium exclusion at the level of xylem parenchyma is considered as marker for the transport-activity and accumulation of Na^+ into the shoot. In this respect, considerable variations in Na^+ translocation were induced by the various salt levels in both wheat and bean cultivars. On the other hand, the increase in NaCl supply, generally, had a considerable stimulatory effect on Na^+ uptake by roots and shoots of both wheat and bean cultivars. Although Na^+ is required in some plants, particularly halophytes (GLENN & al. 1999), high Na concentration is a limiting factor for plant

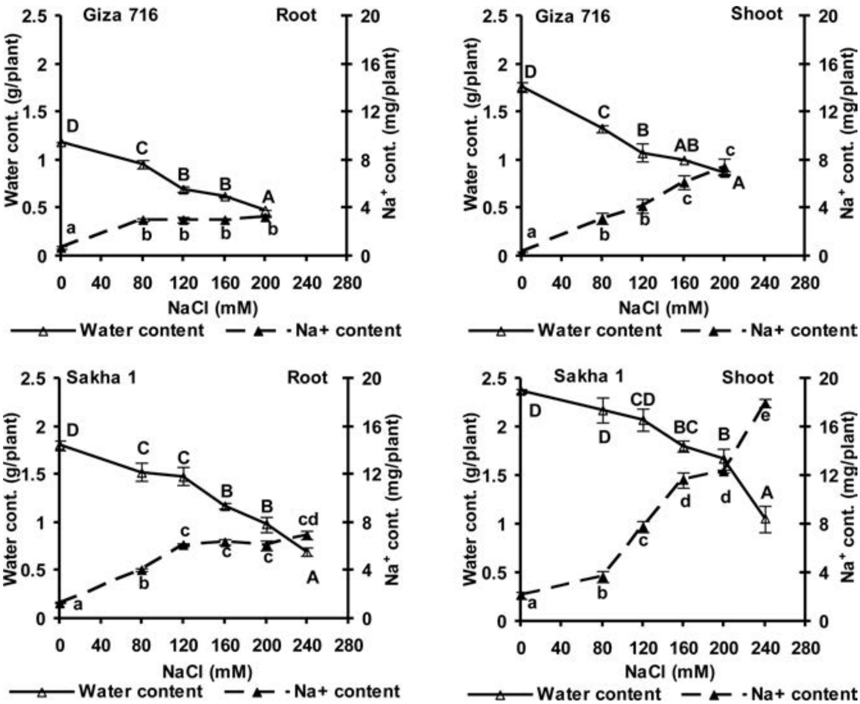

Fig. 3. Effect of different NaCl concentrations on correlations between water content and its sodium content in roots and shoots of Giza 716 (NaCl-sensitive cultivar) and Sakha 1 (NaCl-tolerant cultivar) broad bean cultivars. [The data are given as average of three replicates ± standard error]. Different litters are significantly different at $P < 0.05$.

growth in most crop plants (Francois & al. 1994, Munns 2002, Muranaka & al. 2002). Excessive Na has detrimental effects on electron transport and photosynthesis, and also through stomata closure (Muranaka & al. 2002) which reduces assimilates supply. On the other hand, Flowers 2004 concluded that salt tolerance is not negatively correlated with Na^+ accumulation in different plant species.

With increasing salinity, sodium ions tend to accumulate in roots, resulting in a decreased root water potential, which enables water uptake from saline medium (Quintero & al. 2007). Under non-saline conditions, plants maintain a high cytoplasmic K^+/Na^+ ratio in roots (Akram & al. 2009). Given the negative electrical membrane potential, with the increase in external Na^+ concentration, a large electrochemical potential gradient is developed, which leads to passive transport of Na^+ from the nutrient environment into the cytosol (Apse & Blumwald 2007). Also, in the current investigation the relatively salt tolerant wheat and bean cultivars exhibited higher value of total water content in their shoots and roots compared to the relatively salt sensitive ones. It is noteworthy that the high Na^+ content in the different organs of bean cv. Sakha1 (tolerant cv.) was associated with a marked increase in water content as compared to Giza716 (sensitive cv.). Opposite trend was exhibited by wheat cultivars, where salt stress which activated Na^+ accumulation in roots and shoots of Gemmeza10 (sensitive cv.) induced a sharp reduction in water content as compared to Sakha93 (tolerant cv.). Such a mechanism reflects probably an inclusive behaviour of the plants and a good aptitude to use the dominant ions (Na^+) for the osmotic adjustment (REJILI & al. 2008). However, the sensitive cultivars are unable to adjust their internal osmotic potential. In addition, FLOWERS & YEO 1988 and GLENN & al. 1999 reported that the broad differences between halophytic monocotyledons and dicotyledons have been attributed to differences in water content and hence vacuolar volume. The increase of water content, suggesting that Na^+ ion underwent a certain compartmentation mechanism that helped plants to osmotically adjust themselves and to maintain their water potential gradient, these are essential for the water circulation from the medium to the plant organs (REJILI & al. 2008).

Owing to similar ionic radii, Na^+ is expected to compete with K^+ for binding sites essential for various cellular functions. Moreover, enzymatic activities of a large number of enzymes, exclusively activated by K^+, are disrupted by increasing Na^+/K^+ ratio, leading to Na^+ toxicity (TESTER & DAVENPORT 2003). In addition, Na^+ inhibits uptake of other nutrients by interfering with transporters in root plasma membrane (HU & SCHMIDHALTER 2005). A regulation of translocation of Na^+ from roots to the cotyledons seems to be an important adaptation of seedlings to salt stress (MUNNS 2005). In addition, the results of this study showed that potassium content of roots and shoots of wheat cultivars were profoundly reduced with the increase of NaCl supply. The adverse effects of salinization treatments on K^+ accumulation were more pronounced in wheat than bean cultivars. These results agree with those obtained by previous studies (CRAMER & al. 1991, KHAN & al. 1997, LUTTS & al. 1999). TUNA & al. 2008 reported that K^+ concentration in leaf and root tissues was much lower in salinity stressed maize plants compared to unstressed ones. It is widely accepted that competition exists between Na^+ and K^+ leading to a reduced level of internal K^+ at high external NaCl concentration (GORHAM & al. 1990, BOTELLA & al. 1997). This competition could be at uptake level or transport level or both. In maize, salinity decreased growth due to K deficiency induced by excessive Na which caused reduction in uptake and translocation of K to shoots (BOTELLA & al. 1997).

In the light of these results, the wheat Sakha93 and bean Sakha1 were ranked as the most tolerant, while wheat Gemmeza10 and bean Giza716 were ranked as the lowest tolerant. The remaining cultivars of both wheat and bean showed moderate tolerance to salinity. The decrease in growth parameter confirms the rankings of salt tolerance of wheat and bean cultivars.

References

AKRAM M. S., ASHRAF M. & AKRAM N. A. 2009. Effectiveness of potassium sulfate in mitigating salt-induced adverse effects on different physico-biochemical attributes in sunflower (*Helianthus annus* L.). – Flora 204: 471–483.

APSE M. P. & BLUMWALD E. 2007. Na transport in plants. – FEBS Letter 581: 2247–2254.

BOTELLA M. A., MARTINEZ V., PARDINES J. & CERDA A. 1997. Salinity induced potassium deficiency in maize plants. – J. Plant Physiol. 150: 200–205.

CHARTZOULAKIS K. 2005. Salinity and olive: growth, salt tolerance, photosynthesis and yield. – Agricul. Water Manag. 78: 108–121.

CHARTZOULAKIS K., LOUPASSAKI M., BERTAKI M. & ANDROULAKIS I. 2002. Effects of NaCl salinity on growth, ion content and CO_2 assimilation rate of six olive cultivars. – Sci. Hortic. 96: 235–247.

CORDOVILLA M. P., LIGERO F. & LLUCH C. 1999. Effect of salinity on growth, nodulation and nitrogen assimilation in nodules of faba bean (*Vicia faba* L.). – Appl. Soil Ecol. 11: 1–7.

CRAMER G. R., EPSTEIN E. & LÄUCHLI A. 1991. Effect of sodium, potassium and calcium on salt-stressed barley. II. Elemental analysis. – Physiol. Plant 81: 197–202.

DREW M. C., HOLE P. S. & PICCHIONI G. A. 1990. Inhibition by NaCl of net CO_2 fixation and yield of cucumber. – J. Am. Soc. Hortic. Sci. 115: 472–477.

EL-HENDAWY S. E. 2004. Response of wheat to salinity. In: Salinity Tolerance in Egyptian Spring Wheat Genotypes, pp., 9–10.

FAO 2008. FAO Land and Plant Nutrition Management Service. http://www.fao.org/ag/agl/agll/spush (October 29, 2010).

FLOWERS T. J. 2004. Improving crop salt tolerance. – J. Exp. Bot. 55: 307–319.

FLOWERS T. J. & YEO A. R. 1988. Ion relations of salt tolerance. – In: BAKER D. & HALLS J. (Eds.), Solute transport in plant cells and tissues, pp. 392–416. – Harlow: Longman.

FLOWER T. J. & YEO A. R. 1989. Effect of salinity on plant growth and crop yields. – In: CHERRY J. H. (Ed.), Environmental Stress in Plants, pp. 101–119. – Springer-Verlag, London.

FRANCOIS L. E., DONOVAN T. J., MAAS E. V. & LESCH S. M. 1994. Time of salt stress affects growth and yield components of irrigated wheat. – Agron. J. 86: 100–107.

GHASSEMI F., JAKEMAN A. J. & NIX H. A. 1995. Salinisation of Land and Water Resources. – University of New South Wales Press Ltd, Canberra, Australia.

GLENN E. P., BROWN J. J. & BLUMWALD E. 1999. Salt tolerance and crop potential of halophytes. – Crit. Rev. Plant Sci. 18: 227–255.

GORHAM J., WYN JONES R. G. & BRISTOL A. 1990. Partial characterization of the trait for enhanced K^+-Na^+ discrimination in the D genome of wheat. – Planta 180: 590–597.

GRATTAN S. R. & GRIEVE C. M. 1999. Salinity-mineral nutrient relations in horticultural crops. – Sci. Hortic 78: 127–157.

HOAGLAND D. R. & ARNON D. I. 1950. The water-culture method for growing plants without soil. – California Agric. Exp. Station Cir. 347: 1–32.

HU Y. & SCHMIDHALTER U. 2005. Drought and salinity: a comparison of their effects on mineral nutrition of plants. – J. Plant Nutr. 168: 541–549.

KHAN M. S. A., HAMID A., SALAHUDDIN A. B. M., QUASEM A. & KARIM M. A. 1997. Effect of sodium chloride on growth photosynthesis and mineral ions accumulation of different types of rice (*Oriza sativa* L.). – J. Agron. Crop Sci. 179: 149–161.

LUTTS S., BOUHARMONT J. & KINET J. M. 1999. Physiological characterization of salt-resistant rice (*Oryza sativa* L.) somaclones. – Aust. J. Bot. 47: 835–849.

MANIVANNAN P., JALEEL C. A., SANKAR B., KISHOREKUMAR P. V., SOMASUNDARAM R. & PANNEERSELVAM R. 2008. Mineral uptake and biochemical changes in *Helianthus annuus* under treatment with different sodium salts. – Coll. Surf. B: Biointerf. 62: 58–63.

MARIN L., BENLLOCH M. & FERNÁNDEZ-ESCOBAR R. 1995. Screening of olive cultivars for salt tolerance. – Sci. Hortic. 64: 113–116.

MUNNS R. 2002. Comparative physiology of salt and water stress. – Plant Cell Environ. 25: 239–250.

MUNNS R. 2005. Genes and salt tolerance: bringing them together. – New Phytol. 167: 645–663.

MURANAKA S., SHIMIZU K. & KATO M. 2002. Ionic and osmotic effects of salinity on single-leaf photosynthesis in two wheat cultivars with different drought tolerance. – Photosynthetica 40: 201–207.

QUINTERO J. M., FOURNIER J. M., BENLLOCH M. & RODRÍGUEZ-NAVARRO A. 2007. Na^+ accumulation in shoot is related to water transport in K^+-starved sunflower plants but not in plants with a normal K^+ status. – J. Plant Physiol. 164: 60–67.

REJILI M., TELAHIGUE D., LACHIHEB B., MRABET A. & FERCHICHI A. 2008. Impact of gamma radiation and salinity on growth and K^+/Na^+ balance in two populations of *Medicago sativa* (L.) cultivar Gabès. – Progr. Nat. Sci. 18: 1095–1105.

SHABALA S., BABOURINA O. & NEWMAN I. 2000. In specific mechanisms of osmoregulation in bean mesophyll cells. – J. Exp. Bot. 51: 1243–1253.

SHETTY P., ATALLAH M. T. & SHETTY K. 2003. Stimulation of total phenolics, L-DOPA and antioxidant activity through proline linked pentose phosphate pathway in response to proline and its analogue in germinating faba bean (*Vicia faba* L.). – Process Biochem. 38: 1707–1717.

TATTINI M., GUCCI R., CORADESCHI M. A., PONZIO C. & EDVARD J. D. 1995. Growth, gas exchange and ion content in Olea europaea plants during salinity stress and subsequent relief. – Physiol. Plant. 95: 203–210.

TESTER M. & DAVENPORT R. J. 2003. Na^+ transport and Na^+ tolerance in higher plants. – Ann. Botany 91: 503–527.

TUNA A. L., KAYA C., DIKILITAS M. & HIGGS D. 2008. The combined effects of gibberellic acid and salinity on some antioxidant enzyme activities, plant growth parameters and nutritional status in maize plants. – Environ. Exp. Bot. 62: 1–9.

VIGO C., THERIOS I. N. & BOSABALIDIS M. 2005. Plant growth, nutrient concentration, and leaf anatomy of olive plants irrigated with diluted seawater. – J. Plant Nutr. 28: 1001–1021.

WIEBE B. H., EILERS R. G., EILERS W. D. & BRIERLEY J. A. 2007. Application of a risk indicator for assessing trends in dry land salinization risk on the *Canadian prairies*. – Canad. J. Soil. Sci. 87: 213–224.

WILLIAMS V. & TWINE S. 1960. Flame photometric method for sodium, potassium and calcium. – In: PEACH K. & TRACEY M. V. (Eds.), Modern Methods of Plant Analysis, Vol. 56, pp. 6–12. – Springer-Verlag, Berlin.

ZHU J. K. 2000. Genetic analysis of plant salt tolerance using *Arabidopsis*. – Plant Physiol. 124: 941–948.