Effects of Induced Salinity on Growth, Pod Quality, Root Characteristics and Leaf Nutrient Accumulation of Four Faba Bean (*Vicia faba* L.) Cultivars Differing in Their Broomrape Tolerance

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Abstract: The effects of salinity on growth response, pod quality, root characteristics and leaf ion accumulation of four faba bean (*Vicia faba* L) cultivars (Giza 429, Giza 843 and Misr 1 *Orobanche*-tolerant and Giza 3 *Orobanche*-susceptable) were investigated. The plants were grown in pot experiment for 11 weeks supplied with a nutrient solution with the addition of 0, 50, and 100 mM NaCl for 9 weeks. Salinity stress induced substantial differences between the four faba bean cultivars in the growth, root characteristics, tolerance index and ion accumulation. Salinity significantly decreased Ca^{2+}, Mg^{2+}, K^{+}, HCO_3^- and SO_4^{2-} while significantly increased Na^+, Cl^-, pH, and EC. Thus, salinity significantly increased Na^+/K^+ and Na^+/Ca^{2+} ratios while decreased Ca^{2+}/Na^+ ratio compared with the control. Plant height, number of branches per plant, number of leaves and dry weight per plant, number of pods and pods dry weight per plant, total dry weight of pods per plant and dry weights of root, shoot and root plus shoot dry weight per plant, the salt tolerance indexes of faba plants were significantly reduced by increasing the salinity levels. Application of salinity at 100 mM led to significantly decrease in plant height, total dry matter and salt tolerance index of Giza 3 plants as compared with that obtained from other cultivars. Root length density (cm/cm^3), root mass density (mg/cm^3) and root dry weight per plant (g) were significantly reduced due to application of salinity levels at 50 and / or 100 mM of NaCl as compared with control. Total root length values of G3, G426, G843 and Misr 1 were 21.88, 25.18, 26.33 and 28.40 m per plant, respectively. Although N, P, and K^+, Ca^{2+} and Mg^{2+} contents were negatively affected by salinity, the complete reverse was true with sodium (Na^+) and chloride (Cl^-), thus their concentration showed positive correlation with increasing salinity level to attain its highest level over the non-stressed control plants. The K^+/Na^+ and Ca^{2+}/Na^+ ratios of faba bean leaves gradually decreased by increasing salinity levels to reach their lowest values at the highest level of salinity. The obtained results represent supportive evidence on the positive relationship between *Orobance*-tolerance and salt tolerance in the three cultivars (G429, G843 & M1). This adaptation was due to mainly high degree of accumulation of much more quantities of inorganic osmotic N, P, K^+, Ca^{2+}, Mg^{2+} and lower quantities of Na^+ and Cl^- (through exclude Na^+ and Cl^-), as well as higher K^+/Na^+ and Ca^{2+}/Na^+ ratios. The results obtained in this work suggested that cultivars G429, G843 & M1 could be tolerate the irrigation with NaCl up to 100 mM and can be considered and directed to the production of salt tolerance lines of faba bean plants or the development of salt-tolerant crop genotypes.

Keywords: Faba bean, Ion accumulation, Root characteristics, Salinity tolerance, *Vicia faba*.

INTRODUCTION

Faba bean (*Vicia faba* L.) is the most important leguminous crop used for human nutrition in Egypt. Unfortunately, faba bean is one of the major hosts of *Orobanche crenata* Forsk., thus, its infestation severely affects faba bean productivity (Abdelhamid *et al.*, 2005), and the reduction in faba bean yield may reach to 100% (Abdelhamid, 1996). Therefore, improving faba bean yields in Egypt depends, to a great extent on the selection of *Orobanche*-tolerant Egyptian cultivars, i.e., Giza 429, Giza 843 and Misr1 (Saber *et al.*, 2002).

Faba bean is often grown on saline soils in Egypt, yet few studies have been published on its response to salinity. On the other hands, the susceptibility of faba bean to salinity (Abd-Alla, 1992; Sharma, 1995) will restrict or even prevent its cultivation in such newly reclaimed area in which the use of saline water or even dilution sea water become the only source of irrigation.

Legumes have long been recognized to be either sensitive or only moderately tolerant to salinity (Subbarao and Johansen, 1993). However, considerable variability in salinity tolerance among crop legumes has been reported (Keating *et al.*, 1986; Saxena *et al.*, 1993). The grain legume *Vicia faba* is moderately sensitive to salinity (Delgado *et al.*, 1994), registering 50% growth reduction at 6.7 dS m^{-1} salinity (Maas and Hoffman, 1977).

The differences in the salt tolerance of faba bean genotypes were observed by Heikal *et.al.*, (2000) and Gaballah and Gomaa (2005). Breeding for salt tolerance in crops has usually been limited by the lack of reliable traits for selection (Noble and Rogers, 1992). It is necessary to determine differences in resistance mechanisms between the genotypes and to incorporate characters that improve tolerance into reasonably high-yielding backgrounds. Salinity reduces leaf growth and shortens the period of rapid leaf elongation, thereby producing shorter leaves (Bernstein *et al.*, 1993). Salinity may cause a decrease in biomass production since increased soil salinity results in a lowering of plant water potentials, specific ion toxicities or ionic imbalances (Neumann, 1997).

In most of the salt affected soils of the world, NaCl is the dominant salt, and the high concentration of ions,

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particularly Na^+ in the growing medium can, if taken up by the plant, result in cytoplasmic toxicity. Under salinity stress conditions, osmotic adjustment is usually achieved by the uptake of inorganic ions from the growth media. This accumulation of ions is often accompanied by mineral toxicity and nutritional imbalance. High K^+/Na^+ selectivity in plants under saline conditions has been suggested as an important selection criterion for salt tolerance (Greenway & Munns 1980; Gorham *et al.*, 1997; Ashraf, 2002). The first adaptation mechanism to high salinity is exclusion of Na^+ ion from sodium sensitive sites, which has been proposed to be a function of a Na^+/H^+ antiporter and Na^+- ATPase (Serrano 1996). Chloride (Cl^-) also has been found to be excluded in some crop species. Therefore, Na^+ exclusion (Garcia *et al.*, 1995), K^+/Na^+ discrimination (Asch *et al.*, 2000; Houshmand *et al.*, 2005), and Cl^- exclusion (Noble and Rogers, 1992) traits have proven valuable in screening germplasm for salinity tolerance.

An important current focus of the faba bean development work is the selection of genotypes with greater adaptation to the environmental stresses, i.e., salinity, drought, etc. All of this work, however, is based on shoot morphology, phenology and yield. Variation in root morphology is not measured. It is impractical to measure root morphology in a conventional breeding and selection program that aim to screen large numbers of lines. Various factors affect the ability of roots to extract soil water. These include, root morphology (size of taproot, root length, etc.), water uptake rate and root growth rate. Of these factors least is known about the root morphology and the genetic variation in root morphology with genotype. Faba beans are usually shallow rooting and have a reputation as drought sensitive plants. They are also not well adapted to acid, sandy soils. Restricted root penetration and subsequent limited access to stored soil moisture may be one of the reasons for the poor adaptation to sandy soils. El-Shazly (1993) reported significant differences between 12 faba bean genotypes in total root length on the intact root system in pot and field experiments and found mass production of roots was mostly concentrated in the first 30 cm of the soil.

So far, there are no faba bean Egyptian cultivars released as salinity tolerant and could be recommended for cultivation in the newly reclaimed lands and salt affected soils where salinity is the primary constraint to crop production. Therefore, the aim of this study is to evaluate the salt tolerance of three Egyptian faba bean cultivars (*Orobanche*-tolerant) compared to one (*Orobanche*-susceptable) faba bean cultivar and their different responses to salinity stress with regard to growth, pod quality, root and shoot characteristics and ion accumulation

MATERİALS AND METHODS

Growth condition:

This study was conducted in the greenhouse at the National Research Centre, Dokki, Cairo, Egypt (29.77 N, 31.3 E), from 19 November 2007 to 4 February 2008. Day temperature ranged from 7 to 25 °C with an average of 18.7±3.5 °C while that at night was 9.6±3.2 °C, with minimum and maximum of 1 and 16 °C, respectively. Daily relative humidity averaged 56.8±4.8 %, in a range between 29.9 and 67.0 %. Plants were grown in pots constructed from 12-cm diameter x 30-cm long sections of PVC pipe filled with 1.7 kg soil from Giza, consisting of the upper 10 cm of soil collected from an area of undisturbed native vegetation. To reduce compaction and improve drainage, the soil was mixed with yellow sand in a proportion of 3:1(v:v).

Table (1): Some characteristics of the soil used in the experiment before mixing it with sand before cultivation.

Texture	OM	pH	Ec	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
				meq L^{-1}				meq L^{-1}			
Clay	1.36	8.52	2.05	7.31	3.00	8.26	1.80	–	4.80	7.20	8.36

Granular ammonium sulphate 20.5% N at the rate of 40 kg N ha^{-1}, and single superphosphate (15% P_2O_5) at a rate of 70 kg P_2O_5 ha^{-1} was added. The N and P fertilizers were mixed thoroughly into the soil of each pot immediately before sowing. Soil field capacity in the pots was estimated by saturating the soil in the pots with water and weighing them after they had drained for 48 h. Soil field capacity was 0.36 by weight. Soil water content was checked by weighing and daily loss of water was supplemented twice (morning and afternoon). Soil water content was maintained at about 65% of soil field capacity.

Experimental treatments and management:

Four faba bean (*Vicia faba* L.) cultivars were used in this experiment, namely, Giza 3 (G3) susceptible cultivar for *Orobanche crenata* infestation and Giza 429 (G429), Giza 843 (G843) and Misr 1 (M1) tolerant cultivars for *Orobanche* infestation. Seed weights were 62.7, 85.7, 82.7, and 72.2 g/100 seeds of G3, G429, G843, and M1, respectively.

Four uniform faba bean seeds from each cultivar were sown along a centre of each pot at 30-mm depth, in 4 cultivars x 3 levels of salinity factorial experiment laid out in randomized block design with four replicates. At sowing a commercial rhizobia was incorporated into the top 30-mm of the soil in each pot with the seeds. Two weeks after sowing, the seedlings were thinned to one seedling per pot. Three concentrations of salt (0, 50, and 100 mmoles l^{-1}) in the form of NaCl were used as irrigation water two weeks after sowing (WAS) and the treatments were maintained for nine weeks.

Plants at 9 weeks after imposed salinity were harvested by cutting the top part at the soil surface for measurements of above and below-ground biomass. The plant material was separated into leaves, stems, pods and roots. Plant material, except roots, was dried in a fan forced oven at 70 °C for 72 h and weighed. Roots were extracted by the washing procedures described by Bohm (1979). Root materials were stored in plastic bags and frozen until root length was measured. Prior to washing the roots, the soil /root samples were soaked in water for about 4 hours to facilitate root extraction. The soil/root/water mixture was stirred by hand until it became a homogeneous suspension. Stirring was stopped for a few minutes to allow the heavy sand soil particles to settle. Roots tended to float in this suspension. Then the suspension, without the settled soil particles, was poured into a 1-mm mesh sieve. The process of suspension and decantation was repeated until all roots were transferred to the sieve. Faba bean roots were then collected with tweezers and frozen in small plastic bags until root length could be measured. Root length was measured using the intersection method of Newman (1966), further developed by Tennant (1975). Four counting number of intersections, a shallow glass tray (30 x 40 cm) was used. Paper with a grid unit of 2 cm^2 was placed under the tray, to be visible beneath the glass. The wet root segments were then poured onto the tray with some water and positioned randomly over the grid with forceps. Sometimes the long-branched roots were cut into smaller pieces. Finally, counts were made of the intersections of root segments with the vertical and horizontal grid lines using a hand counter. Root length was calculated using the following formula (Tennant 1975):

$$R = 1.57 \times N$$

Where:

R = total root length in centimeters;

1.57 = length conversion factor, which depends on the grid unit used in the counting;

N = number of intersections counted.

The root material was then dried as the other plant parts and weighed. Root length density was calculated as root length (cm) per cm^3 soil. Root length density (cm/cm^3) was calculated by dividing the mean of root length readings (cm) by the volume of the soil sample (cm^3).

To determine the relative salt stress tolerance of the plants, two additional data sets were generated from the total shoot dry weight (vegetative shoot weight + inflorescence weight) data by dividing the individual dry weights by the mean value of their corresponding controls. These data were termed tolerance indices and are equivalent to the percent dry weight production relative to the control.

Tolerance indices (Ti) of faba plants to NaCl were determined according to Shetty et. al. (1995) as:

$$\text{Tolerance index} = \frac{\text{Total dry weight of salt treated plants}}{\text{total dry weight of control plants}} \times 100$$

Nitrogen was determined using Kjeldahl-method; phosphorus was photometrically determined using the molybdate-vanadate method according to Jackson (1973). Potassium, Ca^{2+} and Na^+ were measured using Dr.Lang-M8D Flame-photometer. Magnesium was estimated using the Perkins-Elmer Atomic Absorption Spectrophotometer. N, P, K^+, Ca^{2+}, Na^+, Mg^{2+} and Cl^- were measured in oven dried faba bean leaves (70 °C for 72 h).

Statistical analysis:

The data monitored in the study were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design applied after testing the homogeneity of error variances according to the procedure outlined by Gomez & Gomez (1984). The significant differences between treatments were compared with the critical difference at 5% probability by the Duncan's test.

RESULTS

Soil properties after harvesting

As shown in Table (2) salinity levels (NaCl at 50 or 100 mM) significantly decreased calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), hydrogen carbonate (HCO_3^-) and sulfate (SO_4^{2-}), while significantly increases in the contents of sodium (Na^+), chloride (Cl^-) ions, pH, and EC (dS m^{-1}) as compared with the control. The increment and decrement were coincided with increasing salinity levels. Carbonate (CO_3^{2-}) was not detected in soil solution after harvesting. Total cations or anions was 16.97, 43.80, 51.07 meq L^{-1} at 0, 50 and 100 mM NaCl and the differences were significant among those salinity levels. Salinity significantly increased Na^+/K^+ and Na^+/Ca^{2+} ratios while decreased Ca^{2+}/Na^+ ratio compared with the control.

Plant growth

The data recorded in Table (3) and Figure 1 reveal that plant height, number of branches per plant, leaves number and dry weight per plant, pods number and pods dry weight per plant, total dry weight (TDW) per plant and the salt tolerance indexes of faba plants were significantly reduced by increasing the salinity levels. The reduction in salt tolerance index was 19 and 43% at 50 or 100 mM NaCl salinity, respectively. However, there was no significant difference found in salt tolerance index among cultivars. Nevertheless, M1 scored significantly the highest value of dry matter compared with the other cultivars. Figure (1) shows the interactive effects of salt stress and cultivars on plant height (cm), total dry matter per plant (g) and tolerance index of faba bean plants at 11 weeks after sowing. Plant height, total dry matter and salt tolerance index of G3 cultivar plants were significantly of the lowest values under the influence of salinity stress at 100 mM compared with other cultivars or other salinity levels (Fig.1).

Root and shoot characteristics

Salinity significantly reduced the total root length from 31.62 m at control to be 26.68 and 18.04 m at 50 and 100 mM salinity, respectively. Table (4) reveals that root length density (RLD), root mass density (RMD), root mass to root length (RM/RL), root dry weight per plant (RDW), shoot dry weight per plant (shoot DW), root to shoot ratio, and root dry weight to total dry weight (RDW/TDW) of faba bean plants after 11 weeks from sowing were significantly reduced due to application of salinity levels at 50 and / or 100 mM of NaCl as compared with the control.

Total root length varied widely between cultivars but much of this variation was related to root and/or shoot weight. The total root length of G3, G426, G843 and M1 were 21.88, 25.18, 26.33 and 28.40 m plant^{-1}, respectively. G3 was significantly less than other three cultivars. G3 had significantly less root length density (RLD), root mass density (RMD), root mass to root length (RM/RL), root dry weight per plant (RDW), and root dry weight to total dry weight (RDW/TDW) of faba bean plants as compared with that obtained from other cultivars. There were no significant differences among G429, G843 and M1 in all abovementioned traits.

Table (2): Some soil properties after imposing NaCl salinity for 9 weeks and growing faba bean plant for 11 weeks.

Treatments	pH	Ec (dS m^{-1})	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	Na^{+}/K^{+}	Na^{+}/Ca^{2+}	Ca^{2+}/Na^{+}
			meq L^{-1}				meq L^{-1}						
0 mM	7.31^{c}	1.71^{c}	6.09^{a}	2.50^{a}	6.88^{c}	1.50^{a}	-	4.0^{a}	6.00^{c}	6.97^{a}	4.59^{c}	1.13^{c}	0.88^{a}
50 mM	7.51^{b}	4.2^{b}	3.50^{b}	2.20^{b}	37.30^{b}	0.80^{b}	-	3.0^{b}	37.80^{b}	3.00^{b}	46.62^{b}	10.66^{b}	0.09^{b}
100 mM	7.71^{a}	5.1^{a}	3.00^{c}	1.00^{c}	46.50^{a}	0.57^{c}	-	1.7^{c}	47.87^{a}	1.50^{c}	81.58^{a}	15.50^{a}	0.06^{c}

Means within a column followed by the same letters are not significantly different according to Duncan's test ($P < 0.05$).

Table (3): Effects of salt stress on growth of faba bean cultivars and salt tolerance index after 11 weeks from sowing.

Treatments	Plant height (cm)	Branch No./plant	Leaf No./plant	Pod No./plant	Pod DW/plant	Leave DW/plant	TDW /plant (g)	Tolerance index (%)
Salinity:								
0 mM	46.5^{a}	2.42^{a}	24.2^{a}	6.1^{a}	2.02^{a}	1.53^{a}	7.20^{a}	100.0^{a}
50 mM	46.1^{a}	2.25^{ab}	21.8^{ab}	5.7^{a}	1.73^{b}	1.35^{b}	5.81^{b}	80.9^{b}
100 mM	42.1^{b}	1.83^{b}	18.5^{b}	4.3^{b}	1.49^{c}	0.86^{c}	4.07^{c}	56.6^{c}
Cultivar:								
G3	$43.9b^{c}$	1.78^{b}	19.3^{b}	5.4^{a}	2.35^{a}	1.11^{b}	5.53^{b}	79.4^{a}
G429	48.7^{a}	2.22^{ab}	20.7^{b}	5.5^{a}	1.63^{b}	1.06^{b}	5.67^{b}	79.8^{a}
G843	40.9^{c}	2.00^{b}	20.0^{b}	5.1^{a}	1.65^{b}	1.16^{b}	5.57^{b}	79.2^{a}
M1	46.1^{ab}	2.67^{a}	26.0^{a}	5.3^{a}	1.35^{c}	1.65^{a}	6.01^{a}	78.2^{a}

Means within a column followed by the same letters are not significantly different according to Duncan's test ($P < 0.05$).

Table (4): Effects of salt stress and faba bean cultivars on root length density (RLD), root mass density (RMD), root mass to root length (RM/RL), root dry weight per plant (RDW), shoot dry weight per plant (shoot DW), root to shoot ratio, root length to root dry weight (RL/RDW), root length to shoot dry weight (RL/RDW) and root dry weight to total dry weight (RDW/TDW) of faba bean plants (after 11 weeks from sowing).

Treatments	RLD (cm/cm^{3})	RMD (mg/cm^{3})	RM/RL (mg/cm)	Root DW (g)	Shoot DW (g)	Root/Shoot ratio	RL/RDW	RL/SDW	RDW/TDW
Salinity:									
0 mM	1.12^{a}	0.49^{a}	0.45^{a}	1.40^{a}	5.80^{a}	24.4^{a}	22.9^{b}	5.5^{a}	0.20^{a}
50 mM	0.94^{b}	0.36^{b}	0.39^{b}	1.03^{b}	4.78^{b}	21.7^{b}	26.1^{b}	5.6^{a}	0.18^{b}
100 mM	0.64^{c}	0.20^{c}	0.32^{c}	0.56^{c}	3.51^{c}	15.9^{c}	32.3^{a}	5.1^{a}	0.14^{c}
Cultivar:									
G3	0.77^{b}	0.26^{b}	0.33^{b}	0.75^{b}	4.79^{a}	15.5^{b}	30.5^{a}	4.7^{b}	0.13^{b}
G429	0.89^{ab}	0.37^{a}	0.40^{a}	1.04^{a}	4.63^{ab}	21.9^{a}	26.0^{b}	5.5^{ab}	0.18^{a}
G843	0.93^{a}	0.39^{a}	0.40^{a}	1.10^{a}	4.46^{b}	23.3^{a}	25.9^{b}	5.7^{a}	0.19^{a}
M1	1.00^{a}	0.39^{a}	0.40^{a}	1.10^{a}	4.90^{a}	22.0^{a}	26.0^{b}	5.7^{a}	0.18^{a}

Means within a column followed by the same letters are not significantly different according to Duncan's test ($P < 0.05$).

Leaves ion accumulation

The results in Table (5) show that mineral ions content including nitrogen (N), phosphorus (P), potassium (K^{+}), calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations in the leaves significantly decreased by increasing salinity levels to reach their lowest values at the highest level of salinity ($P < 0.05$). Although N, P, K^{+}, Ca^{2+} and Mg^{2+} were negatively affected by salinity, the complete reverse was true with sodium (Na^{+}) and chloride (Cl^{-}), thus their concentration showed positive correlation with increasing salinity level to attain its highest level over the non-stressed control plants ($P < 0.05$). The K^{+}/Na^{+} and Ca^{2+}/Na^{+} ratios of faba bean leaves after 11 weeks from sowing gradually decreased by increasing salinity levels to reach their lowest values at the highest level of salinity ($P < 0.05$).

The most interesting finding in the obtained data in Table (5) is that leaves of G429, G843 and M1 showed more higher N, P, K^{+}, and Ca^{2+} concentrations, they could accumulate the lowest quantity of Na^{+} and Cl^{-} as well as the highest K^{+}/Na^{+} and Ca^{2+}/Na^{+} ratios at the highest level of salinity compared with G3 ($P < 0.05$). G429 and G843 were the highest in regards of Mg^{2+} concentration compared with G3 and M1 ($P < 0.05$).

Data illustrated in Fig.1 show that leaves of G429, G843 and M1 cultivar had significantly the lowest concentrations of Na^{+} and Cl^{-} at all the used levels of salinity as compared with that obtained from G3 cultivar. In the same time, G3 significantly had the lowest K^{+}/Na^{+} ratio at each salinity level compared with G429, G843 and M1 ($P < 0.05$). On the other hand, G3 had significantly the highest concentration of Na and Cl and the lowest content of K^{+}/Na^{+} ratio at the highest level of salinity (100 mM) compared with other cultivars or other salinity levels. Positive correlation between K^{+}/Na^{+} and total dry weight per plant (r = 0.934116**) was found.

Table (5): Effects of salt stress and cultivars on nitrogen (N), phosphorus (P), potassium (K^{+}), sodium (Na^{+}), chloride (Cl^{-}), calcium (Ca^{2+}), magnesium (Mg^{2+}), and K^{+}/Na^{+} and Ca^{2+}/Na^{+} ratios of faba bean leaves at 11 weeks after sowing.

Treatments	N	P	K^{+}	Na^{+}	Cl^{-}	Ca^{2+}	Mg^{2+}	K^{+}/Na^{+}	Ca^{2+}/Na^{+}
	(%)							ratio	
Salinity:									
0 mM	2.80^{a}	0.33^{a}	2.70^{a}	1.31^{c}	0.043^{c}	0.99^{a}	1.32^{a}	2.06^{a}	0.75^{a}
50 mM	2.66^{b}	0.31^{b}	2.56^{b}	2.05^{b}	0.088^{b}	0.84^{b}	1.14^{b}	1.25^{b}	0.41^{b}
100 mM	2.58^{c}	0.26^{c}	2.01^{c}	2.73^{a}	0.129^{a}	0.66^{c}	0.95^{c}	0.74^{c}	0.24^{c}
Cultivar:									
G3	2.40^{c}	0.24^{c}	2.10^{c}	2.23^{a}	0.098^{a}	0.72^{c}	1.14^{c}	0.98^{b}	0.32^{c}
G429	2.66^{b}	0.34^{a}	2.41^{b}	2.12^{b}	0.088^{b}	0.80^{b}	1.28^{a}	1.26^{a}	0.38^{b}
G843	2.99^{a}	0.35^{a}	2.69^{a}	1.89^{c}	0.079^{c}	0.91^{a}	1.21^{b}	1.25^{a}	0.48^{a}
M1	2.67^{b}	0.26^{b}	2.48^{b}	1.92^{c}	0.083^{c}	0.90^{a}	0.92^{d}	1.28^{a}	0.47^{a}

Means within a column followed by the same letters are not significantly different according to Duncan's test ($P < 0.05$).

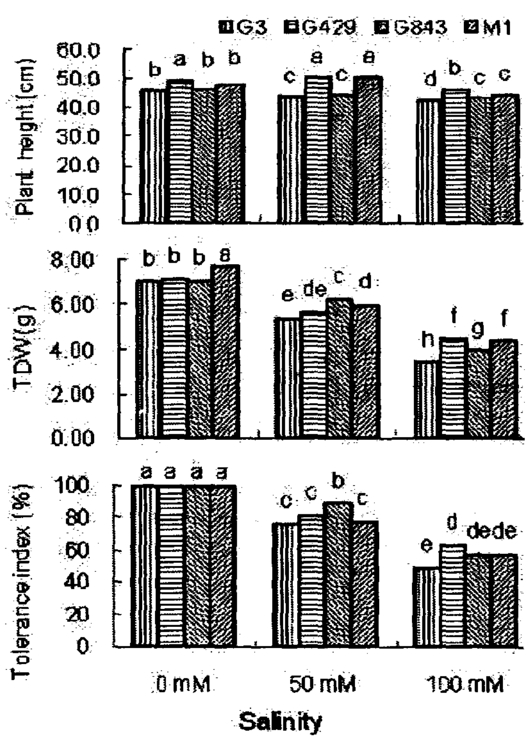

Figure (1): Interactive effects of salt stress and cultivars on plant height (cm), total dry weight (TDW) per plant (g) and salt tolerance index of faba bean plants at 11 weeks after sowing. The vertical bars with different letters are significantly different from each other at $P < 0.05$ according to Duncan's test.

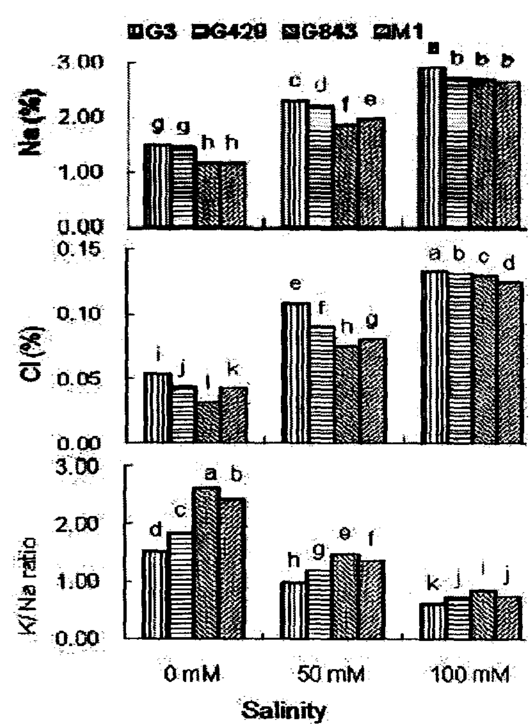

Figure (2): Interactive effects of salt stress and cultivars on sodium (Na), chloride (Cl) and K^{+}/Na^{+} ratio of faba bean plants at 11 weeks after sowing. The vertical bars with different letters are significantly different from each other at $P < 0.05$ according to Duncan's test.

CONCLUSIONS AND DISCUSSION

Under saline conditions, due to excessive amounts of exchangeable Na^+, high Na^+/K^+ and Na^+/Ca^{2+} ratios occur in the soil. In the present study, both salinity levels (50 and 100 mM NaCl), compared with control produced excessive amount of soil Na^+, thus resulted in high Na^+/K^+ and Na^+/Ca^{2+} ratios and low Ca^{2+}/Na^+ ratio (Table 2). Consequently, faba bean plants subjected to such soil conditions, took up high amounts of Na^+, whereas the uptake of K^+ and Ca^{2+} was considerably reduced (Table 5 & Fig. 2). This finding is confirmed by Cramer *et al.* (1991) who found that the low Ca^{2+}/Na^+ ratio of a saline medium plays a significant role in growth inhibition, in addition to causing significant changes in morphology and anatomy of plants.

In general, salinity is one of the major limitations on crop productivity and quality in the world. Manchanda and Garg (2008) found that the negative effects of salinity are reducing the growth rate, biomass reduction, shorter stature, smaller leaves, osmotic effects, nutritional deficiency as well as mineral disorders. In the present study, increasing salt stress resulted in growth reduction in terms of significant reduction in plant height, branch number per plant, leaf number and leaves dry weight per plant, pods number and pods dry weight per plant, root, shoot and total dry weight per plant in both salinity levels compared with control (Tables 2 & 3; Fig.1). Salinity has been reported to affect the plant growth of several legume species, such as faba bean (Cordovilla *et al.*, 1996), soybean (Grattan and Maas, 1988) and chickpea (Elsheikh and Wood, 1990).

The inhibitory effects of salinity on the dry weight accumulation of stressed faba bean plant organs was previously reported by Aly (1987), Abd-Alla (1992) and Cordovilla *et al.* (1995). In this regard, Mass (1986) reported that broad bean was moderately sensitive with a salinity threshold 1.6 dS m^{-1} and 50% reduction in seed yield observed at 5.6 dS m^{-1}. Moreover, Sharma (1995) found that a 50% reduction in seed yield was observed at 9.5 dS m^{-1}. Also, De-pascale and Barbieri (1997) stated that, soil salinity reduced the mean pod weight by 15%, number of pods per plant by 48% and seed yield of faba bean by 67%.

The present results (Table 5) suggest that salinity reduced the uptake of nitrogen and phosphorus by plants. Earlier work (Mer *et al.*, 2000) also indicated reduction in uptake of nitrogen and phosphorus by barley plants with increasing NaCl concentration when grown in black-cotton soil. The decreased N and P concentrations in plants under salt stress are attributed to increased Cl^- uptake (Feigin, 1985; Garg *et.al.*, 1990). Cramer *et al.* (1991) reported that ions at high concentrations in the external solution (*e.g.*, Na^+ or Cl^-) are taken up at high rates, which may lead to excessive accumulation in tissues. These ions may inhibit the uptake of other ions into the root and their transportation to the shoot. On the other hand, calcium is known to play a crucial role in maintaining the structural and functional integrity of plant membranes in addition to its considerable roles in cell wall stabilization, regulation of ion transport and selectivity and activation of cell wall enzymes (Marschner, 1995). The obtained results (Table 5) reported reduction in uptake of calcium by faba bean plants. There is the potential for many nutrient interactions in salt-stressed plants of faba bean, which may have important consequences for growth. There are evidences that a high concentration of cations in plant tissue may inhibit biochemical processes (Greenway and Munns, 1980) and also protein synthesis in cytoplasm (Gibson *et al.*, 1984). Further, it seems logical that differential effects of salinity on the uptake of mineral nutrients may cause a nutritional imbalance, which may be manifested by deficiencies or excess concentrations of various mineral nutrients. This imbalance of nutrients can result in inhibition of plant growth.

Experimentation with wheat indicated that salt tolerance was associated with an enhanced K^+/Na^+ discrimination trait (Gorham *et al.*, 1997). Kafkafi (1984) concluded that roots of the salt tolerant *Beta vulgaris* had a greater affinity for K^+ relative to Na^+ than did the salt sensitive *Phaseolus vulgaris*. In soybean, Läuchli & Wieneke (1979) found that the salt tolerant cv. 'Lee' accumulated more K^+ in its leaves than did the salt sensitive cv. 'Jackson'. Moreover, Kandeel and Abu-grab (1992) found that, salinity application tended to increase the content of Ca, Mg and Na, but decreased that of K content of faba bean plants.

However, Munns & James (2003) have found that although Na^+ exclusion had a positive relationship with salinity tolerance of different tetraploid wheat, K^+/Na^+ ratio showed little relationship. The maintenance of calcium acquisition and transport under salt stress is an important determinant of salinity tolerance (Lynch & Läuchli 1985; Unno *et al.*, 2002). The presented results reported that the *Orobanche*-tolerant cultivars had higher amount of N, P, K^+, Ca^{2+}, Mg^{2+}, K^+/Na^+ and Ca^{2+}/Na^+ ratios, and lower amount of Na^+ and Cl^- (Table 5 & Fig. 2).

Faba beans are usually shallow rooting and have a reputation as drought sensitive plants. Abdelhamid (1996) reported variation in root morphology of faba bean genotypes. Moreover, El-Shazly (1993) reported significant differences between 12 faba bean genotypes in total root length on the intact root system in pot and field experiments.

Finally, the results obtained in the present study represent supportive evidence on the positive relationship between *Orobance*-tolerance and salt tolerance in the three cultivars (G429, G843 & M1). This adaptation was due to mainly high degree of physiological tolerance characterizing the three cultivars by creating more negative osmotic potential (Osmotic adjustment) through the accumulation of much more quantities of inorganic osmotic N, P, K^+, Ca^{2+}, Mg^{2+} and lower quantities of Na^+ and Cl^- (through exclude Na^+ and Cl^-), as well as higher K^+/Na^+ and Ca^{2+}/Na^+ ratios. The obtained results suggest that the cultivars G429, G843 & M1 could tolerate irrigation with NaCl solutions up to 100 mM and can be considered and directed to the production of salt tolerance lines of faba bean plants or the development of salt-tolerant crop genotypes.

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تأثير الملوحة علي نمو و جودة القرن و صفات الجذر و تراكم العناصر في أوراق أربعة أصناف من الفول البلدي مختلفة في درجة تحملها للاصابة بالهالوك

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أقيمت تجربة أصص بالصوبة الخاصة بالمركز القومي للبحوث بالدقي لدراسة تأثير الملوحة علي نمو و صفات الجذر وتراكم العناصر في أوراق أربعة أصناف من الفول البلدي (ثلاثة أصناف متحملة للإصابة بالهالوك و هى جيزة ٤٢٩ و جيزة ٨٤٣ و مصر ١ و صنف حساس للاصابة بالهالوك هو جيزة ٣). نمت النباتات في أصص لمدة ١١ أسبوع و تم امدادها بمحلول من ماء الصنبور مع اضافة ملح الطعام ليعطي تركيز صفر، ٥٠ و ١٠٠ مللي مول من كلوريد الصوديوم لمدة ٩ أسابيع.

أوضحت النتائج المتحصل عليها من تحليل التربة بعد حصاد النباتات أن الرى بالماء المملح قد أدى الى الي خفض تركيزات الكالسيوم، الماغنسيوم، البيكربونات و الكبريتات، بينما رفعت تركيزات الصوديوم و الكلوريد و رقم الحموضة و درجة التوصيل الكهربي لمحلول التربة. و هكذا فإن الملوحة أدت معنويا إلى زيادة معنوية في نسبة الصوديوم الى البوتاسيوم و الصوديوم الى الكالسيوم بينما خفضت نسبة الكالسيوم الى الصوديوم مقارنة بالرى بماء الصنبور.

و قد أدت زيادة تركيز الملوحة الى نقص معنوى فى طول النبات، عدد فروع النبات ، عدد أوراق النبات ووزنها الجاف، عدد قرون النبات و وزنها الجاف ، الوزن الجاف للجذر و الوزن الجاف لاجزاء النبات فوق سطح الارض و الوزن الجاف الكلى للنبات و دليل تحمل الملوحة و قد زاد هذا النقص كلما زاد تركيز الملوحة.

ادى رى نباتات الفول بتركيز ١٠٠ مللى مول كلوريد صوديوم الى نقص معنوى فى طول النبات ، المادة الجافة الكلية للنبات و دليل تحمل الملوحة للصنف الحساس للإصابة بالهالوك (جيزة ٣) مقارنة بالأصناف الثلاثة الأخرى المتحملة للإصابة بالهالوك. كما أدت الملوحة عند مستوى ٥٠ أو / و ١٠٠ مللى مول كلوريد صوديوم الى خفض معنوى لكل من كثافة طول الجذر (سنتيمتر/ سنتيمتر ٣ تربة) كثافة وزن الجذر (ملجم / سنتيمتر ٣ تربة) و وزن الجذر لكل نبات مقارنة بالرى بماء الصنبور.وبقياس أطوال الجذر لكل نبات كانت كالتالى ٢١,٨٨ ، ٢٥,١٨ ، ٢٦,٣٣ و ٢٨,٤٠ متر / نبات و ذلك للاصناف جيزة ٣ ، جيزة ٤٢٩ ، جيزة ٨٤٣ و مصر ١ ، على التو الى.

بالرغم من أن محتوى الأوراق من النيتروجين ، الفوسفور، البوتاسيوم ، الكالسيوم و الماغنسيوم قد تأثر سلبيا بالملوحة إلا أن الصوديوم و الكلوريد قد ارتبطا إيجابيا بزيادة تركيز الملوحة بالمقارنة بالنباتات المروية بماء الصنبور. و بزيادة تركيز الملوحة أيضا انخفضت نسبة البوتاسيوم الى الصويوم و الكالسيوم الى الصوديوم و زاد هذا الإنخفاض تدريجيا مع زيادة تركيز الملوحة الى أن وصل الى أقل قيمة عند أعلى مستوى من الملوحة وتدعم نتائج هذا البحث العلاقة الإيجابية بين قدرة النبات على تحمل الإصابة بالهالوك و قدرتة على تحمل الملوحة فى الأصناف المتحملة للإصابة بالهالوك تحت الدراسة (جيزة ٤٢٩ ، جيزة ٨٤٣ و مصر ١). كما تعزى هذة الأقلمة أساسا الى الدرجة العالية من تراكم كمية أكبر من النيتروجين ، الفوسفور ، البوتاسيوم ، الكالسيوم و الماغنسيوم و كمية أقل من الصوديوم و الكلوريد و أيضا نسبة عالية من البوتاسيوم الى الصوديوم و الكالسيوم الى الصوديوم. ولذلك توصى هذه الدراسة بأن الأصناف جيزة ٤٢٩ ، جيزة ٨٤٣ و مصر ١ قد تتحمل الرى بتركيز يصل الى ١٠٠ مللى مول كلوريد صوديوم و أن هذه الاصناف يمكن الإعتماد عليها و توجيهها لإنتاج سلالات من الفول البلدى تتحمل الملوحة.