EFFECTS OF INDUCED SALINITY ON FOUR *VICIA FABA* CULTIVARS DIFFERING IN THEIR BROOMRAPE TOLERANCE

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ABSTRACT

The effects of salinity on growth response, 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 a pot experiment and exposed to different salinity levels (0, 50, and 100 mM NaCl) for 9 weeks. The K^+/Na^+ and Ca^{2+}/Na^+ ratios in faba bean leaves gradually decreased by increasing salinity levels, and reached their lowest values at the highest level of salinity. The results obtained represent supportive evidence on the positive relationship between *Orobance*-tolerance and salt tolerance in the three cultivars (G429, G843, and M1).

Keywords: Faba bean, Ion accumulation, Orobanche, Root characteristics, Salinity

INTRODUCTION

Faba bean (*Vicia faba* L.) is the most important leguminous crops used for human nutrition in Egypt. Unfortunately, faba bean is one of the major hosts of *Orobanche crenata* Forsk., which is an obligate parasite lacking chlorophyll, so it depends upon its host for water, metabolites and inorganic nutrients. Therefore, infestation of *Orobanche* severely affects faba bean productivity [1]; in severe cases, the reduction in faba bean yield may reach to 100% [2]. Therefore, improving faba bean yield in Egypt depends to a great extent on the selection of *Orobanche*-tolerant Egyptian cultivars, i.e., Giza 429, Giza 843 and Misr 1.

Faba bean is often grown on saline soils in Egypt, yet few studies have been published on its response to salinity. On the other hand, susceptibility of faba bean to salinity [3] restricts or even prevents its cultivation in newly reclaimed area in which the use of saline water or even diluted sea water are the only source of irrigation available.

Breeding for salt tolerance in crops has usually been limited by the lack of reliable traits for selection [4]. It is necessary to determine differences in resistance mechanisms between the genotypes and to incorporate characters that improve tolerance into reasonably high-yielding backgrounds. The differences in the salt tolerance of faba bean genotypes were observed by Gaballah and Gomaa [5].

So far, there are no faba bean Egyptian cultivars released as salinity tolerant and recommended for cultivation in salt-affected soils where salinity is the primary constraint to crop production.

Faba bean has shallow rooting system and is considered as drought sensitive crop. Restricted root penetration and subsequent limited access to stored soil moisture may be one of the reasons for the poor adaptation to sandy soils.

The aim of this study was to evaluate the salt tolerance of three Egyptian faba bean cultivars (*Orobanche*-tolerant) compared to one (*Orobanche*-susceptable) cultivar and their responses to salinity stress with regard to growth, root and shoot characteristics, and ionic distribution.

MATERIALS AND METHODS

This study was conducted at the wire house of National Research Centre, Cairo, Egypt (29.77 N, 31.3 E) from 19 November 2007 to 4 February 2008.

Plants were grown in pots constructed from 12-cm diameter and 30-cm long sections of PVC filled with 1.7 kg clay soil. To reduce compaction and improve drainage, the soil was mixed with sand in a proportion of 3:1(v:v). Soil water content was maintained at about 80% of field capacity and checked by weighing and daily loss of water supplemented twice (morning and afternoon).

Four faba bean cultivars were used in this experiment, namely, Giza 3 (G3), a susceptible cultivar for *Orobanche crenata* infestation, and Giza 429 (G429), Giza 843 (G843) and Misr 1 (M1) tolerant cultivars for *Orobanche* infestation. Four uniform faba bean seeds from each cultivar were sown in each pot at 30-mm depth under three levels of salinity; factorial experiment was 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 mM) in the form of NaCl were used as irrigation water salinity two weeks after sowing (WAS). The treatments were maintained for nine weeks. After this, the plants 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 ºC for 72 h and weighed. Root length was calculated using the formula of Tennant [6]. The concentrations of N, P, K^+, Ca^{2+}, Na^+, Mg^{2+} and Cl^- were measured in oven dried faba bean leaves (70 ºC for 72 h).

The data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design and the significant differences between treatments were compared with the critical difference at 5% probability by the Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Soil properties after harvesting

Irrigation with saline water (NaCl at 50 or 100 mM) significantly reduced Ca^{2+}, Mg^{2+}, K^{+}, HCO_3^{-} and SO_4^{2-}, while significantly increased the contents of Na^{+}, Cl^{-}, pH, and EC in the post-harvest soil samples compared with the control where distilled water was used for irrigation (Table 1). Carbonate was not detected in soil solution after harvesting. In this study, both salinity levels caused an increase in the Na^{+} concentration in soil and thus increased soil SAR (Table 1).

Table (1) Some soil properties after irrigating with saline water for 9 weeks and growing faba bean plant for 11 weeks

Treatment	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	SAR
		dS/m	meq L^{-1}				meq L^{-1}			
0 mM	7.31c[1]	1.71c	6.09a	2.50a	6.88c	1.50a	4.0a	6.00c	6.97a	3.32c
50 mM	7.51b	4.2b	3.50b	2.20b	37.30b	0.80b	3.0b	37.80b	3.00b	22.09b
100 mM	7.71a	5.1a	3.00c	1.00c	46.50a	0.57c	1.7c	47.87a	1.50c	32.88a

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

Elevated concentrations of sodium ions create a plant growth hazard which is measured by one of two methods. The more common method, the Sodium Adsorption Ratio (SAR) [7], is the proportion of sodium (Na^{+}) ions compared to the concentration of calcium (Ca^{2+}) plus magnesium (Mg^{2+}). Another hazard that excess Na^{+} presents in natural soils is the danger of loss of soil structure with the resulting reduction in soil permeability and aeration. SAR increased gradually with increasing concentration of NaCl in irrigation water (Table 1).

Poor quality of irrigation water may result in an increase in soil salinity. Salinity became a problem when enough salts accumulate in the root zone to negatively affect plant growth (Table 2). Excess salts in the root zone hinder plant roots from withdrawing water from surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone [7].

Consequently, faba bean plants subjected to such soil conditions took up high amounts of Na^{+}, whereas the uptake of K^{+},Ca^{2+} and Mg^{2+} was considerably reduced (Table 3). This finding is in line with Cramer et al. [8] who found that low Ca^{2+}/Na^{+} ratio in a saline medium plays a significant role in growth inhibition, in addition to causing significant changes in morphology and anatomy of plants.

Root and shoot characteristics

Table 2 reveals data 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, total plant dry weight (TDW) 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 compared with the control.

Table (2) 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, Total plant dry weight (TDW) and root dry weight to total dry weight (RDW/TDW) of faba bean plants (after 11 weeks from sowing)

Treatment	RLD (cm/cm^3)	RMD (mg/cm^3)	RM/RL (mg/cm)	Root DW (g)	Shoot DW (g)	Root/ Shoot ratio	TDW /plant (g)	RDW /TDW
Salinity:								
0 mM	1.12a[1]	0.49a	0.45a	1.40a	5.80a	24.4a	7.20a	0.20a
50 mM	0.94b	0.36b	0.39b	1.03b	4.78b	21.7b	5.81b	0.18b
100 mM	0.64c	0.20c	0.32c	0.56c	3.51c	15.9c	4.07c	0.14c
Cultivar:								
G3	0.77b[1]	0.26b	0.33b	0.75b	4.79a	15.5b	5.53b	0.13b
G429	0.89ab	0.37a	0.40a	1.04a	4.63ab	21.9a	5.67b	0.18a
G843	0.93a	0.39a	0.40a	1.10a	4.46b	23.3a	5.57b	0.19a
M1	1.00a	0.39a	0.40a	1.10a	4.90a	22.0a	6.01a	0.18a

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

The total root length of G3, G426, G843 and M1 was 21.88, 25.18, 26.33 and 28.40 m $plant^{-1}$, respectively. G3 had significantly less RLD, RMD, RDW, and RDW/TDW of faba bean plants compared with other cultivars. There were no significant differences among G429, G843 and M1 in all above mentioned traits.

Faba beans are usually shallow rooting and have a reputation as drought sensitive plants. El-Shazly [9] reported significant differences between 12 faba bean genotypes in total root length on the intact root system in pot and field experiments.

Leaves ion accumulation

Ions content (N, P, K^+, Ca^{2+} and Mg^{2+}) in the faba bean leaves significantly reduced by increasing salinity levels to reach their lowest values at the highest level of salinity (Table 3). The complete reverse was true with Na^+ and 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.

Table (3) 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 leaves of faba bean plants at 11 weeks after sowing

Treatment	N	P	K^+	Na^+	Cl^-	Ca^{2+}	Mg^{2+}	K^+/Na^+	Ca^{2+}/Na^+
	(%)							ratio	
Salinity:									
0 mM	2.80a[1]	0.33a	2.70a	1.31c	0.043c	0.99a	1.32a	2.06a	0.75a
50 mM	2.66b	0.31b	2.56b	2.05b	0.088b	0.84b	1.14b	1.25b	0.41b
100 mM	2.58c	0.26c	2.01c	2.73a	0.129a	0.66c	0.95c	0.74c	0.24c
Cultivar:									
G3	2.40c[1]	0.24c	2.10c	2.23a	0.098a	0.72c	1.14c	0.98b	0.32c
G429	2.66b	0.34a	2.41b	2.12b	0.088b	0.80b	1.28a	1.26a	0.38b
G843	2.99a	0.35a	2.69a	1.89c	0.079c	0.91a	1.21b	1.25a	0.48a
M1	2.67b	0.26b	2.48b	1.92c	0.083c	0.90a	0.92d	1.28a	0.47a

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

The most interesting finding obtained is that leaves of G429, G843 and M1 showed more higher N, P, K^+, and Ca^{2+} concentrations, and 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. Positive correlation between K^+/Na^+ and total dry weight per plant ($r = 0.93^{**}$) was found.

It has been reported that salinity adversely affects the plant growth of several legume species, such as faba bean [10]. The decreased N and P concentrations in plants under salt stress are attributed to increased Cl^- uptake [11]. Na^+ exclusion [12], K^+/Na^+ discrimination [13], and Cl^- exclusion [4] traits have proven valuable in screening germplasm for salinity tolerance.

Experimentation with wheat indicated that salt tolerance was associated with an enhanced K^+/Na^+ discrimination trait [14]. In soybean, Läuchli and Wieneke [15] found that the salt tolerant cv. 'Lee' accumulated more K^+ in its leaves than did the salt sensitive cv. 'Jackson'. 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 3).

CONCLUSIONS

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 physiological tolerance characterizing the three cultivars 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. These 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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