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Improving Tolerance of Faba Bean during Early Growth Stages to Salinity through Micronutrients Foliar Spray

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Abstract

Salinity, either of soil or of irrigation water, causes disturbances in plant growth and nutrient balance. Previous work indicates that applying nutrients by foliar application increases tolerance to salinity. A pot experiment with three replicates was carried out in the green house of NRC, Cairo, Egypt, to study the effect of micronutrients foliar application on salt tolerance of faba bean. Two concentrations of a micronutrient compound (0.1% and 0.15%) were sprayed in two different treatments prior to or after the salinity treatments. Levels of NaCl (0.00-1000-2000-5000 ppm) were supplied to irrigation water. Results indicated that 2000 and 5000 ppm NaCl inhibited growth and nutrient uptake. Spraying micronutrients could restore the negative effect of salinity on dry weight and nutrients uptake, when sprayed either before or after the salinity treatments. It is suggested that micronutrient foliar sprays could be used to improve plant tolerance to salinity.

Keywords: salinity, faba bean, micronutrients, iron-manganese-zinc-foliar spraying

Introduction

Soil salinity in agriculture soils refers to the presence of high concentration of soluble salts in the soil moisture of the root zone. Salinity is a major factor limiting the crop productivity in the arid and semi arid areas as a result of high evaporation and inappropriate irrigation techniques (Khan and Duke, 2001).

Egypt is present in semi arid region of the world. Thus, sea water utilization has been a recent effort to explore the possibility of obtaining reasonable yield and quality from different crops. Salinity is the most important problem of irrigated agriculture while one fifth of the irrigated land of the world is salt affected. Every year 0.2-0.4 % of the total arable land is going out of cultivation because of salinity and water logging. So, it is essential that income generating agriculture system should be adopted in severely salt affected areas.

Salinity affects plant physiology through changes of water and ionic status in the cells (Hasegawe *et al.,* 2000). Ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- and reduces uptake of other mineral nutrients, such as K^+, Ca^{2+} and Mn^{2+} (Lutts *et al.,* 1999).

Salinity, either of soil or of irrigation water causes disturbances in plant growth and nutrient balance (Tester and Davenport , 2003).Salinity had adverse effects on the biomass and relative growth rate and other morphological parameters of common bean seedlings, also, photosynthesis, transpiration rate and stomatal conductance adversely affected (Gama *et al.,* 2007)

Plants differ greatly in their tolerance of salinity, as reflected in their different growth responses. The variation of salinity tolerance in dicotyledonous species is greater than of monocotyledonous species. Most legume species are sensitive to salinity (Munns *et al.,* 2004).

To improve crop growth and production in the salt-affected soils, the excess salts must be removed from the root zone. Methods commonly used in reclamation such soils are scraping, flushing and leaching. These methods were found to be very expensive.

Recently attention was given to use other new technologies of combating salinity, among them some using halophytes, as a new approach to minimize the harmful effect of salinity through nutrient management. One approach is the use of foliar sprays for increasing plant tolerance to salinity by alleviating Na^+ and Cl^- injury to plants (El-Fouly and Salama, 1999; El-Fouly *et al.,* 2002; El-Fouly *et al.,* 2004).

Previous work was conducted on wheat plant indicating that micronutrient foliar application led to increase plant tolerance to salinity (El-Fouly *et al.,* in press). The objective of this study was to investigate the effect of micronutrient foliar sprays (mixture of, Fe, Mn, Zn) on faba bean regarding the tolerance to NaCl salinity during early growth stages.

Materials and methods

The present study was conducted under greenhouse conditions at the National Research Centre. Seeds were

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sown in Mitcherlich pots filled with 7 Kg soil. Basic fertilizers used were mixed with the soil in doses of 2.0 g triple phosphate (37% P_2O_5), 2.0 g ammonium nitrate (33% N) and 1.0 g potassium sulfate (48-52%) K_2O before sowing. Prior to NPK application, soil was sample and analyzed (Tab. 1). The soil used had a sandy loamy texure and was characterized by high pH, low organic matter, E.C. and $CaCO_3$. Contents of Fe, Mn and Zn were low. 20 days after sowing, plants were irrigated alternatively with saline water and tap water. Levels of NaCl used were 0.00, 1000, 2000 and 5000 ppm. Irrigation was applied to maintain the water level at 60% of the field capacity. Two levels (0.10 and 0.15%) of a chelated micronutrient compound containing Fe, Mn and Zn in ratio 1:1:1 and in concentration 2.8%:2.8%:2.8% was used to correct the nutrient imbalance caused by low mironutrient content and salt stress conditions. Micronutrient treatments were applied on two plant groups. First, before salinity treatments (15 days after sowing) and the second one after salinity treatments (25 days after sowing). At the flowering stage samples were taken for plant growth measurements and determination of nutrient contents according to Chapman and Pratt (1978).

Tab. 1. Soil physico-chemical characteristics

Soil Characteristics							
Sand %	Silt %	Clay %	Texture	pH	EC dS/m	$CaCO_3$%	O.M.%
70.8	6.0	23.2	Sandy Loamy	8.08	1.44	0.04	1.36

Nutrients Concentration								
Macronutrients (mg/100g)					Micronutrients (mg/kg)			
P	K	Mg	Ca	Na	Fe	Mn	Zn	Cu
4	47	86	371	393	7.4	2.2	1.1	6.3

Results and discussion

Effect of salinity on the growth

Faba bean plants exhibited reduction in growth at the low level of salinity (1000 ppm) NaCl (Fig. 1 and Tab. 2). Above this level of salinity (2000 and 5000 ppm) the plants died. The injury effect in response of the high levels of NaCl attributed to that most legume species are sensitive to salinity (Munns and Tester, 2008). Salts in the soil water may inhibit plant growth for two reasons. First, the presence of salt in the soil solution reduces the ability of the plant to take up water, and this leads to reductions in the growth rate. This is referred to as the osmotic or water deficit effect of salinity. Second, if excessive amounts of salt enter the plant in the transpiration stream there will be injury to cells in the transpirating leaves and this may cause further reductions in photosynthesis processes leading to reduction in growth (Munns *et al.*, 2004 and El-Fouly *et al.*, 2002). The reduction in growth in response of NaCl may be attributed to the fact that the plants grown under salt stress conditions alter their stomata resistance due to the increased electronic conductivity in the nutrient solution (Delgado *et al.*, 1993). This reduction has been attributed to salt damage of the photosynthetic tissue,to stomata effects with the consequent restriction of CO_2 availability for carboxylation, or as a result of inhibition the enzymes related to CO_2 assimilation such as PEP carboxylase and CA activity.

Fig. 1. Effect of micronutrients spraying on the growth of faba bean plant grown under salinity treatment. 1=Control (without NaCl and without micronutrient foliar spray); 2=Control + micronutrient foliar spray; 3=1000 ppm NaCl (without micronutrient foliar spray); 4=1000 ppm NaCl + micronutrient foliar spray

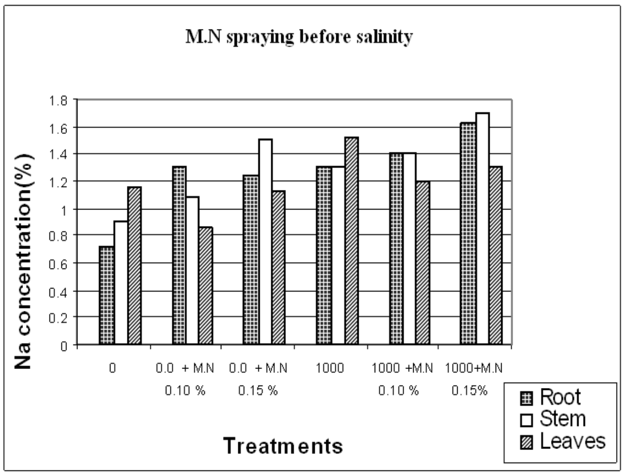
Effect of micronutrient foliar sprays on the growth under salinity conditions

Salinity adversely affected growth as dry weight. Foliar application of micronutrients had a positive effect on increasing the dry weight of different organs of plants grown under salinity conditions (Fig. 1 and Tab. 2). The highest

Tab. 2. Effect of micronutrient spraying before and after salinity treatments on the dry weight of faba bean plant (g/plant)

NaCl level ppm	Roots	Stems	Leaves	Total plant
M.N. Before salinity				
Control	0.90 ± 0.08	1.24 ± 0.03	1.95 ± 0.08	4.02 ± 0.19
Control + 0.10%	1.27 ± 0.08	1.31 ± 0.01	2.48 ± 0.01	5.06 ± 0.08
Control + 0.15%	1.34 ± 0.09	1.38 ± 0.08	2.34 ± 0.05	5.06 ± 0.10
1000	0.34 ± 0.04	0.66 ± 0.06	0.75 ± 0.00	1.75 ± 0.07
1000 + 0.10%	0.70 ± 0.10	0.96 ± 0.04	1.54 ± 0.00	3.20 ± 0.09
1000 + 0.15%	0.65 ± 0.03	1.03 ± 0.02	1.58 ± 0.05	3.26 ± 0.08
M.N. After salinity				
Control	0.90 ± 0.08	1.24 ± 0.03	1.95 ± 0.08	4.02 ± 0.19
Control + 0.10%	0.97 ± 0.01	1.39 ± 0.08	2.28 ± 0.17	4.52 ± 0.20
Control + 0.15%	1.01 ± 0.01	1.13 ± 0.06	1.81 ± 0.00	3.95 ± 0.07
1000	0.34 ± 0.04	0.66 ± 0.06	0.75 ± 0.00	1.75 ± 0.07
1000 + 0.10%	0.82 ± 0.00	1.13 ± 0.08	2.05 ± 0.06	4.00 ± 0.13
1000 + 0.15%	0.53 ± 0.06	1.06 ± 0.03	1.54 ± 0.02	3.13 ± 0.08

M.N. = Micronutrients



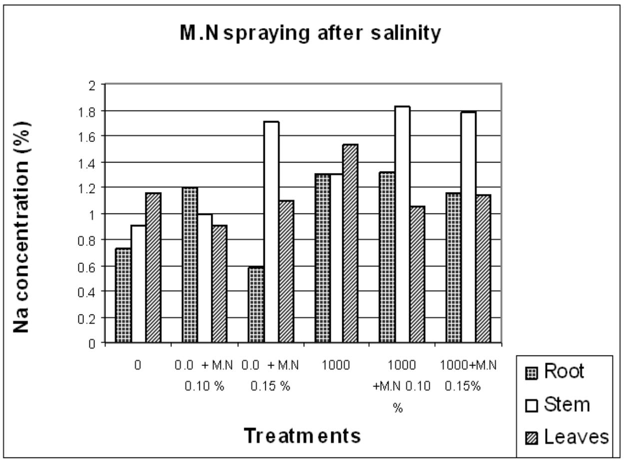


Fig. 2. Effect of spraying micronutrients before and after salinity treatments on Na+ concentration (%) of faba bean plant; 0= without salinity; 1000=1000ppm NaCl; M.N=micronutrient

increase was observed at (0.10%) after salinity treatments. It is intersting to note that spraying micronutrients can improve plant tolerance to salinity by increasing root growth which leads to promote nutrients uptake. The positive effect of Zn, Fe and Mn may be due to their effect as a component of some enzymes or regularory for the others. El-Fouly *et al.* (2002) found that spraying micronutrients being used to prevent nutritional disorders of crops under salinity coditions. . The positive effect of micronutrient foliar applications can be seen on the performance of growth for roots and shoots also.

Effect of salinity and micronutrients foliar spray on Na concentration

Sodium concentration of different plant organs of faba bean seedlings was increased in response to the presence of NaCl in the root growth medium (Fig. 2). Spraying plants with a micronutrient compund after salinity treatment lead to a reduction of Na concentration on roots and leaves, while it was increasd and accumulated in the stem. Micronutrient foliar applications leads to the decrease of Na^+ ions concentrations. Tlis may be contributed to that micronutrients have a control mechanism and/or a regulatory function on the Na uptake and translocation rate. Micronutrient might be involved in the integriry and function of the bio-membrane of plants (Thalooth *et al.,* 2006)

Effect of salinity on nutrients uptake

All macronutrients N, P, K, Mg and Ca uptake (Figs. 3, 4) and micronutrients Fe, Mn, Zn, Cu uptake (Fig. 5) in different organs of faba bean seedlings negatively relate affected with salinity. Mer *et al.* (2000) found that N uptake by barley and wheat plants was reduced as a result of high concentrations of salt in the soil. The reduction of nutrient uptake may be attributed to that high concentration of salts in the soil solution interferes with imbalanced absorption of essential nutritional ions by plants (Lutts *et al.,* 1999; Tester and Davenport, 2003). Grattan and Grieve, 1994 reported that imbalances may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant or may be caused by physiological interactivation of a given nutrient resulting in an increase in the plant's internal requirement for that essential element.

Effect of micronutrient foliar sprays on nutrients uptake under salinity conditions

Concerning nutrient uptake in different organs of faba bean seedlings, it was found that the nutrients content decreased by increasing salinity. El-Arquan *et al.* (2002) reported that nutrients uptake (N, P, K) were decreased by increasing soil salinity levels. This indicates that exssive content of Na^+ and Cl^- ions in growth media has an inhibitory effect on the uptake and translocation procasses of essential nutrients (Thalooth *et al.,* 2006). Micronutrient foliar sprays showed positive effectes with different degrees on all macro- and micronutrients uptake when sprayed either before or after the salinization treatments (Fig. 3, 4 and 5). Foliar feeding with micronutrients could partially counteract the negative effect of NaCl on nutrients uptake through improving root growth and prevented the nutritional disorders and concequently caused an increases for the uptake of nutrients by the roots (El-Fouly *et al.,* 2002).

Nutrient ratios

Concerning the nutrient concentration ratios (Fig. 6) reveals that the ratios were firstely affeced by NaCl stress. Increasing NaCl concentration leads to the decrease of K/Na, Mg/Na ratios. The decrease may be attributed to the increase of Na^+ ions which diminished the concentration of both K^+ and Mg^{++} due to antagonistic interaction.

Spraying plants with a micronutrient compund after salinity treatment lead the reduction of Na concentration of roots and leaves, while it was increased and accumulated in the stems. Consequently, the K^+/Na^+ and $Mg^{++}/$

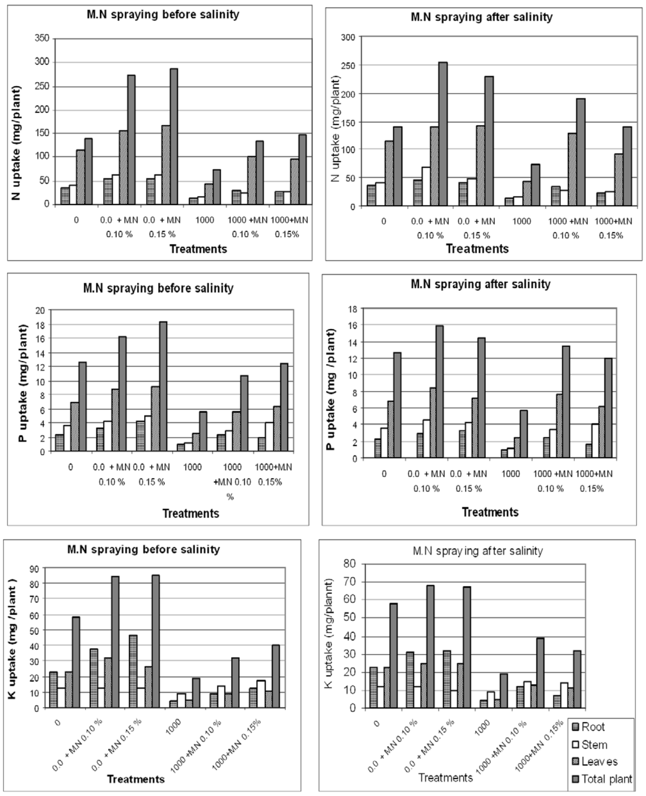


Fig. 3. Effect of micronutrients spraying before and after salinity treatments on N, P, K uptake (mg /plant) of faba bean plant; 0=without salinity; 1000=1000 ppm NaCl; M.N=micronutrient

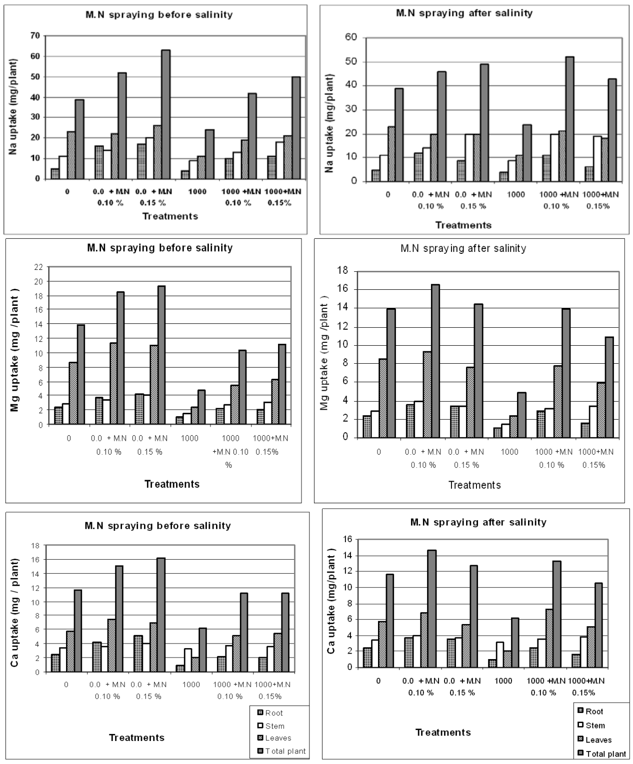


Fig. 4. Effect of micronutrients spraying before and after salinity treatments on Na, Mg and Ca uptake (mg /plant) of faba bean plant; 0 = without salinity; 1000=1000 ppm NaCl; M.N=micronutrient

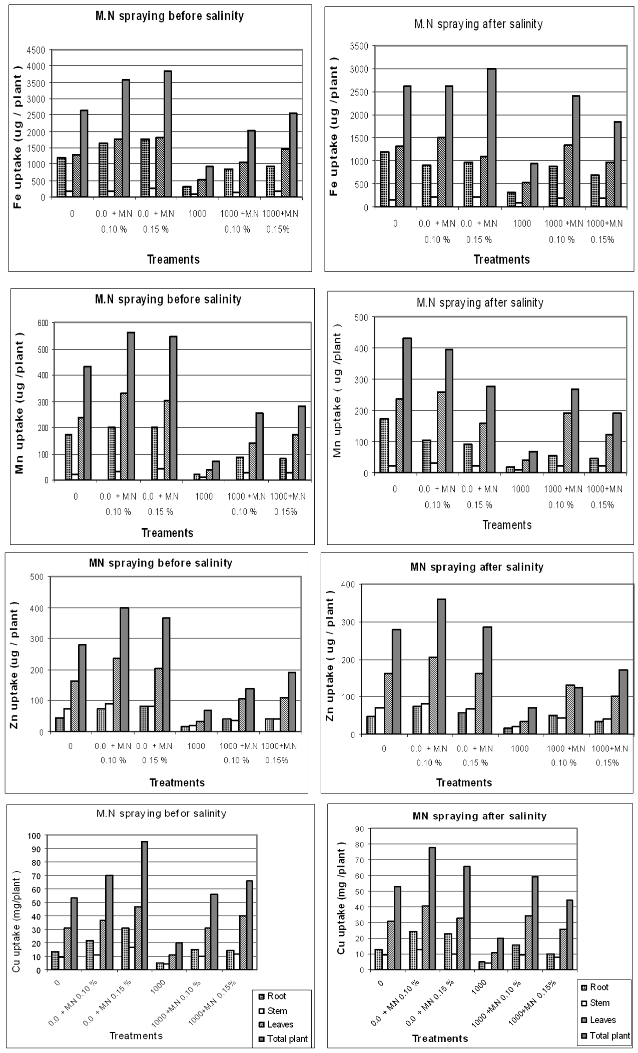


Fig. 5. Effect of micronutrients spraying before and after salinity treatments on Fe, Mn, Zn and Cu uptake (ug/plant) of faba bean plant; 0 = without salinity; 1000=1000 ppm NaCl; M.N=micronutrient

Na^+ ratios in the roots and leaves showed high values, and was reduced in the stem (Fig. 7). This may be attributed to that foliar spray of micronutrients under NaCl stress, that could increase the capability of root system for selectivity K^+ and Mg^{++} ions at high concentration of NaCl, which allows the maintenance of the transportation of both ions and the limitation of Na^+ ion uptake in the shoots (Tattini *et al.,* 1993 and Carvajal *et al.,* 1999). In this respect K/Na ratio might be concedered as a tool of plant tolerance to salinity stress.

Conclusions

From the results obtained, it has been shown that foliar application of micronutrients have a positive effect on growth and nutrients uptake of faba bean plants irrigated with saline water either before or after salinity treatments.

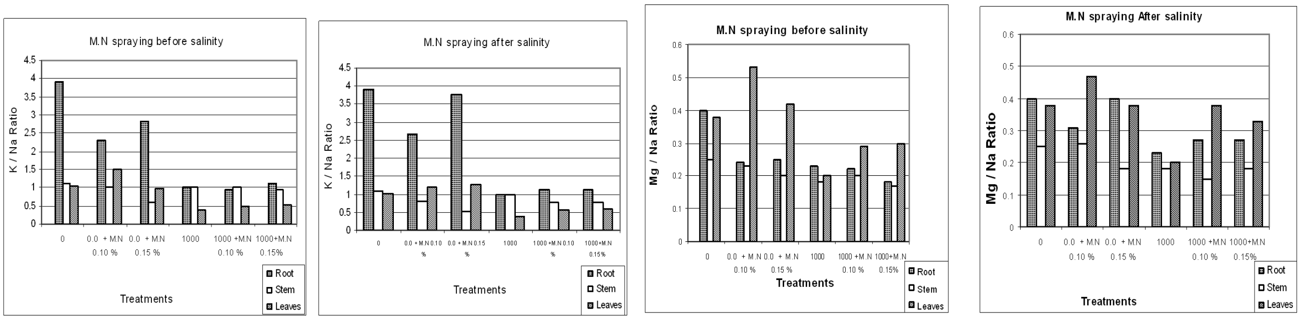


Fig. 6. Effect of micronutrients spraying before and after salinity treatments on K+ / Na+ and Mg++ / Na+ concentration ratios of faba bean plant; 0 = without salinity; 1000=1000 ppm NaCl; M.N=micronutrient

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