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# IMPROVEMENT OF THE PRODUCTIVITY OF *Foeniculum vulgare* UNDER SALT STRESS BY USING PHOSPHATE SOLUBILIZING BACTERIA AS BIOFERTILIZATION

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## ABSTRACT

Effects of phosphate solubilizing bacteria (PSB) and salt stress on soil biological activity, growth, essential oil persent and yield, and nutrient acquisition of fruits fennel plants (*Foeniculum vulgare*) were investigated in pot experiments in two seasons. Under the nonsaline (irrigation with tap water) conditions (0ppm) and moderate salt (irrigation with saline water 1500 and 3000 ppm) the rhizosphere colonization showed a significantly higher bacterial, fungal, and actinomycetes counts than the high salt (4500 ppm). The colonization by PSB decreased with increasing salinity level. Soil enzyme activities (phosphatase and dehydrogenase) decreased with increasing soil salinity, however, the degree of inhibition varied among the enzymes assayed and the amount of salt added. Enzyme activities were higher in the rhizosphere of fennel plants inoculated with PSB than in uninoculated plants. Inoculation with *Bacillus. megaterium* contributed positively to plant nutrient content, growth, essential oil, and mineral nutrition under all salinity levels. Inoculation with PSB induced significantly increase in N, P, K content and protein accumulation as compared to uninoculated treatments. Generally, concentration of all nutrients and protein accumulation decreased as the salinity levels increased in both inoculated and uninoculated treatments. Under nonsaline condition, fruit contents of Cu, Fe, and Zn were higher for treatments inoculated with PSB than uninoculated treatments, but the differences were not significant for Cu at the high salinity level (4500 ppm). The concentration of Na, Mg and Ca increased in fruits under irrigation with saline water compared to the control. The results suggest that fennel plants benefited from inoculation with biofertilizers phosphate solubilizing bacteria especially under salt stress.

## INTRODUCTION

In the natural environment, plants often grow under unfavorable conditions, such as drought, salinity, chilling, high temperature, and other. These conditions are known collectively as abiotic stresses, and any of them can delay growth and development, reduce productivity, and in extreme cases, cause the plant to die. To endure their own survival and the prosperity of their offspring, plants have evolved a range of strategies to cope with various abiotic stresses. Arid saline soils inhibit or reduce plant survival and development. The major causes of saline toxicity in plants include an unfavorable pH, an imbalance of essential cations and anions and an altered water-holding capacity (Al-Karaki 2000). Often in arid or semiarid zones (approximately 7% of the Earth's land surface) crop production is low. The influence of soil salinity on the nutrition to plants is not well understood, but nutrient uptake is known to be affected by the osmotic potential of soil solution. The symptoms of salinity stress resemble those of P deficiency.

Plants relying on a symbiotic relationship for adequate mineral nutrition and water uptake may differ in salt tolerance depending on the tolerance to soil salinity of the plant and symbiont (Reddell *et al.* 1986). On the other hand, plants meet their phosphorus requirement through the uptake of phosphate anions from the soil.

Dissolved salts may directly affect soil organisms by the specific toxicity of high concentrations of ions such as sodium or chloride, or by the non-specific effect of solutes on osmotic potential and, therefore, on water potential (Juniper and Abbott 1993). The lower (more negative) soil water potential becomes, the more difficult it is for organisms to take up water from the soil (Juniper and Abbott 1993).

The ability of rhizosphere bacteria to solubilize phosphorus is important in saline soils, where soil available P is low. Several reports have examined the ability of different bacterial species to solubilize insoluble inorganic phosphate compounds, such as tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate. Among the bacterial genera with this ability are *Pseudomonas*, *Bacillus*, *Rhizobium*, *Burkholderia*, *Achromobacter*, *Agrobacterium*, *Microccocus*, *Flavobacterium* and *Erwinia* (Badr El-Din *et al.*, 1986, Luheurte and Barthelin 1988, Attia and Badr El-Din 1999).

The use of phosphate solubilizing bacteria as inoculants increases P uptake by the plants (Kucey 1988). Especially, strains from the genera *Pseudomonas*, *Bacillus* and *Rhizobium* are among the most powerful phosphate solubilizers. The principal mechanism for mineral phosphate solubilization is the production of organic acids, and acid phosphatases which play a major role in the mineralization of organic phosphorous in soil. In addition, no significant amounts of organic acid production could be detected from a phosphate solubilizer fungus, *Penicillium* sp. It is suggested that the release of $H^+$ to the outer surface in exchange for cation uptake or with the help of $H^+$ translocation ATPase could constitute alternative ways for solubilization of mineral phosphates (Kucey 1988, Atlas and Bartha 1987, Arshad and Frankenberger 1991).

Considerable evidence supports the specific role of phosphate solubilization in the enhancement of plant growth by phosphate-solubilizing microorganisms. However, not all laboratory or field trials have offered positive results. Therefore, the efficiency of the inoculation varies with the soil type, specific cultivars, and other parameters.

The aim of this research was to use the biofertilization by *Bacillus megaterium* as phosphate solubilizing bacteria to improvement productivity in *Foeniculum vulgare* subjected to increasing levels of salinity induced by irrigated with saline water. Phosphatase and dehydrogenase enzyme activities of the soil under salinity stress were used as indicator for improvement of P nutrition.

## MATERIALS AND METHODS

Two greenhouse experiments were conducted during 2001/2002 and 2002/2003 using *Foeniculum vulgare* plants in a calcareous soil. Soil properties were: 16.8% clay, 53.6% silt, 29.6% sand, 0.08 organic matter, pH 8.68 (soil:water 1:1), electrical conductivity (EC) 0.54 dS $m^{-1}$; 14.3 mg P ($NaHCO_3$-extractable), 19.68% $CaCO_3$, 31.33 K, 48.3 Mg, 3.92 Fe, 4.32 Mn, 2.2 Zn, and 0.48 Cu (5 mM DTPA-extractable) in mmol per kg soil. The calcareous soil was dispensed into plastic pots (12 kg soil per pot) for plant growth.

The experiments were sit in a completely randomized block design with four salt stress levels (0, 1500, 3000, and 4500 ppm) and two inoculation treatments (uninoculation and inoculation with PSB) to give a 4x2 factorial with four replicates. Half of the pots were biofertilizated with *Bacillus megaterium* as phosphate solubilizing bacteria (PSB) by adding ten ml of bacterial suspension containing $10^8$ cells $ml^{-1}$ from a 48h old broth medium over seeds of *Foeniculum vulgare*. The *Bacillus megaterium* inoculum was isolated from the rhizosphere and identified at Agricultural Microbiology Dep., NRC (Attia *et al.*, 2002) and multiplied in broth medium (48h/30C). Control treatments received broth medium without bacteria.

Five seeds of fennel (*Foeniculum vulgare*) were planted in each pot and thinned to two plants after germination. Biofertilized soils received half doses of recommended mineral fertilizers. In the mineral fertilizer (NPK) treatment, superphosphate and $K_2SO_4$ were mixed in soil before planting at rates of 200 and 50 kg $acre^{-1}$, respectively, while nitrogen was added at the rate of 90 kg $(NH_4)_2SO_4$ $acre^{-1}$ in three equal doses after planting, 21 and 45 days from planting. Plants were established for 2 weeks before subjecting to the four salt levels using saline water with sodium chloride and calcium chloride (1:1) mixture. The levels are 0 (nonsaline), 1500, 3000, (medium) and 4500 (high salt stress) ppm. The irrigation started just after seed germination. Two hundred and fifty ml of water was added to each pot/two times/week throughout the course of the study. Controls were watered with tap water in the same amount.

Soil samples from each treatment were removed at flowering and maturity stages to determine microbial counts, dehydrogenase and phosphatase enzyme activities. Plant samples were collected at the maturity stage to determine fresh and dry weight of foliage (g $plant^{-1}$), number of umbels and fruit yields. Nitrogen, phosphorus and micronutrients (Zn, Fe, Mn and Cu) contents in fruits were determined according to Kalra and Maynard (1991).

Rhizosphere soil samples were analyzed microbiologically using the standard procedures described by Black *et al.* (1965) and Page *et al.* (1982). A 10-g sub-sample of each soil was diluted in 90 ml sterile water and mixed for 10 min in a magnetic stirrer operating at half speed. The soil suspension was diluted in 10-fold series in 250-ml bottles, and five Petri dishes containing solid media were inoculated from each dilution. The serial dilution plate method was used for counting total bacteria on soil extract yeast agar

medium (Mahmoud *et al.*, 1964), fungi on Martin s medium (Allen 1959), actinomycetes on dextrose-nitrate medium (Allen 1959) and PSB on Bunt and Rovira (1955) medium modified by Louw and Webley (1959).

The activity of soil phosphatase was determined using the method described by Tabatabai and Bremmer (1969). The soil was incubated in a solution with p-NPP and the formation of p-nitrophenol was measured using a spectrophotometer. Dehydrogenase activity was measured by method described by Skujins (1973). Five grams of soil were incubated with 0.1g $CaCO_3$ and 1 ml of 3% aqueous solution of 2,3,5-triphenyltetrazolium chloride (TTC) and 1 ml of distilled water for 24hr at 30°C in darkness. The triphenyl formazan (TPF) produced was extracted with methanol. The intensity of the reddish color was measured on a spectrophotometer at 485 nm.

Data were statistically analyzed by the SPSS (Statistical Package for the Sciences System). All data obtained from the two seasons were subjected to the analysis of variance according to Snedecor and Cochran (1980). All results were collected in triplicate and expressed on oven-dry basis (110°C). Data of PSB, total bacteria, fungi, and actinomycetes were transformed to log10 (X+1). The combined analysis of variance was preformed for the two years. All means were tested for significance using Duncan s multiple range tests at the 5% level for probability.

## RESULTS AND DISCUSSION

Nearly all salinity and biofertilization treatments in the two seasons produced significant effects on yield and nutrient acquisition. Salt x PSB interactions were significant for fruit yield, and counts of PSB, total bacteria, fungi, actinomycetes in the rhizosphere of fennel plants. The same effect was found with N, P and Fe contents in the fruits.

Results of combined analysis for the two experiments show that the rhizosphere of fennel plants, grown in nonsaline soil, had relatively higher bacterial, fungal, and actinomycetes counts, which slightly decreased as soil salinity increased (Fig. 1). These results may be attributed to root exudation of low-molecular-weight organic solutes, mucilage, and sloughed-off cells which may mobilize mineral nutrients either directly or indirectly by providing the energy substrate for microbial activity in the rhizosphere (Marschner *et al.*, 1986). Under the nonsaline conditions (0 ppm) and moderate salt (1500 and 3000 ppm) the rhizosphere showed a significantly higher bacterial, fungal, and actinomycetes counts than the high salt level (4500 ppm) which began to decline till maturity stage. The limited root exudates at the initial phase of bacterial development may restricted the bacterial growth. The limitations of root exudates may result from slower root growth rates in nutrient-deficient soils (Lesica and Antibus 1986).

The number of indigenous phosphate solubilizing bacteria in the rhizosphere was $5.25 \times 10^4$ cells $g^{-1}$ dry soil. The inoculation with *B. megaterium* increased the number till $7.2 \times 10^7$ cells $g^{-1}$ dry soil (Fig. 1). The counts tended than after to follow a slight decline where they proliferated. The colonization of PSB decreased with increasing salinity level. These

decreases may be due to the reduction of absorbed water and decrease the root permeability (Frota and Kucher 1978). The inoculation with *B. megaterium* had no effect on total bacteria, fungi and actinomycetes in the rhizosphere soil. The same trends however, were achieved by bacterial counts, fungi and actinomycetes and where the density of population was affected by the soil salinity. The density decreased by increasing salinity levels (Fig. 1).

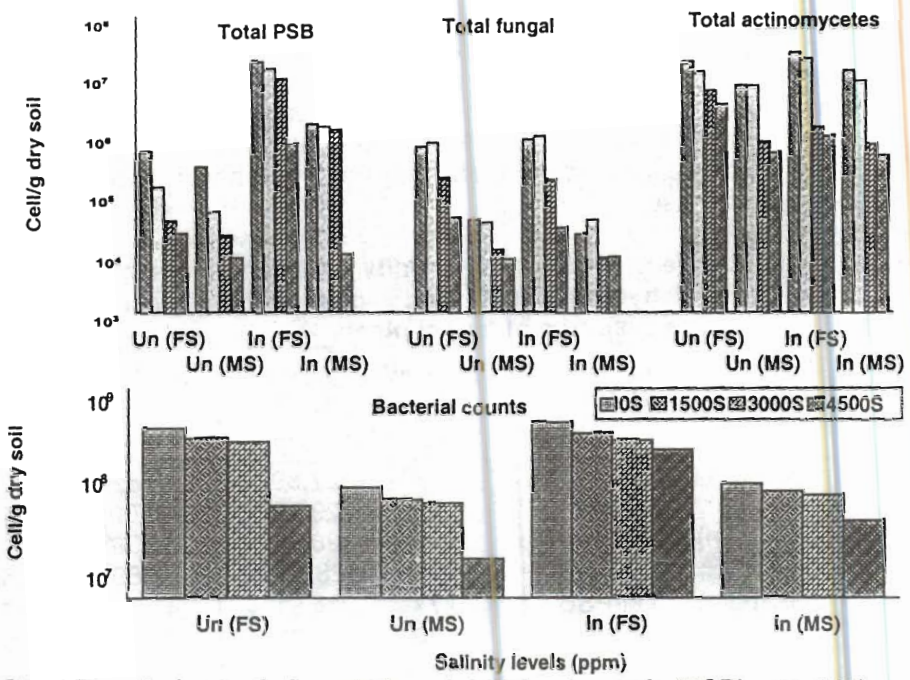


**Fig. 1 Populations of phosphate solubilizing bacteria (PSB), fungi (F), actinomycetes (AC) and total bacterial counts at flowering (FS) and maturity (MS) stages in the rhizosphere of *Foeniculum vulgare* inoculated (In) or uninoculated (Un) with PSB grown at different salinity levels.**

Table 1 shows the influence of increasing salinity on the levels of soil enzyme activities. The phosphatase and dehydrogenase activities decreased with increasing salinity. Phosphatase and dehydrogenase activities ranged between 8.74 to 44.45 *ul* $H_2$/100g soil/24h and 14.04 to 61.02 mg $P_2O_5$/ 100g soil/24h or H $g^{-1}$ $h^{-1}$ respectively. Soil enzyme activities decreased with increasing salinity soil, however, the degree of inhibition varied depending on the enzyme assayed and the amount of salt added. Activity of dehydrogenase was the highest in nonsaline. However, rhizosphere phosphatase activity increased with an increase in salinity levels from nonsaline to 3000 ppm. Enzyme activities were higher in the rhizosphere of fennel plants inoculated with PSB than in uninoculated plants. Rhizosphere enzyme activities were increased in the flowering stage then the activities

decreased to the level of the control at maturity stage. The addition of NaCl (15 mg/100g) was found stimulate to the activities of urease and phosphatase (El-Shinnawi and El-Shimi 1981). This is probably due to the production of phosphatase by organisms other than bacteria, for example, soil protozoa (Hattoria 1993) or other groups. Enzymes in soils do not only originate from microbial sources, but also from animals and plant roots. Phosphatase activity can also be affected by earthworms and other soil animals (Hsek and ? arapatka, 1998). Hsek and ? arapatka (1998) reported that in forest soils other organisms, such as micromycetes can be found, which can increase total soil enzyme activity. Reductions in activity were proportional to salinity increases. The least values were recorded with 4500 ppm. As Frankenberger and Bingham (1982) reported the decrease in soil enzyme activity with the shift in pH and salts contents in the soil. The decline in activity appears to be associated with change in the osmotic potential of the soil and possibly to specific ion effects. Low osmotic potentials of the soil could promote microbial cell lysis releasing intracellular enzymes which become vulnerable to attack by soil proteases.

**Table 1: Effect of different salinity levels and inoculation with PSB on dehydrogenase and phosphatase activities in the rhizosphere of fennel plants**

| Saline solution | Inoculation status | Dehydrogenase (*u*l $H_2$/100g soil/24h) | | Phosphatase (mg $P_2O_5$/100g soil/24h) | |
|---|---|---|---|---|---|
| | | FS | MS | FS | MS |
| 0(ppm) | Un-PSB | $27.96^{e}$ | $27.89^{c}$ | $43.62^{b}$ | $32.86^{b}$ |
| | In-PSB | $44.25^{f}$ | $29.79^{e}$ | $61.02^{f}$ | $44.33^{e}$ |
| 1500(ppm) | Un-PSB | $26.92^{e}$ | $28.75^{d}$ | $55.36^{e}$ | $39.77^{d}$ |
| | In-PSB | $44.45^{f}$ | $28.43^{cd}$ | $50.89^{d}$ | $35.81^{c}$ |
| 3000(ppm) | Un-PSB | $20.77^{c}$ | $14.51^{a}$ | $47.32^{c}$ | $33.75^{b}$ |
| | In-PSB | $24.30^{d}$ | $17.37^{b}$ | $55.61^{e}$ | $33.00^{b}$ |
| 4500(ppm) | Un-PSB | $8.74^{a}$ | $13.81^{a}$ | $33.05^{a}$ | $15.37^{a}$ |
| | In-PSB | $17.49^{b}$ | $16.22^{b}$ | $39.74^{a}$ | $14.04^{a}$ |

**Different letters is each column indicate significant differences at P<0.05 according to Duncan s multiple range tests. PSB=phosphate solubilizing bacteria, Un=uninoculated, In = inoculated**

Results of combined analysis for the two seasons show that in nonsaline soil the umbels and fruits dry weights were generally higher for inoculated than uninoculated plants (Table 2). Salt stress of 1500 ppm and 4500 ppm of NaCl/$CaCl_2$ decreased umbels dry weight. However, inoculation treatments gave the highest umbels dry weight in the two seasons compared with uninoculated treatments. Previous studies have indicated that phosphorus deficiency is one of the most important factors limiting plant growth in calcareous soils. Luheurte and Barthelin (1988) found that plant development was not stimulated by inoculation with PSB in a soluble P deficient medium and root growth significantly increased by inoculation of maize plant with PSB for 5 ppm of soluble P. The effect of bacterial

inoculation on growth of plants depended on the amounts of available P present in the soil. On the other hand, increasing microbial activities in the rhizosphere raised available nutrients content in soil and played special role by decomposing organic substances or transforming inorganic substances to available nutrients for the plant growth and pH of all soils. The role of microorganisms in the production of forms of phosphorus (P) which are available to plants, has been examined, and Oberson et al. (1993) found a high, positive correlation between phosphatase activity and residual P.

**Table 2 Influence of different salinity levels and inoculation with PSB on plant dry weight, seed weight, foliage weight and essential oil in fennel fruits**

| Saline solution | Inoculation status | Dry wet g/plant | Fruits Wet g/plant | Wet. foliage g/plant | Essential oil % Yield/plant | |
|---|---|---|---|---|---|---|
| 0(ppm) | Un-PSB | $16.30^{c}$ | $1.73^{d}$ | $5.58^{d}$ | $2.95^{c}$ | $5.10^{c}$ |
| | In-PSB | $40.02^{f}$ | $3.66^{f}$ | $5.65^{d}$ | $3.12^{d}$ | $11.42^{e}$ |
| 1500(ppm) | Un-PSB | $11.42^{a}$ | $1.52^{cd}$ | $4.46^{bc}$ | $2.8^{c}$ | $4.27^{c}$ |
| | In-PSB | $27.33^{d}$ | $2.34^{e}$ | $4.93^{cd}$ | $2.93^{c}$ | $6.86^{d}$ |
| 3000(ppm) | Un-PSB | $12.39^{ab}$ | $1.13^{b}$ | $4.02^{bc}$ | $1.87^{b}$ | $2.11^{ab}$ |
| | In-PSB | $32.00^{e}$ | $1.36^{bc}$ | $4.46^{bc}$ | $2.34^{c}$ | $3.18^{b}$ |
| 4500(ppm) | Un-PSB | $14.77^{bc}$ | $1.04^{a}$ | $2.83^{a}$ | $1.38^{a}$ | $1.44^{a}$ |
| | In-PSB | $38.60^{f}$ | $1.24^{b}$ | $3.87^{b}$ | $1.56^{a}$ | $1.95^{a}$ |

**Different letters is each column indicate significant differences at P<0.05 according to Duncan s multiple range tests. (PSB=phosphate solubilizing bacteria, Un=uninoculated, In= inoculated).**

Results revealed also that the fruits yield per plant was adversely affected by salinity in both seasons (Table 2). Raising the salt concentration resulted in steady reduction in the fruit yield, which reached its lowest values at the highest salt concentration (Table 2). On the other hand, fruits yield increased by inoculation with PSB compared to uninoculated treatments. The interaction between inoculation and all salinity levels had positive effect in fruit yield than the other treatments without inoculation.

Data recorded in Table 3 show that all salinity levels decreased N% in fruits in both seasons, whereas biofertilization with PSB increases N% in fruits compared with nonbiofertilized ones. These results may be attributed to the synergistic effect of inoculation with biofertilization on N accumulation in fruits. The data also revealed that, the plants grown under saline conditions had a lower N percentage in fruits than the normal condition. The same trend was observed with protein accumulation in fruits where content decreased as salinity levels increased. The least values were recorded with 4500 ppm. Salinity levels cause a delay in the break down of endospermic proteins as well as inhibit translocation of hydrolysed products from endosperm to growing embryo. Inoculation increased protein percentage in fruits during the two seasons. Biofertilization increased protein percentage in fruits in the same manner. The positive effects of inoculation on N% and protein was reported by Omar *et al.* (1993) on rice, El-Sayed *et al.* (1994) on *Sesbania aegyptiaca.*

**Table 3 : Influence of different salinity levels and inoculation with PSB on concentration of fruit nutrients of *Foeniculum vulgare*.**

| Saline solution | Inoculation status | N % | Protein % | P (ppm) | K % | Ca % | Na ppm | Mg % |
|---|---|---|---|---|---|---|---|---|
| 0(ppm) | Un-PSB | 1.70$^{d}$ | 10.65$^{d}$ | 1240$^{a}$ | 3.89$^{d}$ | 1.15$^{a}$ | 17.3$^{a}$ | 0.36$^{a}$ |
| | In-PSB | 1.83$^{d}$ | 11.46$^{d}$ | 2010$^{b}$ | 4.03$^{e}$ | 1.25$^{a}$ | 17.5$^{a}$ | 0.93$^{b}$ |
| 1500(ppm) | Un-PSB | 1.51$^{c}$ | 9.44$^{c}$ | 2120$^{bc}$ | 3.60$^{c}$ | 1.20$^{a}$ | 76.2$^{f}$ | 0.90$^{b}$ |
| | In-PSB | 1.72$^{d}$ | 10.76$^{d}$ | 2230$^{c}$ | 3.80$^{d}$ | 1.70$^{b}$ | 60.7$^{b}$ | 1.08$^{c}$ |
| 3000(ppm) | Un-PSB | 1.20$^{ab}$ | 7.53$^{ab}$ | 2300$^{c}$ | 3.23$^{b}$ | 2.20$^{c}$ | 68.7$^{e}$ | 1.08$^{c}$ |
| | In-PSB | 1.55$^{c}$ | 9.71$^{c}$ | 2650$^{d}$ | 3.59$^{c}$ | 2.51$^{d}$ | 62.5$^{c}$ | 1.26$^{de}$ |
| 4500(ppm) | Un-PSB | 1.04$^{a}$ | 6.50$^{a}$ | 2970$^{e}$ | 2.95$^{a}$ | 2.30$^{cd}$ | 67.1$^{d}$ | 1.14$^{cd}$ |
| | In-PSB | 1.40$^{bc}$ | 8.75$^{b}$ | 3040$^{e}$ | 3.45$^{c}$ | 2.80$^{e}$ | 61.1$^{b}$ | 1.32$^{e}$ |

**Different letters is each column indicate significant differences at P<0.05 according to Duncan s multiple range tests. (PSB=phosphate solubilizing bacteria, Un=uninoculated, In= inoculated).**

Data in Table 3 illustrate the effect of salinity and biofertilizers with *B. megaterium* on the P concentration in fennel fruits. The concentration of phosphorus in fruit was influenced greatly by soil salinity and inoculation with *B. megaterium*. Fruit P contents were generally higher in inoculated treatments than uninoculated ones regardless of salinity level. However, no significant differences were noted in fruit P content between inoculated and uninoculated plants with PSB at the high salinity level (4500 ppm). Fruit P content increased with increasing soil salinity in both inoculated and uninoculated plants. Differences in P content between inoculated and uninoculated plants were noted under nonsaline (0 ppm) and medium (3000 ppm) conditions. It is clear that higher salinity levels enhanced P concentration in fruit. This may be attributed to absorption of excess amount of phosphorus from soil under salt stress. Usually, plant exhibits a high respiration rate which requires a considerable amount of energy. Phosphorus is usually required for the synthesis of metabolic intermediates necessary for the maintenance of this state of disequilibrium (Gates *et al.* 1970). The inoculation with *B. megaterium* increased P concentrations in fruits compared to nonbiofertilized treatments (Mazher and El Masiry 1999).

Fruit K contents were higher in inoculated treatments than uninoculated ones in the nonsaline and medium salinity treatments (Table 3). Generally, potassium content in fruit decreased as salinity levels increased. The least values were recorded with 4500 ppm. The synergistic effects on K percentage were observed by *B. megaterium* compared to nonbiofertilized treatments.

The concentration of Ca++, Na and Mg increased in fruits under irrigation with saline water compared to control (Table 3). The results show that the inoculation treatments increased the Na percentage from 17.3 to 76.2, Mg from 0.36 to 1.32, and Ca from 1.15 to 2.80. Mean values of $Ca_2$++ concentration increased in the treated plant by increasing salinity levels. Theses results are in agreement with those of Schanchtman & Munns (1992) and Nasiem & Ghallab (1998) in wheat plants. The interaction of inoculation and salt stress results indicate that the combination of both factors on Ca++, Na and Mg percentages was more effective than the effect of each factor when applied alone.

Under nonsaline condition, results in Table 4 show that fruit contents of Cu, Fe, and Zn were apparently higher for inoculated with PSB than uninoculated treatments; however, the differences were not significant for Cu at the high salinity level (4500 ppm). Fruit contents of Cu, Fe, and Zn decreased as soil salinity increases. No significant differences were noted for fruit content of Zn in either inoculated or noninoculated plants under high salinity levels (Table 4).

The results suggest that fennel plants benefited from inoculation with biofertilizers phosphate solubilizing bacteria especially under salt stress. Accordingly, it is recommended to decrease the mineral fertilizer doses with inoculation by PSB.

**Table 4 Fruits micronutrients content as influenced by salinity levels and inoculation with PSB**

| Saline solution | Inoculation status | Cu ppm | Fe ppm | Zn ppm |
|---|---|---|---|---|
| 0(ppm) | Un-PSB | $55.0^{c}$ | $634^{e}$ | $206^{f}$ |
| | In-PSB | $87.5^{d}$ | $1041^{f}$ | $307^{g}$ |
| 1500(ppm) | Un-PSB | $21.6^{b}$ | $420^{d}$ | $92^{d}$ |
| | In-PSB | $51.2^{c}$ | $637^{e}$ | $142^{e}$ |
| 3000(ppm) | Un-PSB | $7.8^{a}$ | $181^{b}$ | $40^{b}$ |
| | In-PSB | $19.9^{b}$ | $281^{c}$ | $61^{c}$ |
| 4500(ppm) | Un-PSB | $4.0^{a}$ | $126^{a}$ | $26^{a}$ |
| | In-PSB | $8.7^{a}$ | $189^{b}$ | $57^{bc}$ |

**Different letters is each column indicate significant differences at P<0.05 according to Duncan s multiple range tests. (PSB=phosphate solubilizing bacteria, Un=uninoculated, In= inoculated).**

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## تحسين إنتاجية الشمر تحت الظروف الملحية باستخدام التسميد الاحيائى بالبكتريا المذيبة للفوسفات

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**قسم الميكروبيولوجيا الزراعية[1] والعلاقات المائية والرى الحقلى[2]- المركز القومى للبحوث-القاهرة-مصر**

تم دراسة تاثير البكتريا المذيبة للفوسفات والملوحة على نشاط التربة والنمو الخضرى وانتاجية الزيت والعناصر المغذية لثمار الشمر وذلك فى تجارب اصص لموسمين. وقد وجد انه تحت ظروف عدم الملوحة والملوحة المتوسطة (٠ - ١٥٠٠ - ٣٠٠٠ جزء فى المليون) كان النشاط العام للتربة مرتفع بالمقارنة بالتربة ذات الملوحة العالية (٤٥٠٠ جزء فى المليون). ونقصت اعداد البكتريا المذيبة للفوسفات والنشاط الانزيمى للتربة بزيادة معدلات الملوحة على الرغم من اختلاف درجات التثبيط لكل انزيم بكمية الاملاح المضافة. وقد كان النشاط الانزيمى مرتفع فى حالة التلقيح بالبكتريا المذيبة للفوسفات مقارنة بالتربة غير الملقحة. كذلك اظهر التلقيح بالبكتريا المذيبة للفوسفات تاثيرا ايجابيا على نمو وكمية الزيت المتحصل عليها من ثمار الشمر بالمقارنة بغير الملقحة. وعموما زادت العناصر المغذية للنبات وكمية البروتين المتراكمة فى ثمار الشمر بالمقارنة بغير الملقحة.

ومن النتائج فانه يمكن استخدام التلقيح بالاسمدة الاحيائية المذيبة للفوسفور فى تحسين انتاجية ونوعية زيت الشمر وخاصة تحت الظروف الملحية