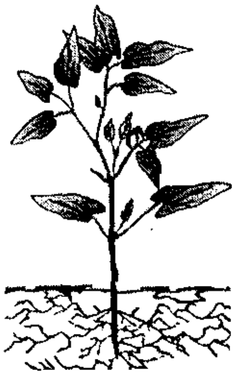

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MICROBIAL SOLUBILIZATION OF PHOSPHATE – POTASSIUM ROCKS AND THEIR EFFECT ON KHELLA (*Ammi visnaga*) GROWTH

[3]

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ABSTRACT

Biofertilizers have been used as sources to improve plant nutrients in sustainable agriculture. Experiments were conducted to evaluate the potential of several phosphate solubilizing bacteria (PSB) *Bacillus megaterium* and potassium solubilizing bacteria (KSB) *Bacillus circulans* to solubilize tricalcium phosphate (TCP), rock phosphate (RP) and feldspar respectively in pure culture and field experiments to determine the effect of these bacteria on releasing P and K as well as their effect on *Ammi visnaga* (khella) growth. Seven strains of *B. megaterium* were selected on the basis of the clearance zone on solid agar media of Pikovskaya containing TCP. *B. megaterium* KL_1, BF_2 (showing the highest of solubilizing index) were tested to study their efficiency to dissolve phosphorus in liquid culture amended with TCP and rock phosphate individually, the latter strain was more effective in releasing phosphate from the two tested sources. Five *Bacillus circulans* strains were tested for their ability to solubilize feldspar in Aleksandrov's liquid medium. Their effectiveness ranged from 2.09 – 8.64 % and generally the pH decreased. *Bacillus circulans* F5 has the highest value of soluble potassium in the medium. A field experiment was conducted during two successive seasons 2006 / 2007 and 2007 / 2008 to determine the influence of : **1-** Phosphate fertilizer namely: calcium superphosphate at the recommended dose (200 kg / fed.), rock phosphate at the rates of (128& 256 kg / fed.) and biofertilization with *Bacillus megaterium* BF2 and their interactions. **2-** Potassium fertilizer namely: potassium sulphate at the recommended dose (50 kg / fed.), feldspar at the rates of (240& 480 kg / fed.) and biofertilization with *B.circulans* F5 and their interactions. The highest values of all parameters were observed when the plants received calcium superphosphate and / or rock phosphate at the high rate. In regard to biofertilizer treatments,all of them led to a significantly increase in the growth criteria during the two successive seasons. The similar results were obtained in potassium treatment.

INTRODUCTION

The use of plant growth promoting rhizobacteria (PGPR), including phosphate and potassium solubilizing bacteria (PSB and KSB) as biofertilizers, was suggested as a sustainable solution to improve plant nutrients and production (**Vessey, 2003**). Phosphate and potassium are major essential macronutrients for plant growth, soluble P and K fertilizers are commonly applied to replace removed minerals and to optimize yield. When phosphate is added into soils as a fertilizer in relatively soluble and plant available forms, it is easily converted especially in alkaline soil like in Egyption soil, into insoluble complexes. Consequently, to achieve optimum crop yields, soluble phosphate,

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fertilizers have to be applied at high rates which cause unmanageable excess of phosphate application and environmental and economic problems (**Brady, 1990**). On the other hand, K deficiencies become a problem because K decreases easily in soils due to crop uptake, runoff, leaching and soil erosion (**Sheng and Huang, 2002**). Direct application of rock phosphate (rock P) and potassium (rock K) materials may be agronomically more useful and environmentally more feasible than soluble P and K (**Rajan *et al* 1996**). Rock P and K materials are cheaper sources of P and K; however, most of them are not readily available to a plant because the minerals are released slowly and their use as fertilizer often causes insignificant yield increases of current crop (**Zapata and Roy, 2004**). PSB have been used to improve rock P value because they convert insoluble rock P into soluble forms available for plant growth (**Bojinova *et al* 1997**). *Bacillus megaterium* var. *phosphaticum* is known for its ability to solubilize rock P material. On the other hand, KSB are able to solubilize rock K mineral powder, such as micas, illite and orthoclases, (**Han and Lee, 2005**). It was shown that KSB, such as *Bacillus mucilaginosus* and *B. circulans* increased K availability in soils and increased mineral content in plant (**Sheng *et al* 2002**). *Ammi visnaga* is one of the important pharmaceutical plants of the Umbelliferae. The fruits contain two main chromones, khellin and visnagin, which are used as diuretic, carminative stimulant, vasodilator and antispasmodic. The promoting effect of Potassium fertilizer on growth, yield and chemical constituents of horticulture plants (*Hibiscus sabdariffa* L.) was supported by **Al-Qubaie (2002)**. He studied the effect of different levels of potassium on plant growth, and the result showed that potassium fertilizer was very effective in enhancing all growth criteria, anthocyanine and flavones. The promoting effect of phosphorus treatments on growth and yield was studied by **Abdel-Gawad (2001)** on Coriander plants and revealed that P fertilization led to increase P and oil contents in plant. **Tomar *et al* (1996)** reported that application of phosphate solubilizing bacteria as a bio-fertilizer to *Cicer arietinum* increased mean seed yield from 2.23 to 2.46 ton/ha.

The aim of the study was to evaluate the potential of the direct application of rock P and K materials with the most effective strains of PSB and KSB for the improvement of P and K uptake and growth of Khella *(Ammi visnaga)* plant grown in field conditions.

MATERIALS AND METHODS

Bacteria and soil type used

Seven strains of *B. megaterium* and five strains of *B. circulans* were used in this study. They were obtained from Unit of Biofertilizer, Fac. Agric., Ain Shams Univ. The physico-chemical properties of soil used in these experiments are given in **Table (1).**

Mineral supplements: Feldspar and rock phosphate sources were obtained from El-Ahram Company for Mining and Natural Fertilizers. The rock phosphate contained 25.06% P_2O_5. The Feldspar contained 10.1% K_2O.

Assessment the efficiency of phosphate- solubilizing bacteria

Bacteria were tested for their ability to solubilize phosphate using Pikovskaya's agar medium (**Subba Rao, 1982**). A loop of active culture of collected strains {seven strains of *B. megaterium* (KL1, KL2, SD, M1, M2, BF1, BF2)} was inoculated onto plates of Pikovskaya's agar medium. This medium contained (g / l) :- glucose, 10; $Ca_3(PO_4)_2$, 5; $(NH_4)_2SO_4$, 0.5; KCl, 0.2; $MnSO_4$ and ferrous sulphate in traces, yeast extract, 0.5 ;$MgSO_4.7H_2O$, 0.1 and agar, 20; pH 7.2. After incubation for 5 days at 28 -30°C, the colonies showing haloes around are phosphate solubilizers. The efficiency of the bacteria to solubilize insoluble phosphate was described by solubilization index {the ratio of the total diameter (colony + halo zone) and the colony diameter} (**Edi Premono *et al* 1996**).

To determine phosphate activity in liquid culture , a Pikovskaya's broth medium was amended separately with 0.5% TCP(tricalcium phosphate) and 0.5% rock phosphate were inoculated by standard inoculum (10^6 cfu/ml) of each of the most potent bacteria (showing highest solubilization index) and inocubated at 28-30°C under shake condition for 14 days. After 2, 6, 10, 14 days of inoculation, the number of cells and changes of pH were measured. The amount of soluble phosphate was determined in culture filtrates at the same time according to **Jackson (1967)** to study the relation between the bacterial growth and soluble P with elapsing of time. On the basis of this experiment the most efficient strain of *B. megaterium* was selected to apply in field experiment.

Table 1. Physico - chemical properties of the experimental soil (extract 1:5)

Partial size distribution (%)				pH	E.C (dSm^{-1})	$CaCO_3$ g kg^{-1}	Water soluble Ions (meq/L)							Available nutrients (mg kg^{-1})		
Sand	Silt	Clay	Texture				$CO_3 + HCO_3$	Cl^-	SO_4^{2-}	Ca^{+2}	Mg^{+2}	Na^+	K^+	N	P	K
25.5	39.8	34.7	loamy	7.9	1.2	2.7	2.9	2.2	6.6	3.4	1.9	6.2	0.21	62.4	9.2	356

Characterization of the effectiveness of silicate bacteria for mobilizing potassium

For this purpose, each of five strains of *B. circulans* (**silicate bacteria**) was inoculated separately into 250 ml flasks containing 100 ml of sterilized Aleksandrov's liquid medium (**Zahra, 1969**) and supplemented with 0.1% feldspar at pH 7. The flasks were inoculated with standard inoculum (10^6 cfu/ml) of each strain and incubated under shaking condition at 30°C for 14 days. Soluble potassium (**Jackson 1967**) and pH were determined in culture filtrates after 14 days of inoculation. The efficiency of all bacteria to solubilize insoluble potassium was described in term of effectiveness:

$$\textit{Effectiveness} = \frac{\textit{Soluble K in treatment} - \textit{Soluble K in control}}{\textit{Total K} - \textit{soluble K in control}} \times 100$$

* Soluble K in Aleksandrov's uninoculated medium was 4.0 ppm

* Total K in feldspar mineral was 100 ppm

The most efficient strain was selected according to the amount of soluble potassium and was inoculated in Aleksandrov's liquid medium supplemented with 0.1% feldspar at the same conditions as the previous .The samples were taken after 2, 6, 10, 14 days of inoculation, then the number of cells and changes of pH were measured , the amount of soluble potassium was determined in culture filtrates to study the relation between the amount of soluble phosphate and bacterial growth with elapsing of time.

Field experiments

Two separate field experiments were carried out in the Experimental Farm of Faculty of Agriculture, Al-Azhar University, Assiut, Egypt during the two successive seasons of 2006 / 2007 and 2007 / 2008, to study the effect of addition of rock phosphate and feldspar rates individually and combination with *Bacillus megaterium* and *Bacillus circulans* (used as seed inoculants) respectively and compared to the recommended doses of calcium superphosphate and potassium sulphate with and without these bacteria (control) on growth, total chromones (khellin and visnagin) and N P K % of *Ammi visnaga* plants.

A split plot design with three replications, rock phosphate rates were recommended dose (**RP_1**=128 kg/fed) & 200% of recommended dose (**RP_2**=256 kg/fed) and recommended doses of calcium superphosphate (**SP**= 200 kg/fed.). Feldspar rates were recommended dose (**Fl_1**= 240 kg/fed) & 200% of recommended dose (**Fl_2**= 480 kg/fed). The previous treatments and the recommended dose of nitrogen (ammonium sulphate 200 kg/fed) were added with soil preparation while recommended doses of potassium sulphate (**PS**=50 kg/fed.) were added after sowing at 1 and 3 months. These were considered the main plots, sub plots with or without inoculation by *B. circulens* F5 and *B. megaterium* BF2. *Ammi visnaga* seeds were soaked in either fermented liquid containing *B. circulens* F5 and *B. megaterium* BF2 ($1x10^8$ cfu /ml) individually or in distilled water for control. The treated seeds were planted on October 30th of the two seasons. The experimental plot was 3 × 3.2 m and contained 4 rows, 60 cm apart. The distances between the hills were 40 cm. and the plants were thinned 45 days later to two plants / hill.

All agricultural practices were performed as usual. At the end of the experiment, the following data were recorded: plant height, number of branches / plant, herb dry weight (g) / plant, number of umbeles / plant, seed yield (g) /plant and the seed yield (kg) /fed. were calculated.

Chemical analysis

Total chromones (khellin and visnagin) in the ripe dry fruits was carried out according to the method of **Egyptian Pharmacopoeia (1984)** with Memphis modification. The determination of N, P and K % in plant and soil were performed according to **Jackson (1967)**.

RESULTS AND DISCUSSION

Effectiveness of phosphate dissolving bacteria

Initially, out of the tested seven strains of *B. megatarium*, two strains were selected on the bases of a zone of clearance on Pikovskaya's medium containing 0.5% TCP. The phosphate solubilization index of the strains ranged from 1.7 to 2.3 mm **(Fig. 1)**. *B. megatarium* KL1, BF2 showed highest values of solubilization index being 2.2, 2.3mm, respectively, so these two strains were selected to determine their potency in liquid culture. Data presented in **Fig. (2)** illustrate the effect of the two selected bacterial strains on the release of soluble P, pH value and count of bacterial cells on 2 sources of insoluble phosphate in liquid culture under laboratory conditions. During the incubation period of the *B. megatarium* KL1, *B. megatarium* BF2 in medium supplements with RP or TCP minerals, the pH and soluble phosphate were measured after 2, 6, 10, 14 days of inoculation. Generally, the pH values showed an inverse correlation with the quantity of soluble phosphorus. In culture media with TCP treatment, the reported values of pH decreased with the time from 7.2 to 4.5, 7.2 to 4.4 for *B. megatarium* KL1, *B. megatarium* BF2 respectively. The bacterial growth was affected by the drooping in pH which resulted in a reduction in the number of cells after 6 days of inoculation because of the pH of growth medium was unsuitable. The maximum values of soluble phosphate were 200, 160 ppm after 10 days for BF2, KL1 respectively.

In culture media supplement with RP, the soluble phosphate generally increased with the time from 10.5, 7.3 ppm to 70.8, 53 ppm for BF2 and KL1 respectively during 2– 14 days, and pH values were higher than TCP treatment through the duration of experiment. The growth of bacteria and the amount of soluble phosphate in TCP treatment was more than in RP treatment. because, It was more feasible to solublize compared with RP. From the above mention result we observed that *B. megatarium* BF2 was more active to release the soluble phosphorus from both insoluble sources. These results are in agreement with **Badr *et al* (2006)**. The previous study confirmed that these bacterial strains produced several organic acids such as acetic, butyric, byruvic and formic acid which can specifically break down mineral structure purpose (**Styriakova *et al* 2003**). The solubilized phosphate may react with Ca and Mg present in rock phosphate as soon as the pH of the medium increases (**Kapoor *et al* 1989**).

Effectiveness of silicate bacteria for mobilizing potassium

The final pH and soluble potassium released by five *B. circulans* strains grown in Alexandrov's liquid medium supplemented with 0.1% feldspar are given in **Table (2).** Different strains showed various abilities on dissolution mineral. Low record of final pH was observed in the culture medium of all strains. *B.circulans* F5 induced the lowest pH in its culture medium being 5.2. A greater amount of soluble potassium was released by *B. circulans* F5 being 12.3 ppm compared with the other strains. A lower amount of soluble potassium was obtained from *B.circulans* F1 being 6.01 ppm .These pronounced capacities were reflected on the records of effectiveness being 8.64% and 2.09% with F5 & F1, respectively.

B.circulans F5 released the highest amount of soluble K, so it was inoculated in Alexandrov's media amended with 0.1% feldspar .pH values, soluble K and bacterial growth were determined at 2, 6, 10, 14 days after inoculation. **Fig. (3)** shows inverse correlation between pH value and soluble K through incubation period. The pH value decreased from 7.1 (zero time) to 5.3 during the experimental period. Soluble K values increased with time to 11.5 ppm at 14 days but the cell count increased to be 60 x 10^7 at 6^{th} days then decreased up to the end. The organic acids produced by microbial colonization on the mineral surfaces greatly accelerated the release of mineral elements to solution from feldspar sample (**Welch and Ullman, 1999**).

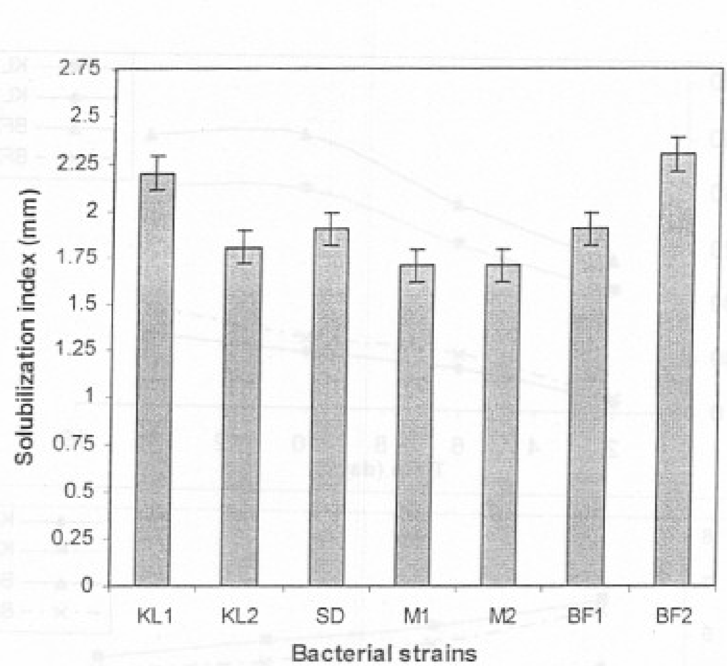

Fig. 1. Solubilization index of *Bacillus megaterium* tested strains on Pikovskaya's agar medium amended with tricalcium phosphate. The bar at the points indicate ± SE

Soil experiments

Large areas of cultivated land in Egypt are deficient in phosphorus and potassium nutrient, so they require adequate fertilization to sustain high productivity. However, due to economic consideration, the costs of applying imported or locally produced water and soluble fertilizers are becoming more expensive. Thus the use of alternative indigenous resources such as feldspar and rock phosphate are gaining importance to alleviate the dependence of imported or costly commercial fertilizers. Therefore, in our experiment we have amended soil with addition of rock P and K and their solubilizing bacteria to increase the available P and K in the soil.

Phosphorus treatments

a- Vegetative growth

Data presented in **Table (3)** reveal that the main effect of phosphate fertilizer treatments on plant height (cm), number of branches/plant and herb dry weight (g/plant) of *Ammi visnaga* was statistically significant in the two experimental seasons. It is clear that all phosphate fertilizer rates led to a significant increase in plant height, number of branches/plant and herb dry weight compared to untreated plants in both seasons. Moreover, it was found that fertilizing the plants with R.P_2 (**200% of recommended dose**) or the recommended doses of calcium superphosphate gave taller plants, maximum number of branches/plant and heavier weight of herb dry than the low rate of RP_1 **(recommended dose)** in the two growing seasons. This finding is in harmony with that obtained by **Shaalan *et al* (2001)** on polish chamomile plants and **Ali (2001)** on *Calendula officinalis*, who found that rock phosphate led to the augmentation of plant height , branches number, herb dry weight.
Concerning the effect of inoculation with *Bacillus megaterium* BF2, data in **Table (3)** reveal that it was significant on plant height, number of branches/plant and herb dry weight of *Ammi visnaga* in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus megaterium* BF2 significantly augmented plant height, number of branches/plant and herb dry weight in comparison with control for the two experimental seasons.

The interaction between phosphate fertilizer and inoculation with *Bacillus megaterium* BF2 on number of branches/plant and herb dry weight (g/plant) of *Ammi visnaga* had significant effect in the two consecutive seasons. Plant height (cm)

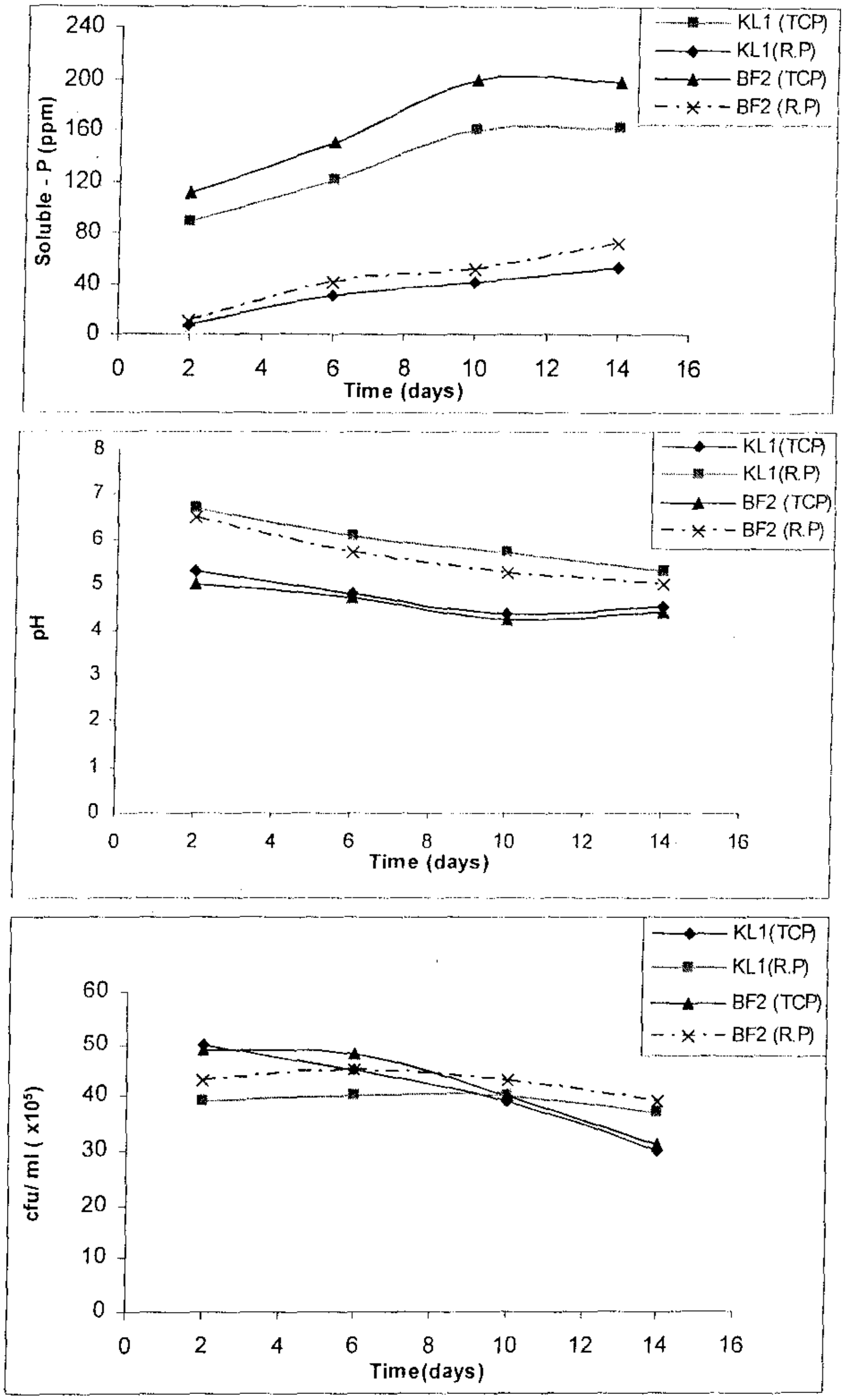

Fig. 2. Soluble phosphate, pH value and cell count of the most efficient phosphate dissolving bacteria (*B.megaterium* KL1&*B.megaterium* BF2) grown on Pikovskaya's liquid medium amended with tricalcium phosphate or rock phosphate during 14 days

Table 2. Final pH and soluble Potassium released by five silicate bacteria strains grown on Aleksandrov's liquid medium for 2 weeks

Strains	pH	Soluble K (ppm)	Effectiveness (%)
B.circulans F1	6.1	6.01	2.09
B.circulans F2	5.5	7.21	2.34
B.circulans F3	5.9	6.73	2.84
B.circulans F4	6.0	7.0	3.12
B.circulans F5	5.2	12.3	8.64

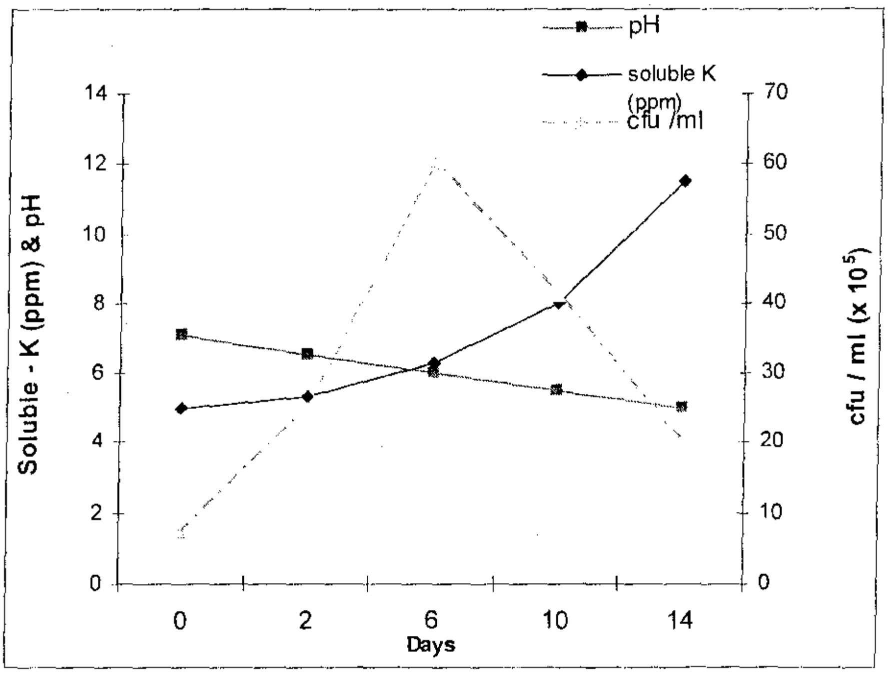

Fig. 3. pH values, soluble phosphate and the growth of *B. circulans* F5 on Aleksandrov's liquid medium amended with feldspar through 14 days

was significant in the two season only. The most effective treatments were obtained due to treating the plants with **RP_2** or the recommended doses of calcium superphosphate fertilizer plus inoculation with *Bacillus megaterium* BF2.These results are on line with **Tomar *et al* (1996)** and **Hassan *et al* (2009)** reported that application of phosphate solubilizing bacteria as a bio-fertilizer to *Cicer arietinum* and *Nigella sativa* L. plants, respectively, stimulated the vegetative growth measurements.

b- The yield parameters

Data recorded in **Table (4)** pointed out that the main effect of phosphate fertilizer treatments on the number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan of *Ammi visnaga* plant was statistically significant in the two experimental seasons. It is clear that all phosphate fertilizer rates led to a significant increase in the number of umbels/plant, seed yield (g) / plant and seed yield

Table 3. Effect of phosphate fertilizers with or without *Bacillus megaterium* BF2 inoculation on vegetative growth of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Phosphate fertilizer treatments (A)	Plant height (cm/plant)					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	115.7	111.3	113.5	118.3	116.7	117.5
S P	149.3	142.0	145.7	154.7	145.7	150.2
$R.P_1$	137.0	129.7	133.3	141.3	138.7	140.0
$R.P_2$	152.3	142.3	147.3	156.3	147.7	152.0
Mean (B)	138.57	131.3		142.7	137.7	
$L.S.D._{0.05}$	A : 1.8 B :1..5 AB : N.S			A : 1.4 B : : 1.6 AB : 3.2		
	Number of branches / plant					
Untreated	5.08	4.17	4.63	5.83	4.47	5.15
S P	5.80	5.42	5.61	6.42	5.90	6.16
$R.P_1$	5.57	5.27	5.42	6.22	5.75	5.98
$R.P_2$	6.33	5.90	6.12	6.87	6.47	6.67
Mean (B)	5.69	5.19		6.33	5.65	
$L.S.D._{0.05}$	A : .24 B : 0.09 AB : 0.18			A : .25 B : 0.15 AB : .31		
	Herb dry weight (g / plant)					
Untreated	135.0	129.7	132.3	136.3	134.0	135.2
S P	158.3	155.3	156.8	163.7	159.3	161.5
$R.P_1$	148.3	144.0	146.2	151.3	146.7	149.0
$R.P_2$	159.0	149.7	154.3	166.3	153.7	160.0
Mean (B)	150.2	144.7		154.4	148.4	
$L.S.D._{0.05}$	A : 1.2 B : 0.8 AB : 1.7			A : 2.16 B : 1.2 AB : 2.40		

Table 4. Effect of phosphate fertilizer with or without *Bacillus megaterium* BF2 inoculation on yield of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Phosphate fertilizer treatments (A)	Number of umbeles / plant					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	8.50	8.00	8.25	9.50	8.88	9.19
S P	12.33	10.12	11.23	12.87	11.92	12.39
$R.P_1$	10.92	9.28	10.10	11.55	10.83	11.19
$R.P_2$	12.87	11.92	12.39	13.72	12.42	13.07
Mean (B)	11.15	9.83		11.91	11.01	
$L.S.D._{0.05}$	A : .47 B : : 0.16 AB : .31			A : .13 B : 0.13 AB : .26		
	Seed yield (g) / plant					
Untreated	8.97	8.84	8.90	9.88	9.15	9.52
S P	13.57	11.83	12.70	15.43	14.20	14.82
$R.P_1$	12.02	11.33	11.68	14.53	13.03	13.78
$R.P_2$	14.27	13.67	13.97	16.37	15.55	15.96
Mean (B)	12.21	11.42		14.05	12.98	
$L.S.D._{0.05}$	A : .85 B : 0.19 AB : .39			A : 1.35 B : 0.19 AB : .26		
	Seed yield (kg) / feddan					
Untreated	209.2	206.2	207.7	230.6	213.5	222.0
S P	316.6	276.1	296.3	360.1	331.3	345.7
$R.P_1$	280.5	264.4	272.4	339.1	304.1	321.6
$R.P_2$	332.9	318.9	325.9	378.0	362.8	370.4
Mean (B)	284.8	266.4		327.0	302.9	
$L.S.D._{0.05}$	A : 19.9 B : 4.54 AB : 9.07			A : 31.19 B : 3.82 AB : 7.65		

(kg) / feddan compared to untreated plants in both seasons. Moreover, it was found that fertilizing the plants with RP_2 or the recommended doses of calcium super phosphate gave maximum number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan compared to the low rate of RP_1 in the two growing seasons. Similar results were reported by **Ali (2001)** on *Calendula officinalis*.

Concerning the effect of inoculation with *Bacillus megaterium*, data in **Table (4)** reveal that it was significantly affect on the number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan of *Ammi visnaga* plant in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus megaterium* significantly augmented number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan in comparison with control for the two experimental seasons.

The interaction between phosphate fertilizer and inoculation with *Bacillus megaterium* on the number of umbels/plant, seed yield (g) / plant and seed yield (kg) / feddan of *Ammi visnaga* had significant effect in the two consecutive seasons. The most effective treatments were obtained due to treating the plants with RP_2 or the recommended doses of calcium super phosphate plus inoculation with *Bacillus megaterium* BF2 in the two successive seasons. **Radwan & Farahat (2002)** proved that bio-fertilizer (phosphate dissolving bacteria) led to a significant increase fruit yield of coriander plant. Inoculation of *Nigella sativa* seeds by *Bacillus megaterium* and some other strains, each of them individually or in combination, revealed that these treatments led to increase growth, yield characters and volatile, fixed oils % **(Shaalan, 2005)**.

c- Chemical constituents

N, P and K percentage

Data recorded in **Table (5)** pointed out that the main effect of phosphate fertilizer treatments on nitrogen, phosphorus and potassium percentage of *Ammi visnaga* plant was statistically significant in the two experimental seasons. It is clear that all phosphate fertilizer rates led to a significant increase nitrogen, phosphorus and potassium percentage compared to untreated plants in both seasons.

Moreover, it was found that fertilizing the plants with RP_2 or the recommended doses of calcium superphosphate **(S P)** gave the highest percentages of nitrogen and phosphorus in the two seasons. **Badran *et al* (1988)** concluded that Safaga rock phosphate was almost equal to calcium superphosphate in increasing plant height, herb, oil %, oil yield, P % and P uptake of yarrow plants and **Ali (2001)** on *Calendula officinalis*, emphasized that Safaga rock phosphate led to the augmentation of plant growth and P % and P content.

Concerning the effect of inoculation with *Bacillus megaterium*, data in **Table (5)** reveal that it was significantly affect on nitrogen, phosphorus and potassium percentage of *Ammi visnaga* plant in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus megaterium* significantly augmented nitrogen, phosphorus and potassium percentage in comparison with control for the two experimental seasons. The interaction between phosphate fertilizer and inoculation with *Bacillus megaterium* BF2 revealed that nitrogen and phosphorus percentage of *Ammi visnaga* had significant effect in the two experimental seasons. Potassium percentage was significant in the first season only. The most effective treatments were obtained due to treating the plants with RP_2 or the recommended doses of calcium super phosphate **(S P)** plus inoculation with *Bacillus megaterium* in the two successive seasons.

Khellin, Visnagin and total Chromones percentage

Data recorded in **Table (6)** show that the main effect of phosphate fertilizer treatments on Khellin, Visnagin and total Chromones percentage of *Ammi visnaga* plant was statistically significant in the two experimental seasons. It is clear that all phosphate fertilizer rates led to a significant increase Khellin, Visnagin and Total chromones percentage compared to untreated plants in both seasons. Moreover, it was found that fertilizing the plants with RP_2 gave the highest Khellin, Visnagin and Total chromones percentage in the two seasons. This result was supported by **Ali (2001 & 2004)**.

Concerning the effect of inoculation with *Bacillus megaterium* BF2, data in **Table (6)** reveal that it was significantly affect on Khellin, Visnagin and total Chromones percentage of *Ammi visnaga* plant in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus megaterium* significantly augmented Khellin, Visnagin and Total chromones percentage in comparison with control for the two experimental seasons. The interaction between phosphate fertilizer and inoculation with *Bacillus megaterium* on

Table 5. Effect of phosphate fertilizer with or without *Bacillus megaterium* BF2 inoculation on N, P and K percentage of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Phosphate fertilizer treatments (A)	N %					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	2.15	1.95	2.05	2.17	2.00	2.09
S P	2.45	2.23	2.34	2.47	2.27	2.37
$R.P_1$	2.31	1.99	2.15	2.35	2.03	2.19
$R.P_2$	2.50	2.21	2.35	2.54	2.25	2.40
Mean (B)	2.35	2.10		2.38	2.14	
$L.S.D._{0.05}$	A : .021 B: 0.017 AB : .034			A : .025 B : 0.013 AB : .027		
	P %					
Untreated	0.270	0.253	0.262	0.283	0.270	0.277
S P	0.327	0.303	0.315	0.340	0.313	0.327
$R.P_1$	0.313	0.283	0.298	0.333	0.307	0.320
$R.P_2$	0.367	0.297	0.332	0.380	0.317	0.348
Mean (B)	0.319	0.284		0.334	0.302	
$L.S.D._{0.05}$	A : 0.005 B : 0.004 AB : 0.009			A : 0.008 B : 0.008 AB : 0.016		
	K %					
Untreated	2.10	2.05	2.08	2.11	2.08	2.10
S P	2.22	2.19	2.20	2.23	2.21	2.22
$R.P_1$	2.13	2.12	2.12	2.16	2.14	2.15
$R.P_2$	2.26	2.21	2.24	2.28	2.24	2.26
Mean (B)	2.18	2.14		2.19	2.17	
$L.S.D._{0.05}$	A : 0.009 B : 0.005 AB : 0.010			A : 0.025 B : 0.008 AB : N.S		

Table 6. Effect of phosphate fertilizer with or without *Bacillus megaterium* BF2 inoculation on Khellin, Visnagin and Total chromones percentage of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Phosphate fertilizer treatments (A)	Khellin %					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	1.96	1.92	1.94	1.99	1.94	1.96
S P	2.03	1.99	2.01	2.06	2.02	2.04
$R.P_1$	2.10	1.95	2.03	2.13	1.99	2.06
$R.P_2$	2.13	2.05	2.09	2.17	2.08	2.13
Mean (B)	2.06	1.98		2.09	2.01	
$L.S.D._{0.05}$	A : .034 B : 0.013 AB : .026			A : .029 B : 0.018 AB : .037		
	Visnagin %					
Untreated	0.82	0.81	0.82	0.85	0.83	0.84
S P	0.96	0.93	0.94	0.98	0.96	0.97
$R.P_1$	0.97	0.89	0.93	0.99	0.91	0.95
$R.P_2$	0.98	0.92	0.95	1.02	0.96	0.99
Mean (B)	0.93	0.89		0.96	0.92	
$L.S.D._{0.05}$	A : 0.006 B : 0.004 AB : 0.008			A : 0.010 B : 0.004 AB : 0.009		
	Total chromones %					
Untreated	2.78	2.72	2.75	2.84	2.77	2.81
S P	2.99	2.92	2.96	3.04	2.98	3.01
$R.P_1$	3.07	2.84	2.96	3.13	2.90	3.01
$R.P_2$	3.11	2.98	3.04	3.19	3.04	3.11
Mean (B)	2.99	2.87		3.05	2.92	
$L.S.D._{0.05}$	A : 0.037 B : 0.013 AB : 0.026			A : 0.031 B : 0.017 AB : 0.034		

Khellin, Visnagin and Total chromones percentage of *Ammi visnaga* had significant effect in the two experimental seasons. The most effective treatments were obtained due to treating the plants with **RP_2** plus inoculation with *Bacillus megatherium* BF2 in the two successive seasons. This study is in agreement with **Shaalan (2005)** on *Nigella sativa* and on *Coriandrum sativum* L. **(Abd El- Kader and Ghaly, 2003).**

Potassium treatments

a- Vegetative growth

Data presented in **Table (7)** reveal that the main effect of potassium fertilizer treatments on plant height(cm), number of branches/plant and herb dry weight (g/plant) of *Ammi visnaga* was statistically significant in the two experimental seasons. It is clear that all potassium fertilizer rates led to a significant increase in plant height, number of branches/plant and herb dry weight compared to untreated plants in both seasons. Moreover, it was found that fertilizing the plants with **Fl_2** (200% of recommended dose) or the recommended doses of potassium sulphate gave tallest plants, maximum number of branches/plant and heaviest weight of herb dry than the low rate of **Fl_1 (recommended dose)** in the two growing seasons. These results are in agreement with **Al-Qubaie (2002)** who studied the effect of potassium treatments on *Hibiscus subdariffa* growth. The results showed that using potassium fertilizer was very effective in enhancing all growth criteria.

Concerning the effect of inoculation with *Bacillus circulans* **F5**, data in **Table (7)** reveal that it was significant on plant height, number of branches/plant and herb dry weight of *Ammi visnaga* in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus circulans* F5 significantly augmented plant height, number of branches/plant and herb dry weight in comparison with control for the two experimental seasons.

The interaction between potassium fertilizer and inoculation with *Bacillus circulans* F5 on plant height of *Ammi visnaga* had significant effect in the two consecutive seasons. The most effective treatments were obtained due to treating the plants with Fl_2 or the recommended doses of potassium sulphate plus inoculation with *Bacillus circulans* F5 in the two successive seasons.

The combined effect between the two factors on the number of branches was significant in the second season only. The best results were detected due to supplying *Ammi visnaga* plants with **Fl_2** and inoculated with *Bacillus circulansF5*. In this regard, the interaction effect between Potassium fertilizer and inoculation with *Bacillus circulans* F5 on heavy dry weight was not significant in the two experimental seasons, as clearly illustrated in **Table (7).** Potassium uptake improved markedly in both cases with inoculation of bacteria in the tested soils compared to corresponding controls.

b- The yield parameters

Data recorded in **Table (8)** pointed out that the main effect of potassium fertilizer treatments on the number of umbels/plant, seed yield (g)/plant and seed yield (kg)/feddan of *Ammi visnaga* plant was statistically significant in the two experimental seasons. It is clear that all potassium fertilizer rates led to a significant increase in the number of umbels / plant, seed yield (g)/plant and seed yield (kg)/ feddan compared to untreated plants in both seasons. Other studies showed a promoting effect of potassium fertilizer on yield of horticulture plants such as anise (*Pimpinella anisum*, L.) (**Bhuvaneshwari *et al* 2002).** Moreover, it was found that fertilizing the plants with **Fl_2** or the recommended dose of potassium sulphate gave maximum number of umbels/plant, seed yield (g) / plant and seed yield (kg)/feddan than the low rate of **Fl_1** in the two growing seasons.

Concerning the effect of inoculation with *Bacillus circulans* **F5**, data in **Table (8)** reveal that it was significantly affect on the number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan of *Ammi visnaga* plant in the two seasons. From the obtained results it seems that inoculating the plants with *Bacillus circulans* F5 significantly augmented number of umbels / plant, seed yield (g) / plant and seed yield (kg) / feddan in comparison with control for the two experimental seasons.

The interaction between potassium fertilizer and inoculation with *Bacillus circulans* F5 on the number of umbels / plant and seed yield (g) / plant of *Ammi visnaga* had significant effect in the two consecutive seasons. The most effective treatments were obtained due to treating the plants with **Fl_2** or the recommended doses of potassium sulphate plus inoculation with *Bacillus circulans* F5 in the two successive seasons. The combined effect between the two factors on seed yield (kg) / feddan was significant in the second season only.

Table 7. Effect of Potassium fertilizer with or without *Bacillus circulans* F5 inoculation on vegetative growth of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Potassium fertilizer treatments (A)	Plant height cm/plant					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	112.3	108.3	110.3	117.7	115.3	116.5
PS	145.0	140.0	142.5	151.7	143.3	147.5
FI_1	135.0	127.3	131.2	139.0	136.0	137.5
FI_2	146.7	139.7	143.2	150.7	144.7	147.7
Mean (B)	134.7	128.8		139.8	134.8	
$L.S.D._{0.05}$	A : 2.30 B : 1.00 AB : 1.90			A : 3.34 B :1.6 AB : 3.20		
	Number of branches / plant					
Untreated	4.42	3.50	3.96	5.33	3.92	4.63
PS	6.22	5.33	5.78	6.25	5.92	6.08
FI_1	5.67	5.17	5.42	5.92	5.47	5.69
FI_2	6.42	5.97	6.19	6.55	6.30	6.43
Mean (B)	5.68	5.19		6.01	5.40	
$L.S.D._{0.05}$	A : .29 B :1.7 AB : N.S			A : .28 B :.11 AB : .21		
	Herb dry weight (g / plant)					
Untreated	130.3	127.3	129.0	133.3	131.3	132.3
PS	156.0	151.0	153.5	157.3	155.3	156.3
FI_1	145.0	141.3	143.2	147.0	142.3	144.7
FI_2	158.0	152.7	155.3	160.0	156.3	158.2
Mean (B)	147.4	143.1		149.4	146.3	
$L.S.D._{0.05}$	A : 2.85 B : 1.1 AB : N.S			A : 2.15 B : 1.0 AB : N.S		

Table 8. Effect of Potassium fertilizer with or without *Bacillus circulans* F5 inoculation on yield of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Potassium fertilizer treatments (A)	Number of umbels / plant					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	8.00	7.50	7.75	8.66	8.00	8.33
PS	12.17	9.17	10.67	12.80	10.50	11.65
FI_1	10.50	9.01	9.76	10.83	10.50	10.67
FI_2	12.17	11.17	11.67	13.00	11.83	12.42
Mean (B)	10.71	9.21		11.32	10.21	
$L.S.D._{0.05}$	A : 0.44 B : 0.01 AB : 0.01			A : 0.43 B :0.15 AB : 0.30		
	Seed yield (g) / plant					
Untreated	8.87	8.50	8.68	9.60	8.92	9.26
PS	13.57	11.67	12.62	15.08	13.33	14.21
FI_1	11.73	11.00	11.37	13.07	12.67	12.87
FI_2	14.17	13.83	14.00	15.83	15.00	15.42
Mean (B)	12.08	11.25		13.40	12.48	
$L.S.D._{0.05}$	A : 0.70 B :0.42 AB : 0.83			A : 0.79 B :0.19 AB : 0.38		
	Seed yield (kg) / feddan					
Untreated	206.9	198.3	202.6	223.7	208.0	215.9
PS	316.6	280.0	298.3	351.9	311.1	331.5
FI_1	273.8	286.7	280.2	304.9	295.6	300.2
FI_2	330.6	322.8	326.7	369.4	350.0	359.7
Mean (B)	281.9	271.9		312.5	291.2	
$L.S.D._{0.05}$	A : 25.58 B : 17.69 AB : N.S			A : 18.67 B : 4.48 AB : 9.00		

c- Chemical constituents

N, P and K percentage

Data presented in **Table (9)** reveal the main effect of potassium fertilizer treatments on nitrogen, phosphorus and potassium percentage of *Ammi visnaga* plant in the two experimental seasons. From the obtained data, it could be noticed that all potassium fertilizer rates led to a significant increase in the N, P and K percentage compared to untreated plants in both seasons. Moreover, the highest percentages of nitrogen and phosphorus were obtained from receiving the plants high rate of feldspar (Fl_2) in the two seasons.

Regarding the effect of inoculation with *Bacillus circulans* F5, data in **Table (9)** reveal that it was statistically significant on nitrogen, phosphorus and potassium percentage of *Ammi visnaga* plant in the two experimental seasons.

The interaction between potassium fertilizer and inoculation with *Bacillus circulans*F5 on nitrogen and potassium percentage of *Ammi visnaga* had a significant effect in the two consecutive seasons whereas phosphorus was significant in the first season only. The most effective treatments were obtained due to treating the plants with Fl_2 plus inoculation with *Bacillus circulans* in the two successive seasons.

The combined effect between the two factors on potassium percentage was significant in the two consecutive seasons. The best results were detected due to supplying *Ammi visnaga* plants with recommended doses of potassium sulphate plus inoculation with *Bacillus circulans* F5 in the two successive seasons.

Khellin, Visnagin and total Chromones percentage

Data presented in **Table (10)** reveal that the main effect of potassium fertilizer treatments on Khellin, Visnagin and total Chromones percentage of *Ammi visnaga* L. plant was statistically significant in the two experimental seasons. Moreover, the highest percentages of Khellin, Visnagin and total Chromones were obtained from the plants which had received a high rate of feldspar (Fl_2) in the two seasons. **Al-Qubaia (2002)** reported that using potassium fertilizer was very effective in enhancing anthocyanine and flavones and these parameters were associated with increasing K levels from 0.0 to 72.0 Kg/ Fed.

From the obtained results, it seems that inoculating the plants with *Bacillus circulans* F5 significantly augmented Khellin, Visnagin and total Chromones percentage compared to untreated plants for the two experimental seasons. The interaction between potassium fertilizer and inoculation with *Bacillus circulans* F5 on Khellin percentage of *Ammi visnaga* had a significant effect in the two consecutive seasons whereas visnagin percentage was not significant in the two seasons. Total chromones were significant in the first season only. The most effective treatments were obtained due to treating the plants with Fl_2 or plus inoculation with *Bacillus circulans* F5 in the two successive seasons.

The significance of soil inoculation in increasing phosphorus uptake was reported by many investigators. Like **Badr *et al* (2006)** who reported that dry matter, soil available K and up take of K of sorghum plant inoculated with silicat dissolving bacteria and with minerals (feldspar and rock phosphate) increased compared to the plants supplied with minerals alone. These bacteria were found to develop in the rhizosphere of the sorghum plants. The release of dissolved K and P – bearing mineral indicates that the silicate dissolving bacteria could grow under the soil conditions and have a potential of mineral dissolution. On the other hand, inoculation of silicate dissolving bacteria without mineral additions apprecially activates the initial K and P content in all soils. Inoculation of silicate dissolving bacteria accelerated the transformation of non-available forms of K and P into an available one. **Welch and Ullman (1999)** stated that bacteria attached to feldspar surfaces could greatly accelerate the rate of feldspar dissolution to gain access to trace or limiting nutrients for metabolic process, primarily by the production of organic ligands. The result of three ligands excretion is the accelerated weathering of feldspar.

Increasing the bio-availability of P and K in soils with inoculation of PGPR or with combined inoculation and rock materials, which may lead to increased P uptake and plant growth, was reported by many researchers (**Lin *et al* 2002; Sahin *et al* 2004). Han *et al* (2006)** reported that rock P and K applied either singly or in combination did not significantly enhance soil availability of P and K, indicating their unsuitability for direct application. PSB was a more potent P-solubilizer than KSB and co-inoculation of PSB and KSB resulted in consistently higher P and K availability and the growth of paper and cucumber than in the control without bacteria inoculum and without rock material

Table 9. Effect of Potassium fertilizer with or without *Bacillus circulans* F5 inoculation on N,P and K percentage of *Ammi visnaga* plant during 2006/2007 and 2007/2008 seasons

Potassium fertilizer treatments (A)	N %					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	2.15	2.06	2.10	2.17	2.09	2.13
PS	2.30	2.19	2.25	2.29	2.22	2.25
Fl_1	2.34	2.21	2.28	2.36	2.23	2.30
Fl_2	2.50	2.49	2.49	2.52	2.51	2.51
Mean (B)	2.32	2.10		2.34	2.26	
$L.S.D._{0.05}$	A : 0.013 B : 0.008 AB : 0.017			A : 0.044 B : :0.020 AB : 0.027		
	P %					
Untreated	0.303	0.290	0.297	0.333	0.270	0.320
PS	0.313	0.290	0.302	0.333	0.303	0.318
Fl_1	0.327	0.293	0.310	0.347	0.313	0.330
Fl_2	0.357	0.350	0.353	0.377	0.350	0.363
Mean (B)	0.325	0.306		0.348	0.318	
$L.S.D._{0.05}$	A : 0.010 B : : 0.005 AB : 0.010			A : 0.014 B : 0.006 AB : N.S		
	K %					
Untreated	3.07	3.13	3.10	3.10	3.15	3.13
PS	3.10	2.24	2.67	3.12	2.25	2.69
Fl_1	2.21	2.25	2.23	2.23	2.26	2.25
Fl_2	2.20	2.27	2.24	2.22	2.31	2.26
Mean (B)	2.64	2.47		2.49	2.67	
$L.S.D._{0.05}$	A : 0.013 B : 0.010 AB : 0.021			A : 0.021 B : : 0.024 AB : 0.047		

Table 10. Effect of Potassium fertilizer with or without *Bacillus circulans* F5 inoculation on Khellin, Visnagin and Total chromones percentage of *Ammi visnaga* L. plant during 2006/2007 and 2007/2008 seasons

Potassium fertilizer treatments (A)	Khellin %					
	First season			Second season		
	Inoculated	Uninoculated (control)	Mean (A)	Inoculated	Uninoculated (control)	Mean (A)
Untreated	1.99	1.91	1.95	2.02	1.93	1.98
PS	2.07	2.02	2.05	2.10	2.04	2.08
Fl_1	2.13	2.00	2.07	2.16	2.04	2.10
Fl_2	2.15	2.11	2.13	2.21	2.13	2.16
Mean (B)	2.10	2.01		2.12	2.04	
$L.S.D._{0.05}$	A : 0.009 B : : 0.010 AB : 0.019			A : .013 B : 0.014 AB : .027		
	Visnagin %					
Untreated	0.85	0.83	0.84	0.87	0.85	0.86
PS	0.93	0.92	0.93	0.97	0.95	0.96
Fl_1	0.91	0.87	0.88	0.91	0.88	0.91
Fl_2	0.96	0.94	0.95	1.00	0.96	0.98
Mean (B)	0.91	0.89		0.94	0.91	
$L.S.D._{0.05}$	A : 0.006 B : 0.005 AB : N.S			A : 0.016 B : : 0.007 AB :NS		
	Total chromones %					
Untreated	2.84	2.73	2.79	2.89	2.78	2.84
PS	3.00	2.94	2.97	3.07	3.00	3.04
Fl_1	3.03	2.87	2.95	3.06	2.92	2.99
Fl_2	3.12	3.04	3.08	3.19	3.09	3.14
Mean (B)	3.00	2.91		3.06	2.95	
$L.S.D._{0.05}$	A : 0.011 B : 0.010 AB : 0.020			A : 0.024 B : 0.019 AB : N.S		

fertilizer. Bacterial inoculation, which can improve P and K availability in soils by producing organic acids and other chemicals, stimulated growth and mineral uptake of plants (**Park *et al* 2003**). It is known that P availability in soils is important for the uptake of N from soils and its utilization in plant (**Kim *et al* 2003**). Finally, it could be recommend to use the locally available feldspar and rock P mineral in combination which silicate and phosphate dissolving bacteria as ecofriendly biofertilizers to replace chemical fertilizers and reduce the cost of crop production.

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حوليــات العلــوم الزراعية
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الإذابة الميكروبية لصخور الفوسفات والبوتاسيوم وتأثيرهم على نمو نبات الخلة *Ammi visnaga*

[٣]

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الموجــــز

يستخدم التسميد الحيوى كوسيلة لتحسين المغذيات النباتية لتدعيم الزراعة. فقد أجريت التجارب لتقييم قدرة عديد من سلالات البكتيريا المذيبة للفوسفات (*B. megaterium*) والبكتيريا المذيبة للبوتاسيوم (*B. circulans*) لإذابة الفوسفات ثلاثى الكالسيوم والفوسفات الصخرى & الفلدسبار على التوالى وذلك على بيئة مغذية بالمعمل ثم طبق أحسنهم فى تجارب حقلية لتقدير تأثير استخدام تلك البكتيريا على تيسر الفوسفات والبوتاسيوم وكذلك تأثيرهم على نمو نبات الخلة *Ammi visnaga*. اختبر ٧ سلالات من *B. megaterium* على أساس قطر الهالة الرائقة المنتجة على بيئة بيكوفسكى الصلبة المحتوية على فوسفات ثلاثى الكالسيوم. وقد أظهرت السلالة (*B. megaterium* BF2) ، (*B. megaterium* KL1) أعلى قيم لـ Solubilization index (دليل الإذابية) وتم اختيارهم لدراسة كفائتهم على إذابة الفوسفور فى بيئة سائلة محتوية على فوسفات ثلاثى الكالسيوم والفوسفات الصخرى كلا على حدة، وأظهرت السلالة الأخيرة أعلى كفاءة فى تيسير الفوسفات من المصدرين المختبرين. كما تم اختبار خمسة سلالات من *B. circulans* لمقدرتهم على إذابة الفلدسبار فى بيئة الكسندروف السائلة. وقد وجد أن فاعليتهم تتراوح من ٢,٠٩ – ٨,٦٤% كما لوحظ حدوث تناقص للـ pH. فقد وجد أن *B. circulans* F5 تعطى أعلى قيمة من البوتاسيوم الذائب فى البيئة. أما التجربة الحقلية فقد أجريت خلال موسمين متتاليين ٢٠٠٦-٢٠٠٧، ٢٠٠٧ – ٢٠٠٨ لتقييم ١- تأثير التسميد الفوسفاتى وذلك فى صورة سوبر فوسفات الكالسيوم بالكمية الموصى بها (٢٠٠ كجم / فدان) ، الفوسفات الصخرى بمعدلات (١٢٨، ٢٥٦ كجم/فدان) وكذلك التسميد الحيوى بـ *B. megaterium* BF2 كلاً على حدة وكذلك التداخل بينهم، ٢- التسميد البوتاسى يتمثل فى سلفات البوتاسيوم بالمعدل الموصى به (٥٠ كجم / فدان)، فلدسبار بمعدل ٢٤٠ ، ٤٨٠ كجم / فدان وكذلك التسميد الحيوى بـ *B. circulans* F5 كلاً على حدة وكذلك التداخل بينهم وقد لوحظ أن أعلى قيم فى جميع القياسات لوحظت فى النباتات المعاملة بالكالسيوم سوبر فوسفات أو بالفوسفات الصخرى بأعلى معدل. وفى حالة استخدام معاملات التسميد الحيوى أدت الى زيادة معنوية لكل قياسات النمو خلال موسمى الزراعة وتتشابه نفس النتائج فى حالة المعاملات البوتاسية.

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