J. Agric. Sci. Mansoura Univ., 33 (6): 4463 - 4477, 2008

RESPONSE OF PEANUT YIELD TO INOCULATION WITH *BOTH Bradyrhizobium* SP. AND SILICATE BACTERIA (*Bacillus circulans*) UNDER GRADED LEVELS OF FELDSPAR AMENDMENT

Kandil, B.A.A.*; F.Sh.F. Badawi*; M.G.M. El-Baz and A.F.M. Abdel-Wahab***

* Agric. Microbiol. Dept., Soils, Water and Environ. Res. Inst., Agric. Res. Center (ARC), Giza, Egypt.

**Oil Crops Dept., Field Crops Res. Inst (A R C) Giza, Egypt.

ABSTRACT

A field experiment was carried out on sandy soil at Ismailia Agricultural Research Station, Ismailia Governorate during the two successive summer seasons of 2006 and 2007 years, under sprinkler irrigation conditions, to study the effect of inoculation with *Bradyrhizobium* and silicate bacteria in sole or in mixture of them in the presence of feldspar amendment applied at rates of (75,114,171 and 228 kg/fed) on nodulation status, growth, yield and some yield components of peanut (cv.Giza 5). A randomized complete block design with four replicates was used.

Results showed that inoculation with *Bradyrhizobium* caused significant increases in peanut nodulation status. Also, inoculation of peanut with silicate bacteria relatively increased nodulation statues. Dual inoculation with *Bradyrhizobium* and silicate bacteria caused significant increases in nodulation statues over the plant inoculated with *Bradyrhizobium* or silicate bacteria alone. However, using dual inoculation under moderate levels of feldspar from 171 kg to 228 kg/fed improved nodulation statues much more. This trend was true in both seasons.

Data of shoot dry weight and its nitrogen and potassium contents revealed that co-inoculation with *Bradyrhizobium* and silicate bacteria remarkably increased plant dry matter and plant contents of nitrogen and potassium. Also, feldspar ore had a significant effect on shoot dry weight, nitrogen and potassium contents in both seasons. However, plant amended with 114 or 171 kg/fed gave significant increases in the above mentioned parameters.

Sole inoculation with *Bradyrhizobium* recorded significant increases in peanut yield and its components compared to the treatment inoculated with silicate bacteria only. Increases occurred in the peanut yield and some of its components were significantly magnified, when peanut seeds were co-inoculated with *Bradyrhizobium* and silicate bacteria conjointly in comparison to sole inoculation during the two investigated seasons. Additionally, co-inoculation with *Bradyrhizobium* and silicate bacteria amended with 114 kg feldspar/fed gave values of peanut yield similar to or higher than values resulted from uninoculated treatment received the recommended dose of NPK fertilizers.

Keywords: Peanut (*Arachis hypogea* L.), *Bradyrhizobium* sp., Silicate bacteria (*Bacillus circulans*), Feldspar amendment.

INTRODUCTION

Peanut (*Arachis hypogea L.*) is considered one of the most important leguminous oil crops. Its seeds are of high nutritional value for human. In addition its green plants are used in forage production. Seeds are characterized by their high oil content (50%), which are utilized in different industries, besides they contain 26 – 28 % protein, 20 % carbohydrates and 5% fiber. However, the cultivated area of oil crops in 2006 season was about 259,000 feddan, out of them, peanut occupied 132,000 feddan. Moreover, peanut is considered one of the important exporting crops, more than 70 % of peanut seed production is exported.

The drastic raising in the chemical fertilizer prices and their adverse effects on environment greatly incited the serious endeavours of many researchers to seek the relevant alternatives of synthetic fertilizers. These may be involving the extension in the practice of sustainable agriculture system, which relies mainly on the legume-*Rhizobium* symbiosis (Jensen and Hauggaard, 2003) in addition of utilizing the natural materials as sources of macro and micronutrients such as rock-phosphate, dolomite, feldspar, crushed lime stone and gypsum with efficient inoculants and organic materials (Rechcigl, 1995; Conacher and Conacher, 1998; Abdel-Wahab *et al.*, 2003 and Mekhemar *et al.*, 2007).

Potassium is an essential element for all living organisms. In plants, it is an important cation involved in physiological pathways (Duke and Collins, 1985 and Steudle, 1994). Thus, efficient cell development and growth of plant tissues, translocation and storage of assimilates and other internal functions, which are based on many physiological, biochemical and biophysical interactions, require adequate K in the cell sap (Ruggiero *et al.*, 1999). In the tropics, where water is a major limiting factor for successful legume production (Steudle and Peterson, 1998), potassium may tempe water stress due to its role in cell turgor control and metabolic activity (Abou–Arab *et al.*, 1998). However, in most tropical soils K contents are low.

The influence of K on growth and yield of food legumes has been demonstrated (Sangakkara, 1990 and El- Sayed and Ghaly, 1996) .However, little is known about the importance of K in partially overcoming its effects of moisture stress in temperate and tropical food legumes and on the process of symbiotic nitrogen fixation.

Numerous microorganisms, especially those associated with roots, have the ability to increase plant growth and productivity by many beneficial strategies comprised the solubilization of unavailable mineral nutrients (Change *et al.*, 1986 and Kloepper *et al.*, 1988).

Bacillus spp. play a dual role by fixation of atmospheric nitrogen and producing antimicrobial agents against deleterious microorganisms (Estevez de Jensen *et al.*,2002; Hassanein and Mekhemar, 2003 and Kloepper, 2003). Another effect includes an increase in mobilization of insoluble nutrients followed by enhancement of its uptake by the plants (Lifshutz *et al.*, 1987).The Indole acetic acid (IAA) producing by *Bacillus* spp. promoted root growth and nodulation when co-inoculation with both *Rhizobium etli* and *Phaseolus vulgaris*. Co-inoculation resulted in increased nodules number, nodules fresh weight, nitrogenase activity , leghemoglobin content and total soluble protein content in the root nodules of *Phaseolus vulgaris* (Srinivasan *et al.*, 1996 and Hassanein *et al.*, 2006).

Rhizobia are widely used in agriculture for crop improvement because of their ability to fix atmospheric nitrogen. Inoculation of legumes with many selective rhizobia lead to increments in seed yield and nitrogen content

(Mekhemar *et al*., 2005). Potentiality for improving plant yield by combining of rhizobacteria with rhizobia have been reported by many workers (Parmar and Dadarwal, 1999 ; Dileep–Kumar *et al*., 2001 ; Abu El-Soud *et al*., 2003 ; Nassef *et al*., 2005 and Abdel-Wahab *et al*., 2008).

This investigation was carried out to study the effect of co-inoculation with *Bradyrhizobium* sp. and *Bacillus circulans* (silicate bacteria) under graded levels of feldspar (natural source of potassium) on nodulation, nitrogen fixation, yield and some yield components of peanut under sandy soil condition.

MATERIALS AND METHODS

Bacterial Strains:

Bradyrhizobium sp. and silicate bacteria (*Bacillus circulans* local isolate) are provided by Biofertilizer Production Unit, Soils, Water and Environment Research Institute, Agric. Res. Center (ARC), Giza, Egypt.

Inoculants preparation:

Bradyrhizobium was cultured in yeast mannitol broth medium (Vincent, 1970), incubated at 28°C for three days on a rotary shaker until early log phase to ensure population density of 4×10^9 cfu / ml culture . Vermiculite supplemented with 10 % Irish peat was packed into polyethylene bags (200 g carrier per bag), then sealed and sterilized with gamma irradiation (5.0×10^6 rads). *Bradyrhizobium* culture was injected into the carrier to 60 % of the maxima water holding capacity. *Bacillus circulans* was grown on nutrient broth medium (Difico Manual, 1984) incubated for 48 hr at 28°C to ensure population density of 5×10^9 cfu/ml culture and injected into sterilized carrier as mentioned before.

The efficiency of used strain of *B. circulans* for dissolving silicate minerals was assayed using powdered mica in the Aleksandrov's liquid medium (Zahara, 1969).

Field experiments:

A field experiment was carried out on sandy soil at Ismailia Agricultural Research Station, Ismailia Governorate during two successive summer seasons of 2006 and 2007 to study the influence of inoculation with *Bradyrhizobium* sp. either individually or in combination with silicate bacteria on nodulation , growth , N and K contents as well as yield and some yield components of peanut under four levels of feldspar amendment (10.5% K_2O) that are equivalent to 25, 50, 75 and 100 % from the recommended potassium fertilizer of (24 kg K_2O/fed). The corresponding values were 57, 114, 171 and 228 kg /fed of feldspar, respectively. The main chemical features of the used feldspar are given in Table (1). The main physical and chemical properties of the experimental soil are shown in Table (2).

Table (1): Some chemical features of the used feldspar

Property	Value
pH	7.81
EC(dS/m)	0.52
K_2O (%)	10.5
P_2O_5 (%)	0.069
CaO (%)	0.43
MgO (%)	0.038
Fe (ppm)	1379.3
Mn (ppm)	64.6
Zn (ppm)	22.7
Cu (ppm)	6.9
Loss of ignition (%)	0.69

Table (2): Physical and chemical properties of the experimental soil

Property	Values	
	2006 Season	2007 Season
Particle size distribution :		
Sand %	90.0	89.5
Silt %	3.5	3.9
Clay %	6.5	6.6
Texture grade	Sandy	Sandy
Saturation percent (S.P %)	22.3	22.1
pH	7.38	7.36
EC ($dS\ m^{-1}$)	0.30	0.32
Soluble cations ($meq\ L^{-1}$)		
Ca^{++}	0.48	0.51
Mg^{++}	0.30	0.33
Na^{+}	1.68	1.74
K^{+}	0.53	0.59
Soluble anions ($meq\ L^{-1}$)		
$CO_3^{=}$	0.00	0.00
HCO_3^{-}	0.82	0.84
Cl^{-}	0.57	0.62
$SO_4^{=}$	1.60	1.71
Organic matter (%)	0.21	0.20
Total soluble N (ppm)	17.62	17.93
Available P (ppm)	8.00	7.79
Available K (ppm)	82.6	94.5
DTPA –extractable (ppm)		
Fe	1.10	1.20
Mn	0.34	0.36
Zn	0.40	0.39
Cu	0.22	0.23
Total count of bacteria	5.2×10^4	1.9×10^4
Total count of fungi	1.0×10^3	1.1×10^3
Total count of actinomycetes	1.1×10^3	1.3×10^3

The following treatments were tested:

1-Uninoculated (received recommended NPK).
2-*Bradyrhizobium* (*Br.*) +57 kg feldspar/fed.
3-*Bradyrhizobium* (*Br.*) +114 kg feldspar/fed.
4-*Bradyrhizobium* (*Br.*) +171 kg feldspar/fed.
5-*Bradyrhizobium* (*Br.*) +228 kg feldspar/fed.
6-*Bacillus circulans*(Silicate bacteria) + 57 kg feldspar/fed.
7-*Bacillus circulans* (Silicate bacteria) + 114 kg feldspar/fed.
8-*Bacillus circulans*(Silicate bacteria) + 171 kg feldspar/fed.
9-*Bacillus circulans*(Silicate bacteria) + 228 kg feldspar/fed.
10- *Br.* + *B. circulans*+ 57 kg feldspar/fed.
11-*Br.* + *B. circulans* + 114 kg feldspar/fed.
12-*Br.* + *B. circulans* + 171 kg feldspar/fed.
13-*Br.* + *B. circulans* + 228 kg feldspar/fed.

The recommended treatment received 40 kg N (ammonium sulphate 20.5 % N), 200 Kg superphosphate (15.5 % P_2O_5) and 50 kg potassium sulphate (48 % K_2O) / fed.

A randomized complete block design with four replicates was used. Each plot was 10.5 m^2 area (1/400 feddan). Seed of Giza 5 peanut cultivar was provided by Oil Crops Research Department, Field Crops Research Institute, ARC, Giza, Egypt. Peanut seeds were inoculated with different inoculants at a rate of 400 g inoculum per 40 kg seed, prior to sowing using gum Arabic solution (16 %) as an adhesive agent, then inoculants was added and thoroughly mixed. Irrigation was done using sprinkle system.

Peanut seeds were sown into hills at 50cm between ridges and 10 cm between hills. After 15 days of sowing, plants were thinned to secure one plant per hill.

Compost at a rate of 3 tons/fed and mono-superphosphate (15.5% P_2O_5) at a rate of 200 kg/fed were applied to all studied treatments 7 days before sowing. The feldspar ore levels, (highly fineness grade) were thoroughly incorporated with compost and P-fertilizer. The main chemical and biological traits of used compost are shown in Table (3).

Nitrogen fertilizer was applied at a rate of 20 kg N/fed in the form of ammonium sulphate (20.5 % N) presowing as activator dose for *Bradyrhizobium* sp. and *Bacillus circulans*.

Five guarded plants were taken at random from each plot at 75 days after sowing to determine nodule number and dry weight, shoot dry weight and total nitrogen & potassium contents.

At harvest, ten guarded plants were randomly taken from each plot to determine yield components, namely number of pods/plant, weight of pods and seeds/plant, 100-seed weight, crude protein percentage and shelling percentage. Plants in the middle three ridges of each plot (3 m^2 area) were harvested and their pods were air dried to calculate pod yield (kg/feddan).

Table (3): The main traits of used compost

Property	Value
pH	6.6
EC	6.5
O.C %	24.82
T.N %	1.28
C/N ratio	19.39
Total-P (%)	1.2
Total-K (%)	0.72
Total soluble N(ppm)	850.2
Available P (ppm)	283
Available K (ppm)	876.2
DTPA-extractable Fe	612.6
DTPA-extractable Mn	58.3
DTPA-extractable Zn	41.3
DTPA-extractable Cu	7.6
Total count of bacteria	12×10^7
Total count of fungi	11×10^6
Total count of actinomycetes	2.2×10^6
Dehydrogenase activity (µg TPF/g)	136.5
Germination test of cress seeds (%)	88.0

Methods of analyses:

- Soil properties and compost traits were determined according to Piper (1950) and Page *et al.* (1982).
- Total nitrogen and potassium in peanut shoot and total-N in seeds were assumed according to Page et *al.* (1982).
- Seed crude protein percentage was calculated by multiplying N % by 6.25 (Tripathi *et al.*, 1971).
- Shelling % was calculated according to the equation:

$$\text{Shelling \%} = \frac{\text{seed weight / plant}}{\text{pod weight / plant}} \times 100$$

- Feldspar properties were measured according to Jackson (1973).
- All data were statistically analyzed according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Peanut nodulation status:

Data in Table 4 showed that number and dry weight of nodules varied depending on feldspar level and inoculation with silicate bacteria and / or rhizobia. Generally, inoculation with *Bradyrhizobium* combined with any level of feldspar recorded significant increases in number of nodules ranged from 169.30 to 203.92% and nodule dry weight from 139.56 to 165.88% over the uninoculated treatment in the first season. The increases ranged from

77.94–132.18% and from 78.18–125.16% for number and dry weight of nodules in the second season, respectively.

Inoculation of peanut with silicate bacteria combined with any level of feldspar enhanced nodulation status of native bradyrizobia (uninoculated treatment) by 28.85–123.14%and 16.47–101.36% in number and dry weight of nodule, respectively as compared to the control, which recorded 17.33 nodule/plant and 196.33 mg/plant at the same order in the first season. Similar trend was obtained in the second season, which recorded 5.08-52.52% for nodule number and 1.01-54.36% for nodules dry weight.

Co-inoculation with *Bradyrhizobium* and silicate bacteria combined with any level of feldspar caused remarkable increases in number of nodules ranged from 59.00 to 89.67 nodule/plant with nodules dray Weight reached to 601.67-916.67mg/plant at the first season , while in the second season these increases were 54.33-81.00 nodule/plant with dry weight of nodules 556.67-831.00 mg/plant.

Table (4): Nodulation status of peanut roots as affected by dual inoculation with *Bradyrhizobium* and silicate bacteria under graded levels of feldspar amendment

Treatment	Season 2006		Season 2007	
	Number of nodules/ plant	Dry weight of nodules (mg/plant)	Number of nodules/ plant	Dry weight of nodules (mg/plant)
Uninoculated (recommended NPK)	17.33	196.33	19.67	198.67
Br. + 57 kg feldspar /fed	46.67	470.33	35.00	354.00
Br. + 114 kg feldspar /fed	48.00	484.67	37.67	380.67
Br. + 171 kg feldspar /fed	51.33	520.67	43.33	445.67
Br. + 228 kg feldspar /fed	52.67	522.00	45.67	447.33
S.b + 57 kg feldspar /fed	22.33	228.67	20.67	200.67
S.b + 114 kg feldspar /fed	28.67	295.33	22.00	228.33
S.b + 171 kg feldspar /fed	31.33	320.67	27.67	286.33
S.b + 228 kg feldspar /fed	38.67	395.33	30.00	306.67
Br.+S.b+57 kg feldspar/fed	59.00	601.67	54.33	556.67
Br.+S.b+114 kg feldspar/ fed	82.33	839.67	75.33	773.33
Br.+S.b+171 kg feldspar/ fed	89.33	914.00	74.67	767.33
Br.+S.b+228 kg feldspar/ fed	89.67	916.67	81.00	831.00
L.S.D 0.05	7.31	74.54	8.65	88.72

***Br.* = *Bradyrhizobium* sp.**
S.b = Silicate bacteria

Feldspar amendment at any level had a significant effect on number and dry weight of nodules in both seasons. The highest number and dry weight of nodules were obtained at the high level of feldspar (228 kg feldspar / fed). Data in Table (4) also, revealed that dual inoculation with *Bradyrhizobium* and silicate bacteria at levels of 171 or 228 kg feldspar/ fed caused significant increases in number and dry weight of nodules in both seasons. The maximum values of nodule number (89.67 and 81.00 nodules/plant) and nodule dry weight (916.67 and 831.00 mg/plant) were achieved by duel inoculation with *Bradyrhizobium* and silicate bacteria under high level of feldspar (228 kg/fed) in the two seasons, respectively.

The promotive effect of co-inoculation with silicate bacteria in the presence of feldspar on the nodulation status of peanut roots may be elucidated by the ability of *Bacillus circulans* to trigger the micro and macrosymbiont with some promotive substances. These promotive substances such as auxin, vitamins B group and flavonoids like substances resulting in promotion of initiation and performance of nodulation as well as creation of more infection sites on the hairs and epidermis (Parmar and Dadarwal, 1999 and Gage and Margolin, 2000). Moreover, rhizobacteria such as *B. circulans* may be hastened the nodulation through their ability to improve nutrient availability via silicate dissolving and phosphate solubilization (Rodelas *et al.*, 1999).These nutrients act to enhance the nodulation performance, particularly the bacteriod efficiency (El-Sayed, 1997 and El-Sayed and Ahmed, 2003).

Shoot dry weight and its nitrogen and potassium contents:

The response of peanut to inoculation with *Bradyrhizobium* either solely or combined with silicate bacteria is presented in Table (5). Results revealed that co-inoculation of peanut with bradyrhizobia and silicate bacteria were superior to other treatments in plant dry matter and its content of nitrogen and potassium. In other words, shoot dry matter produced due to co-inoculation with bradyrhizobia and silicate bacteria was ranging from 17.83 to 23.10 g/plant, which accumulated 400.43 to 686.13 mg/plant from nitrogen and 552.97 to 799.23 mg/plant from potassium in their tissues during the first season (2006).The corresponding values attained in the second season were 18.01 to 25.13 g/plant, which accumulated 479.47 to 731.50 mg N/plant and 563.93 to 854.87 mg K/plant, respectively. Accordingly, co-inoculation strategy seemed to be more valuable.

Irrespective of inoculation, results also showed that feldspar ore had significant effects on shoot dry weight, nitrogen and potassium content in both seasons. However, plants amended by 114 and 171 kg feldspar/ fed gave significant increases in the abovementioned parameters compared to plants unfertilized with potassium or received 57 kg feldspar / fed.

The improvement in plant growth and nutrient uptake may be attributed to the several mechanisms such as biological nitrogen fixation (Chanway and Holl, 1991), synthesis of siderophores, compounds that chelate iron from soil, making it available to the plant, (Kloepper *et al.*, 1986) , solubilization of minerals , or synthesis of plant hormones, such as auxins or gibberellins, (Probanza *et al.*, 2001) or plant hormone regulators, such as 1-aminocycloprophane–1-carbxylate deaminase (ACC) (Glick, 1995 and Glick *et al.*, 1995) an enzyme that decrease endogenous concentrations of ethylene and disease suppression and their coordinated expression were responsible in enhancing plant growth , and nutrient uptake of peanut (Dey *et al.*, 2004 and Tilak *et al.*, 2005).

Table (5): Effect of co-inoculation with *Bradyrhizobium* and silicate bacteria under graded levels of feldspar amendment on shoot dry matter and its contents of N & K at 75 days after peanut sowing

Treatment	Season 2006			Season 2007		
	Dry weight of shoot (g/plant)	Shoot N-content (mg/ plant)	Shoot K-content (mg/plant)	Dry weight of shoot (g/plant)	Shoot N-content (mg/plant)	Shoot K-content (mg/plant)
Uninoculated (recommended NPK)	20.03	561.10	661.03	22.30	628.40	740.10
Br. + 57 kg feldspar /fed	13.83	300.27	276.73	14.27	313.23	293.47
Br. + 114 kg feldspar /fed	14.17	325.27	301.30	15.40	357.80	332.40
Br. + 171 kg feldspar /fed	15.07	364.70	339.20	16.50	402.70	376.23
Br. + 228 kg feldspar /fed	15.80	400.03	371.63	17.33	441.97	416.20
S.b + 57 kg feldspar /fed	6.57	117.60	172.77	9.07	164.00	244.10
S.b + 114 kg feldspar /fed	10.00	188.03	275.10	11.73	222.20	329.27
S.b + 171 kg feldspar /fed	11.17	222.10	319.60	12.17	243.97	353.03
S.b + 228 kg feldspar /fed	13.23	274.03	393.60	14.00	293.00	471.37
Br.+S.b+57 kg feldspar /fed	17.83	400.43	552.97	18.01	479.47	563.93
Br.+S.b+114 kg feldspar/ fed	23.10	686.13	799.23	25.13	731.50	854.87
Br.+S.b+171 kg feldspar/ fed	23.07	664.10	781.33	24.37	687.47	853.07
Br.+S.b+228 kg feldspar/ fed	21.53	537.77	689.07	23.90	659.67	769.77
L.S.D 0.05	2.29	76.08	85.01	4.28	113.84	179.56

***Br.* = *Bradyrhizobium* sp.**
S.b = Silicate bacteria

The increase in total dry weight of plants due to feldspar may be attributed to potassium and another nutrient, particularly micronutrients, which led to increase photosynthetic rate in the plant, causing increases in plant growth and in turn plant dry weight .Similar results were obtained by Hussein *et al.* (2001) and El-Shikha et *al.* (2005). Also, El-Sayed and Ahmed (2003) who reported that potassium plays an important role in the plant metabolism, involving activation of a large group of enzymes.

Peanut yield and its components:

Peanut yield and its components as affected by the co-inoculation with bradyrizobia and silicate bacteria under graded levels of feldspar amendment were presented in Table (6). Results elicited that sole inoculation of peanut seeds with *Bradyrhizobium* sp. resulted in significant increases in pod yield and some yield components as compared with other treatments, which received silicate bacteria only (the percentage increase gained in pod yield ranged from 13.86 to 20.34 during the first season, 2006 and from 12.42 to 19.56 during the second one). Increases occurred in peanut yield and some of its components namely, pod yield, hundred seed weight, shelling percentage, number of pods/plant, pod & seed weight/plant and crude protein were significantly magnified, when the peanut seeds were co-inoculated with bradyrizobia conjugated with silicate bacteria in comparison to sole inoculation of each of them in both seasons. For instance, the percentage increase in pod yield, hundred seed weight, seed weight/plant, number of pods/plant and crude protein in the first season as a function of co-inoculation practice were ranging from 21.80 to 43.32, 10.39 to 15.10, 43.22 to 63.03, 13.73 to 26.87 and 24.16 to 36.73, respectively over that receiving silicate bacteria only. The corresponding values gained in the second season were 24.85 to 45.24, 9.21 to 13.63, 44.46 to 52.79, 18.32 to 34.03 and 22.62 to 35.60, respectively. Additionally, co-inoculation with bradyrizobia and silicate bacteria gave similar peanut yield to that of the fertilized treatment (uninoculated and received full dose of N, P and K fertilizers in mineral form). It is noteworthy that addition of feldspar amendment either with sole or co-inoculation treatments exhibited synergistic effect on yield and its components of peanut.

Table (6): Effect of co-inoculation with *Bradyrhizobium* and silicate bacteria under graded levels of feldspar amendment on peanut yield and its components

Treatment	Pod yield (ardab/ fed)	100-seed weight (g)	Seed weight (g/ plant)	No. of pods/ plant	Crude protein of seed (%)	Shelling %	Pod weight (g/plant)
	Season 2006						
Uninoculated (recommended NPK)	25.91	79.33	47.10	59.23	27.56	63.90	77.70
Br.+57 kg feldspar / fed	20.00	73.00	38.63	49.50	26.75	57.23	64.90
Br.+114 kg feldspar / fed	21.17	75.66	39.43	52.33	25.16	58.66	67.90
Br.+171 kg feldspar / fed	21.76	75.66	41.03	53.30	25.87	57.96	70.53
Br.+228 kg feldspar / fed	22.67	76.00	42.63	54.27	24.75	60.96	72.13
S.b+ 57 kg feldspar / fed	16.62	70.66	27.13	46.87	19.54	53.76	47.70
S.b+114 kg feldspar / fed	18.41	70.66	33.33	48.87	20.34	55.30	55.70
S.b+171 kg feldspar / fed	18.72	72.33	34.57	50.33	20.94	56.53	57.60
S.b+228 kg feldspar / fed	19.91	73.33	35.47	51.00	21.52	58.46	59.43
Br.+S.b+57 kg feldspar/ fed	23.82	78.00	44.23	54.83	25.37	61.40	73.40
Br.+S.b+114 kg feldspar/ fed	26.07	81.33	51.30	62.00	27.81	63.66	80.27
Br.+S.b+171 kg feldspar/ fed	25.27	80.33	50.73	60.53	27.18	64.60	79.83
Br.+S.b+228 kg feldspar/ fed	24.25	81.66	50.80	58.00	26.72	63.23	79.93
L.S.D $_{0.05}$	5.22	1.93	2.77	3.37	0.33	2.13	5.33
	Season 2007						
Uninoculated (recommended NPK)	23.13	78.33	47.93	57.80	26.98	64.60	78.83
Br.+57 kg feldspar / fed	19.68	74.33	37.00	50.90	22.63	57.93	63.83
Br.+114 kg feldspar / fed	20.72	75.00	38.87	51.80	23.37	58.26	65.57
Br.+171 kg feldspar / fed	21.64	76.33	40.63	52.97	24.72	58.80	68.10
Br.+228 kg feldspar / fed	21.81	77.33	41.23	53.47	25.17	61.26	67.70
S.b+ 57 kg feldspar / fed	16.46	70.00	30.23	47.10	20.27	55.23	52.00
S.b+114 kg feldspar / fed	17.22	70.31	34.47	47.90	20.00	56.33	56.70
S.b+171 kg feldspar / fed	19.00	71.33	35.37	49.37	21.66	57.10	61.00
S.b+228 kg feldspar / fed	19.40	72.66	36.07	50.03	21.88	57.56	61.87
Br.+S.b+57 kg feldspar/ fed	21.78	77.33	43.67	55.73	25.00	62.33	74.47
Br.+S.b+114 kg feldspar/ fed	25.01	79.89	52.67	64.20	27.12	65.31	82.40
Br.+S.b+171 kg feldspar/ fed	24.57	79.90	51.90	60.80	27.37	64.00	81.67
Br.+S.b+228 kg feldspar/ fed	24.22	79.35	52.20	62.57	26.83	64.30	81.33
L.S.D $_{0.05}$	3.51	1.85	3.19	3.59	2.67	1.90	6.61

These results clearly emphasized the vital role of legume inoculation with efficient strains of rhizobia to improve productivity in newly reclaimed soils. Also, results exhibited the positive effect of co-inoculation on peanut yield due to improve plant growth rather than its role in silicate dissolving ability (Mishustin *et al.*, 1981). Co-inoculation of peanut with silicate bacteria led to boost nodulation, nitrogen fixation performance, nutrient uptake and plant vigor resulting in enhancement of productivity and quality of peanut. In fact, plant growth promoting rhizobacteria such as *B.circulans* have been shown to greatly improve the productivity and quality of many legumes, when they co-inoculated with rhizobia (Dileep-Kumar *et al.*, 2001; Vessey and Buss, 2002; Mekhemar *et al.*, 2007 and Abdel-Wahab *et al.*, 2008).

However, addition of feldspar amendment in the high fineness grade in the presence of compost and silicate bacteria and other efficient microorganisms, which existed in the used enriched compost (Table 3) may act to increase the release of the plant nutrients from feldspar (Table 1) such as K, P, Ca, Mg and micronutrients leading to boost nitrogen fixation and plant vigor, which reflected on the productivity of the peanut. Similar trends were elicited by Abdel-Wahab *et al.* (2003) and El-Etr *et al.* (2005).

It could be concluded that biofertilization approach and using of natural mineral amendments in the presence of compost are considered an effective strategy for saving chemical fertilizer use and diminishing the risks of environmental pollution particularly with implying the legumes production under sustainable agriculture system.

REFERENCES

Abdel-Wahab, A.F.M; A.M. Biomy and W.M. El-Farghal (2003). Effect of some natural soil amendments on biological nitrogen fixation, growth and green yield of pea plant grown on sandy soil. Fayoum J. Agric. Res. and Dev., 17: 47-54.

Abdel-Wahab, A.F.M.; G.A.A.Mekhemar; F.Sh.F.Badawi and Heba Sh. Shehata (2008). Enhancement of nitrogen fixation, growth and productivity of *Bradyrhizobium*-lupin symbiosis via co-inoculation with rhizobacteria in different soil types. J. Agric. Sci., Mansoura Univ., 33: 469-484.

Abou-Arab, A.A;S.M.Mohamed; M.A. Mohamed and A.M. Ibrahim (1998). Plant productivity, nutrient status and uptake as influenced by soil compaction and water stresses. Egypt. J. Soil Sci., 38(1-4), 229.

Abu El-Soud, A.A.; A.A.Ragab; G.A.A.Mekhemar and F.T. Mekhaeel (2003). Response of faba bean to inoculation with N_2-fixers and phosphate-dissolving bacteria as influenced by different sources of phosphorus. Egypt J. Appl. Sci., 18(1): 73-90.

Change, Y.C.; Y.C. Change; R. Baker; O. Kleifeld and I. Chet (1986). Increased growth of plants in the presence of biological control agent *Trichoderma harzionum* . Plant Dis., 70: 145-148.

Chanway, C.P. and F.B. Holl (1991). Biomass increase and associative nitrogen fixation of mycrrorhizal *Pinus contorta* seedlings inoculated with a plant growth promoting *Bacillus* strain. Can. J. Bot., 69: 507-511.

Conacher, J. and A.Conacher (1998). Organic farming and the environment with particular reference to Australia. A review. Biological Agriculture and Horticulture.16: 145-171.

Dey, R.; K.K. Pal; D.M. Bhatt and S.M. Chauhan (2004). Growth promotion and yield enhancement of peanut (*Arachis hypogaea* L.) by application of growth-promoting rhizobacteria. Microbiol. Res., 159: 371-394.
Difico Manual (1984). Dehydrated Culture Media and Reagents for Microbiology. 10th Edition. Difco Laboratories, Detroit, Michigan, USA.
Dileep-Kumar, B.S.; I. Berggren and A.M. Martensson (2001). Potential for improving pea production by co-inoculation with *fluorescens Pseudomonas* and *Rhizobium*. Plant and Soil. 229: 25-34.
Duke, S.H. and M.M. Collins (1985). Role of potassium in legume dinitrogen fixation. In:Potassium in Agriculture. R.Munns(Ed.) P.443. Soc. Agron. Madison. USA.
El-Etr, Wafaa M.; Wafaa M.A. Seddik and Nadia M.A. Ghalab (2005). Availability of different potassium sources to carrot plants as affected by farmyard manure application and *Penecillum expansum* fungus inoculation. Egypt. J. Appl. Sci., 20 (11B): 690-707.
El-Sayed, S.A.M. (1997). Influence of salinity on growth yield nutrient uptake and biological nitrogen fixation in guar. Egypt. J. Agric. Res., 75(1): 15-81.
El-Sayed,S.A.M. and A.A.Ghaly (1996). Requirements of lentil-species for iron. J. Agric. Sci. Mansoura Univ. 21(11): 4229.
El-Sayed, S.A.M. and M.E. Ahmed (2003). Effect of water shorting and potassium on efficiency of symbiotic nitrogen fixation in some legumes. Egypt. J. Soil Sci., 43: 193-210.
El-Shikha, S.A.; M.O. Easa; S.K. Behiry and M.I. Raslan (2005). Effect of K-fertilization on faba bean productivity under sandy soil condition. Egypt. J. Appl. Sci., 20(1): 335-344.
Estevez de Jensen, C.; J.A. Percich and P.H. Graham (2002). Integrated management strategies of bean root-rot with *Bacillus subtilis* and *Rhizobium* in Minnesota. Field Crops Research.74: 107-115.
Gage, D.J. and W. Margolin (2000). Hanging by a thread: invasion of legume plants by rhizobia. Curr. Opinion Microbiol.,3: 613-617.
Glick, B.R. (1995). The enhancement of plant growth by free-living bacteria. Can. J. Microbiol., 41: 109-117.
Glick, B.R.; D.M. Karaturovic and P.C. Newell (1995). A novel procedure for rapid isolation of plant growth promoting *Pseudomonads*. Can. J. Microbiol., 41: 533-536.
Hassanein, A.M. and G.A.A. Mekhemar (2003). Biological control of soybean damping off caused by *Pseudomonas florescence* and *Pseudomonas putida*. Egypt., J. Appl., Sci., 18: 73-86.
Hassanein, A.M, A.M. El-Garhy and G.A.A. Mekhemar (2006). Symbiotic nitrogen fixation process in faba bean and chickpea as affected by biological and chemical control content of root-rot. J.Agric. Sci. (Mansoura Univ.,Egypt, 31(2): 963-980.
Hussein, A.H.A.; M.A. El-Deeb and S.A. Saleh (2001). Response of faba bean to potassium fertilization at sandy soil in Minia-Nile Valley and Red Sea Regional Program, on Cool-season Food Legume, 64-65.
Jackson, M.L.(1973). "Soil Chemical Analysis". Prentice-Hall of India Private Limited, New Delhi, India.

Jensen, E.S. and H. Hauggaard (2003). How can increased use of biological N_2-fixation in agriculture benefit the environment ?. Plant and Soil. 252: 177-186.

Kloepper, J.W. (2003). A review of mechanisms for plant growth promotion by PGPR. 6th international PGPR workshop. 6-10 October 2003, Calcutta, India.

Kloepper, J.W.; F.M. Scher; M. Laliberte and B. Tipping(1986). Emergence-promoting rhizobacteria: description and implications for agriculture. In *Iron. Siderophres* and *Plant Disease*; Swinburne, T.R., Ed.; Plenum Publishing Crop. New York,USA.

Kloepper, J.W; D.J. Hume; F.M. Scher; C. Singieton; B. Tipping; M. Laliberte; K. Frauley; T. Kutchaw; C. Simonson; R. Lifshitz; I. Zaleska and L. Lee(1988). Growth-promoting rhizobacteria on canola (rapeseed). Plant Dis., 72: 42-46.

Lifshutz., R.; J.W. Kloepper and M. Kozolowski (1987). Growth promotion of canola (rapeseed) seedlings by a strain of *Pseudomonas putida* under genobiotics conditions.Can. J. Microbiol., 33: 390-395.

Mekhemar,G.A.A.; M. Shaaban; A.A. Ragab and A.M.M. Biomy (2005). Response of faba bean to inoculation with *Rhizobium leguminossarum* bv. *viceae* and plant growth promoting rhizobacteria under newly reclaimed soils. Egypt J. Appl. Sci., 20: 126-144.

Mekhemar, G.A.A; F.M. Ismail; F.Sh.F. Badawi and B.A.A. Kandil (2007). Response of Peanut (*Arachis hypogaea* L.) to co-inoculation with *Bradyrhizobium* spp. and phosphate dissolving bacteria under different levels of phosphorus fertilization in sandy soils. Agric. Res. J., Suez Canal Univ., 7 (1) :1-8.

Mishustin, E.N.; G.A. Smirnova and R.A. Lokhmacheva (1981). The decomposition of silicate by microorganisms and the use of silicate bacteria as bacterial fertilizers. Biology Bulletin of the Academy of Sciences of the USSR, 8(5): 400-409.

Nassef, M.A.; G.A.A. Mekhemar; Kh.M. El-Yamani; A.A. Ragab and A.A. Abou El-Soud(2005). Influence of *Rhizobium* inoculation combined with *Pseudomonas* and *Herbaspirillum* on growth, nodulation and yield of faba bean under newly reclaimed soils. J. Agric. Sci. Mansoura Univ., Egypt. 30(10): 6251-6262.

Page, A.L.; R.H. Miller and D.R. Keeney(1982). Methods of Soil Analysis. Part 2. *Chemical and Microbiological Properties*. American Society of Agronomy. Madison Wisconsin. USA. pp:595-624.

Parmar, N and K.R. Dadarwal (1999). Stimulation of nitrogen fixation and induction of flavonoid like compounds by rhizobacteria J. Appl. Microbiol., 86: 36-44.

Piper, C.S. (1950). Soil and Plant Analysis. 1st Ed. Interscience Publishers Inc., New York, USA. pp: 30-229.

Probanza, A.; J.L. Mateos; J.A. Lucas; B. Ramos; M.R. Felipe and Guyierrez Manero F.J. (2001). Effects of inoculation with PGPR *Bacillus* and *Pisolithus tinctorius* on *Pinus pinea* L. growth bacterial rhizosphere colonization and mycorrhizal infection. Microbiol. Ecol., 41(2): 141-148.

Rechcigl, J. (1995). Soil amendments: Impacts on biotic systems. Lewis Publishers, Boca Raton.

Rodelas, B., J. Gonzalez, J. Lopez; M.V. Martinez-Toledo; C. Pozo and V. Salmeron(1999). Influence of *Rhizobium / Azotobacter* and *Rhizobium / Azospirillum* combined inoculation on mineral compositing of faba bean (*Vicia faba* L.). Biol. Fertl. Soils. 29: 165-169.

Ruggiero, C.; S.D. Pascale and M. Fagnano (1999). Plant and soil resistance to water flow in faba bean *Vicia faba* L. major Harz. Plant and Soil. 210, 291.

Sangakkara, U.R. (1990). Effect of fertilizer potassium on growth and yield of mungbean(*vigna radiate*). J. Appl. Seed Prod., 8, 33.

Snedecor, G.W. and W.G. Cochran (1980). Statistical Methods 7th ed., Iowa State Univ. Press USA. pp: 255-269.

Srinivasan, M.; D.J. Petreson and F.B. Holl (1996). Influence of IAA producing *Bacillus* isolates on nodulation of *Phaseolus vulgaris* by *Rhizobium etli*. Can. J. Microbiol., 42: 1006-1014.

Steudle, E. (1994). Water transport across roots. Plant and Soil. 167,79.

Steudle,E. and A. Peterson (1998). How does water get through roots?. J.Exper. Bot; 49:775.

Tilak, K.V.B.R.; N. Rangamaki; K.K. Pal; R. De; A. K.Saxena; C. Shekhar Nautiyal; Shilpi Mittal; A.K. Tripathi and B.N. Tohri (2005). Diversity of plant growth and soil health supporting bacteria. Current Sci., 89: 136-150.

Tripathi, R.D.; G.P. Srivastava; M.S. Misra and S.C. Panday (1971). Protein to some varieties legume. The Allah Abad Farmer. 16: 291-294.

Vessey, J.K and T.J. Buss (2002). *Bacillus cereus* UW85 inoculation effects on growth, inoculation and N-accumulation in grain legumes. Controlled environment studies. Con. J.Plant Sci., 82: 282-290.

Vincent,J.M.(1970). A Manual for the Practical Study of the Root Nodule Bacteria. I B P, Hand book, No. 15,Bluckwell Publishers, Oxford.

Zahara, M.K. (1969). Studies on Silicate Bacteria. M.Sc. Thesis, Fac. Agric., Cairo Univ., Egypt, pp. 44, 71-73.

J. Agric. Sci. Mansoura Univ., 33 (6), June, 2008

استجابة محصول الفول السودانى للتلقيح بكل من البرادى ريزوبيم وبكتيريا السليكات (باسيلس سيركيولانس) تحت مستويات متدرجة من محسن الفلسبار

بلال عبد السميع أحمد قنديل* ، فريد شوقى فريد بدوى* ، محمود جابر محمود الباز** و عاطف فتح الله محمد عبدالوهاب*
* قسم بحوث الميكروبيولوجيا الزراعية- معهد بحوث الأراضي والمياه والبيئة - مركز البحوث الزراعية - الجيزة- مصر.
** قسم بحوث المحاصيل الزيتية- معهد بحوث *المحاصيل الحقلية*- مركز البحوث الزراعية- الجيزة- مصر.

تم تنفيذ تجربة حقلية فى أرض رملية بمحطة بحوث الاسماعيلية خلال الموسمين الصيفين ٢٠٠٦و٢٠٠٧ باستخدام نظام الرى بالرش لدراسة تأثير التلقيح بكل من البرادى ريزوبيم وبكتريا السليكات الميسرة للبوتاسيوم أو الخليط منهما فى وجود مستويات متدرجة من الفلسبار (٥٧ ، ١١٤ ، ١٧١ ، ٢٢٨كيلوجرام/ فدان) على تكوين العقد الجذرية ونمو ومحصول الفول السودانى تحت ظروف الأراضى الرملية. وقد أظهرت النتائج ان التلقيح بالبرادى ريزوبيم أدى إلى زيادة معنوية فى حالة التعقيد لنباتات الفول السودانى. كذلك أدى التلقيح ببكتيريا السليكات إلى زيادة نسبية فى حالة التعقيد. بينما أدى التلقيح المشترك بالبرادى ريزوبيم مع بكتيريا السليكات إلى زيادة معنوية فى حالة التعقيد تفوق النتائج المتحصل عليها من التلقيح المنفرد بأى منهما. ومن ناحية أخرى فإن استخدام التلقيح المشترك فى وجود مستويين من الفلسبار (١٧١ أو ٢٢٨ كيلوجرام / فدان) أدى إلى الحصول على أعلى القيم للقياسات السابقة. وكان هذا التأثير واضح خلال موسمى الزراعة.

أشارت النتائج الخاصة بالوزن الجاف للمجموع الخضرى ومحتواه من النيتروجين والبوتاسيوم أن للتلقيح المشترك بكل من البرادى ريزوبيم وبكتيريا السليكات أعطت أعلى القيم للقياسات السابقة.أيضا كان لاضافة الفلسبار تأثير معنوى على القياسات السابقة. كما أشارت النتائج أن استخدام المعدل ١١٤ أو ١٧١ كيلوجرام فلسبار / فدان أدى إلى زيادة معنوية لجميع القياسات السابقة.

أشارت نتائج المحصول وبعض مكوناته إلى أن التلقيح المنفرد بالبرادى ريزوبيم أدى إلى زيادة معنوية فى محصول الفول السودانى ومكوناته مقارنة بالمعاملات التى لقحت ببكتيريا السليكات فقط. بينما اشارت النتائج إلى أن الزيادة الكبيرة فى محصول الفول السودانى وبعض مكوناته تم الحصول عليها عند استخدام معاملة التلقيح المشترك مقارنة بالتلقيح المنفرد خلال موسمى الزراعة. هذا بالإضافة إلى أن معاملة التلقيح المشترك والمسمدة بمعدل ١١٤ كيلوجرام فلسبار/ فدان أعطت نتائج تشابه أو تزيد عن النتائج المتحصل عليها من المعاملة غير الملقحة والمسمدة بالمعدلات الموصى بها من النيتروجين والفوسفور والبوتاسيوم.

وفى ضوء ما تقدم يوصى باستخدام التسميد الحيوى المشترك مع استخدام المحسن المعدنى (الفلسبار) بمعدل ١١٤ كيلوجرم / فدان كاستراتيجية فعالة فى تقليل تلوث البيئة الناجم عن الإسراف فى استخدام الاسمدة الكيماوية وتشجيع تطبيق أسلوب الزراعة المستدامة وبخاصة التوسع فى إنتاج البقوليات التى تساهم بدور كبير فى حفظ خصوبة التربة والحفاظ على التوازن الحيوى فى الأراضى الزراعية.