Efficiency of Natural Minerals in Presence of Different Nitrogen Forms and Potassium Dissolving Bacteria on Peanut and Sesame Yields

Gehan H. Youssef, Wafaa M. A. Seddik and Mona A. Osman

Soil, Water and Environ. Research Institute, agricultural Research Center (ARC), Giza, Egypt

Abstract: A field experiment was carried out for two summer seasons at Ismailia Agric. Res. Station to study the effect of some natural minerals combined with potassium dissolving bacteria inoculation in the presence of different nitrogen forms on chemical properties of soil, nutritional status and yield of peanut-sesame. Each experiment was designed in a split-split design with three replications. Three forms of nitrogen fertilizer were included along with two natural minerals, in a presence of potassium dissolving bacteria inoculation, as well as one mineral fertilizer as source potassium fertilizer. Furthermore, data show high significant increases in available N due to the application of ammonium nitrate in combination with feldspar, and calcium nitrate in combination with potassium sulfate in a presence of inoculation for peanut and sesame, respectively. However, application of calcium nitrate combined with potassium sulfate, and ammonium nitrate in combination with feldspar, in a presence of inoculation, led to significant increases in K available in soil for peanut and sesame, respectively. Oppositely, the pH values, different to those of EC, decreased either for inoculation or non-inoculation as compared to control. In spite of that, the values of EC and pH of soil were higher with application of either bentonite or bentonite + feldspar in a presence of all nitrogen fertilizer forms. Generally, the highest EC values in soil, after the two studied seasons were encountered with calcium nitrate fertilizer as well as bentonite mineral. Moreover, applying feldspar mineral and ammonium nitrate treatments had recorded the highest values of yield components as well as nutrient (N and K) uptake by either peanut or sesame crops, particularly in the presence of inoculation as compared to those given by other treatments.
[Gehan H. Youssef, Wafaa M. A. Seddik and Mona A. Osman. Efficiency of Natural Minerals in Presence of Different Nitrogen Forms and Potassium Dissolving Bacteria on Peanut and Sesame Yields. Journal of American Science 2010;6(11):647-660]. (ISSN: 1545-1003).

Keywords: Efficiency; Natural Mineral; Nitrogen; Potassium; Bacteria

1. Introduction:

Sandy soils represent the most desert area in Egypt, and they are usually deficient in organic matter and plant nutrients (Abdel Wahab et al, 2003). Potassium is one of the three essential element viz., NPK, for the growth and reproduction of plants; it plays vital roles in its nutrition. The crop production in Egypt relies completely on imports to meet its annual requirement of potash fertilizers; besides the high cost of conventional, water-soluble K fertilizers constrains their use by most of the farmers in the country. In order to reduce the dependence on imported potash, feldspar potash mineral contains 11.25 % K_2O and therefore, it could be a potential K-source for crop production. New approaches are needed to unlock K from the silicate structure of this mineral in order to render K more available for plant nutrition (Badr, 2006). Many researchers showed that microbes can accelerate weathering of minerals and rocks by producing organic acids, phenolic compounds, siderophores and possibly other metabolites, which influence pH and redox conditions. In addition, direct contact between bacteria and minerals may be important in mineral alteration reaction, as microbial surfaces can be complex with metal ions. Some recent reports showed that silicate dissolving bacteria played a promotion role in the release of Si, Fe and K from feldspar (Badr, 2006).

According to Abdel Wahab et al., (2003), the highest values of growth and green yield of pea were obtained in case of organic compost application in combination with chemical or natural sources of P and K. Also, the applied natural sources of P and K gave an almost similar trend to that obtained with the chemical ones combined with the organic compost. The concentrations of phosphorus and potassium in plant tissues increased with increasing compost levels irrespective of their sources. In addition, the combined treatment of organic compost with both sources of P-K achieved the highest values of P and K concentrations in plant tissues.

Significant increases were obtained in height of main stem, branch stem length, number of branches, main stem diameter and leaf area of olive seedlings treated with compost fortified with plant guard and feldspar compared with the control treatment. The same trend was also observed concerning the application of compost and feldspar on micro and macronutrient contents in leaves of the mentioned olive seedlings (Abd El-Motty et al., 2009).

Biofertilizers have been used as sources to improve the status of plant nutrients in sustainable agriculture. Inoculation with bacterial strain Bacillus edaphicus NBT was found to increase root and shoot growth of cotton and rape. Strain NBT could mobilize potassium efficiently in both plants when illite was added to the soil. In cotton and rape growing on soils treated with insoluble potassium and inoculated with strain NBT, the potassium content was increased by 30 and 26 %, respectively. Bacterial inoculation also resulted in higher N and P contents of above ground plant components (Sheng, 2005).

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 (phosphate solubilizing bacteria) was a more potent P-solubilizer than KSB (potassium solubilizing bacteria), and co-inoculation of PSB and KSB resulted in consistently higher P and K availability than in the control without bacterial inoculum and without rock material fertilizer. Combined together, rock material and both bacterial strains consistently increased further mineral availability, uptake and plant growth of pepper and cucumber plants, suggesting their potential use as fertilizer (Han et al., 2006).

Phosphorus and potassium nutritional status in the soil were markedly improved through inoculation with solubilizing bacteria (Bacillus mucilaginosus); groundnut plant dry matter increased by 125 % and the oil content 35.41 % were increased through bacterium inoculation (Sugumaran and Janarthanam, 2007).

Recently, the treatment of Bacillus circulans + rock phosphate + feldspar was superior in plant height, number of branches, number of nodules per plant and fresh yield (ton/fed.) of snap bean plants when compared with control and the un-inoculated plants. The NPK analysis of shoot dry matter of snap plants showed that as a result of addition of alternatives and the viability of B. circulans, there was marked increases in phosphorus and potassium solubilization (Massoud et al., 2009).

The objective of this study was to determine the efficiency of using different natural mineral as alternative potassium fertilizer in the presence of nitrogen forms and potassium dissolving bacteria inoculation adopted for peanut and sesame plants grown on sandy soil.

2. Materials and methods

Two summer successive field experiments were carried out on peanut (Arachis hypogaea) – sesame (Sesamum indicum) cropping sequence in a sandy soil under drip irrigation system at Ismailia Agric. Res. Station (A.R.C).

Some physical and chemical characteristics of the studied soil before cultivation are shown in Table (1).

Table (1): Some physical and chemical properties of soil samples representing the studied location.

Soil characteristics	Values
Particle size distribution %	
Coarse sand	50.4
Fine sand	40.4
Silt	3.20
Clay	6.0
Texture class	Sandy
Chemical properties	
$CaCO_3$ %	1.4
pH (suspension 1:2.5)	7.92
EC dS/m (saturated paste extract)	0.37
Organic matter %	0.40
Soluble cations and anions (meq L^{-1})	
Ca^{++}	0.95
Mg^{++}	0.89
Na^{+}	1.51
K^{+}	0.45
CO_3^{--}	-
HCO_3^{-}	1.42
CL^{-}	1.02
SO_4^{--}	1.36
Available nutrients (mg L^{-1})	
N	40.0
P	15.0
K	55.6

Table (2): Analysis of natural mineral constituents.

Determination	Bentonite	Feldspar
EC dS m^{-1}	2.89	0.44
pH	8.08	8.56
Available nutrients (mgL^{-1})		
N	166	216
P	2.10	5.76
K	151	400

Peanut and sesame were cultivated in a randomized split-split plot design, each treatment being replicated three times. The main plots were either inoculated or un-inoculated with potassium dissolving bacteria (Bacillus pasteurii) as (Biopotash). The sub main plots were three nitrogen sources, including ammonium sulfate, calcium nitrate and ammonium nitrate, added at the rate of 30 kg N/fed. The sources of nitrogen were added in four equal split doses after sowing. The sub- sub plots represented the natural minerals (feldspar and bentonite), which were added individually or in combination (50% bentonite and 50% feldspar, as compared to mineral fertilizer (potassium sulfate)) at the rate of 50 kg K_2O/ fed. Phosphorus fertilizer was added at the recommended dose (200 kg/fed.) for both peanut and sesame in the form of superphosphate 15.5 % P_2O_5. Both potassium and phosphorus fertilizers were completely added to soil before cultivation.

Plant and soil were sampled at 150 days and 120 days after sowing for peanut and sesame respectively, which represent the harvesting stage.

Surface soil samples (0-15 cm depth) were taken after harvesting stage to evaluate soil pH, EC and available nutrients (N and K) were determined according to Page et al. (1982).

Peanut and sesame plant samples were taken at harvesting stage to determine the nutrients status and yield components (straw and grain yield). Plant samples were oven dried at 70 ^{o}C for 48 hrs up to constant dry weight, then ground and wet digested using H_2SO_4:H_2O_2 method described by Page et al. (1982). The digests were then subjected to the measurement of nutrients (N and K) according to procedures described by cottenie et al. (1982).

Obtained results were subjected to statistical analysis using STATISTICA 6.0 (statSoft, Inc, Tusla, USA) according to Hill and Lewicki (2007). Analysis of variance (ANOVA) was employed to examine the independent and interacted effects of inoculation with potassium dissolving bacteria, nitrogen and potassium sources. Also, treatments were compared by using L.S.D. at 0.05 level of probability according to Snedecor and Cochran (1980).

3. Results and Discussion:

1- Influence of nitrogen fertilizer, natural mineral and inoculation with bacteria on some soil chemical characteristics.

As for the effect of nitrogen forms and natural mineral on nitrogen and potassium availability, at the two studied seasons, results in Fig (1 A, B) reveal that calcium nitrate treatment was superior at available N while ammonium nitrate being superior at available K.

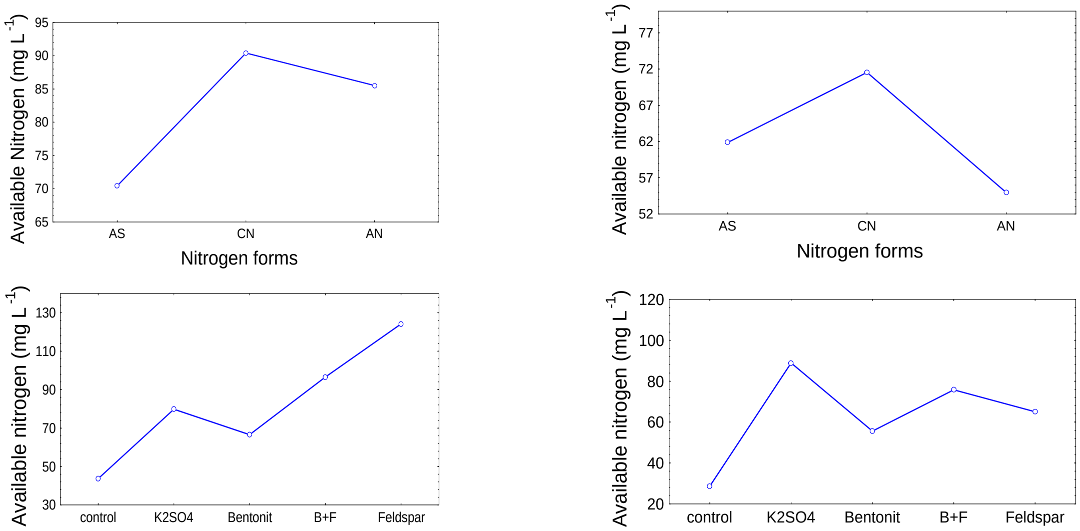
Furthermore, results showed that the highest values of available nitrogen and potassium exist in case of feldspar and potassium sulfate treatments, respectively at the first studied season. Such results are confirmed by Hagin and Shaviv (1990) who reported that the adequate supply of potassium enhances ammonium utilization and thus improves yields. An opposite trend was obtained at second season, which appeared to be highly significant with applied potassium sulfate for available nitrogen with feldspar being highly significant for available potassium. This obtained data could be due to the application of K solubilizing bacteria, which may produce bacterial acids, alkalies or chelates to enhance solubility and release of elements from potassium containing minerals in soil (Lin Qi-mei , et al., 2002 and Seddik, 2006).

To make the picture clearer, it was thought usefully to express the obtained results as interactions between the influences of both natural mineral and nitrogen fertilizer forms; such interactions are shown in Fig (2). For available nutrients (N and K) in soil, at the two studied seasons, values were significantly increased as a consequence of applied natural mineral in the presence of nitrogen fertilizer and inoculation as compared to control. A previous study (Barker, et al., 1997 and Badr, et al., 2006) confirmed that this bacterial strain produces several organic acids such as acetate, butyric, pyruvic, lactic and formic acid during their biological activities. Such acids can increase mineral dissolution rates; carboxylic acid groups, which were shown to promote dissolution of silicate, are also common in extra cellular organic materials. Moreover, some microorganisms in the soil environment contain enzymes that function in ways analogous to chitinase and celluloses. i.e. they specifically break down mineral structures and extract elements required for metabolism or structure purposes (e.g., mineralization).

Also, data in Fig (2) show high significant increases in available N due to the application of ammonium nitrate in combination with feldspar, and calcium nitrate in combination with potassium sulfate in the presence of inoculation for peanut and sesame, respectively. However, application of calcium nitrate combined with potassium sulfate, and ammonium nitrate in combination with feldspar, in the presence of inoculation, led to significant increases in K available in soil for peanut and sesame, respectively.

Peanut **Sesame**

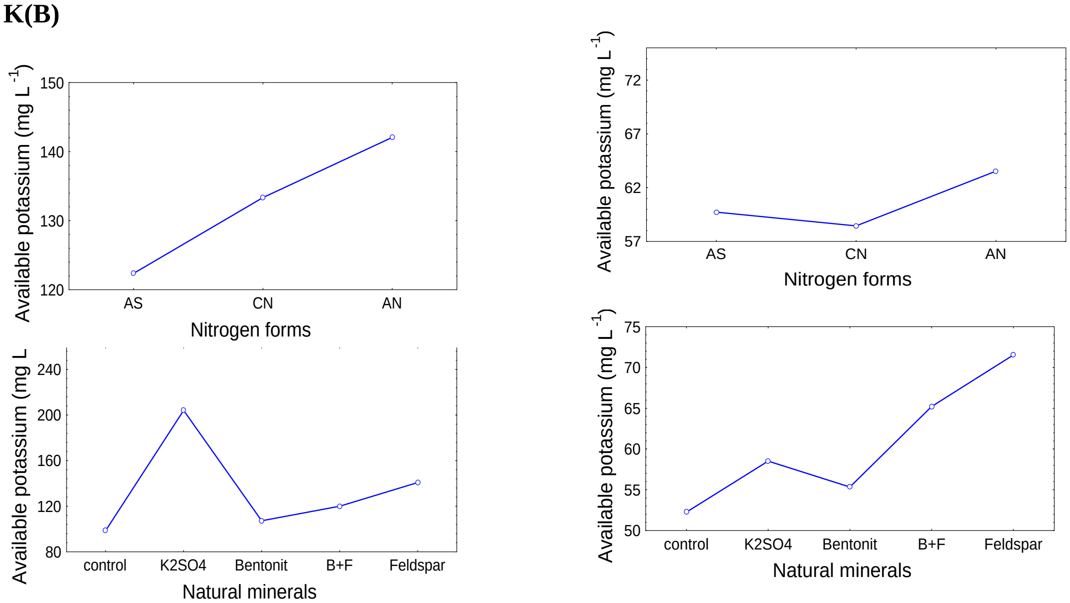
N (A)



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**5.59**	**6.24**
Natural mineral	**8.08**	**5.99**

K(B)



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**14.1**	**2.16**
Natural mineral	**19.5**	**2.52**

Fig (1): Effect of one factor either nitrogen fertilizer or natural mineral on both nitrogen (A) and potassium (B) availability for the tested soil after peanut and sesame harvesting.

Peanut **Sesame**

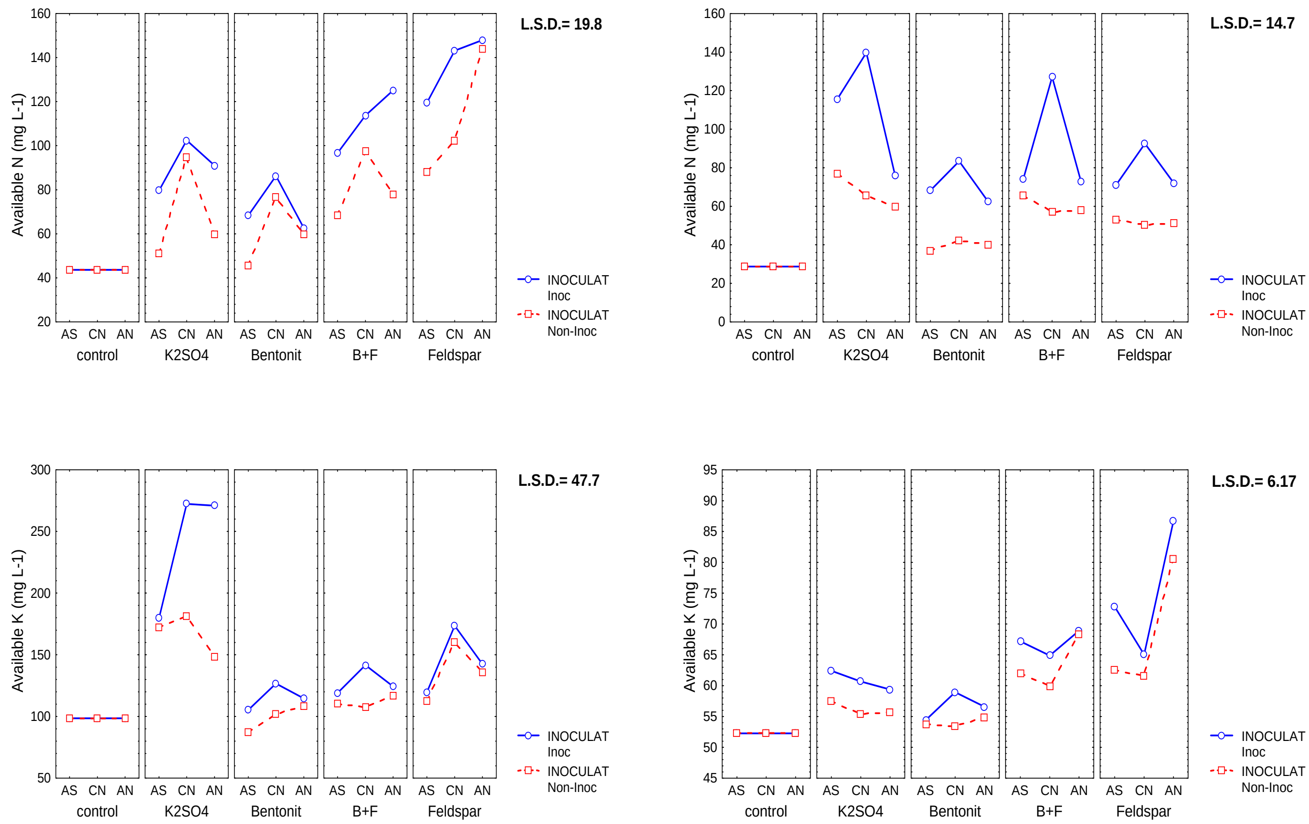


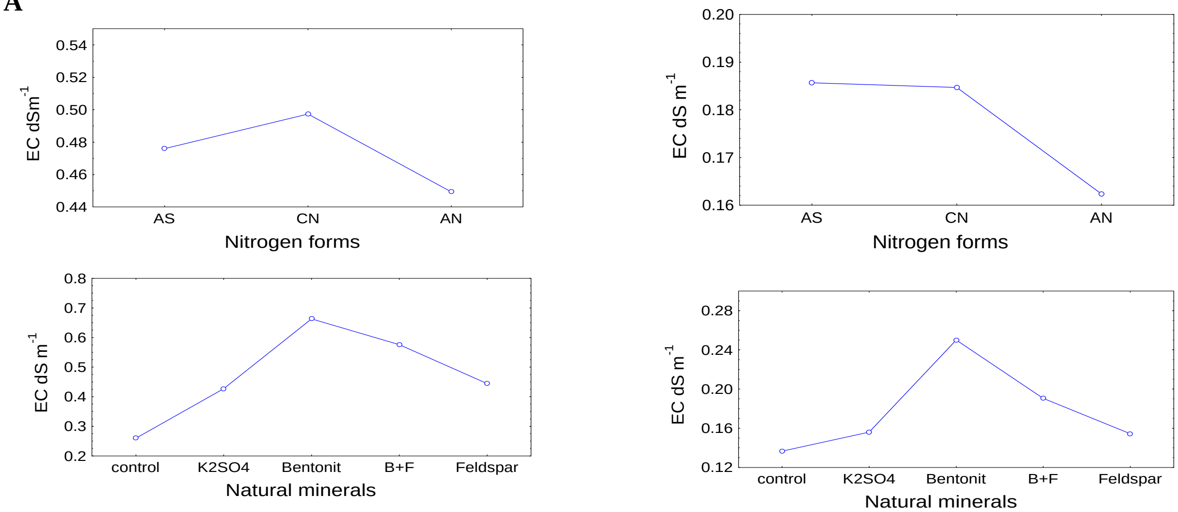
Fig (2): Effect of different sources of natural mineral, nitrogen fertilizer and/ or inoculation with potassium dissolving bacteria on available nutrients (N and K) for the tested soil after peanut and sesame harvesting.

Concerning EC and pH values, the highest EC values in soil following the two studied seasons were reported for calcium nitrate fertilizer as well as bentonite mineral as a source of potassium fertilizer (Fig 3.A). With respect to pH values, the highest values in soil were reported for calcium nitrate at the first season (peanut) and for ammonium nitrate at the second season (sesame). An opposite trend was generally encountered with natural mineral, particularly for applied feldspar, which led to a decrease in pH values at the two seasons as compared to control (Fig 3.B).

Again, to make the picture clearer, it was thought useful to express the obtained results as interactions between the influences of both natural mineral and nitrogen fertilizer forms; such interactions are shown in Fig (4). Data indicated that, for both studied seasons, application of different natural mineral significantly increased the EC values but decreased the pH values of the studied soil in the presence of nitrogen fertilizer forms as compared with control, whether inoculation or non-inoculation was performed. Moreover, the indicated values of EC and pH were higher in case of applying either bentonite or bentonite + feldspar ratio in the presence of all nitrogen fertilizer forms. Soil salinity increase could be due to the relatively high content of salts in bentonite (Gouda, 1984).

Peanut **Sesame**

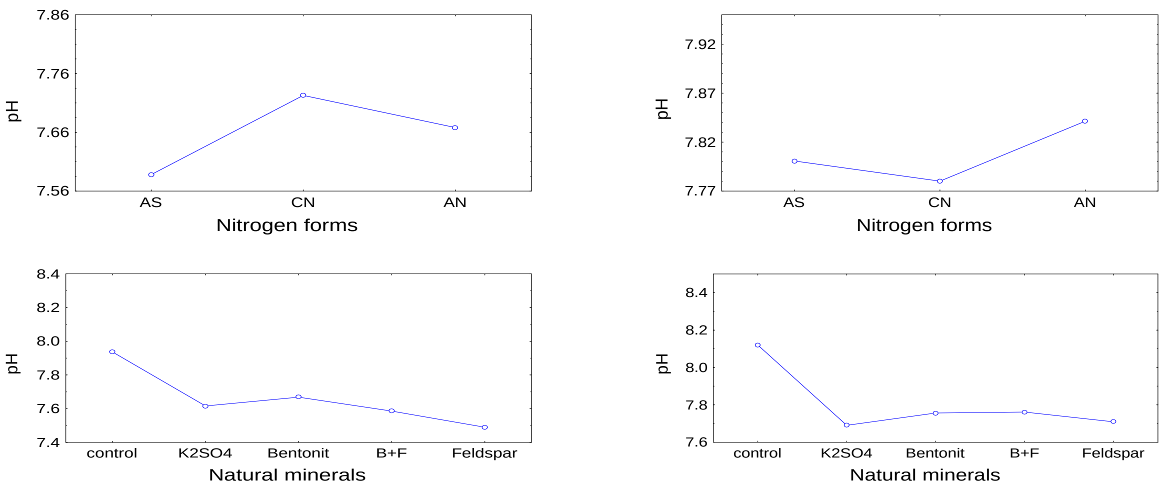
A



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**0.092**	**0.033**
Natural mineral	**0.070**	**0.042**

I



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**0.09**	**0.11**
Natural mineral	**0.11**	**0.15**

Fig (3): Effect of either nitrogen fertilizer or natural mineral on both electrical conductivity (EC) (A) and soil reaction (pH) (B) for the tested soil after peanut and sesame harvesting.

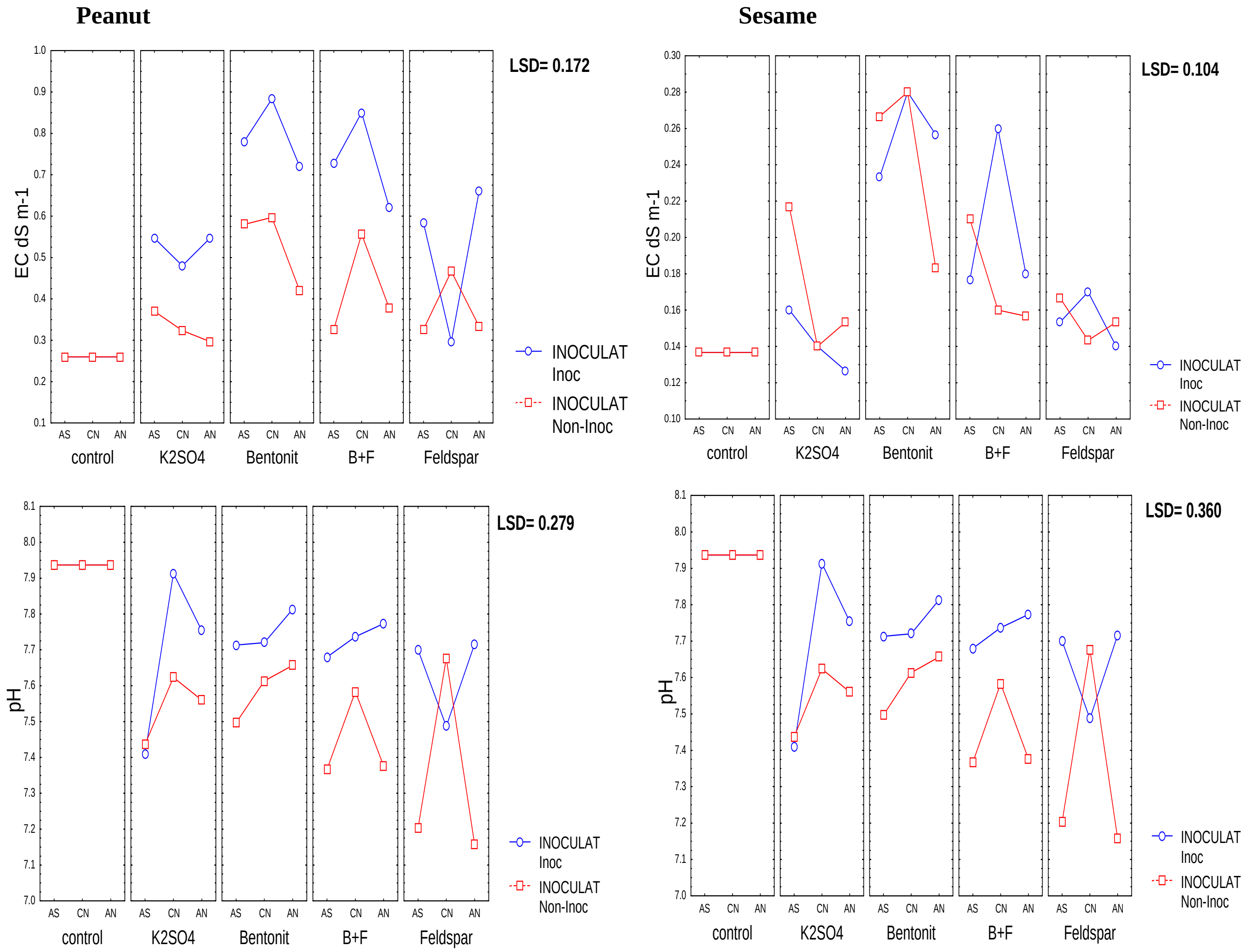


Fig (4): Effect of different sources of natural mineral, nitrogen fertilizer and/ or inoculation with potassium dissolving bacteria on both electrical conductivity (EC) and soil reaction (pH) for the tested soil after peanut and sesame harvesting.

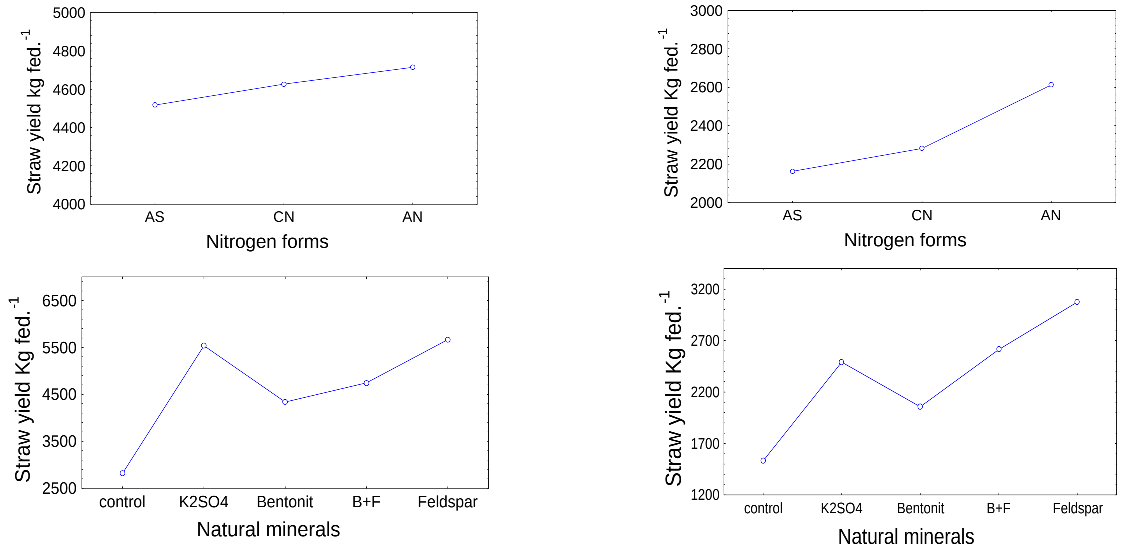
2- Influence of nitrogen fertilizer, natural minerals and inoculation with bacteria on yield components at harvesting stage.

With respect to yield of straw and yield of grains or seeds for both peanut and sesame crops, data shown in Fig (5. A and B) revealed that the highest significant yield components of peanut and sesame crops were reported for ammonium nitrate fertilizer as compared to other treatments. Treatments of nitrogen fertilizer may be arranged as follows: ammonium nitrate > calcium nitrate > ammonium sulfate. Also, feldspar mineral gave the highest values of yield components. Treatments of natural mineral may be arranged as follows: feldspar > potassium sulfate > bentonite + feldspar > bentonite and feldspar > bentonite + feldspar > potassium sulfate > bentonite for peanut and sesame yield, respectively.

In general, to make the picture clearer, it was thought usefully to express the obtained results as interactions between the influences of both natural mineral and nitrogen fertilizer forms; such interactions are shown in Fig (6). Data show that natural mineral was favorable to yields either in the presence of nitrogen fertilizer forms or inoculation with potassium dissolving bacteria as compared to control. Furthermore, results indicate that yield components of peanut and sesame increased in the presence of inoculation with potassium dissolving bacteria as compared to non-inoculation. Such results are confirmed by those of Han and lee (2005) who reported that the inoculation of potassium solubilizing bacteria synergistically solubilized the K materials which were added into the soil and made them more available to the plant. This led to the promotion of their uptake and plant growth. Growth enhancement by Bacillus may be also related to its ability to produce hormones, especially IAA. In short, co-inoculation of plant growth promoting rhizobacteria (PGPR) with different beneficial properties may be the future trend for bio-fertilizer application to enable sustainable crop production.

Peanut **Sesame**

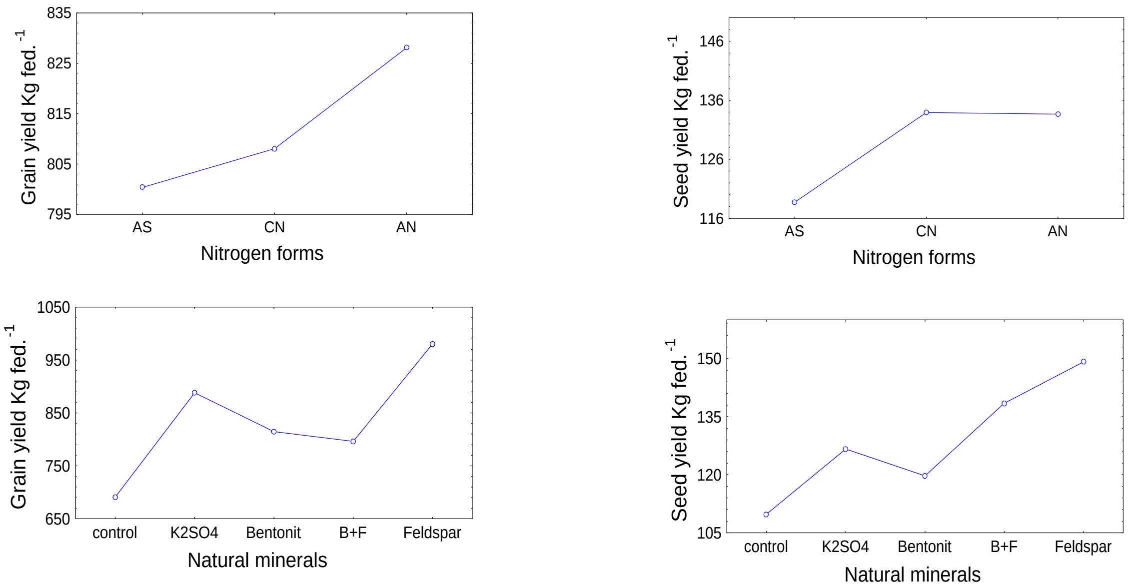
Straw (A)



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**315**	**205**
Natural mineral	**317**	**236**

Grain and Seeds (B)



L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**63.9**	**7.93**
Natural mineral	**77.7**	**7.49**

Fig (5): Response of yield components, straw (A) and grain or seeds (B), (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to one factor either nitrogen fertilizer or natural mineral at harvest stage.

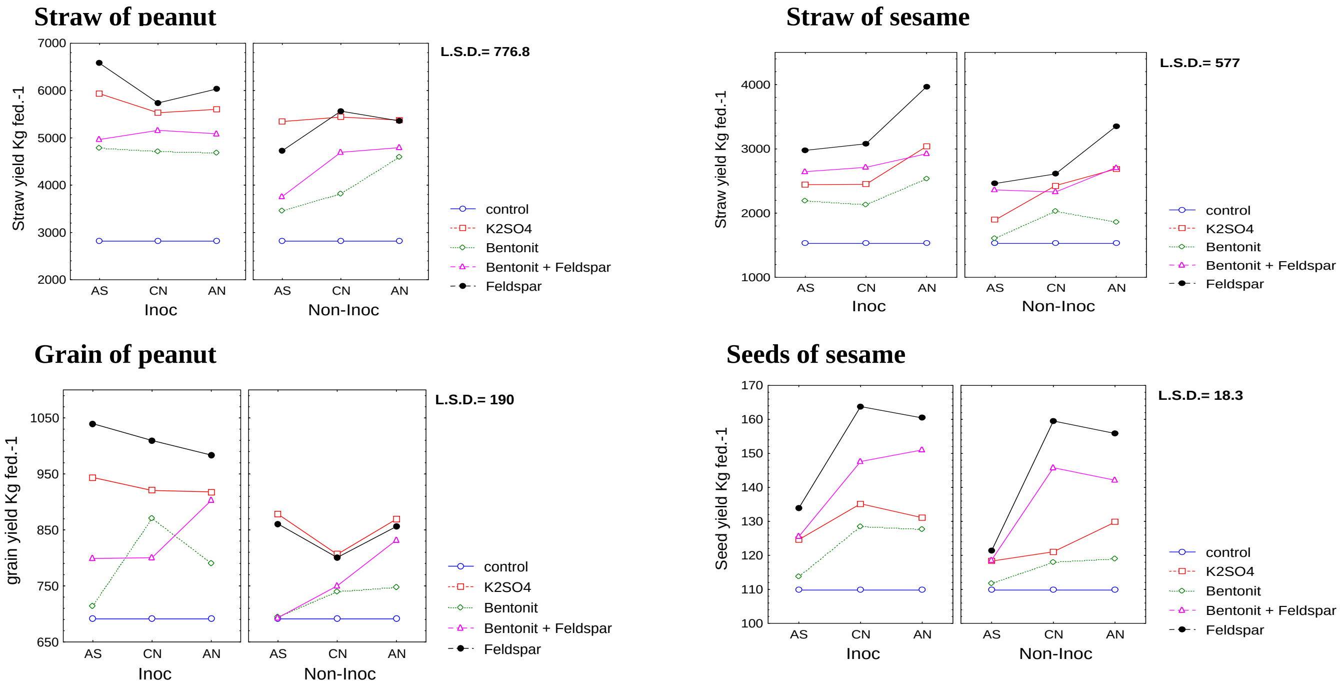


Fig (6): Response of yield components (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to application of different sources of natural mineral, nitrogen fertilizer and/ or inoculation with potassium dissolving bacteria at harvest stage.

Feldspar treatment had recorded the highest values of yield components for either peanut or sesame, particularly in the presence of inoculation as compared to those given by other treatments. These increases in yield components of peanut crop, recorded 117 % and 46.2 % against 118 % and 39.4 % for sesame straw and grains or seeds as compared to control, respectively. These data agreed with the results reported by Badr (2006) who found that the better performance of feldspar-compost plus silicate dissolving bacteria could be attributed to better maintenance of soil nutrient status in the root zone, which in turn helped the plants to utilize nutrients more efficiently; release of potassium took place frequently, and thus favorably affects growth of the crop. Locascio and Hochmuch (1997) reported that potassium supply by the soil is an extremely important factor in yield production, and the high yield depends on the level of K available to the plants. Recently, Massoud et al. (2009) reported that AM-fungi inoculation combined to B.circulans is highly beneficial to the growth of plants. This combination optimizes the K solubilization from feldspar and increased microbial activity in the rhizosphere of plants. So, the weathering of feldspar by AM- mycrrhizal fungi and B. circulans bacteria enhance the release of K ions that led to encouragement for the growth and consequently, the diverse of rhizospheric microflora.

3- Influence of nitrogen fertilizer, natural mineral and inoculation with bacteria on nutrients uptake at harvesting stage.

A- Nitrogen uptake

With respect to nitrogen uptake of peanut and sesame plants, generally, the highest significant increases for nitrogen uptake of straw and grain or seeds for either peanut or sesame yields were reported for ammonium nitrate fertilizer and feldspar mineral compared to other treatments (Fig 7., A and B). Treatments of nitrogen fertilizer may be generally arranged as follows: ammonium nitrate > calcium nitrate > ammonium sulfate for the two studied seasons. On the other hand, treatments of potassium fertilizer may be arranged as follows: feldspar > potassium sulfate > bentonite + feldspar > bentonite at the first season while arranged as follows: feldspar > bentonite + feldspar > potassium sulfate > bentonite for the second season. Also, behavior of nitrogen uptake followed the same trend of those obtained for yield components at the two studied seasons. In fact, Katai et al. (2010) indicated that the large bentonite doses reduced the nitrate- N content along with available phosphorus and potassium contents of soil, which reflected on nutrients uptake by plants.

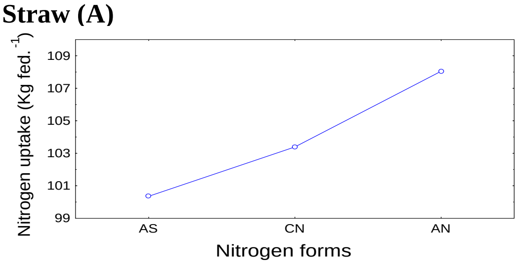
To make the picture clearer, it was thought usefully to express the obtained results as interactions between the influences of both natural mineral and nitrogen fertilizer forms; such interactions are shown in Fig (8). Data show that values at the two studied seasons were positively affected by application of natural mineral in the presence of nitrogen forms either of inoculation or non-inoculation compared to control.

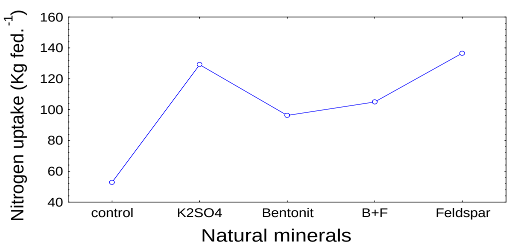
Moreover, results showed that the nitrogen uptake was significantly increased with inoculation by potassium dissolving bacteria. These results are in agreement with those of Han et al. (2006) who reported that the soil inoculation with potassium solubilizing bacteria significantly increased nutrients uptake in pepper and cucumber plants, especially when the respective rock potassium were added. Generally, pattern of nitrogen uptake followed the same trend of those obtained with yield components of both crops (peanut and sesame).

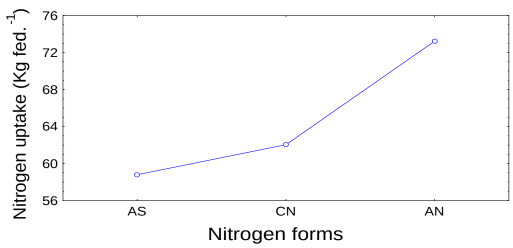
Application of feldspar with ammonium nitrate as a source of nitrogen fertilizer generally improved the uptake of nitrogen in plants, especially in the presence of inoculation compared to control. These increases in nitrogen uptake of peanut crop, recorded 214 % and 301 % against 219 % and 176 % for sesame straw and grains or seeds compared to control, respectively.

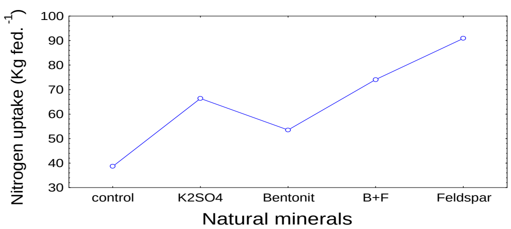
Peanut **Sesame**

Straw (A)



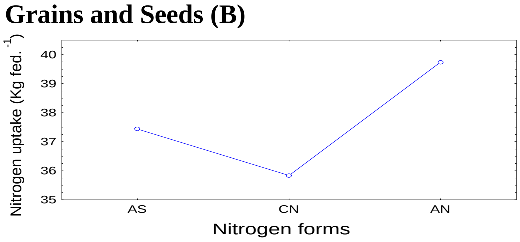


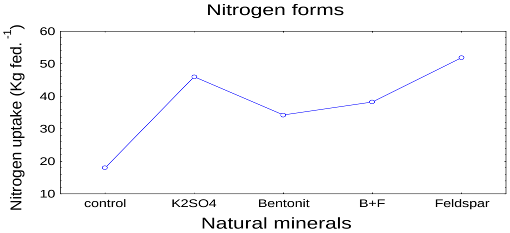


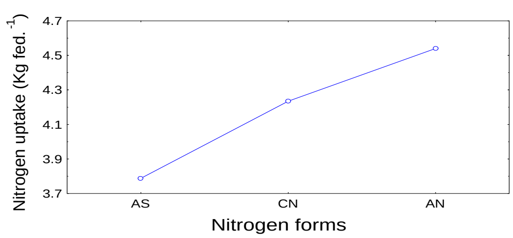


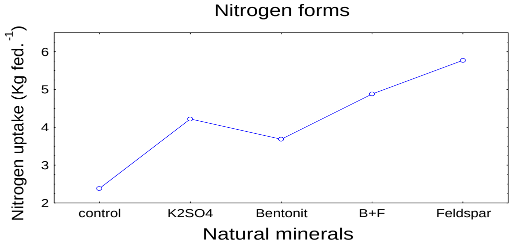
L.S.D at 5%
Nitrogen forms 11.9 **5.62**
Natural mineral 11.5 **6.44**

Grains and Seeds (B)









L.S.D at 5%
Nitrogen forms 3.08 **0.45**
Natural mineral 4.03 **0.49**

Fig (7): Response of nitrogen uptake, straw (A) and grain or seeds (B), (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to one factor either nitrogen fertilizer or natural mineral at harvest stage.

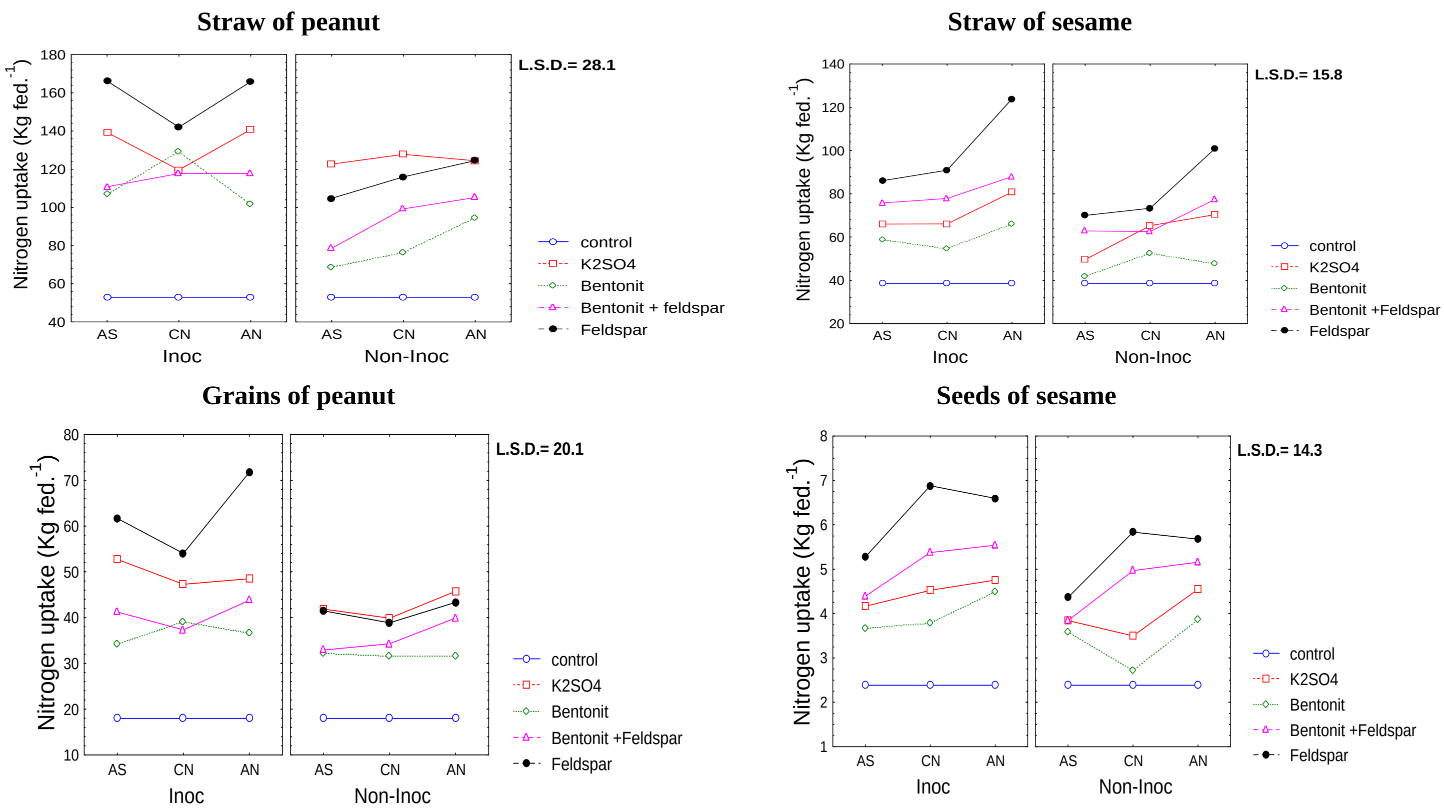


Fig (8): Response of nitrogen uptake (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to application of different sources of natural mineral, nitrogen fertilizer and/ or inoculation with potassium dissolving bacteria at harvest stage.

B- Potassium uptake

However, the highest response for potassium uptake of straw and grains or seeds at the two studied seasons were recorded for ammonium nitrate fertilizer as a source of nitrogen fertilizer with potassium sulfate and feldspar mineral as sources of natural mineral for peanut and sesame yield, respectively. (Fig. 9, A and B).

Treatments of nitrogen fertilizer seemed to follow a trend for potassium uptake similar to those obtained for nitrogen uptake. Regarding to treatments of natural minerals, they could be arranged as follows: potassium sulfate > feldspar > bentonite + feldspar > bentonite for the peanut yield while arranged as follows: feldspar > bentonite + feldspar > potassium sulfate > bentonite for the sesame yield. The last behavior of potassium uptake, again, seemed to follow a trend similar to those obtained for nitrogen uptake for the two studied seasons. In the same concern, Badr (2006) found that the total uptake was greater when feldspar- compost plus silicate dissolving bacteria was applied followed by potassium sulfate while the lower was recorded for feldspar. This may indicate that a major portion of K present in feldspar mineral as well as in the organic materials became available for uptake and contributed considerably towards the nutritional requirements of the crop. Further, loses due to drainage, leaching and percolation of potassium from feldspar charged compost are negligible as compared to soluble potassium salts. Hence, use of feldspar in a biological form should be, further, more economical than imported potash fertilizer.

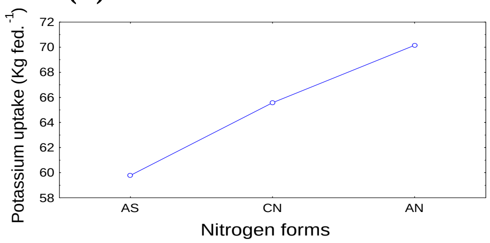
The obtained results as interactions between the influences of both natural mineral and nitrogen fertilizer forms (Fig 10) reveal positive responses for potassium uptake to application of natural mineral treatments in the presence of either nitrogen forms or inoculate as compared to control.

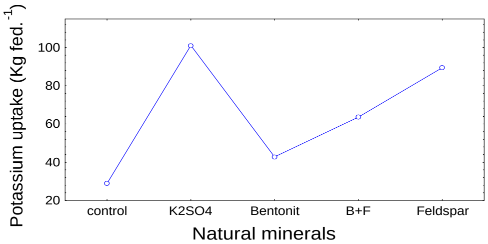
Application of ammonium nitrate with feldspar was generally superior, particularly in the presence of dissolving potassium bacteria. However, an exception being obtained in case of applying calcium nitrate with potassium sulfate for straw at first season compared to control. These increases in potassium uptake of peanut crop, recorded 336 % and 78.3 % against 352 % and180 % for sesame straw and grains or seeds as compared to control, respectively.

From our obtained results, it could be concluded that, the feldspar mineral and ammonium nitrate as a source of potassium and nitrogen recorded the highest values of yield components as well as nutrient (N and K) uptake for either peanut or sesame particularly in the presence of inoculation. Moreover, the effects of both feldspar and feldspar + bentonite was generally similar to that of potassium sulfate, particularly in the presence of inoculation. So, this biofertilizer is highly efficient to achieve the economy of potash fertilizer and reduce the cost of cultivation through the use of cheap and locally potash source.

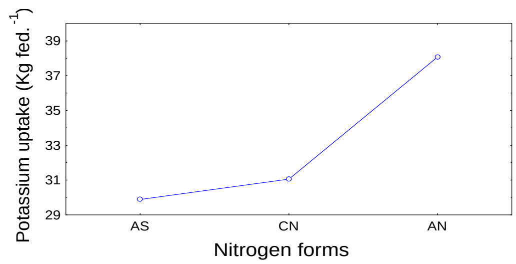
Peanut

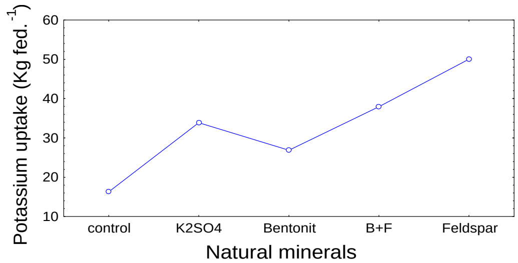
Straw (A)





Sesame

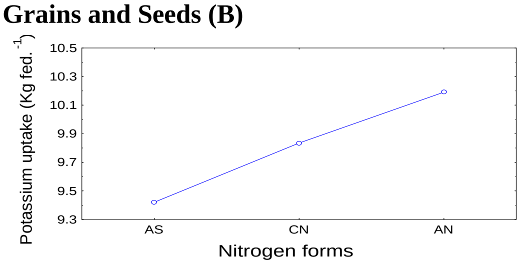


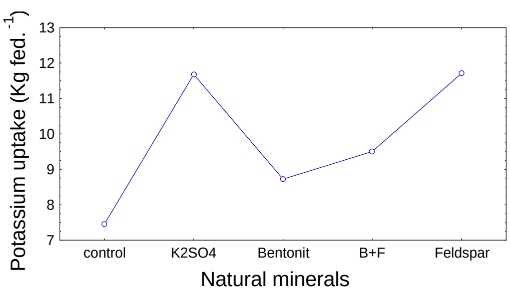


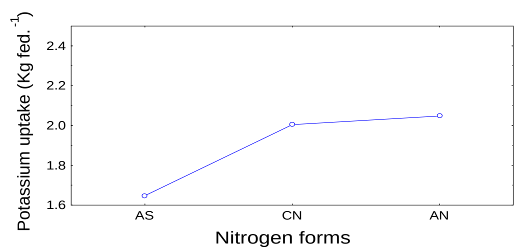
L.S.D at 5%

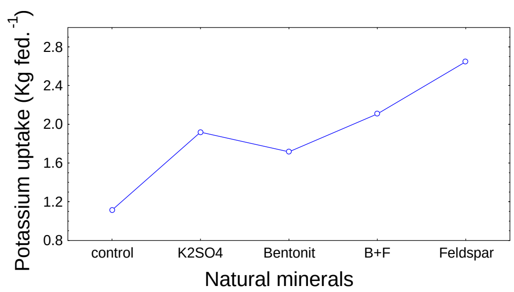
	Peanut	Sesame
Nitrogen forms	**7.68**	**2.81**
Natural mineral	**8.18**	**5.85**

Grains and Seeds (B)









L.S.D at 5%

	Peanut	Sesame
Nitrogen forms	**1.01**	**0.18**
Natural mineral	**1.01**	**0.16**

Fig (9): Response of Potassium uptake, straw (A) and grain or seeds (B), (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to one factor either nitrogen fertilizer or natural mineral at harvest stage.

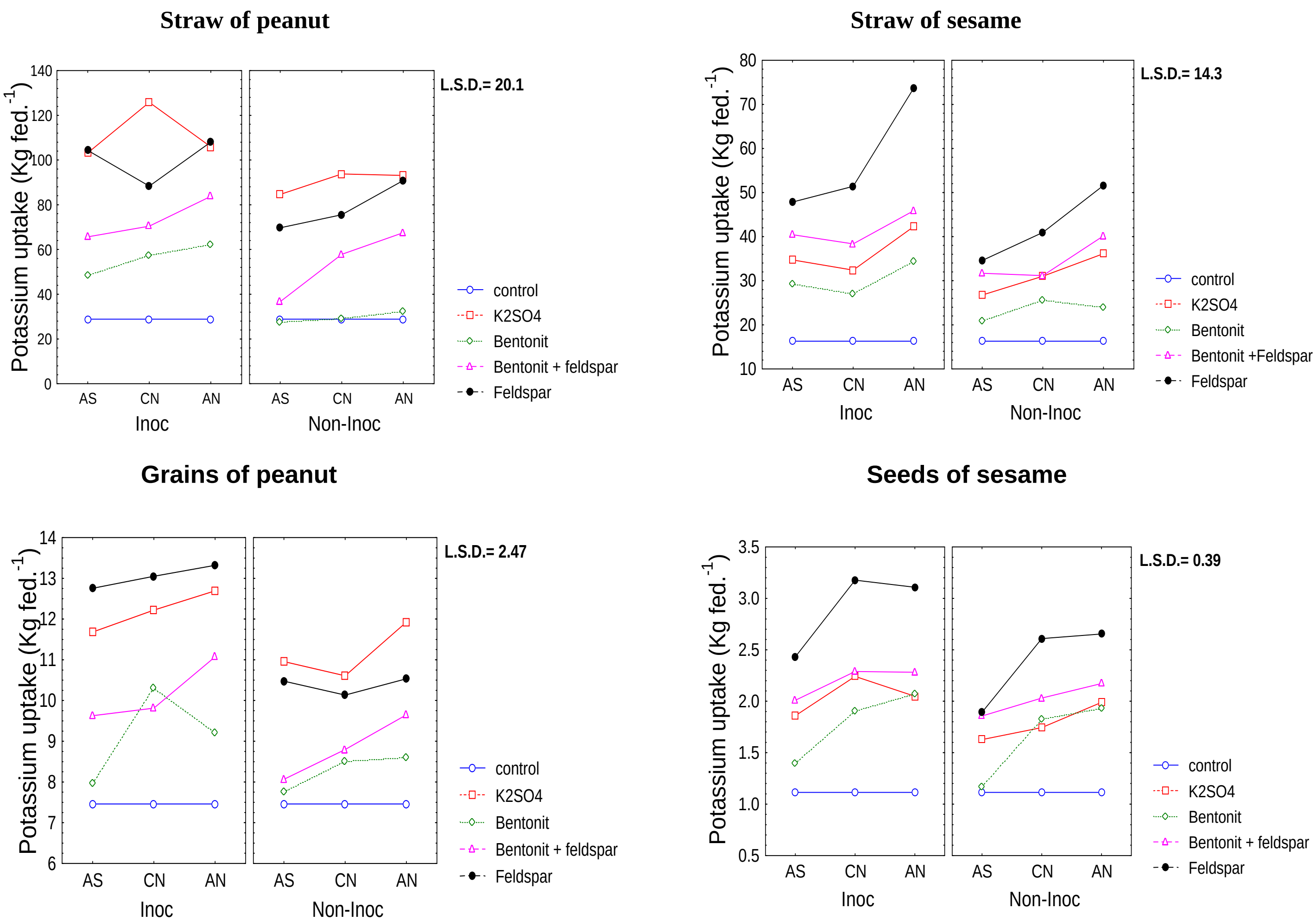


Fig (10): Response of Potassium uptake (Kg fed.$^{-1}$) for both peanut and sesame at two seasons to application of different sources of natural mineral, nitrogen fertilizer and/ or inoculation with potassium dissolving bacteria at harvest stage.

Acknowledgment

The authoresses wish to express their sincere gratitude and appreciation to the Development of Soil Conditioners Project, Dept. of Chemistry and Physics of Soil, Soils, Water and Environ. Res. Inst., Agric. Res. Center (ARC), Giza, Egypt, for introducing all facilities needed to accomplish this study.

Corresponding author
Gehan H. Youssef
Soil, Water and Environ. Research Institute, agricultural Research Center (ARC), Giza, Egypt

4. References:

1- Abd El-Motty Elham Z.; Shahin, M.F.M.; Mabd-El-Migeed, M.M. and Sahab, A.F. (2009). Comparative studies of using compost combined with plant guard and flespar on the morphological, physiological and rhizospheric microflora of olive seedlings. American-Eurasian J. Agric. and Environ. Sci., 6: 372-380.
2- Abdel Wahab, A.F.; Biomy A. H. M. and El Farghal, W.M. (2003). Effect of some natural soil amendments on biological nitrogen fixation, growth and green yield of pea plants grown on sandy soils.Foyoum J. Agric. Res. And Environ. 17: 47-54.
3- Badr, M.A. (2006). Efficiency of K-feldspar combined with organic materials and silicate dissolving bacteria on tomato yield. J. Appl. Sci. Res. 2: 1191-1198.
4- Badr, M.A.; Shafei, A.M. and Sharaf El-Deen S.H. (2006). The dissolution of K and P-bearing minerals by silicate dissolving bacteria and their effect on sorghum growth. Res. J. Agr. and Bio. Sci., 2: 5-11.

5- Barker, W.W.; Welch, S.A. and Banfield, J.F. (1997). Geomicrobiology of silicate minerals weathering. Reviews Mineralogy. 35: 391-428.
6- Cottenie, A.; Verloo, M.; Kiekns, L.; Velghe, G. and Camerlynek, R. (1982). "Chemical analysis of plants and soil" Lab. Anal. And Agroch. St., state Univ., Ghent, Belgium.
7- Gouda, M. A. (1984). Soil and water management of sandy soil. Ph. D.Thesis, Fac. of Agric. Zagazig Univ., Egypt.
8- Hagin, J. and Shaviv, A. (1990). Review of interaction of ammonium- nitrate and potassium nutrition of crops. Journal of plant nutrition. 13: 1211-1226.
9- Han, H.S. and Lee, K.D. (2005). Phosphate and potassium solubilizing bacteria effect on mineral uptake, soil availability and growth of eggplant. Research J. of Agriculture and Biological Sciences. 1: 176-180.
10- Han, H.S.; Supanjani; and Lee, K.D. (2006). Effect of co-inoculation with phosphate and potassium solubilizing bacteria on mineral uptake and growth of pepper and cucumber. Plant Soil Environ. , 52: 130-136.
11- Hill, T. and Lewicki, P. (2007). "Statistics Methods and Applications" Stat Soft, Tulsa, Ok.
12- Katai, J.;Tallai, M.; Sandor, Zs and Olah Zsuposne, A. (2010). Effect of bentonite and zeolite on some characteristics of acidic sandy soil and on the biomass of a test plant. Agrokemia es Talajtan . 59: 165-174.
13- Lin Qi-mei; Rao Zheng-Hug; Sun Yan-Xing; Yao Jun and Xing Li-Jun. (2002). Identification and practical application of silicate-dissolving bacteria. Agric. Sci., China. 1: 81-85.
14- Locascio, S.J. and Hochmuch, G.J. (1997). Potassium source and rate for polyethylene-mulched tomatoes. Hort. Sci., 32: 1204-1207.
15- Massoud, O.N.; Morsy, Ebtsam M. and El-Batanony, Nadia H. (2009). Field response of snap bean (Phaseolus vulgaris L.) to N_2-fixers Bacillus circulans and Arbuscular mycorrhizal fungi inoculation through accelerating rock phosphate and feldspar weathering. Australian Journal of Basic and Applied Sciences. 3: 844-852.
16- Page, A.L.; Miller, R.H. and Keeney, D.R. (1982). "Methods of soil analysis" Amer. Soc. Of Agron. Madison, Wisconsin, U.S.A.
17- Seddik, Wafaa M.A. (2006). Effect of organic manures and feldspar application on some sandy soil physical and chemical properties and their reflection on peanut productivity. J. Agric. Sci., Mansoura Univ., 31: 6675-6687.
18- Sheng, X.F. (2005). Growth promotion and increased potassium uptake of cotton and rape by a potassium releasing strain of Bacillus edaphicus. Soil Biology and Biochemistry. 37: 1918- 1922.
19- Snedecor, G.W. and Cochran, W.G. (1980). "Statistical Methods" 7th Edition. Iowa state univ. press., Ames., IA. USA.
20- Sugumaran, P. and Janarthanam, B. (2007). Solubilization of potassium containing minerals by bacteria and their effect on plant growth. World Journal of Agricultural Sciences. 3: 350-355.

9/9/2010