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Full Length Research Paper

Application of K-bearing rock for fertilization of Cowpea, (*Vigna unguiculata*)

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The main concept of this research work is to apply a mineral source of potassium for supplying the soil by this element in order to substitute the expensive commercial fertilization of some crops.The applied K-feldspar rock has about total potassium of 10.0%, in extractable form 395 ppm and in soluble form 125 ppm. Spectrographic semi-quantitative analysis of this rock revealed that it has 70.40% SiO_2, 15.48% Al_2O_3, 8.38% K_2O, 3.22% Na_2O and traces of other elements such as Fe, Mg, P and Ti. A field experiment was conducted to grow cowpea on poor virgin sandy soil. Four treatments were followed: potassium sulfate only, ½ potassium sulfate + ½ potassium feldspar, ¼ potassium sulfate + ¾ potassium feldspar and potassium feldspar only. There was a highly significant variation between the vegetative growth of the cowpea under the second treatment, in which half K-requirement was added as K-sulfate and the other half as K-feldspar, and all other treatments. The same trend was obtained with respect to the number of branches in the plant, number of kernels and weight of seeds. In spite of the fertilization requirements of nitrogen, phosphorus and organic compost have been added equally to the four treatments, there were some fluctuations in the content of these elements of the yield of cowpea. The content of nitrogen, phosphorus and potassium in the four treatments can be arranged as followed: $2^{nd}>1^{st}>3^{rd}>4^{th}$ treatment. The lowest vegetative and yield quality of plants under the 4^{th} treatment, in which potassium feldspar was added, can be explained by the fact that these minerals are quite resistant to weathering and supply relatively small quantities of potassium during the growing season. However, their cumulative release of potassium over several years is very important acting as slow release fertilizer. The positive influence of the fine grains of the K mineral bearing rocks is improving the poor structure of loose sandy soil, consequently the water and nutrient capacities of this soil will be enhanced and increase their ability to plant uptake.It is worthy to refer that the cost of chemical fertilizer (K-sulfate) is about 7000 LE /ton while the K-feldspar rock is ranging between 600-800 LE /ton.

Keywords: feldspar rock, potassium sulfate, cowpea, sandy soil.

INTRODUCTION

It is well known that potassium is an essential element for plant growth, especially for tuber crops. It is necessary for photosynthesis, and the formation of proteins and carbohydrates in both grains and root tubers crops. Also the resistance to various pests and plant diseases are increased in the presence of potassium and consequently the parameters of crop quality particularly in tuber crops. Munson (1985), pointed out that potassium is added to the soil as chemical fertilizer in the form of K-sulfate or K-nitrate or K-chloride or compound fertilizer (NPK + Zn, Fe, Mn and Mo.) to increase the efficiency of this element and to reduce the costs of transport and storage of fertilizers.

The approach of applying mineral source of potassium from natural deposits has been introduced by many investigators to reduce the tremendous ncrease of chemical fertilizer costs. Rogers et al (1998), examined

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silicate sources of phosphorus and nitrogen elements by characterizing the colonization and weathering of feldspars in situ using field microcosms. They found that feldspars that contain inclusions of P-minerals such as apatite are preferentially colonized over similar feldspars without P. David (2010), emphasized that the high cost of conventional potassium fertilizers justifies further investigation of potassium silicate minerals and their host rocks (which in some cases include basic rocks, such as basalt) as alternative sources of K, especially for systems with highly weathered soils that lack a significant cation exchange capacity. Such soils commonly occur in developing countries, and so this approach affords an opportunity to develop indigenous silicate rock sources of K as an alternative to sometimes prohibitively expensive commercial fertilizers.

Also Sugumaran and Janarthanam (2007), investigated the solubilization of potassium containing minerals by bacteria and their effect on plant growth. The effect of Bacillus mucildginosus (MCRCp1) on solubilization from microcline, orthoclase and muscovite mica minerals was examined and their influence on groundnut plant growth. Their results showed that the available phosphorus and potassium were increased in soil from 6.24 to 9.28 mg kg^{-1} and 86.57 to 99.60 mg kg^{-1}, respectively. Also groundnut plant dry matter increased by 125% and the oil content 35.41% were increased through inoculation of MCRp1 bacteria on muscovite mineral as concluded by Seddik, (2006).

The efficiency of K-feldspars combined with organic materials and silicate dissolving bacteria (SDB) on tomato yield was investigated by Badr, (2006). The obtained results referred that inoculation with SDB into the composting mass enhanced the percent of available K. Also the response of tomato plants to the feldspar-compost inoculated with SDB was obviously high when added to sandy soils of low K-content and more than potassium sulfate fertilizer.

A field experiment was conducted by Hellal et al (2009), on faba bean plants fertilized by rock phosphate and feldspar in sandy soil. They found that mixture of town refuses with rock phosphate and feldspar was superior in plant height, number of branches, seed and straw yield as compared to control. The role of natural alternative fertilizers (NAF) on the N, P and K uptake by bean seeds was investigated, where the highest values were recorded under feldspar treatment except of P which logically observed after rock phosphate addition.

The trend of applying bio-fertilizers to enhance increase the weathering of rock phosphate and feldspars has been followed by Massoud et al, (2009). They concluded that treatment of mixture of fungi symbiotic N-fixers and Bacillus circulans + rock phosphate + feldspar resulted in more plant height, number of branches, numbers of nodules per plant and fresh yield of snap bean (*Phaseolus vulgaris, L.*). Gehan et al (2010), concluded that the application of calcium nitrate combined with potassium sulfate, and ammonium nitrate in combination with feldspar, in the presence of potassium dissolving bacteria inoculation, led to significant increases in potassium available in soil for peanut and sesame, respectively.

MATERIALS AND METHODS

Soil samples were air dried and passed through 2mm sieve and analyzed for the following: pH, total soluble salts, total calcium carbonate content, soluble cations and anions, total nitrogen, phosphorus and potassium contents, (Black et al., 1982).

The forms of potassium had been determined in the sample of feldspar rock, water soluble potassium, exchangeable potassium and total potassium content, (Richards and Bates, 1989). Spectrographic semi-quantitative analysis of the K-feldspar rock was conducted according to Soltanpour et al., (1996).

A field experiment had been carried out in Ismailia Governorate on a sandy soil which was cultivated with cowpea (*Vigna unguiculata*). The type of seeds was Kaha 1 mixed with bacteria (Azotobacter). The recommended doses of phosphorus, nitrogen and potassium fertilizers were added uniformly at the rates of 200 kg/fed as supper phosphate (15% P_2O_2) and 200 kg/fed as ammonium sulfate (15.5% $(NH_4)_2SO_4$), potassium sulfate (48%K_2O) was applied at the rate of 100 kg/fed, according to Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

The experiment included four treatments in four plots; each plot consisted of two replicates:

1) The first treatment contained standard doses of N, P and K (as chemical fertilizers).
2) The second treatment contained standard dose of N, P fertilizer and (½ Potassium sulfate + ½ K-feldspar).
3) The third treatment contained standard of N, P fertilizer and (¼ Potassium sulfate + ¾ K-feldspar).
4) The fourth contained standard of N, P fertilizer and K-feldspar only.

In addition, the fresh and dry weight of plant, fresh and dry roots, plant height, number of branches, number of kernels and weight of seeds in each kernel were recorded also at harvest. The data were statistically analyzed using Costat sofware, (CoHort, 1986).

RESULTS AND DISCUSSION

The main objective of this field experiment on cowpea growth is to evaluate the efficiency of K-feldspar rock to substitute the chemical fertilizer, in particular, potassium sulfate. The applied K-feldspar rocks were natural deposits near the Red Sea Coast and were excavated and processed by El-Ahram Company. This K-source

Table 1. The morphological and measurable parameters of the cowpea plants

Treatment	Plant lengthincm	Mean	Plant freshweightg	Mean	Plant dryweightg	Mean	Roots freshweightg	Mean	Roots dryweightg	Mean
1 A	60.0	61.5	210.0	215.0	85.1	87.6	54.5	52.9	21.2	20.7
1 B	63.0		220.0		90.1		51.2		20.2	
2 A	100.0	105.0	870.0	852.5	400.5	396.3	128.2	129.2	32.2	33.1
2 B	110.0		835.0		392.0		130.1		33.9	
3 A	65.0	65.5	200.0	205.0	84.1	85.2	26.4	27.4	9.8	9.9
3 B	66.0		210.0		86.3		28.3		10.0	
4 A	35.0	35.0	165.0	160.0	76.6	73.3	23.2	22.4	8.8	8.2
4 B	36.0		155.0		70.0		21.5		7.5	

Table 1 Continue 1

Treatment	Number ofbranches/plant	Mean	Number ofkernels/plant	Mean	Kernel weight g	Mean	Seeds weight /kernelg	Mean
1 A	9.0	9.5	45.0	47.5	3.5	3.8	3.0	3.1
1 B	10.0		50.0		4.0		3.2	
2 A	12.0	12.5	60.0	61.0	4.5	4.6	3.0	3.5
2 B	13.0		62.0		4.7		4.0	
3 A	8.0	7.5	40.0	41.0	3.0	3.1	2. 5	2.8
3 B	7.0		42.0		3.2		3.0	
4 A	5.0	5.5	25.0	26.5	2.9	2.8	2.0	2.2
4 B	6.0		28.0		2.6		2.3	

contained, by analysis, a total K of about 10%, K while the soluble form of almost 125 ppm and the exchangeable form of about 395 ppm. It was also found to be nearly non-saline (EC = 0.5 dS/m), non calcareous ($CaCO_3$ = 0.6%) and moderately alkaline (pH = 8.2) feldspar rock material.

The field experiment was conducted on virgin poor sandy soil cultivated with cowpea seeds, as cash crop indicator. After two months of sowing the morphological indicators of the vegetative part were recorded.

The figures in table (1) showed a distinct variation among the four treatments which were followed in this experiment. The second treatment in which half of the required potassium was added as potassium sulfate (K48%) and the other half as K-feldspar rock, had given the highest vegetative growth, (Plate 1).

The fresh weight of the cowpea plants was 852.5 g. under the second treatment compared to 215.0 g. under the control which was supplied with potassium sulfate only. Generally, the fresh and dry weights of the plants and roots had the following order: $2^{nd} > 1^{st} > 3^{rd} > 4^{th}$.

The measurements of the vegetative parameters of the cowpea (Table 1) revealed that the optimum growth occurred under the second treatment and the lowest was under the fourth treatment in which K-feldspar only was added. The same trend was proved from the number of branches, and weight of kernels and weight of seeds per plant. Similar results had been obtained by Hellal et al (2009) on faba bean fertilized by rock phosphate and feldspars. Positive results had been also recorded by Massoud et al (2009), who combined the feldspars and rock phosphate by fungi, N-fixer and Bacillus cirulans in the fertilization of snap beans *(Phaseolus vulgaris, L.)*.

The highest vegetation growth which was obtained from addition of K-feldspar rock (about 10% K) can be related to the influence of the fine grains of these minerals (microcline, orthoclase, quartz and others) in improving the physical conditions of the sandy soil. Consequently

Plate 1. Cowpea cultivation under different experimental treatments.

Table 2. Spectrographic semi-quantitative analysis of the K-feldspar rock.

Elements as oxides %								
SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Fe_2O_3	MgO	P_2O_3	TiO_2
70.4	15.48	8.38	3.22	1.53	0.01	0.01	0.01	0.01

the water and nutrients capacity of this soil will be enhanced and increase their availability to plant. The beneficial effect of these feldspar rocks also related to their content of some minor elements, such as Fe, Mn and Zn which contribute to plant nutrition and increase the vegetative growth and grains.

Spectrographic semi-quantitative analysis was carried on the K-feldspar sample which was used in this experiment, (Table 2). The results referred that the silicon and aluminum oxides constitute about 85.88% while potassium oxide about 8.38%, sodium oxide 3.22% and calcium oxide 1.53%. The other elements as P, Fe, Mn and Mg were found in very low concentrations or rare. This semi-quantitative analysis indicated that this source of K has no hazardous elements and can be added safely to the soil.

Dealing with feldspar chemistry, El-Taher (2010), determined the elemental content of 8 feldspar samples from Gabel El-Dubb, Eastern Desert, outcropping. A total of 16 elements (Na, Mg, K, Sc, Ga, Cr, Fe, Co, Zn, Nb, Ba, Ce, Eu, Hf, Th and U) were determined by instrumental neutron activation analysis (INAA) and 21 elements as oxides by XRF (x-ray fractionation). The author found that oxides of potassium (9.2%) and sodium (2.76%) are the major elements after SiO_2 (64.95%). The rest of the 16 elements appear as trace elements.

The application of feldspar rock affected the major nutrients contents of cowpea plants and the results were recorded in table 3. In spite of the fertilization requirement of N, P and organic compost had been added equally to the four treatments there were some fluctuations in the contents of N, P and K of the cowpea plants. The contents of these elements in the plants under the four treatments can be arranged as follows: 2nd > 1st > 3rd >4th treatment.

The lowest figures in the 4th treatment, in which K-feldspar is added, can be explained as the availability of K from these minerals requires several days and convenient conditions of pH, moisture, temperature and specific micro-organisms, (Rahim, 2003). These requirements may be deficient in the first stages of cowpea growth and consequently inadequate concentration of K is present.

It is worthy to refer that the feldspar rock as a source of K is considered a slow release fertilizer since it amends the plant with the element in the successive stages of

Table 4. Some chemical properties of the soil before and after cowpea cultivation.

No.	(1:1) pH	EC dS/m	$CaCO_3$ %	Ca++	Mg^{++}	Na^+	K^+	CO_3^{--} and Cl^-	SO_4^{--}	HCO_3^-
					Before cultivation					
1 (0-30 cm)	7.89	0.29	2.7	0.7	0.4	1.3	0.5	-	2.0	0.9
2 (30-60 cm)	7.82	0.75	3.9	2.0	1.4	3.2	0.9	-	5.12.4	
Treatment No.					**After cultivation**					
1	8.40	0.42	2.3	1.2	0.8	1.7	0.5	0.2	3.0	1.0
2	8.20	0.36	3.5	1.0	0.5	1.5	0.6	0.2	2.7	0.7
3	8.45	0.30	3.0	0.8	0.4	1.0	0.8	0.2	2.2	0.6
4	8.25	0.19	2.1	0.5	0.3	0.7	0.4	0.1	1.5	0.3

Table 5. Nutrient content of the soil after cowpea cultivation.

Sample no.	Total N (ppm)	Total P (ppm)	Total K (ppm)
1	58.8	45.4	17.5
2	68.6	50.0	19.2
3	39.2	32.5	13.0
4	29.4	30.7	11.4

Table 6a. LSD for fresh weight of cowpea vegetative part .

Ranking	Treatment	Mean	Non–significant range
1	2	852	a
2	1	215	b
3	3	205	b
4	4	160	c
LSD 0.01 = 26.7497			

Table 6b: LSD for length of cowpea vegetative part.

Ranking	Treatment	Mean	Non– significant range
1	2	105.0	A
2	3	65.5	B
3	1	61.5	B
4	4	35.3	C
LSD 0.01 = 7.23			

growth, particularly if combined with silicate dissolving bacteria and organic source of fertilization. In case of adding the chemical fertilizer as K-sulfate (48%K), it is readily soluble and more available to the plant but it is subject to be lost in drainage water.

The soluble K in soil can be fixed on clay particles and became slowly released because of the equilibrium between the various forms of this element.

The impact of K-feldspar application on some soil properties has taken into consideration. The poor sandy soil is slightly alkaline, non saline and has low $CaCO_3$ content, (Table 4).

The Nile irrigation water from derived channel, used for cowpea was considered of good quality (EC = 0.32dS/m and pH = 7.65). After the harvest of cowpea crop, the soil has been analyzed for the four treatments plots.

The figures of the major nutrient contents, (Table 5) indicated that the highest values of N, P and K were recorded in soil of the second treatment where half the K requirement was added as K-sulfate and half as K-feldspars. The lowest contents, however, were occurred in the fourth treatment with K-feldspar only.

Statistical analysis

Four components had been focused on, namely; fresh weight and length of the cowpea vegetative part, and number and weight of kernels per plant, and statistically analyzed using CoStat, (CoHort, 1986).

The obtained results (Tables 6a and b), showed that fresh weight and length of cowpea plants were differently

Table 6c. LSD for number of cowpea kernels/plant.

Ranking	Treatment	Mean	Non–significant range
1	2	61.0	a
2	1	47.5	b
3	3	41.0	c
4	4	26.5	d
LSD 0.01 = 4.44			

Table 6d. LSD for weight of cowpea kernels/plant

Ranking	Treatment	Mean	Non–significant range
1	2	4.6	A
2	1	3.8	B
3	3	3.1	C
4	4	2.8	D
LSD 0.01 = 0.447			

Table 7. The critical levels of available potassium in some soils, (FAO, 2005).

Type of soil	Available K (ppm)		
	Low	Medium	High
Sandy	<85	85-170	>170
Sandy clay loam	<125	125-250	>250
Calcareous	<175	175-350	>350

influenced by the applied treatments. There was highly LSD between the second and all other treatments in the fresh weight and length of the cowpea vegetative part under the conditions of the current experiment. Although, there was no difference in vegetative parts of the plants that were grown under first and third treatments, they both showed a highly LSD with the fourth treatment.

As number and weight of cowpea kernels are concerned, the field experiment proved that the four treatments had different effects on the cowpea yield.

The LSD results (Tables 6c and d), confirmed clearly that there were highly significant differences between kernels of the plants that were grown under the second treatment and all other treatments. They had the following descending order: 2nd, 1st, 3rd and 4th treatments.

It is worthy to conclude that, the second treatment which contained half of the required K applied as feldspar and the other half as potassium sulfate fertilizer had the superior effect, than the other treatments on cowpea vegetable.

It is obvious from the obtained low values of K concentration (Table 4) in the four treatments after cultivation of cowpea that the soil is very poor and requires continuous amendment of K-fertilization. In this respect FAO (2005), referred to the critical levels of available potassium, (Table 7).

The low concentration of K in the first treatment in which readily soluble potassium sulfate fertilizer was added can be explained by the fact that K in soil solution is subject to considerable leaching loss, particularly in structureless sandy soil.

The various forms of K in soil are usually occurred in equilibrium:

Non-exchangeable ↔ Exchangeable K ↔ Soil solution K

The category of exchangeable form of K is very limited in sandy soil due to the low content of colloidal and clay constituents. Therefore, most of the commercial K-fertilizer added to the soil are partly absorbed by plants and the rest is mostly lost by leaching.

This loss of K is more critical by the tendency of some plants to take up soluble K far in excess of their needs if sufficiently large quantities are present, and this excess of absorbed K does not increase crop yields to any extent.

Munson (1985), pointed to the feldspar bearing rocks are quite resistant to weathering and supply relatively small quantities of K during given growing season. In the meantime their cumulative release of K over several years is of some importance. This release is enhanced by the solvent action of carbonate and organic acids.

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