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Improving the Availability of Potassium from Feldspar in Sandy and Calcareous Soils, Egypt

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SANDY and calcareous soils are very poor in plant nutrients, especially potassium, and such great problem may be solved by applying organic matter and clay minerals. Therefore, when using natural sources such as clay mineral (feldspar) a designed specific management programme for applying these sources may become a suitable solution for reducing use of chemical fertilizers. Three treatments (control, feldspar, and feldspar mixed with compost) were applied in two types of soil (calcareous and sandy). Results show that the addition of both compost and feldspar individually or together increased available potassium content as compared to control. The application of feldspar alone increased the available potassium content in calcareous soil more than in sandy soil (6.62 and 5.24 %), respectively. Results also indicated that applying a mixture of organic manure and feldspar in calcareous and sandy soils led potassium to increase by 35.22 and 23.50 %, respectively. Therefore, the experiment cleared that the optimum way for using the feldspar in calcareous and sandy soils must be by combining it with organic matter. Finally, the application of K-feldspar in calcareous was better than in sandy soils in increasing the potassium level.

Keywords: Feldspar, Compost, Sandy soils, Calcareous soils.

Feldspar is the name of an important group of rock-forming minerals, which make up perhaps as much as 60% of the Earth's crust. Feldspars crystallize from magma in both intrusive and extrusive rocks; they may occur as compact minerals, as veins, and present in many types of metamorphic rocks. Feldspars may also be found in many types of sedimentary rocks. In addition, the most important sources of potassium in soil are the primary alumino-silicates, which include K-feldspar. Direct application of K and P bearing rock may be agronomically and environmentally more useful and more feasible than mineral fertilizers of phosphorus and potassium, (Rajan *et al.*, 1996). For the effect of microorganisms on feldspar solubility (Seddik, 2001), showed that microorganisms solubilize the minerals by direct enzymatic attack and those which promote the degradation through their metabolites. Co-inoculation of phosphate solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) in conjunction with direct application of rock P and K materials into the soil increased N, P and K uptake, photosynthesis and the yield of eggplant grown on P and K limited soils, (Han & Lee, 2005). Also combining rock P and K

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materials with bacterial strains consistently increased further mineral availability of P and K uptake and plant growth of pepper and cucumber, providing its potential use as fertilizer, (Han & Lee, 2006). On the other hand, application of feldspar and organic compost demonstrated good results for the plant growth parameters. Abdel Wahab *et al.* (2003), declared that the highest values of plant growth parameters were obtained in case of organic compost application in combination with the chemical or natural sources of potassium as feldspar. El-Etr *et al.* (2005), reported that the application of farmyard manure with low level ($10m^3$/fed), to carrot cultivation accompanied with Penicillium expansum fungs helped in releasing potassium from feldspar more than those from potassium sulphate, which in turn reflected in improving the growth and yield of carrot crop. Finally, Badr *et al.* (2006) recorded that using feldspar and compost in the field was found to be economic as well as environmentally safe as there are no leaching loses of nutrients from feldspar and the equivalent quantity of K_2O from such fertilizer will be from three to four times cheaper than in imported potash.

The aim of this study was to investigate and evaluate the potential of the direct application of feldspar, alone or mixed with compost, in sandy and calcareous soils.

Material and Methods

For studying the effect of compost and type of soil on the availability of potassium from feldspar, the study was carried out in calcareous and sandy soils. Soil samples were from Wadi El-Natrun, Egypt. Soil samples were air dried and passed through 2mm sieve and analyzed for the following: particle size distribution, pH, total soluble salts, total calcium carbonate and organic matter content (Black *et al.*, 1982), available potassium content (Richards & Bates, 1989) and total potassium (Soltanpour *et al.*, 1996).

In laboratory, pots (20cm diameter, 20cm deep and 5kg soil) of the two soils were treated with feldspar, a mixture of feldspar and compost and without any treatment as control.

Feldspar (250µm size fraction) was added to the soil at a rate of 5g/kg soil while compost was added at a rate of 20g/kg soil. Distilled water was added to reach the maximum water holding capacity. The soil samples were irrigated at appropriate intervals for three months. Soil samples from each pot were analyzed to determine the amount of available potassium.

Results and Discussion

Some soil characteristics of the two soils are shown in Table 1. The analytical data of compost and feldspar are presented in Table 2.

TABLE 1. Some chemical and physical characteristics of the soils.

Type of soil	Sand %	Silt %	Clay %	Texture	EC1:5 dS/m	pH 1:2.5	$CaCO_3$ %	Av.K ppm	O.M %
Sandy	81.7	6.7	11.6	L.S	0.65	8.1	1.2	52.4	0.39
Calcareous	83.7	5.8	10.7	L.S	0.71	8.6	25.2	42.3	0.28

TABLE 2. Some characteristics of compost and feldspar materials.

Material	pH 1:2.5	ECdS/m	O.M%	Total K%
Compost	6.53	3.75	30.3	1.13
Feldspar	8.1	0.46	-------	7.5

They were classified as Typic Torripsamments and Typic Calciorthids according to Keys to Soil Taxonomy, (USDA, 2006). Both soils contained high quantity of sand, with values corresponding to 81.7 and 83.71% in sandy and calcareous soils, respectively. The calcium carbonate content was 25.2% in calcareous soil. Available potassium content in different treatments was determined after three months and the obtained results are presented in Table 3.

TABLE 3. The available potassium under different treatments of sandy soil.

Available-K $mgkg^{-1}$ soil	Control	Sandy with Feldspar	Sandy with Compost and Feldspar
K. $mgkg^{-1}$	52.4	55.3	68.5
Increase of K in %	----------	5.24	23.50

For the sandy soil, results indicate that the highest value of available potassium content (68.5mgkg^{-}1) was recorded for compost mixed with feldspar treatment. When feldspar was applied alone the availability of potassium was found to be 55.3mgkg^{-1}. With respect to control, the feldspar and compost mixture increased the potassium availability by a percentage of 23.5, while the feldspar alone by only 5.24. The ameliorative effect of the compost may be explained by the role of its organic matter. Previous studies emphasized that the decomposition of organic matter produces several organic acids such as acetic, butyric and formic acids, able to specifically break down a mineral structure and extract elements required for metabolism or structure purpose (Styriakova *et al.*, 2003). On the other hand, the mechanisms that help on releasing potassium from feldspar are the hydrolysis processes. In the presence of water, orthoclase hydrolyzes to kaolinite :

$$2KAlSi_3O_8 + 11H_2O \rightarrow Al_2(Si_2O_5)(OH)_4 + 4Si(OH)_4 + 2K^+ + 2OH^-$$

Hydrolysis reactions, such as the one above, form clay minerals (*e.g.*, kaolinite), and release ions and molecules into soil solution. The released potassium ions may be adsorbed and utilized by grown plants or other organisms, adsorbed on to the negatively charged surfaces of humus or phyllosilicate clay colloids in the soil, or leached into the ground water.

The effect of different treatments on the availability of potassium in the calcareous soil was studied and the obtained results are shown in Table 4.

TABLE 4. The available potassium under different treatments of calcareous soil.

Available-K $mgkg^{-1}$ soil	Control	Calcareous with Feldspar	Calcareous with Compost and Feldspar
K. $mgkg^{-1}$	42.3	45.3	65.3
Increase of K in %	----------	6.62	35.22

The data in Table 4 show clearly that the available potassium of the calcareous soil increased under both treatments but at a greater extent under the treatment compost combined with feldspar (from 42.3 of control to 65.3 $mgkg^{-1}$, with a 35.22% increase), while the application of feldspar alone raised the amount of the element to 45.3 $mgkg^{-1}$(only 6.62% of increase). The comparison between the results of the two soil types put in evidence the effect of the soil type on the potassium release from the used natural resources. Calcareous soil achieved better results than sandy soil under all treatments, probably due to the role of organic matter. The main reason of the increased availability of potassium from feldspar is attributable to the reduction of pH induced by the production of organic acid by microorganisms such as citric, tartaric and oxalic acids (Welch & Ullman, 1993). Moreover, the addition of organic compost to the soil encourages the growth of soil microorganisms, according to the results of Singh *et al.* (2002), who found that the application of farmyard manure increased the crop uptake of potassium. Indeed, microorganisms catalyze oxidation of organic matter in calcareous soil and, if representing organic matter by carbohydrate (CH_2O), the reaction is: $CH_2O + O_2 \leftrightarrow CO_2 + H_2O$. The carbon dioxide and water can then combine and form carbonic acid. Therefore, calcium carbonate leads to the production of carbon dioxide, which can break down many common minerals, represented in equation 1, 2.

$$H_2CO_3 + CaCO_3 \rightarrow Ca\,(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O \qquad \{1\}$$

The reaction with feldspar produces common clays according to the reaction:

$$2KAlSi_3O_8 + 2H + 2HCO^-_2 + H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2K+ +2HCO^-_3 + 4SiO_2 \qquad \{2\}$$

Therefore, potassium available content in the calcareous soil was higher than in the sandy soil due to the effect of organic manure and carbonic acid.

Conclusion

The aforementioned discussion leads to the conclusion that the best way to use the feldspar as a source of potassium can be its combination with a source of organic matter, able to accelerate potassium-releasing processes from feldspar. In particular, the effect of compost was found more effective when applied in calcareous soil than in sandy soil. Therefore, direct application of feldspar and compost manure is a promising and sustainable alternative to the use of mineral fertilizers.

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تحسين تيسر البوتاسيوم من الفلسبار فى الأراضى الرملية والجيرية- مصر

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تهدف هذه الدراسة الى تعظيم الاستفادة من استخدام الفلسبار البوتاسى فى الأراضى المصرية لذلك تمت التجربة على الأراضى الجيرية الرملية والأراضى الرملية الممثلة من وادى النطرون حيث تم خلط الأراضى بالفلسبار البوتاسى والمادة العضوية ممثلة فى الكمبوست سويا، والفلسبار منفردا بالأرض فى معاملة أخرى. وقد فسرت بعض الميكانيكيات لانطلاق عنصر البوتاسيوم تحت تلك الظروف بواسطة المعادلات الكيميائية ، حيث أوضحت النتائج أن فى جميع معاملات الفلسبار مع الأراضى زيادة فى عنصر البوتاسيوم الميسر ، إلا إنه فى حالة خلط الكمبوست بالفلسبار أعطى قيم أعلى وعلى وجه التحديد فى الأراضى الجيرية يليها الرملية حيث كانت النسبة 35.22 ، 23,50٪ على التوالى. كما أوضحت النتائج مع تفسير الميكانيكية لانطلاق عنصر البوتاسيوم من الفلسبار أن استخدام الفلسبار مع الكمبوست كمصدر للمادة العضوية فى الأراضى الجيرية الرملية أعطى نتائج أفضل من تطبيقه فى الأرض الرملية حيث تساهم كربونات الكالسيوم فى زيادة نسبة غاز ثانى أكسيد الكربون الذى يتحول بدورة إلى حمض كربونيك حيث أن معدن الفلسبار (سيليكات ألومونيوم وبوتاسيوم أو صوديوم أو كالسيوم) ضعيف تحت تأثير حمض الكربونيك ويتحلل تحت تأثير أيون الأيدروجين من الحمض ويطرد جزيئاً من السيلكا أيون من البوتاسيوم ويتحول إلى معدن الكاولينيت بالإضافة الى دور المادة العضوية. ولذلك يجب خلط الفلسبار بالمادة العضوية لتحقيق أقصى استفادة من الفلسبار البوتاسى فى الأراضى الجيرية الرملية والرملية.