

Application of Glauconite Mineral as Alternative Source of Potassium in Sandy Soils

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ABSTRACT

Two experiments (incubation and greenhouse) were carried out in end of 2018 to evaluate the addition effect of glauconite rock rates on the release of K and some chemical properties as well as the uptake of potassium by wheat plants of sandy soil. Glauconite mineral rates (0, 3, 6, and 9 g kg⁻¹) were mixed with 300 g (w/w) soil in plastic pot, and then the distilled water was added to the field capacity of soil and incubation for four time periods (0, 30, 60, 90, and 120 days). The results indicated that, glauconite rates resulted in significant increases in the available K of studied sandy soil compared to the control treatment. These increases depended upon the application rate and the time of incubation. Additions of glauconite rates and incubation periods caused increases in most soil K forms (soluble, exchangeable, non-exchangeable, residual of K) of the studied soil samples. Also, soil pH values of treated soils decreased with increasing the applied rate of glauconite and incubation periods. On other side, the soil salinity (EC) and cation exchange capacity (CEC) were increased compared to the control treatment. The dry weight, concentration and uptake values of K were significantly increased with increasing the level of glauconite by wheat plant compared to the control treatment.

Key Words: Potassium, Glauconite, Incubation, Sandy soils.

INTRODUCTION

Potassium is one of the essential nutrients for plant growth (Wang et al., 2018). This nutrient is added to soils mainly in the form of chemical K-fertilizers. In Egypt, K-fertilizers were imports mainly to meet their annual requirements beside of the continuous increases in prices of these fertilizers. Thus, there is an actual need to introduce a low-cost source of K to substitute the traditional chemical fertilizers. In the New valley governorate, especially El-Dakhla oasis, there exists some rocks that contain Kand these mineral rocks are used to reduce the dependence on K-fertilizers as an indigenous alternative source of potassium element. In such an area, potassium (K) is found saturated in layers with mica, vermiculite and monturillonite. In this concern, glauconite is a naturally occurring mineral mined from ocean deposits from a sedimentary rock. It is often an olive-green colored sandstone rock found in layers in many sedimentary rock formations

(Abdelhafez et al., 2016). The study on glauconite in the New Valley is very recent and the research published in this field is few.

Alkali feldspars, muscovite, biotite and illite are considers the most important potassium bearing minerals in soils, which release K upon weathering (Mengel 2007). Glauconitic sandstone is among the rocks that may have the potential to release potassium and can be considered as a potassium fertilizer. Glauconite is a micaceous mineral containing K, Fe and Mg, as well as Al and Si. The chemical formula of glauconite in general can be written as: (K, Na) (Fe (III), Al, Mg)₂ (SiAl)₄ O₁₀(OH)₂ (Karimi et al., 2011).

Glauconite is a clay mineral that occurs in the form of dark green granules in many marine sands. The major chemical formula of glauconite is: ((K, Na) (Fe+3, Al, Mg)₂(Si, Al)4O10(OH)₂). The granules are more or less equal in size to the particles of the sand matrix in which they occur (GEOTECHNIEK. 2012).

(http://www.geotechniekvo.be/sites/default/files/article/Glauconiethoudende%20zanden/glauconiethoudende_zanden.pdf).

Heckman and Tedrow, (2004) reported that the addition of glauconite to sandy soils enhances the ability of the soil to increase the exchangeable macromicronutrients in soil, especially potassium. These desirable physical and chemical properties may explain how greensand can be useful as a soil amendment. Also, found that pure glauconite generally contains up to 8% K₂O and small amounts of phosphorus, calcium, and trace elements. Also, other studies found that glauconite is a rock of sedimentary origin which has a K₂O content ranging from 6 to 14%, showing the agronomic value of this rock to fertilize crop fields (Piza et al., 2011; Silva et al., 2012). The application of glauconite as a fertilizer is related mainly to its high content of potassium (5-9.5%) and micronutrients (El-Habaak et al., 2016).

Karimi et al. (2011) mentioned that the effectiveness of glauconitic sandstone powder as a potassium fertilizer could be estimated on bases on evaluating its consequences on plant growth rate. They found that the application of 400 g glauconitic sandstone recorded significant increases in plant growth and can be utilized in combination with other potassium fertilizers. Such an

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effect was more pronounced in the hydroponic culture than the sand culture.

The recent studies in Western Desert, Egypt indicated that El-Gedida glauconite deposits are mineralogically, physically and chemically suitable for exploitation and can be benefited as an optional alternative for potassium fertilizer (El-Habaak et al., 2016a). In addition, several experiments were found that the direct application of glauconitic sands would provide an efficient and economical alternative source of potassium (Liliana and Selvia, 2003).

Glauconite sediment has been used as natural potassium source, especially in forage crops, for over 100 years. The commercial value of glauconite is attributed to its slow release potassium content, especially in light textured soil where K-fertilizers are subjected to leaching from the rhizosphere. Besides, this mineral source is rich in nitrogen and phosphorous (Dooley, 2006 and Ryoung et al., 2006).

On the other hand, 90 to 98% of total soil potassium is found within the structure of soil minerals (Brady and Weil 2007) that can be desorbed and come into soil solution when come into contact with soil solution according to the equilibrium conditions. Although, the water -soluble K is easily absorbed form of K by plant roots (Mengel 2007); however, its content is low l in the sandy soils when compared with the concentrations of K detected in the fine-textured soils (Abd El-Hamid, 1983). Use of glauconite as a potassium fertilizer in millet farms resulted in a higher potassium content and superior yield (Rao and Rao1999).

The objectives of this study were investigated effect of glauconite rates on release of potassium forms, growth, and uptake of potassium by wheat plants.

MATERIALS AND METHODS

1. Soil Sampling

A soil sample was collected from the surface layers (0-30 cm) of a sandy soil located in the Agriculture faculty farm, Assiut Univ., New Valley, Egypt. This sample was air-dried, ground and sieved through a 2-mm sieve. Some physical and chemical properties of the studied soils sample are shown in Table (1).

2. Glauconite mineral.

The glauconite samples were collected from Tonida village, El-Dakhla oasis, between longitude 29° 23' 35" E and latitude 25° 28' 51" N (Fig 1). The collected samples were crushed and sieved through a 2-mm sieve. Some physical and chemical properties of the studied soils samples are shown in Table (1).

Table 1. Some physical and chemical properties of the selected soil samples under study.

Property	Soil sample
Partical-siz distribution	
Sand (%)	91.30
Silt (%)	6.20
Clay (%)	2.50
Texture	Sand
Saturation capacity (%)	
pH (1:2.5)	8.10
EC (1:2.5 dS/m)	3.11
Organic matter (%)	0.03
CaCO ₃ (%)	6.53
CEC (cmol ⁽⁺⁾ /kg)	7.86
Soluble cations and anions (mmol/kg)	
Na ⁺	10.23
K ⁺	1.83
Ca ⁺²	4.51
Mg ⁺²	3.11
HCO ₃ ⁻	3.25
Cl ⁻	2.34
SO ₄ ⁻²	9.36
Potassium forms (mg/kg)	
Soluble K	53.21
Exch. K	43.34
Non-Exch. K	326.14
Residual K	1058.23
NH ₄ -AOC-extractable K (g/kg)	92.85
Total K (mg/kg)	1475.33

Table 2. Some chemical characteristics of glauconite mineral

Property	Unit	Glauconite
pH (1: 2.5)	---	6.79
EC (1:2.5)	(dS/m)	2.86
N	(%)	2.88
P	(%)	1.65
K	(%)	4.46
OM	(%)	0.012
Fe	(mg/kg)	1325
Mn	(mg/kg)	175
Zn	(mg/kg)	188
Cu	(mg/kg)	4.23

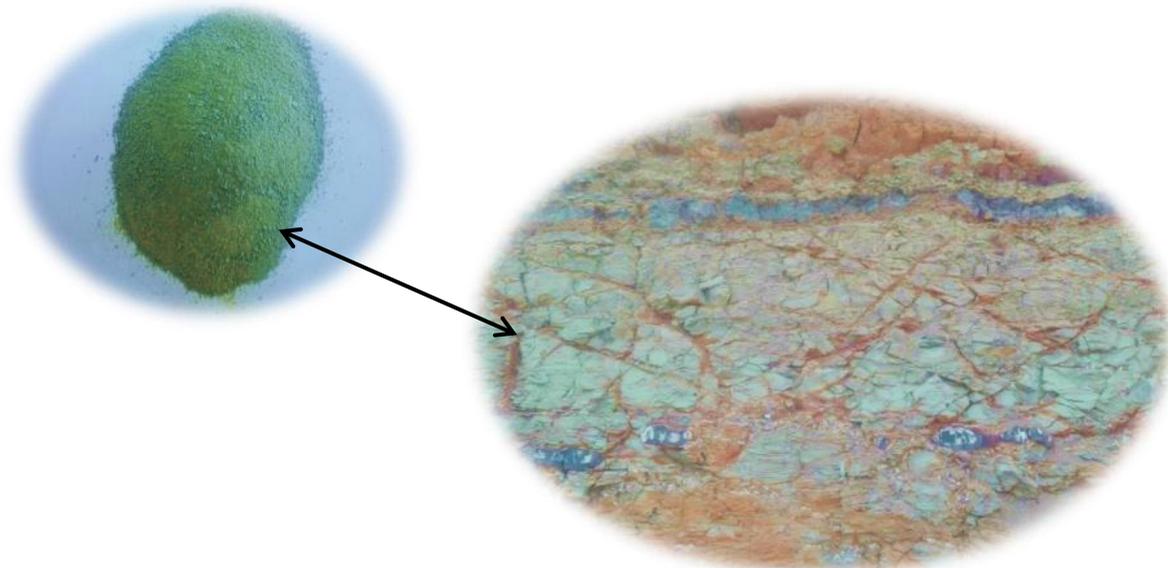


Fig. 1. Location and sample of glauconite mineral

3. An incubation experiment

The objective of this experiment was to investigate the direct impact of application of Glauconite mineral on enriching soils with available K and improving plants grown thereon. Besides, this experiment investigates the impacts of this mineral on improving some chemical properties of the study soil. Glauconite mineral rates (applied at 4 different rates i.e. 0, 7.14, 14.29, and 21.43 ton hectare⁻¹) were mixed thoroughly with soil. Afterwards, soil portions, equivalent to 300 g soil were packed in plastic pot, then the distilled water was added to bring soil moisture to the field capacity. The incubation period lasted for 120 days at 25±2°C, during this period; soils were sampled at four incubation time periods (0, 30, 60, and 120 days). Each treatment was replicated three times.

4. A greenhouse experiments

A greenhouse experiment was carried out to evaluate the addition effect of the applied Glauconite mineral rates to the studied soil on the growth, uptake and concentrations of potassium within wheat plants (*Triticum aestivum*). Plastic pots, containing 3 kg of studied soil sample, were used to attain this aim in which glauconite mineral were mixed with soil at the above-mentioned rates (i.e. 7.14, 14.29, and 21.43 ton hectare⁻¹) before soil packing. On the 15th of November 2018, five seeds of wheat were sown in each pot and moistened by water up to field capacity. After 15 days from seed germination, the plants in each pot were thinned to two plants and the recommended amounts of

N and P fertilization were added to each pot with irrigation water. Plants in all pots were harvested 60 days after planting, washed with tap water then distilled water and dried at 70°C for 72 hours. Thereafter, the dried plant samples, collected from each pot, were weighed and kept for chemical analysis.

5. Soil analysis

Particles-size distribution, Organic matter, and electric conductivity (in soil paste extract) of the soils were performed using the methods described by Jackson (1973). Total calcium carbonates were determined by the calcimeter method, according to Nelson (1982). Soil pH was determined in 1:2.5 water suspension of soil to water using a glass electrode as reported by (McClean, 1982). Potassium fractionation of the soil was assessed using a variety of chemical extractions as follows: 1) Soluble K was extracted by distilled water in 1:10 proportion. 2) Soluble plus exchangeable K was extracted using 1 N NH₄OAc at pH 7 (Carson (1980). 3) Soluble, exchangeable, and non-exch K was extracted by boiling 2 g of soil with 20 ml of 1M HNO₃ solution for 25 min. (Pratt, 1965). 4) Total K extracted by HNO₃-HClO₄ digestion as described by Jackson (1977) and the difference between K extracted by 1 M HNO₃ and that extracted using HNO₃-HClO₄ digestion gives a measure of the residual K.

RESULTS AND DISCUSSION

1. Effect of glauconite on some soil chemical properties and the availability of K in sandy soil.

Application of both glauconite rates (0, 3, 6 and 9 ton fed⁻¹) and incubation periods (0, 30, 60, 90 and 120 day) on soil pH, soil salinity (EC), cation exchangeable capacity (CEC) and available (Olsen extracted) K are shown in Table 3. The results indicate that the pH values of treated soils decreased; however insignificantly, with increasing the applied rate of glauconite and decreased slightly with increasing the incubation periods. This might be attributed to the acidic effect of decomposable products (Natsher and Schwetrmann, 1991). In case of soil salinity (EC), application of glauconite mineral resulted in concurrent increases in soil EC when compared to the control treatment. It seems that the EC value of soil increased with increasing the application level of glauconite up to 90 days (Abdel-Moez et al., 1995) while decreased thereafter (120 days). The reduction in the EC of soils after 120 days of incubation was observed at studied levels of glauconite mineral. The highest EC values

induced adding glauconite rates of 3, 6 and 9 ton fed⁻¹ were ranged from 2.15 dS/m to 2.33, 2.43 and 2.45 dS/m, respectively, after 90 days of incubation. Meanwhile, the lowest EC values and from 2.12 dS/m to 2.22, 2.26 and 2.41 dS/m, respectively, after zero time of incubation. Increasing EC of the soil treated with glauconite might result from the increases that took place from soluble salts that released to soil upon its degradation. On the other hand, the reductions in soil EC after 90 days of incubation may be attributed to formation of insoluble salts due to the release of the polyvalence cations and anions from glauconite degradation react with soluble salts in the soil. physical and chemical properties may explain how greensand can be useful as a soil amendment. The cation exchangeable capacity also increased with increasing the rate of glauconite and incubation periods and ranged from 7.88 to 8.67, from 7.95 to 8.74, from 8.02 to 9.04, and from 8.08 to 9.09 (cmol / kg) for zero time, 30 days, 60 days, and 90 days of incubation, respectively. Results contained here in indicate that the high values of CEC were recorded by the end of the incubation periods.

Table 3. Effect of adding glauconite levels and the incubation time on the electrical conductivity (dS/m) cation exchangeable capacity (cmmol/kg) and available K (mg kg⁻¹) of study soil.

Property	Glauconite levels (ton/fed.)	Incubation time (day)				
		0	30	60	90	120
pH	0	7.98	7.94	7.88	7.85	7.84
	3	7.91	7.84	7.81	7.76	7.73
	6	7.84	7.80	7.78	7.74	7.72
	9	7.80	7.77	7.71	7.69	7.67
	R L.S. D _{0.05}	NS				
EC	0	2.12	2.14	2.14	2.15	2.02
	3	2.22	2.23	2.28	2.33	2.12
	6	2.26	2.29	2.35	2.41	2.23
	9	2.41	2.43	2.45	2.45	2.36
	R L.S. D _{0.05}	0.036				
CEC	0	7.88	7.95	8.02	8.08	8.07
	3	7.94	8.02	8.26	8.36	8.29
	6	8.40	8.59	8.70	8.71	8.70
	9	8.67	8.74	9.04	9.09	9.07
	R L.S. D _{0.05}	0.104				
Avail. K	0	111.72	119.40	130.47	142.85	115.57
	3	125.61	132.45	149.11	163.74	132.40
	6	143.36	154.81	171.44	189.87	159.70
	9	177.12	179.06	199.53	215.71	177.94
	R L.S. D _{0.05}	NS				

NS= Nonsignificant at 0.05

Such relatively increases may be the slow decomposition of glauconite with the incubation time. Similar results indicate that the application of glauconite mineral recorded positive effects on soil properties and raised potassium availability for plants (Yapparov et al., 2015). These results are also in an agreement with those obtained by Heckman and Tedrow (2004) who reported that the addition of glauconite to sandy soils enhances the physical and chemical properties.

2. Soil available potassium

The effect of the investigated glauconite rates (3, 6 and 9 ton fed.⁻¹) and incubation periods (0, 30, 60, 90 and 120 days) on the available K of the studied sandy soil is shown in Tables 3. The results indicated that glauconite effectively increased the available K of studied sandy soil compared to the control treatment. These increases depended upon the application rate and the time of incubation. Also, these increases of available K attributed to the high content of K (5-14%) in glauconite mineral (Rodrigo et al., 2015 and El-Habaak et al., 2016a).

In most cases, the available K of the studied soils treated with the investigated glauconite rates increased with increasing the level of glauconite and incubation time, but non-significant between the reaction (levels and Incubation time). Greensands were used as slow acting potash fertilizer by direct application to agricultural fields.

The high values of the available K were 142.85, 163.74, 189.87 and 215.71 mg/kg for application of glauconite rates at 0, 3, 6, and 9 ton fed.⁻¹, respectively (after 90 days of incubation). On the other hand, the lowest values of available K were observed at the zero time of incubation (Table 3). The application of glauconite mineral had positive effects on increase of potassium availability in soil and hence formed favorable conditions for enhancing plant growth and development (Yapparov et al., 2015). The increase of potassium availability over time in the treatments is possibly related to organic acids and acidification generated by microorganisms which reacts with the mineral, modifying its structure (Rodrigo et al., 2015). Rao and Rao (1999) found that use of glauconite as a potassium fertilizer in millet farms resulted in a higher potassium content and superior yield. Also, several experiments were found that the direct application of glauconitic sands would provide an efficient and economical alternative source of potassium (Liliana and Selvia, 2003).

3. Addition Effects of Glauconite Rates on Potassium Forms of Sandy Soils

Potassium forms in the studied soils as affected by addition of glauconite at different rates are present in Tables 4. Increasing glauconite rates increased the different fractions of K in soil. Such increases depended on the level of glauconite mineral as well as the incubation period.

Addition of glauconite mineral rates recorded the highest increases in soluble K after 90 days of incubation. In this concern, the high rate (9 ton fed.⁻¹) of glauconite, recorded the highest content of soluble K. This is because Glauconitic sandstone released potassium. The amount of potassium extractable by water after 24 h incubation was only 0.002% of the total potassium content of this sandstone (Karimi et al., 2011). It seems as if this amount was not enough to fulfill the plant needs; hence, this slow release fertilizer can effectively continuously supply the grown plants with K. Results obtained herein indicate that the application of glauconite at either levels of 3, 6, or 9 ton fed.⁻¹, increased the soluble K from 28.28 mg/kg (control) to 94.04, 102.63 and 118.06 mg/kg, respectively, after 90 days of incubation periods. According to Rao and Rao (1999), levels of potassium soluble in water resulted from the application of Indian glauconitic sandstone depend on the particle size of the sandstone. This amendment raised soluble K up to 13 to 20 mg kg⁻¹, which agrees with our results. This indicates that the glauconitic sandstone powder can release K into solution and may be used as a potassium fertilizer. Yapparov et al. (2015) conclusion that the incubation time also played a significant role in the solubilization process of K from this amendment.

Once K-content increases in soil, K is held by the negative surface charges on clay minerals and organic matter (Tisdale et al., 1993; Pal et al., 1999). It is easily exchanged with cations and is quite readily available to plants (Sparks, 1989). Levels of the exchangeable K fractions in the sandy soil as influenced by the application of glauconite rates are presented in Table 3. Exchangeable K increased with increasing the dose of applying glauconite mineral incubation time. The higher values of the exchangeable K were recorded with the applications of the highest rate (9 ton fed.⁻¹) of glauconite. On the other hand, such increases were noticed up to 90 days of the incubation period. The increases of exchangeable K agreed with those reported by El-Habaak et al., (2016b). Levels of the exchangeable K induced application rates (3, 6 and 9 ton fed.⁻¹) of glauconite to sandy soil were 45.55, 54.07, 62.94, 83.06 mg kg⁻¹, and from 60.57, 69.70, 87.23, 97.66 mg kg⁻¹ after zero time and 90 days, respectively. These results

indicated that the glauconitic mineral could release potassium and can be utilized in combination with other potassium fertilizers (Karimi et al., 2011). Yapparov et al. (2015) found that the concentration of exchangeable potassium increased under the influence of glauconite sands in comparison with control by 62.0 and 72 mg kg⁻¹.

The non-exchangeable K form which is held as fixed ions in the lattice structure of clay minerals which may be exist as part of the structures of minerals (Tisdale et al., 1993). The influence of glauconite rates on the non-exchangeable K levels of the sandy soil are present in Tables 3. Levels of the non-exchangeable K form of studied soil increased with increasing the application level of glauconite and such increases were more pronounced with increasing the incubation periods. It is obvious from the results that the highest rate of glauconite gave the highest levels of this form in the

studied soil. Non- exchangeable K were 364.66 to 379.86, 395.10, 424.37 mg kg⁻¹, and from 392.66, 437.28, 473.28, 513.99 mg kg⁻¹ after zero time and 90 days, respectively. A decrease in glauconite mineral particle size, increase in the exposure time of particles to the extracting solution and elevation of the extractant temperature all increased the amount of extractable K (Rao and Rao 1999).

The effects of the investigated glauconite rates on the residual K of the sandy soil are present in Tables 3. Generally, levels of residual K of the studied soil increased with increasing the rates of glauconite mineral. The highest values of the residual K were attained at zero time of incubation periods, while the lowest ones were found after 90 days of application.

Table 4. Effect of adding glauconite levels and the incubation time on the potassium forms (mg/kg) of the study soil.

Incubation (day)	Level ton/fed.	Potassium forms (mg kg ⁻¹)			
		Soluble K	Exch.K	Non-exch.K	Residual K
0	0	66.20	45.55	364.66	1069.95
	3	71.54	54.07	379.86	1056.70
	6	80.42	62.94	395.10	1042.61
	9	94.06	83.06	424.37	1035.17
30	0	70.62	48.78	373.84	1059.76
	3	74.80	57.64	390.82	1046.23
	6	83.46	71.35	424.83	1038.10
	9	93.61	85.45	465.51	1012.94
60	0	76.20	54.27	376.81	1039.04
	3	84.20	64.91	425.25	1028.47
	6	94.85	76.59	452.42	1003.89
	9	103.63	95.91	504.78	953.20
90	0	82.28	60.57	392.66	1010.82
	3	94.04	69.70	437.28	1001.81
	6	102.63	87.23	473.28	964.60
	9	118.06	97.66	513.99	927.82
120	0	69.28	46.29	368.75	1062.01
	3	77.27	55.14	397.59	1072.83
	6	88.18	71.52	456.36	1011.69
	9	95.98	81.96	487.12	992.45

Table 5. Effect of adding glauconite rates on concentration and uptake of potassium by wheat plants.

Glauconite rates	Dry matter(g/pot)	Concentrations (%)	Uptake (mg/pot)
0	1.22	0.26	3.12
3	2.27	0.77	17.46
6	2.58	0.89	22.88
9	3.06	0.97	29.79
L.S.D	0.15	0.044	1.78

The values of residual K owing to the application of glauconite rates (0, 3, 6 and 9 ton fed.⁻¹) ranged from 1069.95 to 1056.70, 1042.61 and 1035.17 mg kg⁻¹ after zero time of incubation and from 1010.82 to 1001.81, 964.60 and 927.82 mg kg⁻¹ after 90 days of incubation time. Such reductions in the residual K with increased the time of incubation may be due to K release from glauconite, thus the residual K-form share in the concurrent increases of K in the other K forms (Hamed et al., 2012). Harley and Gilkes (2000) reported that release of potassium for soils minerals of low solubility was mainly attributed by the action of organic and inorganic acids produced by biological activity, which act by releasing H⁺ or complex and ligands.

4. Potassium Absorption by Wheat Plants Grown in Glauconite Mineral Treated Soils

Table 5 show that the concentration and uptake values of K were significantly increased upon increasing the level of glauconite mineral compared to the control treatment. Concentration and uptake values at levels of 0, 3, 6 and 9 ton/fed of glauconite were 0.26% and 3.21 mg/kg, 0.77% and 17.46 mg/kg, 0.89% and 22.88 mg/kg, 0.97% and 29.79 mg/kg, respectively. These results indicated that the highest rate (9 ton/fed) of glauconite gave the highest concentration and uptake of K compared to the control treatment by wheat plants. This result is an agreement with those obtained by Karimi et al. (2011) who reported that addition of glauconite treatment could provide sufficient potassium for plants over 80 days of cultivation in hydroponics and sand culture and they concluded that the addition of glauconitic may be used as a potassium fertilizer. Chandra (2001) reported that using glauconitic sandstone powder as a potassium fertilizer an increase in yield in rice and wheat plants farms. Also, Heckman and Tedrow, (2004) reported that potato tuber yields were on average 16% higher where the glauconite mineral treatments were applied and the crop was uniformly fertilized with 108, 7, and 134 lb/A of nitrogen (N), P₂O₅, and K₂O, respectively.

CONCLUSIONS

Glauconite has been applied in many fields to be economical and environmentally friendly amendment

that can partially substitute K fertilizers in light textured soil. This amendment is a porous silica mineral with the associated clay minerals and quartz grains, feldspar, and calcite. These remaining materials are easily homogenized with the soil. Thus, Glauconitic mineral can be applied directly as slow-release potash fertilizer in agricultural fields, especially sandy soils.

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الملخص العربي

إضافة معدن الجلوكونيت كمصدر بديل للبوتاسيوم في التربة الرملية

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التحضير. أدت إضافة معدلات الجلوكونيت وفترات التحضير الى زيادة في صور البوتاسيوم (الذائب، المتبادل، غير المتبادل، المتبقى) في التربة تحت الدراسة.

كذلك أدت زيادة إضافة معدلات الجلوكونيت وفترة التحضير الى انخفاض رقم الحموضة. بينما أدت زيادة إضافة معدلات الجلوكونيت وفترة التحضير الى زيادة في قيم الملوحة والسعة التبادلية الكاتيونية مقارنة بمعاملة الكنترول. أيضا أعطت زيادة إضافة معدلات الجلوكونيت زيادة معنوية في قيم الوزن الجاف ومعدل تركيز وامتنصاص البوتاسيوم بواسطة نبات القمح مقارنة بمعاملة الكنترول.

أجريت تجربتين (تجربة تحضير وتجربة زراعة) في نهاية عام 2018 لتقييم تأثير إضافة معدلات معدن الجلوكونيت على إطلاق البوتاسيوم وتحسين بعض الخصائص الكيميائية للتربة وكذلك الكمية الممتصة من البوتاسيوم بواسطة نباتات القمح في الاراضى الرملية. تم خلط معدلات معدن الجلوكونايت (صفر، 3، 6، 9 جم/كجم) مع 300 جم تربة رملية في أصيص بلاستيك ثم اضافة الماء المقطر عند السعة الحقلية وتم تحضير التربة لاربع فترات (صفر، 30، 60، 90، 120 يوم).

أظهرت إضافة معدلات معدن الجلوكونيت زيادة معنوية في البوتاسيوم الميسرفى التربة تحت الدراسة مقارنة بمعاملة الكنترول. واعتمدت هذه الزيادة على معدل الاضافة وفترة