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Effect of Organic Amendments on Soil Chemical Properties and Potassium Availability to Sorghum Plants grown on a Calcareous Sandy Soil

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Abstract

A pot experiment was conducted to evaluate the effect of a mineral fertilizer (K_2SO_4) and some organic amendments (filter mud cake, sheep manure and poultry manure) on potassium (K) forms and availability to sorghum plants (*Sorghum bicolor*) grown on a calcareous sandy soil. Soil chemical properties (pH, salinity and organic matter) were also investigated. The treatments were added at levels of 0, 25, 50 and 100 kg/fed., on the K-equivalent basis.

The results showed that organic amendments incorporated into the calcareous sandy soil affected the forms of soil K and K availability to sorghum plants. Water-soluble K, NH_4OAc-extractable K, and HNO_3-extractable K significantly increased with increasing the application level of K_2SO_4 or organic amendments. The highest increases in soil extractable K content and potassium uptake by sorghum plants were found with sheep manure application than for other treatments. Moreover, the application of both sheep manure and poultry manure showed a significant decrease in the soil pH and significant increases in the salinity and the organic matter content of the soil, especially with increasing the addition level. Therefore, recycling of organic amendments may be suitable for improving the soil chemical properties and potassium status of light textured soils.

Keywords: Organic amendments, Potassium forms and Potassium uptake.

Introduction

Potassium (K) is a dynamic nutrient in the soil system. Its forms in the soil are in equilibrium with each other (Usman and Gameh, 2008). It has been reported that K could be distributed among different fractions including: soil solution, exchangeable, non-exchangeable‹ fixed and mineral forms of soil K. However, its dynamic and equilibration in the soil differ and appear to depend upon soil characteristics (Bhattacharyya et al. 2007; Usman and Gameh, 2008).

Organic fertilizers including farmyard manure, sheep manure

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and poultry manure may substitute the chemical fertilizers for crop production. The importance of the organic manures can not be over looked. Worldwide, there is a growing interest in the use of organic manures due to the depletion in the soil fertility (Delate and Camberdella, 2004). Organic amendments are currently used in agricultural soils to improve their physical and chemical properties. Generally, organic matter plays an important role in the redistribution of K among its various forms (Khamis, 2000; Bhattacharyya et al., 2006 and 2007; Usman and Gameh, 2008). The equilibrium reactions between K forms markedly affect whether the applied potassium to become available in the soil and subsequently is taken by plants, leached into lower soil layers or converted into un-available forms (Sparks and Huang, 1985; Usman and Gameh, 2008).

The objective of this work is to study the effects of organic amendments or mineral K fertilizer (K_2SO_4) on K forms and its availability to sorghum plants grown in a calcareous sandy soil. The soil chemical properties were also investigated.

Materials and Methods

1. Soil samples and treatments

A pot experiment was carried out to evaluate the addition effects of organic amendments as well as the mineral K fertilizer on K forms and some soil chemical properties of a calcareous sandy soil. Soil samples were collected from the surface layer (0-30 cm) of a sandy soil at Wadi El-Assiuti of Egypt. Some chemical properties of this soil are present in Table 1. Three organic amendments (filter mud cake, sheep manure and poultry manure) were used in this experiment. The chemical characterization of these organic amendments is shown in Table 2. Each organic amendment was added to the studied soil at three levels i.e., 0, 25, 50 and 100 kg K/fed. Table 3 shows the amount of each organic amendment as well as potassium sulfate added to 5 kg soil to meet the three required levels.

The experiment was conducted in a complete randomized design with three replications in plastic pots. Each pot contained 5 kg of air-dried soil. Sorghum seeds (5) were sown and thinned to three plants after 10 days of germination. Soil moisture was maintained at the field capacity during the experiment time. The recommended amounts of N and P fertilizer doses of 250 Kg/fed., (1.25 g/pot) of ammonium nitrate 33.5% N and 150 Kg/fed., (0.75 g/pot) of super phosphate 15.5% P_2O_5 were added at two equal doses with irrigation water after 15 and 30 days from planting. The plants in all pots were harvested after 60 days of planting, washed with distilled water and dried at 70 ^{o}C for 72 hours. The dried plants of each pot were weighed, ground and kept for chemical analysis.

2. Soil properties

The particles-size distribution of the soils was performed using the pipette method that is described by Piper (1950). Organic matter content of the soil samples was determined using the dichromate xidation method described by Wakley and Black (Jackson, 1973). Soil calcium carbonate was estimated using the calcimeter according to (Nelson, 1982). Soil pH was determined in 1:2.5 suspension of soil to water using a glass electrode (Mclean, 1982).

Table (1). Some chemical characteristics of the studied soil.

Property	Soil Sample
Partical-siz distribution	
Sand (%)	90.50
Silt (%)	6.00
Clay (%)	3.50
Texture	Sand
Saturation capacity (%)	22
pH (1:2.5)	8.08
EC (1:2.5 dS/m)	1.45
Organic matter (%)	0.02
$CaCO_3$ (%)	18.50

Table (2). Some chemical characteristics of the studied organic amendments.

Property	Unit	Filter Mud cake	Sheep Manure	Poultry Manure
pH (1: 2.5)		6.92	7.85	6.78
EC (1:2.5)	dS/m	1.69	4.88	2.96
Total N	(%)	2. 27	2.22	2.88
Total P	(%)	1.29	1.33	1.65
Total K	(%)	0.95	3.85	3.00
Organic matter	(%)	30.80	37.95	55.51
Fe	(mg/kg)	5610	3876	1325
Mn	(mg/kg)	266	134	175
Zn	(mg/kg)	96	85	188
Cu	(mg/kg)	129	29	32

The electrical conductivity (EC) of 1:2.5 extract of soil to water was measured using a conductivity meter according to Jackson (1973).

Table (3). Amount of each organic amendment as well as potassium sulfate added to 5 kg soil to meet the three required levels of K per feddan.

Amendment	Level		
	25kg K_2O/fed.	50kg K_2O/fed.	100kg K_2O/fed.
	Amount (g) added to 5kg soil		
Potassium sulfate	0.125	0.25	0.50
Filter mud cake	13.16	26.32	52.64
Sheep manure	3.26	6.52	13.04
Poultry manure	4.17	8.34	16.68

3. Potassium extraction

Potassium fractionation of the soil was assessed before and after an experiment using a variety of chemical extractions as follows:

(I) Water-soluble K was extracted by distilled water in 1:10 proportion. (II) Soluble plus exchangeable K (soil available K) was extracted using 1 N NH_4OAc at pH 7 as described by Carson (1980) and the difference between K extracted using distilled water and that extracted using 1 N NH_4OAc gives a measure of the exchangeable K.I. (III) Soluble, exchangeable and non-exchangeable K was extracted by boiling 2 g of the soil with 20 ml of 1M HNO_3 solution for 25 min. (Pratt, 1965). The difference between K extracted by 1 N NH_4OAc and that extracted using 1 M HNO_3 gives a measure of the non-exchangeable K (slowly available K). (IV) Total K was determined by digesting the soil sample with HNO_3-$HClO_4$ mixture (Jackson, 1977). The difference between K extracted by 1 M HNO_3 and that extracted using HNO_3-$HClO_4$ digestion gives a measure of the residual K (mineral K).

4. Plant analysis

Plant samples of 0.2g were digested using a mixture of sulfuric acid and hydrogen peroxide was followed (Parkinson and Allen, 1975). The digests were analyzed for K using the flame photometer.

5. Statistical analysis

The statistical analysis of data was done according to the methods described by Snedecor and Cochran (1980).

Results and discussion

I. Effect of organic amendments on Soil Chemical Properties

The added organic amendments to the studied soil had significant effects on the soil chemical properties: electrical conductivity (EC), soil pH, and soil organic matter (OM) content (Table 4). The applied organic amendments varied in their effects on the soil salinity (EC) depending upon their type and the application level.

Applying the organic amendments showed increases in the soil EC values compared to the control soil. The EC of the soil increased with increasing the application level. These increases of soil EC could be resulted from the organic amendments salinity. Previous similar results were obtained by Chang *et al* (2007), Awad (2007) and Usman and Gameh (2008).

Application of organic amendments to the investigated soil had a negative significant effect on soil pH (Table 4). Moreover, the pH of the organic amendment treated soils decreased with increasing the level of organic amendment. In most cases the highest mean value (8.00) of the soil pH was observed for the soil treated with sheep manure. The lowest mean value (7.82) of the soil pH was found for the soil treated with filter mud cake.

Table (4). Effect of organic amendments and their levels on the soil chemical properties.

Treatment	Level (Kg/fed.)	EC (dS/m)	pH	OM (%)
Control	0	1.05±0.04	7.88±0.05	0.05±0.01
Potassium sulfate	25	1.11±0.03	7.98±0.03	0.09±0.02
	50	1.14±0.02	7.96±0.09	0.12±0.01
	100	1.16±0.02	7.94±0.03	0.13±0.02
Filter mud cake	25	1.18±0.03	7.91±0.02	0.13±0.01
	50	1.20±0.02	7.87±0.03	0.16±0.02
	100	1.26±0.02	7.82±0.02	0.19±0.02
Sheep manure	25	1.39±0.02	8.00±0.04	0.20±0.05
	50	1.41±0.03	7.97±0.03	0.30±0.02
	100	1.49±0.02	7.94±0.05	0.34±0.01
Poultry manure	25	1.31±0.02	7.93±0.02	0.40±0.03
	50	1.33±0.02	7.90±0.02	0.46±0.02
	100	1.41±0.02	7.85±0.04	0.54±0.03
$L.S.D._{0.05}$		0.04	0.06	0.05

These decreases in soil pH induced by the addition of organic amendments can be attributed to the acidic effect of decomposable products of organic materials (Natsher and Schwetrnmann, 1991). Production of organic acids and the release of H^+ ions during the decomposition of organic amendments in the soil result in a decrease the soil pH. As shown in Table 4, the organic amendments gave significant increases in the organic matter content of the studied soil compared either to control soil or to K_2SO_4 treatment. These results agree with other studies that applying the organic materials to soils improves the soil physicochemical properties of these soils (Arafat et al. 1992;

Gemtos et al., 1999; Usman and Gameh, 2008).

The organic matter content of the soil clearly increased with increasing the application level of the organic amendment. The highest increase in the organic matter content amended with the poultry manure were 45, 51 and 57% for the added level of 25, 50 and 100kg/fed, respectively. Poultry manure gives a higher soil organic matter content than other organic amendments. So, poultry manure may be used as an organic amendment to restore the degraded soils (Sanchez-Monedero et al., 2004).

Treatment Effects on Potassium Forms

The results showed that the addition of organic amendments caused increases in most soil K forms. Generally, the residual K (mineral K) was the dominant form followed by the non-exchangeable, the exchangeable and the water soluble K (Table 5). Potassium concentrations in the different soil forms significantly changed with increasing the applied level of K regardless the K source. As compared to the untreated soil, water-soluble, NH_4OAc-extractable, and HNO_3-extractable K forms significantly increased with increasing the application level of both organic amendments and potassium sulfate.

The sheep manure amended soil showed the highest increase in water-soluble, NH_4AOc-extractable, and HNO_3-extractable K forms. Moreover, these forms of potassium in poultry manure amended soil were also greater than in filter mud cake or K_2SO_4 -treated one. The NH_4OAc- extractable K in the control, K_2SO_4, filter mud cake, sheep manure and poultry manure treated soils at the highest level (100 kg/fed.) was 81.13, 136.51, 115.42, 167.73 and 149.57 mg/kg,respectively.

Table (5). Distribution of various K forms (mg/kg) in the soil treated with different organic amendments and potassium sulfate.

Treatment	Level	Soluble-K	NH_4OAc-K	Exch.K	1N HNO_3-K	Non-Exch.K	Residual-K
	Kg/fed	mg/kg					
Control	0	50.64	81.13	30.49	396.29	315.16	1121.16
Potassium sulfate	25	51.70	91.29	39.59	442.82	351.53	1061.03
	50	63.72	112.86	49.41	524.68	411.82	1008.55
	100	77.29	136.51	59.22	653.27	516.76	927.10
Filter mud cake	25	52.48	88.15	35.67	420.11	331.96	1056.37
	50	60.39	98.55	37.86	477.13	378.58	1029.43
	100	71.60	115.42	43.82	569.53	454.11	1002.65
Sheep manure	25	56.76	120.85	64.10	552.10	431.22	1060.93
	50	77.50	146.69	69.19	668.85	522.16	1040.90
	100	90.86	167.73	76.87	699.97	532.24	1051.38
Poultry manure	25	55.57	108.02	52.46	485.68	377.66	1069.94
	50	69.10	130.35	61.28	544.67	414.32	1033.97
	100	82.01	149.57	67.56	629.84	480.26	1022.64
L. S. $D._{0.05}$		1.12	3.38	3.65	6.83	5.72	8.18

The amounts of K extracted by 1N HNO_3 (K-supplying power) were 396.29, 653.27, 569.53, 699.97 and 629.24 mg/kg in the control, K_2SO_4, filter mud cake, sheep manure and poultry manure, respectively, treated soils at 100 kg/fed. It appears that there is a dynamic equilibrium between the non-exchangeable K and the other forms of soil K (soluble and exchangeable K). The non-exchangeable K significantly increased with increasing application level of both treatments (K_2SO_4, filter mud cake, sheep manure and poultry manure). However, some treatments gave significant decreases for the residual k (mineral k) compared to the control soil. The highest increases in the water-soluble and exchangeable K concentrations were found in the soil treated with sheep manure and poultry manure indicating that applying organic amendments may be the cause of increasing the soil available K. It has been reported that soil organic matter plays an important role in the redistribution of K among its various forms (Dhanorkar et al., 1994; Khamis, 2000; Bhattacharyya et al., 2006 and 2007; Usman and Gameh, 2008). The fixed K can be replaced under appropriate conditions, either by ion exchange, or by dissolution, particularly through the acidification. Hydrogen ions dissociated from the organic acids might be responsible for the K release (Singh and Goulding, 1997; Bhattacharyya et al., 2006).

Treatment Effects on Dry Matter Yield and K Uptake by Sorghum Plants.

The results in Table 6 showed the application effect of the investigated organic amendments on the dry matter yield of sorghum plants. The organic amendments added to the soil significantly increased the dry matter yield of sorghum plants compared to the control. This result indicates the beneficial effect of such amendments on improving the nutritional status and the productivity of soil.

Table (6): Dry matter yield, concentration and uptake of K by sorghum plants grown in the studied soil amended with chemical fertilizer and some organic amendments.

Treatment	Level (Kg/fed.)	Dry matter yield (g/pot)	Potassium Conc. (%)	Potassium Uptake (mg/pot)
Control	0	0.60	0.23	1.38
Potassium sulfate	25	0.66	0.25	1.64
	50	0.78	0.27	2.13
	100	0.97	0.33	3.24
Filter mud cake	25	0.75	0.40	2.99
	50	1.00	0.46	4.57
	100	1.18	0.52	6.12
Sheep manure	25	0.85	0.61	5.19
	50	1.16	0.67	7.75
	100	1.52	0.79	11.99
Poultry manure	25	0.77	0.56	4.27
	50	0.97	0.64	6.21
	100	1.33	0.72	9.64
L.S.D. $_{0.05}$		0.15	0.29	0.28

Addition of organic amendments could increase soil organic matter (SOM), moisture holding capacity, and concentrations of N, P, K, Cu, Zn, Fe and Mn that certainly promote the growth of plants (Deksissa et al., 2008). Arafat, (1994) and Arafat et al., (1992). The dry matter yield of sorghum plants was greater in sheep or poultry manure-amended soil than in the filter mud cake amended or K_2SO_4 treated one. These results also showed that the concentration of K and its uptake by sorghum shoots were significantly affected by the application of organic amendments and K_2SO_4 application (Table 6). It was observed that K recovery by sorghum culms increased with increasing the application level of organic amendments and mineral potassium fertilizer. Organic amendments -amended soils showed higher K uptake than the control soil or K_2SO_4 treated one. The results agree with the studies of Usman and Gameh (2008). Water-soluble, NH_4OAc-extractable, exchangeable and non-exchangeable K forms were significantly correlated at 0.01 (0.837, 0.915, 0.582 and 0.738, respectively) to the uptake of K by sorghum plants. The HNO_3-extractable K is correlated to K nutrition of sorghum plants. It showed a significant correlation at 0.01 (0.782) with K uptake.

Conclusion

The application of organic amendments had significant effect on some soil chemical properties, soil K availability and K forms. The greater effect on improving soil chemical properties, soil K availability and K forms was produced when sheep manure and poultry manures were used. Therefore, recycling of organic amendments may be suitable for improving the soil chemical properties and K status of light textured soils.

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تأثير الإضافات العضوية على خصائص التربة الكيميائية وتيسر البوتاسيوم لنباتات الذرة الرفيعة النامية على تربة رملية جيرية

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أجريت تجربة صوبة زراعية لتقييم تأثير إضافة السماد المعدنى (كبريتات البوتاسيوم) والأسمدة العضوية من (طينة المرشحات ' سماد الأغنام ' سماد الدواجن) على صور البوتاسيوم فى التربة ومدى تيسر البوتاسيوم لنبات الذرة الرفيعة النامية فى تربة رملية جيرية. أيضا تم تقدير الخصائص الكيميائية للتربة (درجة التوصيل الكهربى ' درجة حموضة التربة ' المحتوى من المادة العضوية) . تم إضافة المعاملات بكمية متكافئة من البوتاسيوم (K) عند مستويات (0 ' 25 ' 50 ' 100 كجم/ فدان).

أظهرت النتائج أن الإضافات العضوية للتربة الرملية الجيرية أثرت بوضوح على صور البوتاسيوم ودرجة تيسره لنبات الذرة الرفيعة. فقد أدى زيادة المستوى من التسميد المعدنى والأسمدة العضوية الى زيادة معنوية فى البوتاسيوم الذائب والمستخلص بـ NH_4OAc والمستخلص بـ HNO_3.

كما أدى إضافة سماد الأغنام إلى زيادة كبيرة فى صور البوتاسيوم وزيادة فى الكمية الممتصة بواسطة نباتات الذرة الرفيعة عن بقية المعاملات الأخرى. بينما أظهرت معاملتى سماد الأغنام وسماد الدواجن إنخفاضاً معنوياً فى درجة الحموضة وزيادة معنوية فى ملوحة التربة ومحتواها من المادة العضوية بزيادة مستوى الإضافة. لذلك ، فان إعادة تدوير الموادالعضوية قد تكون مناسبة لتحسين الخصائص الكيميائية للتربة وحالة البوتاسيوم فى الترب خفيفة القوام .