J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 2 (8): 861 - 870, 2011

ASSESSING THE ROLE SOME SOIL AMENDMENTS ON PHOSPHORUS AVAILABILITY UNDER CALCAREOUS SOIL CONDITIONS

El-Hadidi, E.M. ; A. A. Taha ; A. A. Mosa and Sally F. AboElezz
Soils Department, Faculty of Agriculture, Mansoura University

ABSTRACT

Laboratory and pot experiments were conducted at Soils Dept., Fac. of Agric., Mansoura Univ. during seasons of 2008 and 2009 to investigate the effect of some soil amendments on phosphorus availability, plant growth and nutritional status of faba bean and sorghum under calcareous soil conditions. The used experimental design was split plot design with three replicates. Compost, poultry manure and humic acid were arranged in main treatments at rates of 40, 10 Mg Fed^{-1} and 50 Kg Fed^{-1}, respectively. However, subtreatments were presented mineral amendments i.e. control, bentonite, vermiculite and sulfure at rates of 0, 10, 10 and 100 Kg Fed^{-1}, respectively. The obtained results indicated that soil addition of humic acid was superior for increasing the mean values of available P followed by poultry manure and finally the treatment of compost. Regarding the effect of soil mineral amendments, using of sulfur was more effective than other additives on increasing the mean values of available P under different forms of organic manure. The positive effect of humic acid on increasing available P in soil was reflected in increasing vegetative growth parameters and nutrients concentration in faba bean and sorghum plants. On the other hand, the mineral application of sulfur was more efficient than other mineral additives (bentonite and vermiculite) on stimulating vegetative growth parameters and increasing nutrients concentration in plant.

Keywords: Phosphorus, organic amendments, mineral amendments, calcareous soil, faba bean, sorghum.

INTRODUCTION

Phosphorus is an essential nutrient for plant growth and development. However, due to the highly reactive nature of phosphate anions, these may be immobilized through sorption and/or precipitation with cations such as Ca^{+2}, Mg^{+2}, Fe^{+2} and Al^{+3}. Application of phosphorus fertilizers in agricultural calcareous soils has introduced some problems. Mainly due to P fixation, low recovery and accumulation in soil. The low availability of P fertilizers is suggested to be a complex function of several factors such as: soil chemical composition, amount and reactivity of silicate clays, $CaCO_3$, Fe-oxides, P addition rates and time (Afif *et al*., 1993 and Kumar *et al*., 1999).

One of the most important strategies to increase P availability is to modify the soil properties by adding different organic and mineral amendments. Application of organic manures could participate in increasing soil organic matter content, particularly for the calcareous soils in Egypt, which have less than 1%. Therefore, improve its physical, chemical and biological properties. Phosphatase activity is expected to be enhanced by the application of various organic manures, which manifests in enhancing P availability in soil. The slow and continuous dissolution of phosphate minerals in soil by HS may have led to increase P availability in the root zone (Pal and Sengupta, 1985). Moreover, the improvement of phosphatase activity by humic acid may increase P availability as phosphatase hydrolyses the phosphate esters into inorganic phosphorus (Malcolm and Vaughan, 1979). In addition, the application of humic acid may have increased P availability by complexing ions into stable compounds, allowing the phosphorus ion to remain exchangeable for plant's uptake (Seyedbagheri, 2010).

Several reports demonstrated that application of poultry manure was associated with higher P availability. This could be due to the enhancement of phosphatase activity coupled with its higher P content and other soil chemical changes such as release of weak organic acids (Bahl and Singh, 1993, Toor and Bahl, 1997, El-Sherbiny, 2007 and Shipra and Bahl, 2008) have been reported to P availability in soils.

In the same context, compost became one of the most used manures in organic farming systems. Many suggestions have been made to explain how compost reduces the P adsorption capacity. One possibility is that the calcium, iron or aluminum combines with humic or organic acids released by the decomposition of organic matter, thereby reducing P adsorption (Barrow 1989). Another suggestion is that P adsorption sites become preoccupied by organic P, especially phytic acid (Chen 1996). It has also been suggested that adsorption sites may be preoccupied by inorganic P ions dissolved from organic fertilizer or released by the mineralization of organic P fractions (Chen 1996). A fourth explanation is that the surface charge on soil colloids is variable after compost has been applied, because of changes in the soil pH.

On the other hand, there are several inorganic additives proved to be efficient in increasing P availability under calcareous soil conditions. Recently, S-deficiency has become an increasing problem for agriculture, resulting in decreasing crop quality parameters and yield (Hawkesford, 2000). Attention has been paid for application of elemental sulfur to soil in order to correct its deficiency. Elemental sulfur is oxidized by soil microorganisms to sulfuric acid, which in turn lowers soil pH, improves soil structure and increases the availability of certain macro- and micronutrients (El-Shahawy, 2004).

Recent investigations indicate that clay minerals are not only important in cation exchange reactions in soils but they are perhaps a major factor in governing the availability of phosphate in many soils. Clay minerals (bentonite and vermiculite) have active adsorption sites, which may be able to adsorp phosphate ions against its precipitation.

The main aim of this experiment is to investigate the role of different organic amendments (compost, poultry manure and humic acid) and different mineral amendments (sulfur, bentonite and vermiculite) on phosphorus availability under calcareous soil conditions. Also, to study the role of these soil additives on vegetative growth parameters and nutritional status of faba bean and sorghum.

MATERIALS AND METHODS

Location of the experiment.

Laboratory and pot experiments were conducted at Soils Dept., Fac. of Agric., Mansoura Univ. during seasons of 2008 and 2009 to investigate the effect of different organic and mineral soil additives on phosphorus availability, plant growth and nutritional status of plants grown under calcareous soil conditions.

Soil sampling and analysis.

The soil used for this experiment was collected from the surface layer of a private farm Near El-Salheia District, El-Sharkeia Governorate. The collected samples were air-dried, ground, and passed through a 2-mm sieve. Particle size distribution for soil was carried out using the pipette method as described by Dewis and Fertias (1970). Soil field capacity was determined using the methods described by Richards (1954). Total carbonate was estimated according to Dewis and Fertias (1970). Soil reaction (pH) was measured in saturated soil paste as mentioned by Richards (1954). Total soluble salts were determined by measuring the electrical conductivity in the extraction of saturated soil paste in dS m^{-1} as explained by Jackson (1967). Available concentrations of nitrogen, phosphorus and potassium were extracted and determined as described by Hesse (1971). Available iron, zinc and manganese were extracted using DTPA method (Lindsay and Norvell, 1978), and measured using atomic absorption spectrophotometer PerkinElmer model 5000. Some physical and chemical properties of the experimental soil were presented in Table (1).

Table (1): Some physical and chemical properties of the experimental soil.

Physical analysis	Particle size distribution					S.P.%	OM%	$CaCo_3$%
	Coarse sand	Fine sand	Silt	Clay	Texture			
	23.8	48.2	19.4	8.6	Sandy loam	33	0.41	15.8
Chemical analysis	EC (1:5)	pH (1:2.5)	Available nutrient (mg kg^{-1})					
			N	P	K	Zn	Fe	Mn
	0.83	8.3	45	5.3	275	0.48	4.9	3.2

Organic residues analysis

Values of pH and EC were determined in 1:2 manure/water slurry as described by Peters *et al*., (2003). Organic carbon was determined by Walkley and Black method according to Hesse (1971). Total N was determined using macro-Kjeldahl method, as described by Peters *et al*., (2003). In order to determine the elemental concentration of organic residues, 0.5 g of each sample was digested using nitric acid, hydrochloric acid and hydrogen peroxide as described by Peters *et al*., (2003). Phosphorus was determined colorimetrically using spectrophotometer according to Jackson(1967). Potassium was determined using flame photometer as described by Black (1965). Chemical analysis of the used organic residues is presented in Table 2.

Table (2): Some chemical properties of organic residues.

Type of organic residues	OM%	C%	N%	C/N	P%	K%	pH	Ec dS m^{-1}
Compost	67.3	39.1	1.69	23.1	0.22	2.12	7.12	4.82
Poultry manure	55.7	32.4	1.93	16.8	0.29	2.43	6.45	3.75
Humic acid	58.2	33.8	2.39	14.1	0.19	3.47	7.74	0.92

Layout of the experimental treatments.

The used experimental design was split plot design with three replicates. Compost, poultry manure and humic acid were arranged in main treatments at rates of 40, 10 Mg Fed^{-1} and 50 Kg Fed^{-1}, respectively. However, subtreatments were presented mineral amendments i.e. control, bentonite, vermiculite and sulfur at rates of 0, 10, 10 and 100 Kg Fed^{-1}, respectively. Before sowing, Ca-superphosphate (15.5% P_2O_5) was mixed with the soil of each treatment at the rate of 200 Kg Fed^{-1}. All other Agricultural practices were carried out as recommended by the Ministry of Agriculture and Soil Reclamation.

The incubation and cultivation experiments.

Incubation experiment was conducted in plastic cups with perforated bottom fitted with filter paper and filled with 400 g soil mixed with different organic and mineral additives as mentioned before. These cups were saturated with water and incubated for 70 days at $32^oC\pm2$. Five samples were taken from the soil to determine available P. The First sample was taken after 10 days; however, other samples were taken at 15 days intervals. Available phosphorus concentration was determined as mentioned before.

Plastic pots (40 cm height and 30 cm diameter) were filled with 10 kg of soil. Different organic and mineral amendments were well incorporated with the soil before planting. Sorghum vulgare var. Saccharatum and Faba Bean cv. Giza 3 were sown on June 28 and December 16, 2008, respectively. Eight seeds from each plant were sown, thinned to the most uniform four plants. Plant samples were randomly taken from each treatment after 60 days from sowing and the vegetative growth parameters in expression of plant height(cm). fresh and dry weights $g.plant^{-1}$ were determined .Subsamples were digested with a mixture of H_2SO_4:$HClO_4$ (1:1) to measure N, P and K concentration (Peterburgski, 1968).

Statistical analysis.

All data were statistically analyzed according to the procedure outlined by Duncan (1955) using CoStat (Version 6.303, CoHort, USA, 1998-2004). Means of treatments were considered significantly when they were more than the least significant differences (LSD) at the confidence level of 5% according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The incubation experiment

Application of phosphorus fertilizers in calcareous soils has introduced some problems mainly due to P- fixation, low recovery and accumulation in soil. Information on the chemical forms of phosphorus is fundamental to understanding phosphorus dynamics and its interactions in calcareous soils that are necessary for management of P-fertilizers. The low availability of P is suggested to be a complex function of several factors such as: soil chemical composition, amount and reactivity of silicate clays, $CaCO_3$, Fe oxides, P addition rates and time (Bahl and Singh, 1993; Kumar *et al.,* 1999 and Shipra and Bahl, 2008).

Data presented in Table (3) revealed the effect of organic and mineral amendments on available P at different incubation periods. Concerning the effect of organic amendments, it could be observed that soil addition of humic acid was superior for increasing the mean values of available-P (252.3 mg Kg^{-1}) followed by poultry manure (228.5 mg Kg^{-1}) and finally compost (221.9 mg Kg^{-1}). Regarding the effect of mineral soil amendments, data in the same table proved that sulfur was most affective than the other amendments for increasing the mean values of available-P under different forms of organic amendments.

Table (3): Indicated the effect of incubation period on the availability of phosphorus as affected by the mixture of organic manures and some soil ammendments studied in calcareous soil.

Organic and mineral amendments		Incubation period (days)					Mean
		10	25	40	55	70	
Poultry manure	Control	221.6	229.4	241.2	232.3	217.9	228.5
	Bentonite	245.8	259.7	266.4	250.8	228.2	250.2
	Vermiculite	253.6	266.9	269.2	252.1	221.7	252.7
	Sulfur	269.2	281.3	293.4	297.3	262.8	280.8
Humic acid	Control	237.5	251.4	262.7	266.8	243.2	252.3
	Bentonite	260.9	276.5	285.3	270.7	255.4	269.8
	Vermiculite	258.3	269.2	281.6	258.8	239.6	261.5
	sulfur	274.8	295.9	312.4	281.3	272.6	287.4
Compost	Control	213.8	229.3	241.6	218.2	206.7	221.9
	Bentonite	225.3	233.7	245.2	212.6	203.3	224.0
	Vermiculite	223.4	239.8	251.3	218.4	205.6	227.7
	sulfur	236.9	255.5	268.9	260.3	231.2	250.6
Mean		243.4	257.4	268.3	251.6	232.4	

Data in Table 3 revealed that available phosphorus was increased as the period of incubation increased up to 40 days. However, the lowest values were recorded after 70 days from incubation. In this respect, the heights mean values of available P; 312.4, 293.4 and 268.9 mg Kg^{-1} were recorded for the treatments of HA + sulfur, poultry manure + sulfur and compost + sulfur, respectively.

Organic amendments have a positive role on increasing P availability through various mechanisms. Organic acids, which formed during the decay of organic residues inhibit the precipitation of hydroxyapatite (Inskeep and Silverthooth, 1988), and favor the formation of dicalcium phosphate dihydrate. On the other hand, high molecular weight organic acids are more effective inhibitors of hydroxyapatite precipitation than those of low molecular weight acids (Inskeep and Silverthooth, 1988). Thus, the addition of organic compounds such as humic and fulvic acids to soil may increase the efficiency of applied P fertilizer in calcareous soils by increasing the fraction of applied P that remains as highly soluble Ca phosphates (Fixen *et al*., 1983; Havlin and Westfall, 1984).

On the other hand, sulfur proved to be more efficient than other mineral amendments for increasing P availability in the calcareous soil. Beside its application as an important macronutrient, S is added as soil amendment for the purpose of reducing pH, and therefore increasing P availability to crops (Gabriel *et al*., 2008). The microbial oxidation of elemental S to SO_4 produces acidity, which reacts with the soil and reduces pH. This will lead to releases P bound to Ca and Fe minerals into soil solution. However, the buffering capacity of these calcareous soils is strong and can counteract the acidifying effects of S oxidation, thus effects of amendments are temporary and may need to be repeated each growing season (Beverly and Anderson 1986).

The cultivation experiment.

Plant growth parameters.

Data illustrated in Table (4) showed the effect of organic and mineral soil amendments and their interactions on the vegetative growth characteristics of faba bean and sorghum plants. As shown in table (4), the highest mean values of all plant growth parameters were realized due the addition of humic acid as soil application followed by poultry manure and compost, respectively. The difference between mean values of such traits was significant for the two plants under investigation.

Concerning mineral amendments, data in table (4) indicated that using of bentonite, vermiculite and sulfur as soil amendments led to a significant increase in all plant growth parameters of faba bean and sorghum plants as compared with the untreated plants. Meanwhile, the highest mean values of all the aforementioned traits were realized for the plants treated with sulfur.

The interaction affect between organic manures and soil amendments on plant growth parameters of faba bean and sorghum plants are presented in Table (4). It is cleared that; the most effective treatment on such traits was connected with the plants treated with humic acid alongside with sulfur application.

These results are confirmed with those obtained from the incubation experiment. Beside its vital role for increasing P availability, which mentioned before, humic acid have several effects on plant physiology. The chemical analysis of humic acid showed considerable amounts of plant nutrients. Also it has been demonstrated that humic acid could induce an increase in the root absorptive surface by affecting root morphology (Schmidt *et al*., 2007). Furthermore, recent studies indicate that HS could interact with root organic acid exudation, changing root area, primary root length, number of lateral roots and lateral root density (Canellas *et al*., 2008).

Regarding, the superiority of S as compared with other mineral amendments; it is well known its importance in plant nutrition as one of the most important macronutrients. This is beside its crucial role for changing the chemical properties of calcareous soil, even for a short time.

Table 4: Plant height (cm), fresh and dry weight (g/plant) in faba bean and sorgum plant as affected by P-fertilization, soil ammendments and their interactions during season 2008-2009.

Organic and mineral amendments		Plant height (cm)		Fresh weight (g /plant)		Dry weight (g /plant)	
		sorgum	Faba bean	sorgum	Faba bean	sorgum	Faba bean
Organic manures							
Poultry manure		68.3 b	43.00 b	45.55 b	21.51 b	8.35 b	2.28 b
Humic acid		72.3 a	45.55 a	48.20 a	22.76 a	8.84 a	2.41 a
Compost		62.4 c	39.28 c	41.59 c	19.73 c	7.62 c	2.08 c
L.S.D for 5%		**1.88**	**0.55**	**0.56**	**0.18**	**0.43**	**0.09**
Mineral Soil aoolitives							
Control		63.2 c	39.80 c	42.17 c	19.91 c	7.73 b	2.11 b
Bentonite		66.9 b	42.17 b	44.64 b	21.20 b	8.18 a	2.23 a
Vermoculite.		67.1 b	42.30 b	44.83 b	21.21 b	8.17 a	2.24 a
Sulfur		73.7 a	46.40 a	49.13 a	23.20 a	9.0142.6 a	2.46 a
L.S.D for 5%		**0.43**	**0.36**	**0.40**	**0.52**	**0.33**	**0.10**
A*B: interaction							
Poultry manure	**Control**	61.7 f	38.8 f	41.13 f	19.42 e	7.54 cd	2.06 de
	Bentonite	67.5 e	42.5 e	45.03 e	21.27 d	8.26 bc	2.25 cd
	Vermoculite	68.2 e	43.0 e	45.49 e	21.48 d	8.34 bc	2.27 cd
	Sulfur	75.8 b	47.7 b	50.54 b	23.87 ab	9.27 ab	2.53 ab
Humic acid	**Control**	68.1 e	42.9 e	45.42 e	21.45 d	8.33 bc	2.27 cd
	Bentonite	72.8 c	45.9 c	48.56 c	22.93 bc	8.90 abc	2.43 abc
	Vermoculite	70.6 d	44.5 d	47.07 d	22.23 cd	8.63 bc	2.35 bc
	Sulfur	77.6 a	48.9 a	51.73 a	24.43 a	9.48 a	2.59 a
Compost	**Control**	59.9 g	37.7 g	39.95 g	18.86 e	7.32 e	2.00 e
	Bentonite	60.5 g	38.1 fg	40.32 fg	19.04 e	7.39 e	2.02 de
	Vermoculite	61.5 f	38.7 f	40.99 f	19.35 e	7.51 de	2.05 de
	Sulfur	67.7e	42.6 e	45.11 e	21.30 e	8.27 cd	2.26 cd
L.S.D for 5%		**0.73**	**0.62**	**0.70**	**0.90**	**0.58**	**0.17**

The effect of organic and mineral amendments on N, P and K concentration in faba bean and sorghum is illustrated in Table 5. The same trend was also observed as humic acid was the superior organic source and sulfur was the superior mineral amendment.

Table 5: N, P and K% in faba bean and sorgum plant as affected by P-fertilization, soil ammendments and their interactions during season 2008-2009.

Organic and mineral amendments		N %		P %		K %	
		sorgum	Faba bean	sorgum	Faba bean	sorgum	Faba bean
Organic manures							
Poultry manure		3.15 b	3.44 b	0.364 b	0.409 b	2.69 b	2.79 b
Humic acid		3.33 a	3.64 a	0.386 a	0.432 a	2.85 a	2.96 a
Compost		2.87 c	3.15 c	0.333 c	0.373 c	2.46 c	2.56 c
L.S.D for 5%		**0.03**	**0.06**	**0.008**	**0.003**	**0.03**	**0.03**
Mineral soil aoditives							
Control		2.91 c	3.19 c	0.337 c	0.378c	2.49 c	2.59 c
Bentonite		3.08 b	3.37 b	0.357 b	0.401 b	2.64 b	2.74 b
Vermoculite.		3.09 b	3.38 b	0.358 b	0.402 b	2.64 b	2.75 b
Sulfur		3.39 a	3.71 a	0.393 a	0.441 a	2.90 a	3.02 a
L.S.D for 5%		**0.04**	**0.04**	**0.005**	**0.006**	**0.04**	**0.04**
A*B: interaction							
Poultry manure	**Control**	2.84 f	3.11 f	0.329 e	0.369 e	2.43 f	2.52 f
	Bentonite	3.11 e	3.40 e	0.360 d	0.404 d	2.66 e	2.76 e
	Vermoculite	3.14 e	3.44 e	0.364 d	0.408 d	2.68 e	2.79 e
	Sulfur	3.49 b	3.82 b	0.404 a	0.453 a	2.98 b	3.10 b
Humic acid	**Control**	3.13 e	3.43 e	0.363 d	0.407 d	2.68 e	2.79 e
	Bentonite	3.35 c	3.67 c	0.389 b	0.436 b	2.87 c	2.98 c
	Vermoculite	3.25 d	3.56 d	0.377 c	0.422 c	2.78 d	2.89 d
	Sulfur	3.57 a	3.91 a	0.414 a	0.464 a	3.05 a	3.18 a
Compost	**Control**	2.76 f	3.02 f	0.320 e	0.358 e	2.36 f	2.45 f
	Bentonite	2.78 f	3.05 f	0.323 e	0.362 e	2.38 f	2.48 f
	Vermoculite	2.83 f	3.10 f	0.328 e	0.368 e	2.42 f	2.52 f
	Sulfur	3.11 e	3.41 e	0.361 d	0.405 d	2.66 e	2.77 e
L.S.D for 5%		**0.08**	**0.06**	**0.009**	**0.011**	**0.06**	**0.07**

CONCLUSION

Results obtained from this study increased our knowledge concerning the efficacy of different organic and mineral amendments on the availability of P under calcareous soil conditions. Several reports attributed the instantaneous influx of P in calcareous soil to the plant root exudates. Therefore, we thought about the incubation experiment to discuss the effect of soil amendments solely without the effect of any other factor. The obtained results from the incubation experiment was confirmed with those of cultivation experiments. Based on results obtained from our study it could be concluded that application of humic acid at 50 Kg Fed^{-1} alongside with sulfur at 100 Kg Fed^{-1} is recommended to increase P availability under calcareous soil condition. This will lead to promote plant growth and yield and enhance nutritional status of plant.

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تقييم دور بعض محسنات التربة علي صلاحية الفسفور تحت ظروف التربة الجيرية

السيد محمود الحديدي, أحمد عبد القادر طه, أحمد علي موسي و سالي فادي أبو العز
قسم الأراضي – كلية الزراعة – جامعة المنصورة

أجريت تجربتي تحضين وأوعية بقسم الأراضي – كلية الزراعة – جامعة المنصورة خلال موسمي ٢٠٠٨ و٢٠٠٩ لدراسة تأثير بعض محسنات التربة علي صلاحية الفسفور ونمو النبات والحالة الغذائية لنباتي الفول والسورجم تحت ظروف الأراضي الجيرية. كان التصميم التجريبي المستخدم هو تصميم القطع المنشقة بثلاث مكررات. كانت المعاملات الرئيسية هي معاملات المحسنات العضوية وهي الكمبوست – سماد الدواجن – حمض الهيوميك بمدلات إضافة ٤٠و١٠ طن للفدان و ٥٠ كجم للفدان علي التوالي. بينما مثلت المعاملات الشقية صور المحسنات المعدنية وهي معاملة المقارنة – البنتونيت – الفيرموكيوليت والكبريت بمدلات إضافة صفر, ١٠, ١٠ و ١٠٠ كجم للفدان علي التوالي. أظهرت النتائج المتحصل عليها أن معاملة إضافة حمض الهيوميك كانت هي الأفضل في زيادة قيم الفسفور الصالح في التربة وتبعتها معاملة إضافة سماد الدواجن ثم أخيرا معاملة إضافة الكمبوست. فيما يتعلق بالإضافات الأرضية المعدنية اتضح أن معاملة إضافة الكبريت كانت أكثر تأثيرا بالمقارنة بباقي المعاملات لزيادة قيم الفسفور الصالح في التربة والذي انعكس علي زيادة النمو الخضري وتركيز العناصر في نباتي الفول والسورجم.
علي الجانب الاخر كانت معاملة إضافة الكبريت المعدنية أكفأ من المعاملات المعدنية الأخري (البنتونيت والفيرموكيوليت) في زيادة النمو الخضري وتركيز العناصر الغذائية للنبات.

قام بتحكيم البحث

أ.د / زكريا مسعد الصيرفى	**كلية الزراعة – جامعة المنصورة**
أ.د / جمال الدين عبد الخالق بدور	**مركز البحوث الزراعية**