SOIL ORGANIC CARBON AND PHOSPHORUS STATUS AFTER COMBINED APPLICATION OF PHOSPHATE ROCK AND ORGANIC MATERIALS IN A GYPSIFEROUS SOIL*

N. M. Muhawish R. K. Al-kafaje
Assis. Prof. Researcher
**Soil Sci. & Water Res. Dept., College of Agric., Tikrit Univ., Tikrit, IRAQ
noor_muhawish@yahoo.com

ABSTRACT

Gypsiferous soils in Iraq are suffering from low fertility due to low levels of organic matter and limited availability of nutrients especially phosphorus (P). Therefore, two experiments were conducted to study the impact of combination of low cost phosphate rock (PR) and organic materials (OM) on soil organic carbon (SOC) and P status. The first experiment was an incubation experiment which was conducted to determine level of organic carbon (OC) required for the second experiment, this experiment was consisted of two factors the first was level of OC (as sheep manure) applied at nine levels viz: 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, and 0.60% of soil weight, the second factor was level of PR (0, 20, 40, and 60 mg P kg^{-1} soil). The second experiment was a greenhouse pot experiment with two factors, the first was P source [Triple Super Phosphate (TSP), PR, PR+ Peat, and PR+ Manure), the second factor was P level (0, 30, 60, and 90 mg P kg^{-1} soil). Wheat (*Triticum aestivum*) was grown in the second experiment. Results from incubation experiment showed that increasing OC application increased available P (Avail. P) and Water Soluble P (WSP) as expressed by power and exponential models, respectively. Available P was also increased linearly by increasing P level in soil (incubation experiment). Results of pot experiment revealed that the fourth treatment (PR+manure) was significantly superior over other treatments in increasing root weight, organic P (OP), and Avail. P, while the third treatment (PR+Peat) was significantly superior over other treatments in increasing SOC.

Keywords: Available P, Gypsiferous soils, Manure, Organic P, Peat, PR, SOC, TSP, WSP.
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حالة كاربون التربة العضوي والفسفور بعد الأضافة المشتركة للصخر الفوسفاتي والمواد العضوية في تربة جبسية

نور الدين محمد مهاوش رغد قاسم الخفاجي
أستاذ مساعد باحث
قسم علوم التربة والموارد المائية – كلية الزراعة – جامعة تكريت
noor_muhawish@yahoo.com

المستخلص

تعاني الترب الجبسية في العراق من خصوبة متدنية بسبب المستويات المنخفضة من المادة العضوية والجاهزية المحدودة للمغذيات وخصوصاً الفسفور.لذلك فقد أجريت تجريتان لدراسة أثر الأضافة المشتركة للصخر الفوسفاتي واطيء الكلفة والمواد العضوية في حالة كاربون التربة العضوي والفسفور في التربة. التجربة الأولى كانت تجربة تحضين والتي أجريت لتحديد مستوى الكاربون العضوي المطلوب للتجربة الثانية، وتألفت هذه التجربة من عاملين الأول كان مستوى الكاربون العضوي (كمخلفات أغنام) أضيفت بتسعة مستويات هي: 0.2 و0.25 و0.3 و0.35 و0.4 و0.45 و0.5 و0.55 و0.6 % من وزن التربة، وكان العامل الثاني كان مستوى الصخر الفوسفاتي (0و 20و 40و 60 ملغم فسفور .كغم تربة$^{-1}$). التجربة الثانية كانت تجربة أصص بعاملين، الأول كان مصدر الفسفور (سوبر فوسفات الثلاثي، الصخر الفوسفاتي، الصخر الفوسفاتي + خث النبات، الصخر الفوسفاتي+ سماد حيواني)، وكان العامل الثاني مستوى الفسفور (0 و30 و60 و90 ملغم فسفور. كغم تربة $^{-1}$). زرعت الأصص بمحصول الحنطة في التجربة الثانية. بينت نتائج تجربة التحضين بأن زيادة إضافة الكاربون العضوي زادت من الفسفور الجاهز والفسفور الذائب بالماء كما عبر عنهما بموديلات القوى والأسي، على التوالي. وأزداد الفسفور الجاهز أيضاً خطياً بزيادة مستوى الفسفور في التربة (تجربة التحضين). أظهرت نتائج تجربة الأصص أن المعاملة الرابعة (صخر فوسفاتي + سماد حيواني) تفوقت معنوياً على المعاملات الأخرى في زيادة وزن الجذور، الفسفور العضوي، الفسفور الجاهز فيما تفوقت المعاملة الثالثة (صخر فوسفاتي + خث النبات) معنوياً على بقية المعاملات في زيادة كاربون التربة العضوي.

الكلمات المفتاحية: كاربون التربة العضوي، الصخر الفوسفاتي، الفسفور الجاهز، الفسفور الذائب بالماء، سماد حيواني، سوبر فوسفات الثلاثي.
*بحث مستل من رسالة ماجستير للباحث الثاني.

INTRODUCTION

Gypsiferous soils

Barzanji et al. (6) stated that gypsiferous soils are the soils which contain more than 3% of gypsum (dihydrated calcium sulfate $CaSO_4.2H_2O$) in effective root layers to affect plant growth. Gypsiferous soils are suffering from low fertility status due to low levels of organic matter; also, there is a deficiency in other available nutrients like nitrogen (28 mg kg^{-1}), potassium (113 mg kg-1) and micronutrients (2).

Carbon in soils

Soil organic carbon (SOC) as an index of soil fertility and a means for carbon sequestration, has attracted much attention over the past decades (20). High SOC usually results in high crop yield and biomass. Consequently, high biomass would lead to more organic carbon input into soils thus enhanced carbon storage as SOC. Hence, SOC management would provide benefits for both food security and mitigation (28). Organic amendments (e.g. straw incorporation and farmyard manure application) are recommended practices as substitute for mineral fertilizers and as extra nutrient inputs. Although organic amendments may have various effects (e.g. none or significantly positive, even negative effects) on crop yield (10), organic amendments have been proven to enhance soil carbon sequestration through direct inputs of organic carbon into soils. When organic amendments are added to the soil, a part of these is stabilized as SOC and distributed into different pools (7). Schlesinger (20) previously found that crop biomass or residue when returned to the land replenishes soil organic carbon (SOC) that typically has been reduced 30 to 50% of pre-cultivation levels. Majumder *et al.* (13) evaluated three organic amendments (FYM, Paddy straw, and green manure) along with inorganic fertilizer in a 19– yr rice– wheat cropping system in India, and found that cropping with only N-P-K plus organics increased SOC by 24.3% over the control. Patterns showing soil organic C decreasing with depth have been established for semi-arid ecosystems among other biomes (12), but rates of C accumulation in surface layers are less well known.

Organic matter and P status:

The addition of organic amendments could represent an important strategy to maintain soil fertility and several studies have been conducted on the protective effect of OM from different sources on P- insolubilization in soils. Braschi *et al.* (8) found that the percent Olsen –P in soil increased from 20% (for OM untreated soil 1.9%) to 53% (for OM treated soil 6.2%) of the initially applied amount of P. The combined addition of poultry manure and P –fertilizer to different soils caused a continuous increase in extractable P and kept P in available form for a longer period than P alone (25). Inputs of litter are greatest at the surface, and these residues contribute to organic C and associated P, which is mineralized to inorganic P (14). The role of organic phosphorus in soil is generally overlooked, mainly because in cultivated mineral soils the greater part of the total phosphorus is in inorganic form; it is therefore assumed that any contribution from organic phosphorus to phosphate uptake by plants is small in temperate regions. Moreover, application of P fertilizers results in the buildup of organic P in soils under pastures. For example, Ciampitti *et al*. (9) found that 82% to 100% of such fertilizer, added at the rate of 172 kg P ha^{-1}, was transformed into organic P under irrigated pastures by using a radiotracer technique, and it was observed that 40% of the P applied as superphosphate to the soil under pasture in subtropical environments appeared as organic P within 28 days of application.

P fertilizers effects on OM and P status:

Ciampitti et al. (9) found in a six– year cropping systems experiments that P fertilization increased total organic carbon (TOC) from 0.5 to 2.5 g C kg^{-1} and total P (TP) from 24.1 to 77.4 mg P kg^{-1} in the 0- 20 cm depth. The constraint of low phosphorus can be removed at least partly, by application of phosphate rock (PR). Phosphate rock, which is a slow release phosphate fertilizer, is cheaper than triple superphosphate (TSP) and has a longer residual effect and can be a source of P under certain conditions. The problem of phosphate rock is its low solubility, so various ways such us chemical, biological, and biochemical can enhance the solubility of PR, but these need to be properly evaluated (11, 27). Iraqi phosphate rock from Akashat mines proved some kind of efficiency in some Iraqi calcareous soils compared with TSP especially in combination with different organic materials where it enhanced yield and a buildup of soil phosphorus (16). However, limited information exists on the effect of organic matter applications and PR on organic C and P status in gypsiferous soils. Therefore, the objective of this study was to study the impact of combination of low cost phosphate rock (PR) and organic materials (OM) on soil organic carbon (SOC) and P status.

MATERIALS AND METHODS

Soils: soil samples were collected from the surface layer 0- 30 cm from soil department experimental field at the College of Agriculture– Tikrit University. The samples were mixed to form a composite sample, air dried, and crashed to pass through 4 mm sieve for incubation and cropping experiments and 2 mm for analyses which were conducted according to the standard methods as mentioned in Page et al. (18). Table 1 shows some physical and chemical properties of the soil.

Table 1. Some physical and chemical properties of the soil used in the study

Property	unit	value	Property	Unit	Value
Sand		520	Organic P	mg kg $^{-1}$	78.1
Silt	gm kg^{-1}	280	Available K	mg kg $^{-1}$	109.4
Clay		200	Soluble Ions		
Texture	-	S C L	Calcium	mmol L^{-1}	12.5
pH		7.30	Magnesium	mmol L^{-1}	5.0
EC	dS m^{-1}	2.50	Sodium	mmol L^{-1}	1.6
OM	gm kg^{-1}	7.64	Potasium	mmol L^{-1}	0.14
CEC	Cmol$_+$ kg^{-1} soil	9.39	Chloride	mmol L^{-1}	2.80
Gypsum	gm kg^{-1}	60.6	Sulfate	mmol L^{-1}	16.24
Lime	gm kg^{-1}	195	Carbonate	mmol L^{-1}	Nil
Available N		18.2	Bicarbonate	mmol L^{-1}	1.90
Bicarbonate extractable P (Available P)	mg kg^{-1}	5.8			
Water soluble P		0.1			

Incubation experiment:

Materials: PR was brought from Akashat which represent the Iraqi sole source of phosphate fertilizers (The State Enterprise of Phosphate) (Table 2), Sheep manure (from Animal production dept. field- College of Agric. –Tikrit Univ.) (Table 3). Treatments: (1) Organic carbon level (as sheep manure) was applied in nine levels namely: 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55 and 0.6 % of soil weight. (2) Phosphate rock was applied in four levels namely: 0, 20, 40, and 60 mg P kg $^{-1}$ soil. Procedure: This experiment was conducted to determine the right level of organic carbon (OC) required for the second experiment. A factorial experiment with two factors (level of OC and level of PR) was conducted according to RCBD in three replicates (48 experimental units). The experiment was conducted in the laboratory under room temperature (25° c ±7). One kilogram of soil was packed in plastic pots after being mixed with organic matter and P treatments. The moisture was maintained daily on the basis of field capacity using gravimetric method. The incubation continued for 60 days, and after completion of incubation, soil samples were taken, air dried, crashed to pass through 2 mm sieve and prepared for analyses. Available P (Olsen P) was determined by the method of Olsen et al. (17) as mentioned by Page et al.(18). Water soluble P was determined after extraction with distilled water at (1 soil : 10 water) ratio by the method mentioned in Page et al. (18) and the blue color was developed using ammonium molybdate and ascorbic acid. The P concentration was measured using spectrophotometer at 840 nm wavelength as mentioned in (18).

Table 2. Some chemical characteristics of phosphate rock used in the study

Characteristic	P_2O_5	P	CaO	Ca	CO_2
Unit			(%)		
Value	30	13	56 - 58	36	2.5

Analyses of the phosphate rock were made by The State Enterprise of Phosphate (Akashat).

Table 3. Some chemical characteristics of the organic materials used in the study

	N	P	C	C/N	C/P	EC	pH
Unit		(%)				dS m^{-1}	
Sheep manure	2.9	0.655	43.32	14.93	66.137	11.82	7.60
Peat moss	2.08	0.257	45.79	22.01	178.17	3.28	6.10

Cropping experiment: Materials: PR, Peat (Peat moss produced by Floragurad Co. – Germany), Sheep manure (from Animal production dept. field- College of Agric. – Tikrit Univ.) (Table 3) Treatments:

- Four sources of phosphorus namely: TSP, PR, PR + peat, PR+ manure. Peat and manure were applied on the basis of 6.0 g OC kg $^{-1}$ soil (0.6%).
- Four levels of P viz: 0, 30, 60, and 90 mg P kg-1 soil.

Procedure: In the light of the results obtained from incubation experiment through which the optimum level of OC to be applied was known (6 g OC kg^{-1}soil), this experiment was conducted in the greenhouse to evaluate efficiency of phosphorus source and accompanied organic material used through plant and soil characteristics (root weight, organic P (OP), and available P. A factorial experiment was conducted with two factors (source of P and level of P) in three replicates using randomized complete block (RCBD). Six kilograms of soil was packed in plastic pots. A similar application of N and K were applied to all experimental units. Nitrogen was applied as urea (46%N) with irrigation water at the rate 200 kg Nha-1 in two portions the first was at planting, while the second was applied after 45 days of planting. Potassium fertilizer was applied as potassium sulfate K_2SO_4 (41.5% K) at the rate 50 kg K at planting. The soil was mixed with P treatment and organic materials and then returned back to the pots. Irrigation was achieved daily using distilled water on the basis of field capacity using gravimetric method. 20 seeds of wheat (*Triticum aestivum* L.) variety Tamouz were planted in each pot. After germination the plants were thinned to 10. Before harvest water application was stopped and plants were harvested by taking the shoots and soil samples were taken for analyses. The soil with the roots was taken and placed on a sieve and after moistening them with water, a light stream of water was directed toward roots to extract the whole root system for each pot. Then all the roots were put in a paper bags and transferred to the oven to dry them at 70 °c (until constant weight), and weight of roots was taken. Available P in soil was determined as mentioned before. Organic P (OP) in soil was determined after soil combustion at 550 °c for 1 hr, then P was extracted by H_2SO_4 (0.5*M*) according to Page et al., (1982). The blue color method was developed using ammonium molybdate and ascorbic acid, and the measurement was done by spectrophotometer at 840 nm as mentioned by Page *et al.*, (18). Statistical analysis: Relationships between different parameters were plotted and linear regression coefficients for incubation experiment were assessed for OC vs. Available P, OC vs. WSP, and P applied vs. Available P. Correlation and regression analyses were done using SPSS software. The data of cropping experiment were statistically analyzed using analysis of variance (ANOVA) technique in randomized complete block design (RCBD) with three replicates (Steel & Torrie (1980).

RESULTS AND DISCUSION

Incubation experiment:

Effect of OC on available P: Organic materials application as sheep manure caused an increase in available P (Fig. 1). There was a positive polynomial relationship between org. C and available P. The trend of curves was similar for all P levels applied as phosphate rock (PR) (15).

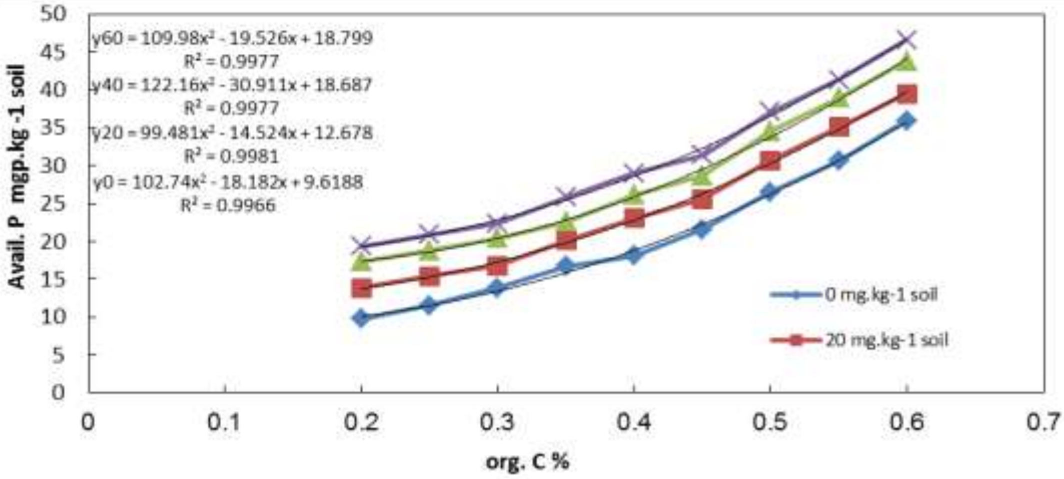

Fig.1 Effect of percent org.C application and four levels of P applied from PR (mgP. kg^{-1} soil) on concentration of available P (Olsen P) for incubation experiment

Available P was increased due to the increase in org. C which was attributed to the increase in moisture content retained which caused P solubilization from PR (3) which is also in agreement with Muhawish (16). The increase in available P may be due also to organic matter decomposition and releasing some organic acids which help in solubilizing P from PR, besides releasing P from OM. The level of P applied had a significant role in increasing available P and least values were recorded for zero application of P while the highest values were recorded for the treatment 60 (mg P kg^{-1} soil) which agreed with the results of Al-Dilaimi (1). The P levels were ranged in descending order as follows: 60>40 >20>0 mg P kg $^{-1}$ soil. Many researchers found that available P in soil decreased linearly with time upon application of P fertilizers (4, 15) when P was applied without OM but when the application was combined with OM the relationship turned to positive (3, 16) and the available P increased. Value ranges of available P were from 9.7 -35.9, 13.8 - 39.5 , 17.3 - 43.8 , 19.3 - 46.6 mg P kg^{-1} soil for P application treatments 0, 20, 40, and 60 mgP kg^{-1}soil, respectively. The effects of OC application on available P show that the 60 days period of incubation was enough to support a dense activity for the microorganisms to decompose OM which reflect itself on level of available P (5). The increase in available P by increasing OC application may be explained by the cumulative effect of OC applied on available P. These findings gaining a great importance in gypsiferous soils which is often poor in OM and many plant nutrients like P (26). The coefficients of determination reached 0.99, means that 99% of the variance between observed values of available P can be explained or interpreted on the basis of the relationship between organic C and available P in soil, which is considered as a proof on the great importance of the effect of OC on available P according to the polynomial regression.

Effect of OC on WSP:

The effect of sheep manure on water soluble P (WSP) in soil after 60 days of incubation is illustrated in Fig. 2. Increasing percentage of org. C caused an increase in WSP values and the relationship was best expressed as exponential relationship which demonstrates the action of microorganisms and their activity in decomposing organic materials (23). The increase in WSP may be due to the fact that increasing OM content increases the moisture content which triggered concentration of WSP and enhance PR dissolution.

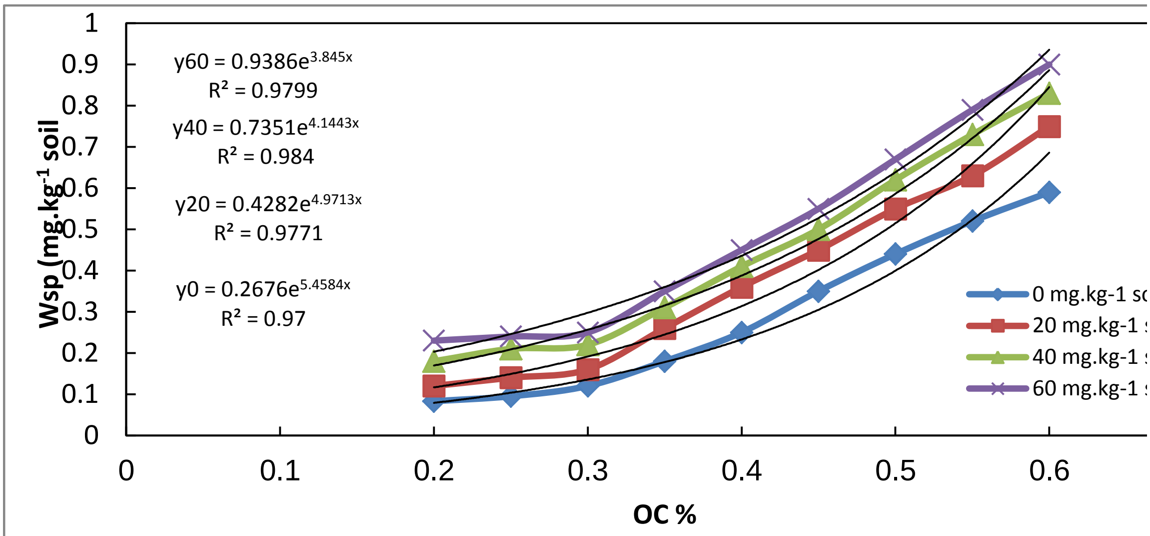

Fig.2 Effect of percent Org.C application and four levels of P applied from PR (mgP. kg-1 soil) on concentration of water soluble P (WSP)

There is also the action of microorganisms in releasing organic acids upon OM decomposition which have an acidifying effect on PR (11), besides, the release of P from organic materials (sheep manure) which contain a considerable amount of P (Table 3). The level of P applied played its role in increasing WSP significantly. The least values were recorded where no P was applied (0 mg P kg^{-1}soil) while the highest values were noticed for the 60 mg P kg^{-1}soil treatment. The P levels ranged in descending order with regard to their effect on WSP as follows: 60 > 40 > 20 > 0 mgP kg^{-1} soil. The coefficient of determination ranged from 0.97 to 0.98 means that 97% to 98% of the variance between observed values of WSP can be explained or interpreted on the basis of the relationship between OC content and WSP in soil and this is considered enough indication on the critical importance of the effect of OC on WSP according to the exponential regression. Values of WSP ranged from 0.1 – 0.6, 0.1 – 0.7, 0.1 -0.8, 0.2 –0.9 mg P kg-1 soil for P application treatments 0, 20, 40, and 60 mgP kg^{-1}soil, respectively. These results indicate a close relationship between org. C and WSP in soil and especially gypsiferous soils which suffer from many determinants (26) hindering P availability and its role in plant nutrition (24). Again, the increase in WSP for the zero P treatment is due to the initial content of P in OM (6.55 g kg^{-1}) as mentioned in Table 1, and the increase in WSP by increasing OC application may be explained through the cumulative content of OC applied and its effect on WSP.

Cropping experiment

Root weight: Results of Table 4 clarify the effect of source and level of P (mg P kg^{-1}soil) and organic material applied and the interaction between them on root weight of wheat grown in pots. The PR+Manure treatment with a value reached 9.51 g pot^{-1} was superior over the other.

Table 4. Effect of source and level of P applied (mg P kg^{-1} soil) and organic materials on root weight (g pot^{-1}) at the end of the experiment.

P source	P levels (mg P kg^{-1} soil)				
	0	30	60	90	Mean P source
TSP	5.10 f*	6.67 e	8.10 c	8.65 c	7.13 B*
PR	4.45 g	5.40 f	6.55 e	7.28 d	5.92 C
PR+ Peat	5.25 f	5.53 f	6.59 e	7.41 d	6.19 C
PR+ Manure	7.50 d	8.39 c	10.18 b	11.95 a	9.51 A
Mean P level	5.58 D	6.50 C	7.86 B	8.82 A	

***Means with the same letter did not differ significantly according to Duncan test. Each number represent mean of three replicates**

treatments followed by the treatment TSP then the two treatments PR+Peat and PR which did not differ significantly. Regarding the effect of P level, there was a significant effect on root weight which is in accord with Al-Kafaje (2012), where it is shown that increasing P level caused a significant increase in root weight and the percent increase in root weight reached 16.56, 40.90, and 58.30 % for P levels 30, 60, and 90 mg P kg^{-1}soil, respectively compared with the level 0 mg P kg^{-1}soil. The effect of interaction between P level and P source treatments with organic materials revealed that the PR+Manure at the P level 90 mg P kg^{-1} soil gave the highest values of root weight per pot which was 11.95 g pot^{-1}, while the PR at the level zero (control) gave the lowest value of root weight which was 4.45 g pot^{-1}. The reason behind the increase in root weight for the treatments and their interaction is due to the increase in available P in soil and P uptake by plants which increased metabolism and activity of root system (3). The reason may be due also to the role of P which contributes in development and division of the cells and help root growth and forming a strong and dense root growth with high efficiency in absorbing water and nutrients from different depths of soil. It is also noticed that PR+Manure with the level 30 mg P kg^{-1}soil gave nearly the same weight of roots as TSP at the level 90 mg P kg^{-1}soil, in a clear indication of the importance of OM application on P fertilizer use reasoning and increasing P availability (16) and some other characteristics which their effect was higher than the effect of TSP at the relatively higher levels and then affected plant growth characteristics and yield in this gypsiferous soil.

SOC after cropping:

Table 5 illustrates the effect of P level and source applied with organic materials and the interaction between them on level of org. C remained after cropping. In the mean P source it was noticed that that PR+Peat was significantly superior over the other treatments followed by PR+Manure then PR and TSP which did not differ significantly, The reason for the superiority of PR+Peat over PR+Manure is that the OM in Peat treatment was exposed to decomposition before application and the organic matter became more stable while the decomposition of manure took place after application and therefore some of the organic matter was lost upon decomposition which led to a higher content of OC in peat treatment compared with the manure although they were applied at the same rate of OC. Also, the initial OC content in peat was higher than manure and the ratio C/P was 3 folds (Table 3).

Table 5. Effect of source and level of P applied (mg P kg^{-1} soil) and organic materials on soil organic carbon (g kg^{-1} soil) at the end of the experiment

P source	P levels (mg P kg^{-1} soil)				
	0	30	60	90	Mean P source
TSP	5.01 ef	5.56 e	5.35 e	4.53 f	5.12 C
PR	4.18 ef	5.56 e	5.28 e	5.22 ef	5.22 C
PR+ Peat	11.19 a	9.96 bc	9.62 c	10.74 ab	10.37 A
PR+ Manure	8.17 d	7.76 d	8.10 d	7.59 d	8.05 B
Mean P level	7.30 A	7.21 A	7.09 A	7.16 A	

***Means with the same letter did not differ significantly according to Duncan test. Each number represent mean of three replicates.**

P levels did not affect org. C content significantly. The interaction treatments caused a significant effect on org. C where PR+Peat at the level 0 mg P kg^{-1}soil gave the highest value (11.19 g kg^{-1}soil) which may be attributed to the fact that this treatment was characterized with the less values in growth and yield characteristics (4) and also in its effect on WSP and available P. Therefore, and due to the stability of these plant residues the residual of organic matter was more than the other treatments especially the manure treatment. While the TSP at the level 90 mg P kg^{-1} soil gave the lowest effect with a value reached 7.81 g kg^{-1} which may be explained by the gypsiferous soils being suffered from a shortage in OM and the treatment TSP has no accompanied OM. It is well known that increasing OC content acquires a special importance in gypsiferous soils poor in OM. The advantages of increasing SOC in gypsiferous soils include increasing CEC, increasing natural chelation characteristics for nutrient elements, improving nutrient balance and improving physical characteristics of gypsiferous soils which suffer from problems related to soil structure and water movement (26).

Organic P after cropping: Organic P is one of the important indicators of P status in soil

(24) especially in gypsiferous soils which suffer from problems related to plant nutrition or nutritional balance in soil solution among which are low level CEC, low content of OM, high content of calcium in soil solution. Table 6 illustrate the effect of P level and source applied with organic material and the interaction between them on OP content in soil after cropping.

Table 6. Effect of source and level of P applied (mg P kg^{-1} soil) and organic materials on organic P (mg P kg^{-1}soil) at the end of the experiment.

P source	P levels (mg P kg^{-1} soil)				
	0	30	60	90	Mean P source
TSP	79.0 k	105.0 j	115.6 i	127.3 h	106.8 D
PR	80.4 k	117.6 i	131.6 g	142.4 f	118.0 C
PR+ Peat	104.5 j	112.0 i	147.5 f	171.2 d	133.8 B
PR+ Manure	164.5 e	207.5 c	220.9 b	241.0 a	208.5 A
Mean P level	107.1 D	135.5 C	153.9 B	170.5 A	

***Means with the same letter did not differ significantly according to Duncan test. Each number represent mean of three replicates**

It was noticed in the mean P source that the treatment PR+Manure was significantly superior over other treatments followed by PR+Peat, PR, and then TSP with values reached 208.5, 133.8, 118.0, and 106.8 mg P kg^{-1}soil for each, respectively. The superiority of PR+Manure and PR+Peat over other treatments in organic P was attributed to the fact that applying OM as manure or peat increase percent SOM which means increasing of organic P in soil (21). Besides, these organic materials contain 0.655 and 0.257% of P as a total content (Table 3). P levels applied had a significant effect on organic P content, the level 0 mg P kg-1soil gave the least value 10.7.1 mg P kg^{-1}soil while the level 90 mgPkg^{-1}soil gave the highest value 170.5 mg P kg^{-1}soil with a percent increase reached 26.5, 43.7, and 59.2% for the levels 30, 60, and 90 mg P kg-1 soil, respectively, compared with the level 0 mg P kg^{-1}soil. There was also a significant effect for the interaction between source and level factors on organic P, where the treatment PR+Manure at the level 90 mg P kg^{-1}soil gave the highest value which was 241.0 mg P kg^{1}soil, while the treatments TSP and PR at the level 0 (mg P kg^{-1}soil) (control) gave the least significant effect with values reached 79.0 and 80.4 mg P kg^{-1}soil, respectively, and they did not differ significantly. It was observed that the animal organic treatment (PR+Manure) at the level 0 (mg P kg^{-1}soil) gave the value 164.5 which was highest than the highest level of TSP treatment at the level 90 mg P kg^{-1} soil which was 127.3 mg P kg^{-1}soil with a high significant difference. This result is considered very important for gypsiferous soils with low content of organic P. Therefore application of organic materials to these soils increases content of both organic and mineral P in these soils which is in agreement with Muhawish (16).

Available P after cropping:

Phosphorus source and level applied had their effect on available P in soil (Fig. 3). It was noticed that the treatment PR+Manure was superior over other treatments in avail. P content remained in soil. The superiority of PR+Manure can be explained by the rate of decomposition of animal residue which was faster and have the ability of releasing arganic acids which tend to reduce soil pH on one hand, from the other hand the manure forms chelating organo-phosphate complexes (23) which prevent P precipitation and decreasing surface area exposed to applied phosphate, in other words organic manure increased avail. P, this increase is due to OM role in increasing heterotrophic bacteria and fungi population and then increasing types and concentration of organic acids which in turn increased solubilization of PR and availability of PR, besides the decomposition of OM release CO_2 and ammonia, the first transferred (with water) to carbonic acid and the second oxidized with nitrification bacteria to produce nitric acid, these two acids contribute also in PR solubilization, moreover the organic manure itself contains P (Table 3).

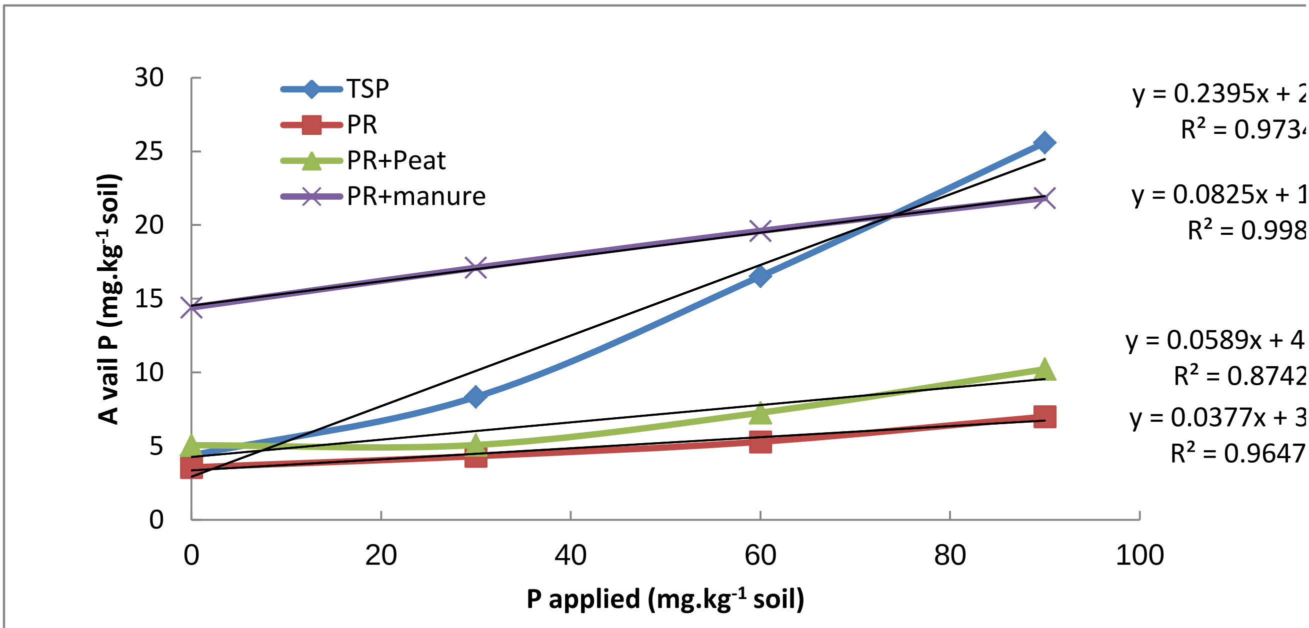

Fig.3 Effect of P source and level applied (mgP kg^{-1}soil) and organic materials

The slight increase in avail.P from PR (compared with control) was due to the fact that PR contains P which was not available but root exudates and the accompanied OM and its decomposition led to P solubilization and release of a little amount of avail. P. These findings refer to the importance of PR in availability and the possibility of using it as a P source if it applied with decomposed or no decomposed OM. P levels enhance a large effect on avail. P, the level 0 mg P kg-1soil gave the least values for each source while the level 90 mg P kg^{-1}soil gave the highest values for each source. The reason for the difference in avail. P values may be due to the difference in solubility and P release of these sources, besides the effect of of organic sources which were mixed with PR and their effect on avail. P release which caused a better availability for plant especially the animal manure which reflect itself on many parameters of plant growth, straw yield, grain yield, and total P uptake (3) which were better than TSP, was the reason for the less values of residual P (avail. P) after harvest for PR+Manure treatment compared with TSP at the level 90 mg P kg^{-1}soil. The relationship between P applied and available P was best expressed as a linear relationship with high to very high coefficient of determination ranged between 0.87 – 0.99 which means that 87% - 99% of the variance between observed values of Avail. P can be explained or interpreted on the basis of the relationship between applied P and avail. P according to the linear regression (Steel & Torri, 1980). It was noticed also that after the value 70 (mg P kg^{-1}soil) of P applied there was an overthrow in the curves of TSP and PR+Manure, where the TSP was superior with a value reached 25.59 (mgP kg^{-1}soil) compared with PR+Manure (21.83 mgP kg^{-1}soil) meaning that the power of TSP to release P was beyond that of microorganisms to release P from PR or manure. Table 7 shows the effect of P level and source (with organic materials) and the interaction between them on available P content (residual) after cropping. It was found that that the treatment PR+Manure was significantly superior over other treatments in available P content remained in soil after cropping followed by TSP, PR+Peat, and finally PR with values reached 18.36, 13.70, 6.91, and 5.05 mg P kg^{-1}soil, respectively. The reason for this superiority was mentioned earlier. P levels differed significantly with the highest value reached by the level 90 mg P kg^{-1}soil which was 16.16 mg P kg^{-1}soil and the lowest value for the level 0 mg P kg^{-1}soil which was 6.97 mg P kg^{-1}soil. The percent increase in avail. P with increased level of P were 24.9, 74.5, and 131.7 % for the levels 30, 60, and 90 mg P kg^{-1}soil, respectively compared with the level 0 mg P kg^{-1}soil (control). The increase in P availability with increased application was attributed to the increase in P content applied from TSP (1) and the effect of organic materials on P solubilization which led to the increase in the residual amount of avail. P in soil and it may be due to application of high amount of PR (insoluble in water) which has low solubility in soil solution because of the high content of carbonate minerals and gypsum and the high pH, but application of organic materials to PR improved the effect of PR. So, the main effect of P level came from the treatments which receive organic materials and TSP (Table 7) in other words the average for the effect of P levels came from the effect of interactive treatments (22).

Table 7. Effect of source and level of P applied (mg P kg^{-1} soil) and organic materials on available P (mg P kg^{-1}soil) at the end of the experiment.

P source	P levels (mg P kg^{-1} soil)				
	0	30	60	90	Mean P source
TSP	4.37 j	8.34 h	16.52 e	25.59 a	13.70 B
PR	3.56 k	4.32 j	5.30 i	7.00 h	5.05 D
PR+ Peat	5.06 i	5.08 i	7.27 h	10.22 g	6.91 C
PR+ Manure	14.91 f	17.10 d	19.60 c	21.83 b	18.36 A
Mean P level	6.97 D	8.71 C	12.17 B	16.16 A	

***Means with the same letter did not differ significantly according to Duncan test. Each number represent mean of three replicates**

The effect of interaction was significant and indicates that TSP at the level 90 mg Pkg-1soil achieved the highest value of avail. P (25.59 mg P kg^{-1}soil) with a significant difference while the lowest value was achieved by the treatment PR at the level 0 mg Pkg^{-1}soil which was 3.56 mg Pkg-1soil. The treatment PR+Manure was superior also at all levels of P applied over other treatments except TSP at the level 90, where it was superior at the levels 0, 30, and 60 mg P kg^{-1}soil even over TSP at these levels. Therefore, it can be concluded that Phosphate Rock (PR) proved to be a good and cost effective source of P if it combined with organic materials. This study proved that there was a double benefit for PR application with organic materials in gypsiferous soils; these are improving OC and P status for these soils.

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