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The Effect of Organic Matter Application on Phosphorus Status in the Calcareous Soil

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Abstract:

A field experiment is conducted to study the effect of different levels of peat (0, 25, 50, 75, and 100 Mg ha^{-1} to uncropped and cropped soil to wheat. Soil samples are taken in different period of time (0, 3, 30, 60, 90, 120, and 180 days after cultivation to determine ($NaHCO_3$-Exteractable P at 3 different depths (0-10, 10-20, and 20-30 cm). Field Experiment is conducted in a randomized complete block design (RCBD) with four replicates. Wheat, Al-Rasheed variety, is cultivated as a testing crop. The entire field is equally dived in two divisions. One of the two divisions is cultivated to wheat and the second is left uncropped. The effect of five levels of peat namely 0, 25, 50, 75, 100 Mg ha^{-1} is investigated. Soils are fully analyzed to determine its physical and chemical characteristics. The soil samples are collected after 3, 30, 60, 90, 120, and 180 days for determining essential parameters and indicators that reflect the effect of the level of peat applications. Sodium bicarbonate - extractable P in uncropped and cropped soils at all depths, markedly decreases with time after peat application which has been attributed to plant uptake and rapid reaction of P with soil constituents. Sodium bicarbonate - extractable P with time in soil receiving 50 Mg ha^{-1} in both uncropped and cropped soil linearly decreases with the time of cultivation.

Key words: Compost, Addition levels, Time of addition, ($NaHCO_3$) extractable phosphorus, Soil depth, Cropped soil, Uncropped soil.

Introduction:

Phosphorus, compared with other essential nutrients, is the least mobile and least available to plants under most soil conditions [1]. Phosphorus exists in soil solution at little concentrations of overall soils; however it is supplied as a soluble fertilizer, because of complexion via soil minerals (i.e. positive charge) [2]. Accordingly, Phosphorus frequently becomes a major limiting factor for plant growth.

Many studies indicate that Phosphorus availability to plants in soils is improved by applications of organic matter through several mechanisms [3, 4, 5, and 6]. However, the applications of organic matter to soils may increase phosphate availability via decomposition and mineralization of organic phosphorus, or by abiotic processes, for instance ligand-exchange effects on phosphate sorption [7]. Furthermore, humic compounds from organic matter decomposition are capable of complexing with Fe, Al, and to a lesser degree Ca to adsorb Phosphate [8] possibly via the formation of ternary compounds [9].

Mixing of organic residue with high phosphorus-fixing mineral soil will result in more organic phosphorus remaining as available form in soil solution for plant use compared to that in uncultivated mineral soil [10]. This influence would be in applications to the increased decomposition and release of phosphorus that is a well-known effect of cultivation. When organic residues are added to soils, the dissolution from precipitated Phosphate (with Ca, Al, and Fe) will be possible [11], and subsequently can make phosphorus more available. Since organic residues decompose, soluble phosphate is released and this can become adsorbed to oxide surfaces [12]. However, dissolution of solid phases depends on organic acids such as citrate and formic acids which acts as H^+ source [13].

Accordingly, Organic matter affects nutrient availability for plants either directly or indirectly. Organic matter mineralization is the direct effect which will result in releasing nutrients which are going to be available to plants, like nitrogen [14], a manner which also supplies phosphorus [14] and Sulfur [15, 16]. Indirect effect of organic matter is the contribution to the mineral nutrition of plants in soils through combination of nitrogen and sulfur into humic materials during decomposition or by complexation of calcium (Ca), Al, and Fe from their particular phosphates by humic materials to increase concentrations of soluble phosphate [3].

Organic acids, particularly low molecular weight, show an essential role in soil phosphorus mobilization [17, 18, and 19]. There are many mechanisms for plant to acclimate the deficiency of phosphorus in soil, one of these is the exudation of organic acid from plant root [20, 21, 22, and 23], then mobilizing of unavailable soil phosphorus [24]. These organic acids dissolve phosphoric minerals via lowering the pH of soil, or chelate cationic such as Ca, Al and Fe of the phosphate ions and directly release phosphorus into the soil solution [25].

Studies on the influence of organic acids on phosphate sorption indicate that organic acids (citrate, oxalate, polygalacturonate, and malate) decrease phosphate sorption by oxides of Fe and Al, kaolinite in the soil [26, 27, and 28]. On the other hand, organic matter and phosphate anions can compete for A1 and Fe binding sites, the phosphate sorption capacity will be reduced. Anions of organic acids such as citrate, oxalate, phytate, tartrate, malate, malonate [29, 30, 27, and 28] and fulvic acids [31] have been revealed to inhibit organic phosphorus sorption predominantly by competing for sorption sites or complexing organic phosphorus. Organic materials containing carboxylic or phenolic functional groups can bind to oxide surfaces, and then reduce the number of sites available for sorption of inorganic anions.

The displacement of orthophosphate ion with organic ligands or anions is another process responsible for the release of Phosphorus from organic matter added to soil. These organic ligands are from plant residues having the important metabolites di- and tri-carboxylic acids, for instance oxalic, oxalo-acetic, malic, fumaric, succinic, c-cetoqlutaric, isocitric, and citric acids [1].

Furthermore, the organic ligands not only compete with phosphate for sorption sites [32], but also reduce the amount of Al and Fe-phosphates in soils [11]. Moreover, numerous organic ligands such as aromatic hydroxy acids and aliphatic hydroxy acids are effective in preventing phosphates from combining chemically with Al and Fe or in the displacement of phosphate [33, 11].

Therefore, the current study is conducted to determine effect of various levels, of well decomposed organic matter, and period of cultivation on status of phosphate in calcareous soils of Iraq.

Material and Methods:

This experiment is established in December, 04, 2014 at Al-Tuwaitha farms of Soil and Water Resources center, which locates 18 km South East of Baghdad, Iraq. The experimental design is arranged in a randomized complete block design (RCBD) with four replicates. Al- Rasheed wheat crop variety is sown manually to the field at a rate of 100 Kg ha^{-1} wheat seeds in December, 04, 2014 and it is harvested on June 2015.

Four levels of OM (25, 50, 75, 100 Mg ha^{-1}) are applied to four randomly assigned replicate plots, each plot with area of (2 x 2) m^2 in dimension. A further four plots served as control plots and received no compost. The experiment, therefore, consists of 40 plots, 20 of which (5 treatment levels × 4 replicates) are uncropped and 20 plots are cropped to Al-Rasheed. The mineral fertilizers of N and P are added to the soil according to the recommendations usually assigned for wheat in such soil in rate of 200 kg N ha^{-1} and 100 kg P ha^{-1}, respectively.

Soil samples are collected before planting of wheat-crop on December 2014, therefore, sampling is repeated by lord sampler after 3, 30, 60, 90, 120, and 180 days of planting at the depths 0-10, 10-20, and 20-30 cm. The soil samples of each plot are collected and mixed to ensure the homogeneity in one main sample for each depth. Soil samples of each plot are air dried, mixed, rolled via mortar, screened through a 2 mm opining sieve. The soil particle size is carried out via the hydrometer method utilizing sodium hexametaphosphate, and then the soil texture is based on the ratio of soil particles (clay, silt, sand). Soil chemical properties such as EC, pH, cations and anions are determined in 1:1 weight/volume soil – water suspension utilizing EC and pH meters [34, 35]. The measurement of total soil organic carbon is established by multi EA 2000 analyzer equipped with software (multiwin) version 3.06.

Measurement of sodium bicarbonate extractable phosphate is carried out by shaking five grams of soil sample with 100 ml of sodium bicarbonate (0.5 *M*) for 1 hour period; and the pH of this solution is adjusted to 8.5. Therefore, Phosphate concentration is determined, in ten mL of soil extract, calorimetrically with the blue color method described by [36] at 860 nm using spectrophotometer (SPECORD 205) equipped with software (winASPECT) verstion 2.0.

Results and Discussion:

Soil Characterization:

Soil of the field is silt clay loam textured class which is considered as heavy textured soils. Calcium carbonate content is 25.0% and the pH of soil is 7.41. Consequently, field use in the study is of a typical calcareous soil of the arid region. The results in (Table 1) show that EC increases with the increase of OM applications being the least 1.63 dS m^{-1} at 0 Mg OM ha^{-1} and being the highest 2.05 dS m^{-1} at 100 Mg OM ha^{-1} applications. Substantial increase in EC and cations with the increase of levels of peat application may be attributed to natural content of peat of salts and various cations. The rapid liberation of cations and anions from the well decomposed peat added to soils may indicate that this peat material is easily decomposed organic matter. Furthermore, the soil is of 0.8% organic matter content (Table 1) at zero Mg ha^{-1} level which increase with the increase of peat levels, since, it attends to 1.9% at 100 Mg ha^{-1}, while CEC values being 17.5 and attend up to 21.6 cmol$_C$ kg^{-1}, respectively. A similar trend has been found with total phosphorus after application of different peat levels.

Table (1): Characterization of Soil

	Compost Addition Levels (Mg ha^{-1})				
	0	**25**	**50**	**75**	**100**
	Water soluble at ratio 1 : 1 Soil : Water				
EC (dS m^{-1})	1.63	1.71	1.80	1.94	2.05
pH	7.41	7.55	7.38	7.42	7.38
Na^{1+} (mg L^{-1})	73.70	65.66	55.17	105.82	97.63
K^{1+} (mg L^{-1})	15.35	19.38	23.94	29.85	35.87
Ca^{2+} (mg L^{-1})	136.80	140.65	108.25	78.45	114.15
Mg^{2+} (mg L^{-1})	46.69	48.48	51.08	53.41	57.65
Cl^{1-} (mg L^{-1})	214.32	249.03	275.98	297.31	328.96
SO$_4^{2-}$ (mg L^{-1})	501.47	539.01	604.99	737.05	618.60
-------------------- Total Elemental Analysis ---------------					
N %	0.414	0.426	0.364	0.493	0.577
P %	0.063	0.066	0.068	0.070	0.072
O.C %	0.303	0.449	0.667	0.788	0.871
OM %	0.895	1.158	1.551	1.769	1.917
CEC (cmol$_c$ kg^{-1})	17.53	20.48	20.13	21.15	21.68

Peat Characterization:

Total elemental analysis of added peat is given in (Table 2), which indicates that the peat used in this study is of high cations and trace elements content. That may explain the tremendous increase in the cations and trace elements with the increase of level of peat added to soil.

Table (2): Characteristics of Peat Used

Total elemental analysis		**Water soluble (Mmol kg^{-1}) at ratio (1:5)**	
Na (mg kg^{-1})	2259	**Na^{1+}**	47.79
K (mg kg^{-1})	8072	**K^{1+}**	85.75
Ca (mg kg^{-1})	63350	**Ca^{2+}**	32.43
Mg (mg kg^{-1})	13138	**Mg^{2+}**	20.46
Zn (mg kg-1)	196	**EC dS m^{-1}**	1.75
Cu (mg kg^{-1})	55	**pH**	7.16
Fe (mg kg^{-1})	3396		
Mn (mg kg^{-1})	299		
N %	1.63		
P %	0.48		
O.C %	20.0		
OM %	36.4		
C : N Ratio	12.3		

Effect of Peat Levels Application on NaHCO$_3$ Extractable P:

Effect of peat levels application on NaHCO$_3$ extractable P is shown in Figure 1 (a, b) for cropped and uncropped soils three days after application, respectively. Obviously, for both cases extractable P is of cubic equation shape at soil depths of 0-10, 10-20 and 20-30 cm. This may be explained on the basis that the level of extractable P at 0 level of peat application is low and it increases with the increase of peat application to soil. Accordingly, one may conclude that extractable P may increase significantly with the increase of peat application [7]. The greatest extractable P at all levels of peat applications is at 0-10 cm depth and the least is at 20-30 cm depth as indicated by the location of the curves for the cropped and uncropped soils. The data in both cases are best fitted to cubic equation. Equations of 3 depths are similar to high significant regression coefficient. It is clear that extractable P is a function of the cubic of amount of peat added under uncropped soil and cropped soil, this result agree with [10].

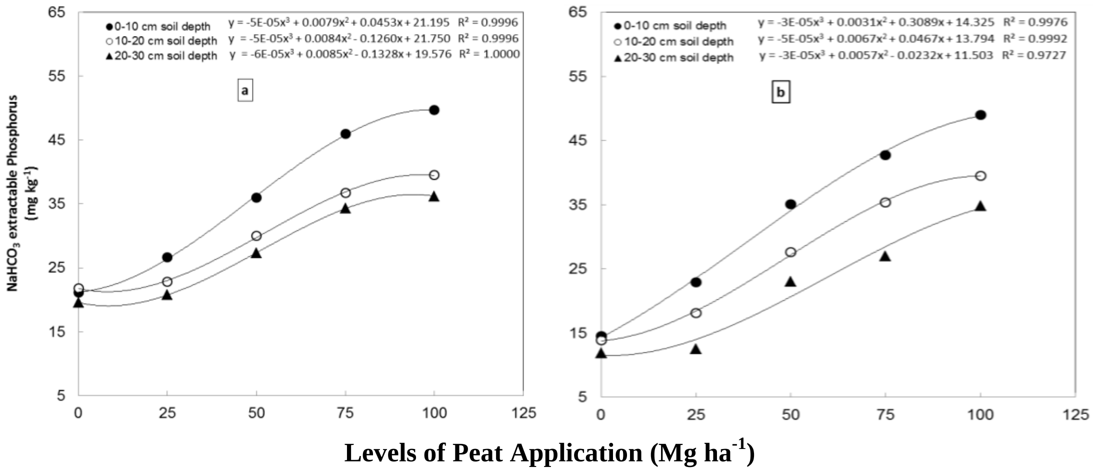

Fig.(1): Effect of Levels of Organic Matter Applications to Soil on $NaHCO_3$ Extractable Phosphorus Three Days after Application to (a) Uncropped and (b) Cropped Soil.

Figure 2 shows the extractable P for cropped and uncropped soil 30 days after peat application. Extractable P in cropped soil at 10-20 cm depth is very close to that at 20-30 cm depth. However, extractable P at 0-10 cm depth is higher than those other two depths as indicated by the location of the curve.

Data in both cases (cropped and uncropped soil) are best fitted to cubic equations of 4 parameters. Under uncropped soil extractable P after one month of application is the greatest at 0-10 cm depth and the least is at 20-30 cm depth. Extractable P 90 days after application under cropped and uncropped soils is given in Figure 3 (a, b) respectively. Apparently, extractable P at all depths for cropped soil is markedly reduced compared to that at 3 days and after 30 days after application. This may be attributed to plant uptake and rapid reaction of P with soil constituents, which renders the phosphate less extractable by $NaHCO_3$. After five months of peat application $NaHCO_3$ -P (Figure 4) is in the same trend as the previous period being the greatest at 0-10 cm depth and to decrease with depth. The data are also best fitted to cubic equation with significant regression coefficients under cropped and uncropped soil, these results agree with [10].

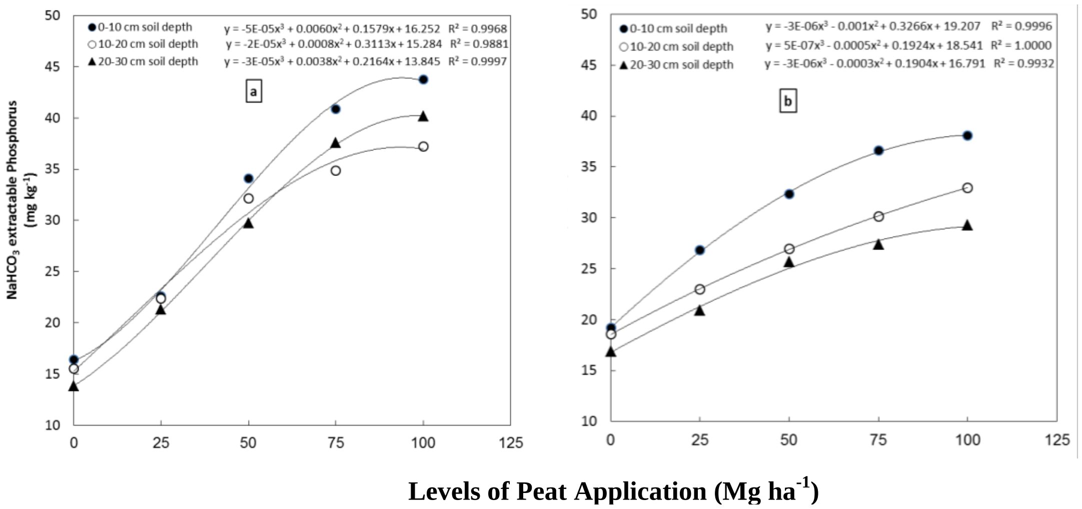

Fig. (2): Effect of Levels of Organic Matter Applications to Soil on Extractable P 30 Days after Application to (a) Uncropped and (b) Cropped Soil.

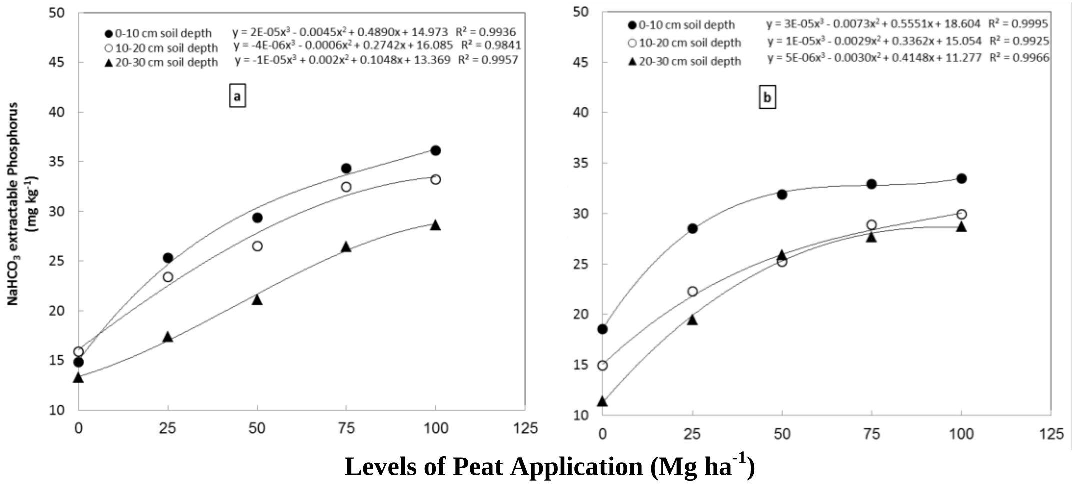

Fig. (3): Effect of Levels of Organic Matter Applications to Soil on Extractable P 90 Days after Application to (a) Uncropped and (b) Cropped soil.

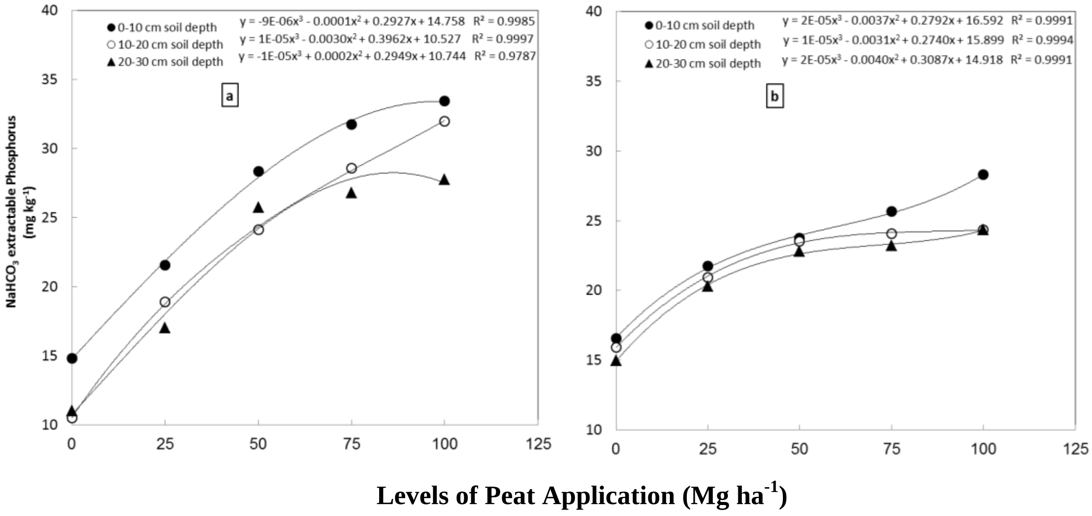

Fig.(4): Effect of Levels of Organic Matter Applications to Soil on Extractable P 150 Days after Application to (a) Uncropped and (b) Cropped Soil.

Extractable P after 180 days (Figure 5) is almost similar in behavior and depth distribution to that of 3 days after application however, extractable P decreases with the time after application being the least after 180 days and the greatest 3 days of application.

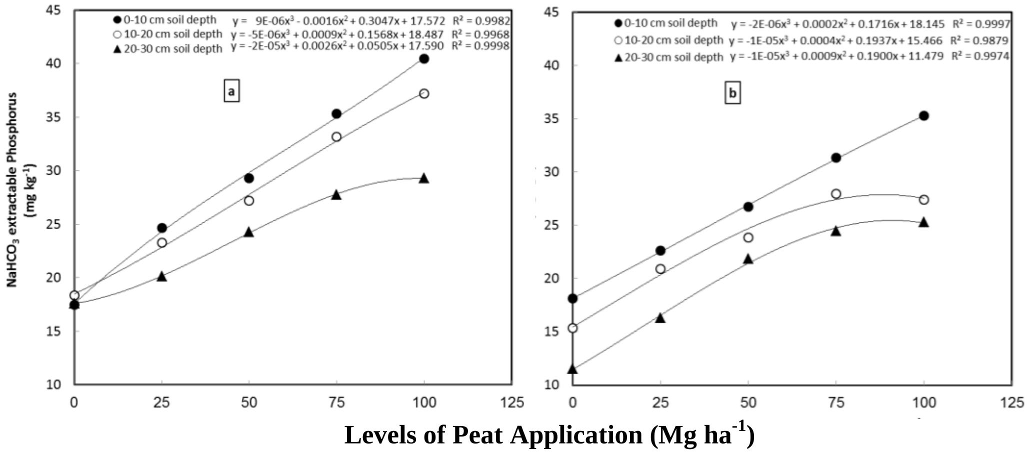

Fig.(5): Effect of Levels of Organic Matter Applications to Soil on Extractable P 180 Days after Application to (a) Uncropped and (b) Cropped Soil.

Figure 6 shows the effect of NaHCO$_3$-extractable P with time in soil receiving 50 Mg ha^{-1} peat for the whole 0-30 cm depth. It is obvious that NaHCO$_3$ –P in both cropped and uncropped soil decreases linearly with time of cultivation. However liner model of NaHCO$_3$ extractable for uncropped soil is higher than that for cropped soil as indicated by the location of the curve. However, rate of NaHCO$_3$-P decrease is relatively equal, this means that NaHCO$_3$-P in soil is large enough to meet plant requirement. The linear decrease of P with time is in agreement with what had been previously reported by many scientists like [2, 1]. Orthophosphate reaction in soils is rapid and usually results in less soluble P compounds.

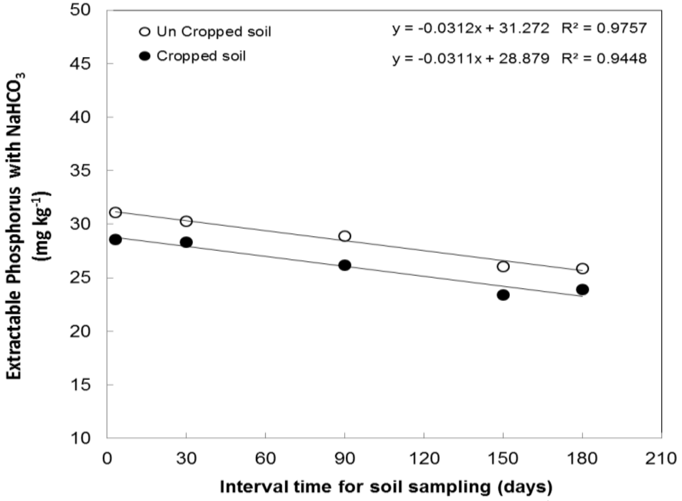

Fig. (6): Effect of Organic Matter Applied at 50 Mg ha^{-1} on NaHCO$_3$ Extractable – Phosphorus for Soil at Different Interval Time.

Conclusion:

Although, NaHCO$_3$- extractable P decreases linearly with time after applications, in the soil receiving various applications of organic matter in both cropped and uncropped soil, its level is very much higher than the critical level expected for this soil. These results usually indicate the important role of organic matter in releasing P to soil and in turn increasing plant available P. Extractable P increase with the increase of peat level of applications and decreases with time after application and soil depth. However, extractable P under any peat level of applications and at any depth is much higher than that of zero peat application level.

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تأثير اضافة المادة العضوية في حالة الفسفور في التربة الكلسية

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الخلاصة:

اجريت الدراسة الحالية لتقدير تأثير مستوى وفترة التحضين للمادة العضوية في حالة الفوسفات في التربة. اجريت التجارب بصفة تجربة حقلية بتصميم الالواح التامة التعشية (RCBD) بأربعة مكررات. استعملت بذور الحنطة لصنف الرشيد كمحصول اختبار. تم تقسيم الحقل بالكامل الى قسمين متساويين. احدى القسمين تم زراعته بالحنطة والقسم الثاني ترك بدون زراعة. تم تقدير تأثير خمسة مستويات من المادة العضوية بصيغة بيت وهي 0، 25 ، 50 ، 75 ، 100 ميكا غرام هكتار$^{-1}$. اجريت تحاليل كاملة على الترب لتقدير خصائصها الفيزيائية والكيميائية. جمعت نماذج من التربة بعد 3، 30، 60، 90، 120 و 180 يوم لتقدير المعايير الاساسية والمؤشرات التي تعكس تأثير مستوى المادة العضوية المضافة. انخفض بشكل واضح الفسفور المستخلص ببيكاربونات الصوديوم في الترب غير المزروعة والمزروعة عند كل الاعماق مع زمن الاضافة والذي يعزى الى امتصاصه من قبل النبات و تفاعل الفسفور السريع مع مكونات التربة. انخفض مع زمن التحضين بشكل خطي الفسفور المستخلص ببيكاربونات الصوديوم في التربة التي تلقت 50 ميكا غرام مادة عضوية هكتار$^{-1}$ في كلتا الترب المزروعة وغير المزروعة.

الكلمات المفتاحية: كومبوست، مستويات الاضافة، الفترة الزمنية للإضافة، الفسفورالمستخلص بـ($NaHCO_3$)، اعماق التربة، تربة مزروعة، تربة غير مزروعة.