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PHOSPHORUS BIOAVAILABILITY IN CALCAREOUS AND SANDY SOILS

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ABSTRACT: An incubation experiment was conducted under laboratory conditions to study the availability of ordinary super phosphate (OSP) at the rates of 0, 60 and 120 kg P_2O_5 fad.$^{-1}$ (0, 50 and 100% recommendation dose (RD)), either singly or combined with organic soil amendments *i.e.* chicken manure (CM) at the rates of 10 and 20 Mg fad.$^{-1}$ (1 and 2%), potassium humate (KH) at the rates of 1 and 2 Mg fad^{-1} (0.1 and 0.2 %) and phosphorus dissolving bacteria (PDB) at a rate of 2 ml Kg^{-1} soil through different incubation periods *i.e.* 10, 30, 60, 90, 120 and 150 days in the two different soils, the first was calcareous soil, collected from El-Noubaria Research Station beside El-Noubaria county, Northern Part of Tahreer Province. The second one was sandy soil, which collected from the Farm of the Faculty of Agriculture, El-Khattara District, Zagazig University, Sharkia Governorate. The obtained results can be summarized as follows: In absence of organic soil amendments and biofertilization (PDB), the highest average value of available phosphorus was obtained at the rate of 100% of RD (OSP) comparing with the other individual rates of (OSP). Wherever, in absence of biofertilization (PDB) all rates of (OSP) combined with 2% CM gave the greatest average value of available phosphorus if compared to the corresponded (OSP) rates combined with 0.2% KH in the two tested soils. The treatment of 100% of RD (OSP) + 2% CM + PDB in the two studied soils showed beneficial effect on the average value of available phosphorus if compared to the other treatments. The most (OSP) rates applied either singly or combined with organic soil amendments and/or biofertilization lead to the increase soil available phosphorus content after 60 days of incubation, while it decreased after 30, 90,120 and 150 days of incubation. The average values of available phosphorus for most treatments were greater in sandy soil than in calcareous one. Results showed that the use of half of the recommended dose of phosphatic fertilizer (OSP) combined with organic manures and/or biofertilizer (PDB) may reduce the phosphatic dose and production cost, consequently contamination soil salinity.

Key words: Phosphatic fertilizer (OSP), organic soil amendments (chicken manure (CM) and potassium humate (KH)), biofertilizer(PDB), calcareous and sandy soils.

INTRODUCTION

Phosphorus is the second most commonly soil limiting nutrient element after nitrogen. Phosphorus is very important element to plant growth and plays a key role in metabolic processes such as the conversion of sugar into starch and cellulose (Mengel and Kirkby, 1987; Vance, 2001).

Indeed, it is estimated that 5.7 billions of hectares worldwide contain too little available phosphorus for sustaining optimal crop production. Barber (1984) reported that, total phosphorus content of soils may vary from 0.02 to 0.05% with an average of approximately 0.03%. He added that, the total amount of phosphorus in top soil, as an average is 400 Kg P fad.$^{-1}$ This is especially true since a large fraction of the phosphorus present in a mineral form is not readily available for plants. The forms, contents, distributions, transformations, and availability of P in soils vary among soil types and may depend on one or combinations of soil properties. The soil properties that influence soil P pools are discussed by Tiessen

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et al. (1984), Sharpley (1985), O' Halloran *et al.* (1987) and Borggaard *et al.* (1990). Strong correlation between these soil properties and various P pools were reported. These soil properties include soil pH (Havlin *et al.,* 1999; Brady and Weil, 2002), clay content and nature of clay minerals (O' Halloran *et al.,* 1987; Sharpley *et al.,* 1989; Hesse, 1994; Harris *et al.,* 1996; Yu, 1997; McIntosh *et al.,* 1999; Pandey *et al.,* 2000), soil organic matter (Bloom *et al.,* 1979; Curtin *et al.,* 1996; Yan *et al.,* 1996) and soil CEC (Hesse, 1994). Amorphous and crystalline Al and Fe oxides in acidic soils and calcite minerals in basic soil have close relationships with P pools (Sharpley, 1985; Borggaard *et al.,* 1990).

In Egypt, most of the newly reclaimed soils are sandy and calcareous, which are poor in their content of organic matter and available phosphorus (Sharpley, 1985). Conditioning sandy and calcareous soils with different amendments such as phosphate solubilizing microorganisms, chicken manure and potassium humate became a necessity to increase agricultural production and to overcome the deficiency in food requirements (El-Kholy *et al.,* 2000; Hassanien *et al.,* 2007 ; Telep, 2008).

Evidence of the involvement of microorganisms in solubilization of inorganic phosphates was reported as early (Kucey *et al.,* 1989; Khan *et al.,* 2007). Since then, extensive studies on the solubilization of mineral phosphates by microorganisms have been detected (Golstein, 1986; Kucey *et al.,* 1989; Tarafdar *et al.,* 2003; Achal *et al.,* 2007; Aseri *et al.,* 2009). Phosphate solubilizing microorganisms (PSMs) are ubiquitous, and their numbers vary from soil to soil.

Poultry residue is an excellent organic manure, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al.,* 2008). It was also indicated that poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008).

Potassium humate is the salt of humic acid and it is dark colored, water soluble but alkali insoluble. Humic acid influence the plant growth both directly and indirectly. The indirect effect of humic acid improves physical, chemical and biological condition of soil. Its direct effects attributed due to its metabolic activity in plant growth (Mallikarjuna *et al.,* 1987).

This work is aiming to:

- Obtain the safe food (organic farming) by using organic and biofertilization.
- Reduce the amount of mineral phosphate fertilizers and production costs.
- Reduce the environmental pollution and soil salinity.
- Provide nutrients to soil and plant.

MATERIALS AND METHODS

Materials

Soil samples

Two surface soil samples (0-30 cm) were collected for this study. The first, represents a calcareous soil from El-Noubaria Research Station beside El-Noubaria county at Northern part of Tahreer Province, Egypt and the second representing a sandy soil was from El-Khattara Farm owned by Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt.

Soil samples were air dried, crushed, sieved through 2 mm plastic screen, thoroughly mixed and stored in plastic bags for analysis and experimental work. Table 1 shows some physical and chemical characteristics of the investigated soils.

Organic amendmentes

Two types of organic soil amendments were used in this work *i.e.* chicken manure (CM) and potassium humate (KH). Some characteristics of organic amendments are shown in Table 2.

Inorganic fertilizer

Mineral fertilizer which used in this work was as follow:

Ordinary super phosphate (OSP) (6.5% P).

Table 1. Physical and chemical properties of the investigated soils

Soil characteristic	Soil location	
	El-Noubaria	El-Khattara
Soil particles size distribution		
Sand (%)	60.13	92.19
Silt (%)	21.26	6.69
Clay (%)	18.61	1.22
Textural class	Sandy loam	Sand
Field capacity (FC) (%)	19.67	10.22
$CaCO_3$ (g kg^{-1})	286	13.0
Organic matter (g kg^{-1})	13.37	3.24
pH*	8.13	8.37
EC (dSm^{-1}) **	3.67	0.78
Soluble ions (mmolc l^{-1})**		
Ca^{++}	23.54	2.46
Mg^{++}	2.36	0.88
Na^{+}	9.84	3.51
K^{+}	.96	0.95
$CO_3^{=}$	-	-
HCO_3^{-}	4.31	2.04
Cl^{-}	13.62	4.13
$SO_4^{=}$	18.77	1.63
Total macronutrient (g kg^{-1})		
N	6.37	4.2
P	0.42	0.18
K	2.9	1.37
Available macronutrient (g kg^{-1})		
N	162	31.08
P	23.5	27.4
K	803	163
Mineral phosphorus (mg kg^{-1}soil)	179	97
Organic phosphorus (mg kg^{-1}soil)	241	83

* Soil-water suspension 1: 2.5   ** Soil paste extract

Table 2. Some characteristics of chicken manure and potassium humate used

Characteristic	Chicken manure	Potassium humate
EC** dSm^{-1}	6.57	9.75
pH*	6.18	12
Organic matter (g kg^{-1})	412	431
Humic acid (g kg^{-1})	-	900
Total N (g kg^{-1})	32.17	1
Total P (g kg^{-1})	9.51	2
Total K (g kg^{-1})	23.15	60
C/N ratio	7.42	249.98
Water holding capacity (WHC) (%)	367	512

* Manure-water suspension 1 : 5 ** Manure water extract 1: 5

Biofertilization

Biofertilization was done by addition *Bacillus megatherium,* which was active as phosphorus dissolving bacteria (PDB) in the soil at a rate of 2 ml kg^{-1}. This Biofertilizer was obtained from the Soil Microbiology Unit of the Soil, Water and Environments Research Institute of the Agriculture Research Center, Giza, Egypt.

Experimental Methods

An incubation experiment was carried out to study the change in soil content of available phosphorus during incubation periods (10, 30, 60, 90, 120 and 150 days) as affected by different rates of phosphatic fertilizer added either singly or combined with various organic amendments and biofertilizer to calcareous and sandy soils. 200 g of the soil sample placed in small plastic containers. Ordinary super phosphate (OSP) 6.5% P was added at the rates of 0, 26.2 and 52.4 mg P kg^{-1} soil (0,50 and100% of RD) either alone or mixed with chicken manure (CM) at the rates of 10 and 20 Mg fad.$^{-1}$ (1 and 2%), potassium humate (KH) at the rates of 1 and 2 Mg fad.$^{-1}$ (0.1 and 0.2%) and biofertilizer as phosphorus dissolving bacteria (PDB) at a rate of 2 ml kg^{-1} soil.

Treatments were replicated two times and containers were kept under laboratory conditions. The soil moisture content was adjusted at the field capacity through the experimental period. The plastic containers were covered through the experimental time and incubated at room temperature (2±29˚C approximately). Soil samples were taken at intervals of 10, 30, 60, 90, 120 and 150 days, and available phosphorus was determined.

Analytical Methods

The methods used for different analyses conducted could be described briefly as follows:

The routine soil analysis

The particles size distribution of the soil samples was determined using the international pipette method as described by Piper (1950).

The electrical conductivity (EC) of soil paste extract was determined by using the bridge (Jackson, 1958).

Calcium carbonate content of the soil was determined volumetrically using Collions calcimeter described by Piper (1950).

Soil pH was measured using glass electrode pH meter in a 1:2.5 soil water suspension (Cottenie *et al.,* 1982).

Soluble cations sodium, potassium, calcium and magnesium were determined following the versenate method (Jackson, 1958) and anions were determined in (1:5) soil paste extract (Black *et al.,* 1965).

The experimental treatments were as follow:

0% of RD (OSP) (control)	50% of RD(OSP)	100% of RD(OSP)
Chicken manure (CM) 2%.	50% of RD (OSP)+2% CM	100% of RD (OSP)+2% CM
Potassium humate (KH) 0.2%.	50% of RD(OSP)+ 0.2% KH	100% of RD (OSP)+ 0.2% KH
phosphorus dissolving bacteria (PDB)	50% of RD(OSP)+ PDB	100% of RD (OSP)+ PDB
2% CM+ PDB	50% of RD(OSP)+2% CM + PDB	100% of RD (OSP)+2% CM + PDB
0.2% KH+ PDB	50% of RD (OSP) + 0.2% KH + PDB	100% of RD (OSP)+ 0.2% KH + PDB
1% CM + 0.1% KH	50% of RD (OSP)+ 1% CM + 0.1% KH	100% of RD (OSP)+1% CM + 0.1% KH
1% CM + 0.1% KH + PDB	50% of RD (OSP) + 1% CM + 0.1% KH + PDB	100% of RD (OSP)+ 1% CM + 0.1% KH+PDB

Organic matter was determined following Walkelly and Black method, as described by Jackson (1958).

Total nitrogen in soil was digested by conc. (10 ml H_2SO_4 + 5 ml $HClO_4$) and determined using the microkjeldahl method according to Jackson (1958).

Total potassium in soil was determined by flame photometer according to Jackson (1958).

Total phosphorus in soil was digested by conc. (10 ml H_2SO_4 + 5 ml $HClO_4$) and determined colourmetrically using ascorbic acid method (Watanabe and Olsen, 1965).

The available and mineral soil phosphorus were extracted as follows

Available phosphorus was determined using Watanabe and Olsen (1965) method, 5 grams of soil sample being shaken with 50 ml 0.5 M $NaHCO_3$ solution (pH 8.5) with one gram activated charcoal for 0.5 hour and filtered.

Mineral phosphorus being extracted by acid – 0.5 N NH_4F solution (Jackson, 1958), 1 gram soil sample being shaken with 50 ml acid – 0.5 N NH_4F solution for 1 hour and filtered and determined mineral phosphorus using Watanabe and Olsen (1965) method. Organic phosphorus was estimated by subtracting the mineral phosphorus from the total phosphorus.

Chemical characteristics of chicken manure and potassium humate used in this study were determined according to Page *et al.* (1982) and tabulated in Table 2. Water holding capacity was estimated using method as described by Wilde *et al.* (1979) and tabulated in Table 2.

RESULTS AND DISCUSSION

Results in Tables 3 and 4 demonstrate the effect of applied various rates of phosphatic fertilizers (OSP), organic amendments (CM and KH) and biofertilizer (PDB) on phosphorus availability in calcareous and sandy soils during incubation for successive intervals. Obtained results can be discussed under following tobecs.

Effect of Phosphatic Fertilizer Rates

Results revealed that values of phosphorus availability in the untreated calcareous soil, over the different periods of incubation, ranged from 24.9 to 31.2 mg P kg^{-1} with an average of 27.9 mg P kg^{-1}. The corresponding range in sandy soil was from 29.2 to 35.5 mg P kg^{-1} with an average of 33.1 mg P kg^{-1}. While in the treated calcareous soil with only (OSP 50% RD) ranged from 33.7 to 47.5 mg P kg^{-1} with an average of 39.7. While in sandy soil it ranged from 36.3 to 41.2 mg P kg^{-1} with an average of 38.6 mg P kg^{-1}. In the treated calcareous soil with only (OSP 100% RD) the range was from 38.9 to 48.4 mg P kg^{-1} with a general average of 45.4 mg P kg^{-1}. The corresponding range in sandy soil was from

Table 3. Effect of phosphatic fertilization, different organic soil amendments and biofertilizer on available phosphorus (mg p kg^{-1}) in a calcareous soil during incubation periods

Phosphatic fertilizer rate (OSP)	Organic soil amendments	Biofertilizer (PDB)	10	30	60	90	120	150	Average
0% of RD (OSP)	Without	Without	27.8	26.6	29.9	31.2	26.9	24.9	27.9
	Without	With	32.4	33.2	37.3	35.1	35.6	36.7	35.0
	2% CM	Without	25.3	22.3	45.9	43.4	42.8	39.6	36.6
		With	24.8	22.0	46.7	43.7	46.1	45.1	38.1
	0.2% KH	Without	31.1	28.6	33.4	30.9	28.8	27.1	30.0
		With	32.0	34.0	33.6	32.2	27.9	32.6	32.1
	1% CM + 0.1% KH	Without	25.6	22.1	42.1	39.3	40.7	36.1	34.3
		With	26.2	22.4	39.9	41.0	52.7	40.6	37.1
50% of RD (OSP)	Without	Without	33.7	39.9	47.5	42.0	38.4	36.7	39.7
	Without	With	34.3	44.5	48.5	46.3	41.8	40.7	42.7
	2% CM	Without	23.3	21.8	73.8	68.9	64.7	57.3	51.7
		With	22.1	21.5	76.6	73.3	70.2	64.6	54.7
	0.2% KH	Without	41.9	46.4	55.0	51.3	45.6	42.5	47.1
		With	38.0	41.7	56.9	53.3	54.8	51.2	49.3
	1% CM + 0.1% KH	Without	26.0	25.2	70.0	65.2	60.1	56.0	50.4
		With	28.2	25.7	72.2	68.9	65.4	63.9	54.0
100% of RD (OSP)	Without	Without	38.9	45.9	48.4	48.4	47.4	43.4	45.4
	Without	With	41.2	45.5	52.3	48.8	45.9	46.5	46.7
	2% CM	Without	31.6	28.6	73.2	68.1	64.5	65.1	55.2
		With	26.9	25.4	78.3	75.4	59.0	68.8	55.6
	0.2% KH	Without	47.2	49.0	56.9	57.9	53.8	48.0	52.1
		With	38.5	41.2	58.7	55.2	48.3	44.5	47.7
	1% CM + 0.1% KH	Without	34.0	31.3	71.3	68.9	65.1	62.0	55.4
		With	32.8	32.0	68.7	65.4	61.8	65.1	54.3

Treatment; Incubation period (day) for columns 10–Average.

OSP: Ordinary super phosphate CM: Chicken manure KH: Potassium humate

PDB: Phosphate dissolving bacteria

Table 4. Effect of phosphatic fertilization, different organic soil amendments and biofertilizer on available phosphorus (mg P kg^{-1}) in a sandy soil during incubation periods

Treatment			Incubation period (day)						
Phosphatic fertilizer rate (OSP)	Organic soil amendments	Biofertilizer (PDB)	10	30	60	90	120	150	Average
0% of RD (OSP)	Without	Without	29.2	31.2	34.7	35.5	34.3	33.8	33.1
	Without	With	31.9	31.3	41.8	39.2	37.0	34.1	35.9
	2% CM	Without	27.5	26.7	61.8	53.1	48.2	43.3	43.4
		With	28.1	26.4	76.0	71.6	69.7	57.5	54.9
	0.2% KH	Without	36.3	39.2	48.5	42.6	40.6	36.0	40.5
		With	37.5	44.2	48.6	46.6	44.5	38.6	43.3
	1% CM + 0.1% KH	Without	36.3	31.8	57.1	53.4	49.7	45.4	45.6
		With	34.0	29.9	58.8	58.2	54.3	47.4	47.1
50% of RD (OSP)	Without	Without	36.3	37.3	41.2	39.4	38.7	38.8	38.6
	Without	With	40.4	42.7	47.4	46.7	45.2	43.1	44.2
	2% CM	Without	31.6	28.4	78.8	82.5	64.7	60.0	57.7
		With	31.4	28.3	81.1	75.9	69.0	65.6	58.5
	0.2% KH	Without	42.2	50.9	55.9	55.2	51.3	46.3	50.3
		With	38.4	48.8	51.6	47.9	44.5	44.8	46.0
	1% CM + 0.1% KH	Without	37.0	35.3	74.4	73.2	51.1	52.5	53.9
		With	35.9	32.1	77.0	73.6	54.3	50.9	54.0
100% of RD (OSP)	Without	Without	42.1	46.8	47.7	48.3	45.3	44.1	45.7
	Without	With	43.4	56.4	53.7	60.1	50.4	46.6	51.8
	2% CM	Without	40.1	35.3	83.2	77.9	71.1	68.7	62.7
		With	39.3	38.1	87.1	81.1	78.3	75.6	66.6
	0.2% KH	Without	50.4	53.1	57.7	50.4	47.9	53.5	52.2
		With	46.4	60.1	63.2	55.7	50.2	48.4	54.0
	1% CM + 0.1% KH	Without	42.6	35.8	71.0	64.5	61.4	58.5	55.6
		With	40.9	38.4	77.6	71.9	71.5	55.0	59.2

OSP: Ordinary super phosphate CM: Chicken manure KH: Potassium humate

PDB: Phosphate dissolving bacteria

42.1 to 48.3 mg P kg^{-1} with an average of 45.7 mg P kg^{-1}.

The average values of available phosphorus were increased with increasing addition of ordinary super phosphate (OSP) to the two soils under study.

An average content of available phosphorus in untreated calcareous soil was lower than that in untreated sandy one. This result could be due to the great native content of calcium carbonate in calcareous soil (Table 1)

Effect of Organic Soil Amendments and Their Rates

Results presented in Tables 3 and 4 show that in absence of ordinary super phosphate(OSP) and biofertilizers (PDB), the values of available-P in the calcareous soil treated with (2% CM), (0.2% KH and (1% CM + 0.1% KH), durig the different incubation periods ranged from 22.3 to 45.9 mg P kg^{-1}, 27.1 to 33.4 mg P $kg^{-1}$and 22.1 to 42.1 mg P kg^{-1} with an average of 36.6, 30.0 and 34.3 mg P kg^{-1}, respectively. The corresponding ranges in the sandy soil were 26.7 to 61.8 mg P kg^{-1}, 36.0 to 48.5 mg P $kg^{-1}$and 31.8 to 57.1 mg P kg^{-1} with an average of 43.4, 40.5 and 45.6 mg P kg^{-1}, respectively. The corresponding ranges of the same treatments under the application of 50% of RD (OSP) to calcareous soil were 21.8 to 73.8 mg P kg^{-1}, 41.9 to 55.0 mg P $kg^{-1}$and 25.2 to 70.0 mg P kg^{-1}, with an average of 51.7, 47.1and 50.4 mg P kg^{-1}, respectively. While in sandy soil they were from 28.4 to 82.5 mg P kg^{-1}, 42.2 to 55.9 mg P kg^{-1} and 35.3 to 74.4 mg P kg^{-1}, with an average of 57.7, 50.3 and 53.9 mg P kg^{-1}, respectively. On the other hand, the application of 100% of RD (OSP) gave the corresponding values in calcareous soil ranging from 28.6 to 73.2 mg P kg^{-1}, 47.2 to 57.9 mg P $kg^{-1}$and 31.3 to 71.3 mg P kg^{-1}, with an average of 55.2, 52.1and 55.4 mg P kg^{-1}, respectively. While in the sandy soil the values ranged from 35.3 to 83.2 mg P kg^{-1}, 50.4 to 57.7 mg P kg^{-1} and 35.8 to 71.0 mg P kg^{-1}, with an average 62.7, 52.2 and 55.6 mg P kg^{-1}, respectively. The beneficial effect of different organic soil amendments combined with various rates of (OSP) in the absence of biofertilizer (PDB) on the available-P in the two tested soils followed the descending order, (2% CM) > (1% CM+ 0.1% KH) > (0.2% KH), except the treatment of (1% CM+ 0.1% KH) without OSP and biofertilizer in sandy soil which gave greater available-P than that of each (2%CM) and (0.2% KH) treatments.

The increase of available phosphorus in the studied soils treated with chicken manure either alone or combined with potassium humate may be due to mineralization of organic forms of phosphorus and the solubilizing action of some mineral and organic acids, produced during organic manure decay as well as displacement of phosphate by organic anions formed from break down of these indicated organic acids. These findings are in agreement with those obtained by Gill and Meelu (1983), Mohamed (1990) and Merwad (2009).

In general, the average values of available phosphorus in the studied soils were higher with chicken manure treatments than with potassium humate ones under application of different rates of ordinary super phosphate (OSP) and in absence of biofertilizer. These results may be due to one or all the four of the following possibilities:

1. The difference in C/N ratio, the chemical composition (Table 1) and decomposition rate of the organic manures under study. This finding is in accordance with that obtained by Mohamed *et al.* (1991) and Awad *et al.* (2013).
2. The release of organic acids, especially amino acids as a result of the decomposition of chicken manure lead to reduceing the Ca^{+2} activity in the soil solution. This finding is in agreement with that obtained by Hassan *et al.* (2002).
3. The total phosphorus content in chicken manure was greater than that in potassium humate (Table 2). This result is in agreement with that obtained by El-Kholy *et al.* (2000) and Basyouny (2001).
4. The accumulated carbon dioxide values due to decomposition of chicken manure were greater than those from decay of potassium humate as well as the solubilizing action of certain organic acids which produce during manure decomposition. This finding agreed with that obtained by Mohamed *et al.* (1991), Salem *et*

al. (2004), Merwad (2009) and Awad *et al.* (2013).

In generally, the treatments of [50% of RD (OSP) + 2% CM)], [50% of RD (OSP) + 1% CM + 0.1 KH] were more beneficial effect than the individually treatment of [100% of RD (OSP)] in the two different soils under study. Therefore, these results show that applying organic manures combined with half of recommended dose of (OSP) fertilizer reduced the consumption of phosphatic fertilizer and production cost, consequently environmental contamination.

Effect of biofertilizer (PDB)

Results presented in Table 3 and 4 reveal that phosphorus dissolving bacteria (PDB) affected the available-P, where the values in calcareous soil, over the different incubation periods ranged from 32.4 to 37.3 mg P kg^{-1}, with an average of 35.0 mg P kg^{-1}. The corresponding ranges in the sandy soil varied between 31.3 and 41.8 mg P kg^{-1}, with an average of 35.9 mg P kg^{-1}. The available-P values due to the application of 50% of RD (OSP) to calcareous soil ranged from 34.3 to 48.5 mg P kg^{-1}, with an average of 42.7 mg P kg^{-1}. On the other hand, the values in the sandy soil varied between 40.4 and 47.4 mg P kg^{-1}, with an average of 44.2 mg P kg^{-1}. Results in the same table show that, in absence of organic soil amendments, obtained results indicated that the application of PDB either alone or mixed with any rate of OSP gave an increase in the available phosphorus in the two tested soils if compared to the control treatment. These results may be due to the solubilizing action of some organic acids as exudates from microorganisms and as products during soil organic materials decay. These results are in agreement with those of Merwad (2009)

Under addition of phosphorus dissolving bacteria (PDB) combined with 2% chicken manure in absence of phosphatic fertilization (OSP), the available phosphorus values in calcareous soil ranged from 22.0 to 46.7 mg P kg^{-1}, with an average of 38.1 mg P kg^{-1}, while in the sandy soil they were the 26.4 to 76.0 mg P kg^{-1}, with an average of 54.9 mg P kg^{-1}. The values of the same treatment under application of 50% of RD (OSP) to calcareous soil were from 21.5 to 76.6 mg P kg^{-1}, with an average of 54.7 mg P kg^{-1}. While in sandy soil they were from 28.3 to 81.1 mg P kg^{-1}, with an average of 58.5 mg P kg^{-1}. Treating calcareous soil with PDB combined with 100% of RD (OSP) gave available-P ranged from 25.4 to 78.3 mg P kg^{-1}, with an average of 55.6 mg P kg^{-1}. The corresponding ranges in the sandy soil were from 38.1 to 87.1 mg P kg^{-1}, with an average of 66.6 mg P kg^{-1}.

Under the treatment of phosphorus dissolving bacteria (PDB) combined with 0.2% potassium humate (KH) without (OSP), the available-P values in calcareous soil, ranged from 27.9 to 34.0 mg P kg^{-1}, with an average of 32.1 mg P kg^{-1}, while in the sandy soil they were from 37.5 to 48.6 mg P kg^{-1}, with an average of 43.3 mg P kg^{-1}. The corresponding ranges of the same treatment in presence of 50% of RD (OSP) were from 38.0 to 56.9 mg P kg^{-1}, with an average of 49.3 mg P kg^{-1}, in a calcareous soil, while in the sandy one they were from 38.4 to 51.6 mg P kg^{-1}, with an average of 46.0 mg P kg^{-1}. The corresponding ranges of the same treatment in presence of 50% of RD (OSP) were from 41.2 to 58.7 mg P kg^{-1}, with an average of 47.7 mg P kg^{-1} in the calcareous soil, while in the sandy one they were from 46.4 to 63.2 mg P kg^{-1}, with an average of 54.0 mg P kg^{-1}.

In the phosphorus dissolving bacteria (PDB) treatment combined with (0.1% C.M + 0.1% KH) and in the absence of (OSP) , the values of available-P in the calcareous soil, ranged from 22.4 to 52.7 mg P kg^{-1}, with an average of 37.1 mg P kg^{-1}. While in the sandy soil they were from 29.9 to 58.8 mg P kg^{-1}, with an average of 47.1 mg P kg^{-1}. The ranges of available-P with the same treatment combined with 50% of RD (OSP) were from 25.7 to 72.2 mg P kg^{-1}, with an average of 54.0 mg P kg^{-1}, in calcareous soil, while in the sandy soil one they were from 32.1 to 77.0 mg P kg^{-1}, with an average of 54.0 mg P kg^{-1}. The corresponding ranges of the same treatment mixed with 100% of RD (OSP) were from 32.0 to 68.7 mg P kg^{-1}, with an average of 54.3 mg P kg^{-1}, in the calcareous soil, while in the sandy soil they were from 38.4 to 77.6 mg P kg^{-1}, with an average of 59.2 mg P kg^{-1}.

The beneficial effect of biofertilizer combined with any organic amendments either in absence or in presence of OSP on the average values of available phosphorus in the two tested soils followed the order (PDB + 2% CM) > (PDB +

1% CM+ 0.1% KH) > (PDB+ 0.2% KH), these results may be attributed to the solving and chelating action of the certain organic acids and solubilizing action of dominant mineral acids produced during organic materials decomposition as well as its solving ability of PDB for insoluble phosphate compounds in soil. This finding is in agree with those obtained by Merwad (2009) and Awad *et al.* (2013).

In generally, the application of 50% of RD (OSP) mixed with any tested organic manures and biofertilizer (PDB) was more beneficial effect than the solely addition of 100% of RD (OSP). Therefore these result show the benefit important of supplementing various organic manures and biofertilizer (PDB) to reduce amortizing phosphatic fertilizer(OSP) and production cost, consequently environmental contamination.

Effect of incubation time

After 10 days of incubation, the greatest values of available phosphorus (47.2 and 50.4) were found with the treatment of (100% of RD (OSP) + 0.2% KH) without PDB in the calcareous and sandy soils, while the lowest ones (22.1 and 27.5) were observed with the treatment of (50% of RD (OSP) + 2% CM + PDB) in calcareous soil and with solely treatment of (2% CM) in a sandy one.

After 30 days, the greatest values of available phosphorus (49.0 and 60.1) were found with treatments of (100% of RD (OSP)+ 0.2% KH) and (100% of RD (OSP) + 0.2% KH + PDB)in calcareous and sandy soils, respectively, while the lowest ones (21.5 and 26.4) were found with the treatments of (100% of RD (OSP)+ 2% CM+PDB) and (2% CM + PDB) without OSP in calcareous and sandy soils, respectively.

After 60 days, the greatest values of availabile phosphorus (78.3 and 87.1) were found due to the treatments of (100% of RD (OSP) + 2% CM + PDB) in calcareous and sandy soils, respectively, while the lowest ones (29.9 and 34.7) were found with the untreated calcareous and sandy soils, respectively.

After 90 days, the treatments of (100% of RD (OSP) + 2% CM+ PDB) gave the highest values of availabile phosphorus (75.4 and 81.1) in calcareous and sandy soils, respectively, while the lowest ones (30.9 and 35.5) were observed with the treatment of (only 0.2% KH) in calcareous soil and in untreated sandy soil, respectively.

After 120 days, the treatments of (50% of RD (OSP) + 2% CM) and (100% of RD (OSP) +2% CM) in presence of phosphorus dissolving bacteria (PDB) gave the greatest values of availabile phosphorus (70.2 and 78.3) in calcareous and sandy soils, respectively, while the lowest ones (26.9 and 34.3) were found with the untreated of calcareous and sandy soils, respectively.

After 150 days, the treatments of (100% of RD (OSP) + 2% CM + PDB) gave the greatest values of available phosphorus (68.8 and 75.6) in calcareous and sandy soils, respectively, while the lowest ones (24.9 and 33.8) were found with the untreated of calcareous and sandy soils, respectively.

As a general result, the available phosphorus was increased after 60 days of incubation for the calcareous and sandy soils, respectively.

Results revealed that after 30 days from the beginning of incubation, the available phosphorus level decreased in the tested soils for all studied treatments, except the some treatments then increased after 60 days in the two soils under study, except the treatments of (0.2% KH+PDB) in a calcareous and (100% of RD (OSP)+PDB) in a sandy soil, but decreased again after 90 days for all tested treatments in the two soils under study, except the individual treatments of (0% of RD (OSP) and (100% of RD (OSP)) in calcareous and sandy soils respectively and (50% of RD (OSP) + 1% CM + 0.1% KH + PDB) and (100% of RD (OSP)+0.2% KH) in the calcareous soil and (50% of RD (OSP)+2% CM) and (100% of RD (OSP)+PDB) in a sandy soil, then again decreased after 120 for most treatments in both soils, except some treatments of (0% of RD (OSP) + PDB), (0% of RD (OSP) +2 % CM + PDB) and (0% of RD (OSP)+1% CM + 0.1% KH) with or without (PDB) and (50% of RD (OSP) + 0.2% KH) with (PDB) in a calcareous soil, then after 150 days decreased for most tested treatments, except (0% of RD (OSP)), (0% of RD (OSP)+0.2% KH+PDB) and (100% of RD (OSP)+2% CM) with or without (PDB) and (100% of RD (OSP)+PDB) and (100% of RD (OSP)+1% CM+0.1% KH+PDB) in the calcareous soil and (50% of RD (OSP) +

0.2% KH + PDB) and (50% of RD (OSP)+1% CM+0.2% KH) and (100% of RD (OSP)+0.2% KH) in the sandy soil.

The decrease in available phosphorus level after 30 days in the tested soils may attributed to assimilation by microorganisms. Montasser (1987) and Merwad (2009) suggested a possibility for fixation of phosphorus released from applied manure. The increase in the available phosphorus level in the two soils under study after 60 days may be due to the mineralization of organic phosphorus and solubilizing action of certain organic acids produced during manure decomposition. Montasser (1987); Mohamed *et al*. (1991) and Merwad (2009) suggested that the decomposition of organic residues changes the status of phosphorus sorption by soil. The reduction in available phosphorus level after 90,120 and 150 days in the two soils, dependent on features of the type of organic soil amendments, rate of decomposition and/or immobilization of the organic manure source. This finding is in agreement with that obtained by Mohamed *et al.* (1991); El-Fahham (1997); Merwad (2009) and Silber *et al.* (2010).

Such results may be due to release of P in available form is dependent on the chemical composition of applied organic manure and mineralization of its phosphorus as well as the positive effect of the organic manure decay products and microbial activities.

In general, it could be concluded that the treatment of 2% chicken manure combined with phosphate dissolving bacteria (PDB) under application of 100% recommended dose ordinary super phosphate (OSP) may be more beneficial under the condition of calcareous and sandy soils.

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التيســـــر الحيـــوي للفـــوســـفور فـــي الأراضـــي الجيـــرية والرمليـــة

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تم إجراء تجربة تحضين تحت ظروف المعمل لدراسة تأثير السوبرفوسفات العادى بمعدلات صفر، ١٢٠,٦٠ كجم فو$_{٢}$أ$_{٥}$ للفدان (صفر، ٥٠%، ١٠٠% من المعدل لموصى به) أما منفردا أو مخلوطاً مع مصلحات التربة العضوية مثل سماد الدواجن بمعدل ١٠،٢٠ ميجاجرام للفدان (٢,١%) وهيومات البوتاسيوم بمعدل ٢,١ ميجاجرام للفدان (٠,١ و ٠,٢%) والبكتريا المذيبة للفوسفور بمعدل ٢ ملليلتر لكل كجم تربة على محتوى التربة من الفوسفور الميسر خلال فترات تحضين مختلفة وهى ١٠ ، ٣٠ ، ٦٠ ، ٩٠ ، ١٢٠ و١٥٠يوم فى تربتين مختلفتين، الأولى كانت تربة جيرية أخذت من محطة بحوث النوبارية بالقرب من النوبارية، بالجزء الشمالى من منطقة التحرير أما الثانية فكانت تربة رملية غير جيرية أخذت من مزرعة كلية الزراعة بمنطقة الخطارة والتابعة لجامعة الزقازيق، محافظة الشرقية، يمكن تلخيص النتائج المتحصل عليها كما يلى: فى غياب مصلحات التربة العضوية والتسميد الحيوي، تم الحصول على أعلى قيمة للفوسفور الميسر عند إضافة ١٠٠% من المعدل الموصى به لسماد سوبر الفوسفات العادى مقارنة بالمعدلات الاخرى، أما فى حالة غياب التسميد الحيوى فإن جميع معدلات سماد سوبر فوسفات الأحادى العادى مخلوطا مع ٢% سماد دواجن أعطت أعلى قيمة متوسطة من الفوسفور الميسر مقارنة بنفس المعدلات من السوبر فوسفات العادي مخلوطا مع معدل ٠,٢% من هيومات البوتاسيوم فى الأراضى تحت الدراسة، ولقد اظهرت المعاملة المحتوية على ١٠٠ % من المعدل الموصى به لسماد سوبر الفوسفات العادى مصحوبا بإضافة معدل ٢% سماد دواجن وإضافة السماد الحيوى تأثيراً مفيدا على تيسر الفوسفور مقارنة بالمعاملات الاخرى فى كلا التربتين، وقد لوحظ أن إضافة معظم معدلات السوبر فوسفات العادى أما منفردة أو مصحوبة بالتسميد العضوى و/أو التسميد الحيوى أدت إلى زيادة محتوى التربة من الفوسفور الميسر بعد ٦٠ يوم من التحضين فى التربتين تحت الدراسة، وبينما انخفض محتوى التربة من الفوسفور بعد ٣٠، ٩٠، ١٢٠ و ١٥٠ يوم من التحضين فى الأراضى تحت الدراسة، ولقد أعطت معظم المعاملات قيم متوسطة للفوسفور الميسر أعلى فى الأراضى الرملية مقارنة بالأراضى الجيرية، ولقد أوضحت النتائج أيضا ان إستخدام نصف المعدل الموصى به من سماد السوبر الفوسفات العادى مختلطا مع الأسمدة العضوية و/أو السماد الحيوى مذيب للفوسفور قد قللت من كمية السماد الفوسفاتى وبالتالى تقلل تكلفة الإنتاج وتقلل التلوث التربة.

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