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EFFECT OF APPLICATION OF RICE STRAW COMPOST AND BIO-FERTILIZER ON P AVAILABILITY IN CALCAREOUS SOILS: 1- RESPONSE OF P UPTAKE AND P - QUANTITY – INTENSITY PARAMETERS IN TWO DIFFERENT CALCAREOUS SOILS

[42]

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ABSTRACT

Two different calcareous soils (15 and 31 % $CaCO_3$ contents) were subjected to application of 0, 2 and 4 % mature P enriched rice straw compost with and without inoculation with ***Bacillus megatherium***, the phosphate dissolving bacteria (PDB) before planting barley grains in pots containing 4 kg soil under greenhouse conditions. Measurements of plant growth and P uptake as well as evaluation of Olsen-P and P- Q / I kinetic parameters in cultivated soils were followed up at 3, 6 and 9 weeks from planting. Obtained results confirmed the significant beneficial action of compost and/or PDB applications in increasing growth and P uptake by plants grown on both tested calcareous soils with values were dramatically lower in the 31% than in the 15% $CaCO_3$ soil. Values of measured Olsen –P were affected by the application of compost and PDB in both tested soils in a manner similar to that of P uptake where significant increases were recorded particularly as the growth season gets advanced with lower values were obtained in the high $CaCO_3$ soil. Application of rice straw compost and/or PDB activated the kinetic parameters describing P availability in both tested calcareous soils. Correlation coefficients between P uptake by whole plants and the different parameters expressing P availability in soils revealed high sensitivity of the parameters of phosphorus buffering capacity (PBC) and Olsen-P in predicting soil P status and subsequently controlling P fertilization for long growth season plants grown on the lower calcareous soil (15% $CaCO_3$). The parameter of Q_0 proved its significant possibility to be used for very short growth season plants grown on both lower and higher (15 and 31% $CaCO_3$) calcareous soils. Other tested parameters, even the Olsen-P, lost their sensitivity in predicting P status in the higher calcareous soil; the application of rice straw compost and/or bio fertilizer couldn't meet sufficiently or meet hardly P requirements of plants grown on the high $CaCO_3$ soil. So, additional work seemed to be needed to cover this shortage in controlling P fertilization in the high $CaCO_3$ content soil.

INTRODUCTION

In Egypt, there is an increasing demand to cultivate additional areas of land to face the food gab resulted from the increasing human population. Unfortunately, most of added soils in West Delta region are characterized as calcareous soils having complex nutritional problems particularly if phosphorus was taken in consideration **(Leytem and Mikkelsen, 2005)**. Parallel to that, most Egyptian rice farmers in the North and Middle Delta used to burn rice straw (about 3.5 million ton annually) in their fields **(Abdel-Azeem, 2001)**; as a result, the smog phenomenon usually appears and harmful environmental responses could be recorded in different regions especially at Cairo and many other cities.

Thus, there is a growing national concern to recycle rice straw into compost to limit smog phenomenon and / or improve newly reclaimed soils such as calcareous ones partially via contributing in solving P problems incident in such soils. In this concern, **Van-Wandruszka (2006)** stated that addition of composts to calcareous soils has signifi-

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cant effects on subsurface P retention. Manure not only affects sorption and precipitation of P, but often contains significant amounts of the element, which is thereby – deliberately or incidentally – added to the soil. Although humic materials (the breakdown products of the total biota in the environment) generally aren't classified as a major source of P, they have a mobilizing effect on it in the subsurface of soil particles. **Richardson (2001)** added that microorganisms are involved in a range of processes affecting P transformation and thus influence the subsequent P availability to plant roots. In particular, microorganisms can solubilize and mineralize P from inorganic and organic pools of total soil P. In addition, microorganisms may effectively increase the surface area of roots. Also, the microbial biomass itself contains a large pool of immobilized P that potentially is available to plants. The aim of the present work is to evaluate using the mature P enriched rice straw compost alone or as combined with the bio fertilizer, PDB, in activating phosphorus status in calcareous soils differed in their CaCO3 contents. Such evaluation includes following up the P uptake by grown plants as well as Olsen-P and P quantity-intensity kinetic parameters in the tested soils. Correlations between P uptake and measured P parameters in soils will be also adopted to test the sensitivity of these parameters in predicting P fertilization requirements in such soils.

MATERIALS AND METHODS

Two different soil samples of approximately 15 and 31 % $CaCO_3$ contents were subjected to addition of 0, 2 and 4 % mature P enriched rice straw (5 kg super phosphate /100 kg rice straw before composting process) compost with and without inoculation with the bio-fertilizer of ***Bacillus megatherium*****,** the phosphate dissolving bacteria (PDB) which was brought as a generous gift from the MERCIN unit, Agric. Fac., Ain Shams University. The bio-fertilizer was added at the rate of 20 ml / pot containing 4 kg soil with each 1 ml of the used bio-fertilizer containing 10^8 bacterium cells. The soil particle size distribution and $CaCO_3$ contents **(Table, 1)** were determined as described by **Piper (1950)** while $CaCO_3$ fraction in soils was determined as described by **Baruah and Barthakur (1997)**. The chemical analysis of both tested soils and compost materials, however, was performed according to **Jackson (1973)** while the available and total nutrients were determined according to **Page *et al* (1982).** After good homogeneity of soils and compost as well as the used bio fertilizer, 15 barley grains (Hordeum vulgare, variety Giza 123) were cultivated in pots containing 4 kg soil samples under green house conditions to be then thinned to 10 homogenous seedlings. Each pot received the recommended rates of N and K fertilization with no addition of P fertilization to evaluate the effect of the suggested treatments in altering P status in the tested soils. Each treatment was repeated 9 times. Three replicates were taken out of the indicated nine ones to represent a plant and soil sample at 3, 6 and 9 weeks from cultivation, respectively. In each sample, plant materials were dried at 65 – 70°C and dry weights were recorded and P content was determined in wet digests as described by **Page *et al* (1982)**. Each soil sample was subjected to measurement of several parameters expressing P availability. Olsen-P was determined according to **Jackson (1973)** and (Q / I) parameters were determined according to **Baruah and Barthakur (1997)** as the following:-

5 gm soil was shaken with 50 ml of 0.01M $CaCl_2$ containing one of the following P concentrations as K H_2PO_4 (0, 15, 20, 25 and 30 mg P/L) overnight to assure equilibrium. The differences between initial and final P concentrations (Δ P or Q) which may be positive or negative were then plotted, as shown in **Fig. (1)**, against values of P intensity (I) expressed as phosphate potentials which were calculated as the following:-

$$\textit{Phosphate potential} = \tfrac{1}{2}\,\rho Ca + \rho H_2PO_4$$

The three parameters of P Q / I relationship were then calculated as the followings:

(1) Values of Q_0 which usually expresses labile P that would have to be added or removed to reduce I to zero were chosen as the intercept of Q when I = 0.
(2) Values of equilibrium P potential (EPP or Ie) which usually expresses the need for P fertilization was chosen as the intercept of I when Q = 0.
(3) Values of phosphate buffering capacity (PBC) were calculated as the slope of yielded straight relationship ($\Delta Q / \Delta I$).

RESULTS AND DISCUSSION

Increase in barely growth and P uptake by application of rice straw compost and/or bio-fertilizer in the 15% $CaCO_3$ soil **(Table, 2)** indicated that increasing the rate of compost application had a

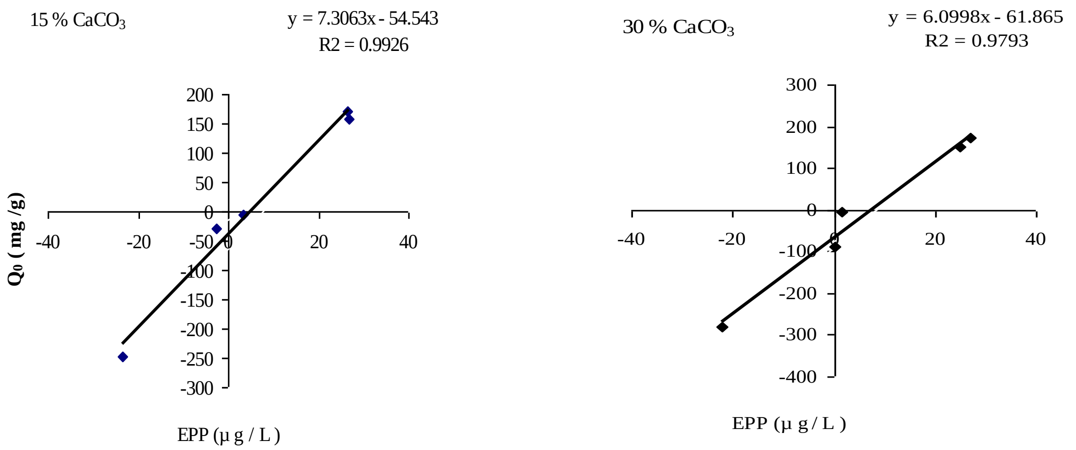

Fig. 1. Phosphorus quantity – intensity relation ship in both tested calcareous soils

Table 2. Effect of application of rice straw compost and bio- fertilizer on barley growth and P uptake as well as Olsen-P in the cultivated calcareous soils

Treatment	15 % $CaCO_3$ soil			31 % $CaCO_3$ soil		
	Dry matter (g/ pot)	P uptake (mg/pot)	Olsen-P (mg/kg)	Dry matter (g/ pot)	P uptake (mg/pot)	Olsen-P (mg/kg)
1st growth period						
Control	7.56 o	12.6 m	12.5 p	4.27 g	4.24 o	6.67 o
2 % compost	8.64 m	17.3 l	23.9l	4.50 p	7.01 n	18.6h
4 % compost	9.35 l	19.8 j	26.1 k	5.20 n	9.81 k	16.4 j
PDB	9.38 l	19.4 j	20.1 n	5.53 o	9.36 l	12.9 n
PDB + 2 % compost	10.75 i	32.0 f	26.7 k	6.74 j	15.36 h	11.3 d
PDB + 4 % compost	12.06 e	38.5 de	37.1 e	6.65 k	14.33 j	18.0 i
Mean	**9.62 C**	**23.2 C**	**24.4 C**	**5.61 C**	**10.01C**	**15.8 C**
2nd growth period						
Control	8.32 n	18.1 kl	19.5 o	5.77 m	9.11 l	14. 9 k
2 % compost	9.91 j	27.5 h	31.8 i	6.48 i	14.92 i	22.3 d
4 % compost	11.42 g	37.4 e	36.3 g	8.03 g	18.59 e	25.2 b
PDB	9.5 k	24.9 i	26.3 k	7.45 h	16.33 g	18.7 h
PDB + 2 % compost	11.16 h	38.5 d	38.4 d	8.44 e	23.31 c	27.3 a
PDB + 4 % compost	13.08 c	51.1 b	44.0 b	9.59 c	24.54 a	21.9 e
Mean	**9.62 C**	**23.2 C**	**24.4 C**	**7.68 B**	**17.76 B**	**21.7 A**
3rd growth period						
Control	9.37 l	18.9 jk	21.5 m	6.11 l	7.84 m	13.7 m
2 % compost	11.64 f	29.8 g	33.3 h	8.27 f	16.90 f	19.2 g
4 % compost	15.44 b	43.5 c	36.6 f	9.76 b	21.35 d	21.8 e
PDB	11.13 h	29.0 g	28.1 j	9.22 g	16.45 g	14.2 l
PDB + 2 % compost	12.80 d	43.8 c	41.7 c	9.05 d	24.10 b	23.7 c
PDB + 4 % compost	16.08 a	66.3 a	51.8 a	10.34 d	23.21 c	20.1 f
Mean	**12.73 A**	**38.5 A**	**35.5 A**	**8.62 A**	**18.27 A**	**18.8 B**

-Values having the same small latter(s) within a column are not significantly different at 95% confidence level
-Values having the same capital latter(s) within a column are not significantly different at 95% confidence level
-PDB refers to the used phosphate dissolving bacteria (Bacillus Megatherium)

significant effect in increasing both plant growth and P uptake. The effect was more evident as the growth period gets advanced. In fact, the enhancement of plant dry matter production by compost application could be attributed to the prominent roles of decomposed organic matter in improving physical, chemical and biological properties of the cultivated calcareous soils. In this concern, **Sakr *et al* (1992)** reported that the dry matter yield of plant showed a pronounced increase by addition of organic manures. Such increase may be attributed in part, to the production of humus substances which should improve physical and chemical properties of a soil leading to increasing nutrients release and availability to the growing plants. Besides, **Holguin *et al* (1999)** found that the organic matter usually contains promoting substances such as vitamins, amino acids, auxins and gibberellins which, when released during decomposition, stimulate growth. Increasing of nutrient availability via decreasing rhizosphere pH and microbial activity as well as enhancement of root proliferation and consequently boosting plant growth, due to compost application, were repeatedly reported to be effective in promoting plant growth and nutrient, i.e. P, uptake (**Tisdale *et al* 1993).**

Speculating the role of using the bio-fertilizer in activating the superior role of compost application, obtained data **(Table, 2)** revealed that inoculating the cultivated calcareous soil with phosphate dissolving bacteria (PDB) had a significant synergetic action in increasing barley growth and P uptake. This is true if PDB added alone or with compost with the action being more superior as the growth period gets advanced. In fact, obtained pattern wasn't unexpected since several reports have assured it. Findings of **Whitelaw (2000)** revealed that bacillus bacteria were more active in solubilizing P than the other microorganisms. In addition, **Ali *et al* (2003)** indicated that application of rice straw with *Bacillus megatherium* led to improve soil physical, chemical biological properties as well as the supplying power of available nutrients in soils. Moreover, **El-Eltr *et al* (2004)** and **Lela (2005)** concluded that inculating different composted materials by *Bacillus megatherium* led to increase nutrient uptake by wheat plants grown on different soils.

Comparing the indicated response of plant growth and P uptake to the application of rice straw compost and PDB to the high $CaCO_3$ soil **(Table, 2)** revealed that the application of compost and /or PDB continued to be significantly effective in increasing dry matter production by grown barley plants as well as P uptake and accumulated by them throughout all growth periods. In contrast, obtained figures in the cultivated 31 % $CaCO_3$ soil were dramatically lower compared to those yielded in the tested 15 % $CaCO_3$ one. In general, the reduction rate in P uptake was more pronounced than that of plant growth. In fact, this pattern wasn't unexpected due to not only the high $CaCO_3$ % but also due to more finesse nature of the second soil **(Table, 1).**

Regarding the response of residual P availability in both tested calcareous soils **(Table, 3)**, application of rice straw compost significantly increased Olsen – P values. This promoting action was more pronounced as compost was added in combination with the bio-fertilizer (PDB) particularly as the growth season gets advanced. This action could be explained on the basis of bio-compost (compost + bio fertilizer) including ***Bacillus megatherium*** bacteria which should introduce some activation in solubilizing soil inorganic P (**Lela, 2005).** The decomposition of organic materials in soils had been reported to have a positive role in solubilizing phosphate by producing organic acids which decrease soil pH and subsequently increase the dissolution of bound forms of phosphate. Also, some of hydroxyl acids may chelate calcium to finally mobilize and utilize soil phosphates. Another explanation for the role of organic composts was reported by **Cavigelli and Thien (2003)** who reported that incorporation of composts in soils can further increase P availability by releasing CO_2, forming H_2CO_3 in the soil solution and resulting in the dissolution of primary P – containing minerals. They also pointed out that organic acids, released during decomposition, may help dissolving soil mineral P. In soils with high P-fixing capacities, organic compounds released during decomposition processes may increase P availability by blocking P- adsorption sites or via anion exchange phenomenon.

Comparing P availability in both tested calcareous soils proved that high existence of $CaCO_3$ resulted in lower values for measured Olsen –P. This could be explained on the basis of P chemistry in calcareous soils described by **Samadi and Gilkes (1998)** who clarified the role of $CaCO_3$ in diminishing P availability in calcareous soils to be due to not only percentage of existed $CaCO_3$ but also due to the finesse degree of $CaCO_3$ particles which should give high specific surfaces.

Regarding the improvement of P- Q/I kinetic parameters, obtained values **(Table, 3)** of the Q_0 (the capacity factor which considered as an

Table 3. Effect of application of rice straw compost and bio-fertilizer on P quantity-intensity parameters in the cultivated calcareous soils

Treatment	15 % $CaCO_3$ soil			31 % $CaCO_3$ soil		
	Q_0 (mg / kg)	EPP **(I_e)** (µg / l)	PBC (L/kg)	Q_0 (mg / kg)	EPP **(I_e)** (µg / l)	PBC (L/kg)
1st growth period						
Control	27.7 c	41.1 d	673 g	11.5 n	49.5 f	232 m
2 % compost	30.9 b	34.9 f	885 d	13.4 i	39.5 j	341 f
4 % compost	31.1 b	31.2 i	999 c	17.5 b	28.4 n	614 b
PDB	28.3 c	34.2 f	826 e	14.2 g	45.8 i	309 g
PDB + 2 % compost	32.3 a	30.7 i	1053 b	16.9 c	37.1 l	456 c
PDB + 4 % compost	32.9 a	26.6 l	1235 a	20.7 a	27.9 o	742 a
Mean	**30.5 A**	**33.1C**	**945 A**	**15.7 A**	**38.0 C**	**449 A**
2nd growth period						
Control	13.7 k	52.4 b	261 m	11.0 p	56.7 b	193 o
2 % compost	17.7 h	34.5 f	514 i	13.1 j	55.6 c	235 l
4 % compost	23.6 e	32.4 gh	727 f	15.6 d	54.7 d	285 i
PDB	14.9 j	39.5 e	376 k	12.9 k	46.7 g	276 j
PDB + 2 % compost	19.9 f	29.5 j	674 g	13.8 h	46.2 h	299 h
PDB + 4 % compost	25.1 d	28.5 k	881 d	15.3 e	34.8 m	439 d
Mean	**19.1 B**	**36.1 B**	**572 B**	**13.6 B**	**49.1 B**	**288 B**
3rd growth period						
Control	9.6 l	53.7 a	180 o	8.97r	61.4 a	146 q
2 % compost	10.0 l	32.9 g	306 l	9.32q	56.9 b	164 p
4 % compost	13.7 k	45.0 c	306 l	11.0 o	55.5 c	199 n
PDB	10.0 l	45.1 c	223 n	12.5 m	51.9 e	241 k
PDB + 2 % compost	16.5 i	34.3 f	481 j	12.7 l	45.9 i	277 j
PDB + 4 % compost	18.4 g	32.0 h	575 h	14.3 f	37.9 k	376 e
Mean	**13.1 C**	**40.5 A**	**345C**	**11.5 C**	**51.6 A**	**234 C**

-Values having the same small latter(s) within a column are not significantly different at 95% confidence level.
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-PDB refers to the used phosphate dissolving bacteria (Bacillus Megatherium).

estimate for labile P) increased significantly in both tested calcareous soils by rice straw compost application. The action was more pronounced as compost application rate increased. Moreover, application of PDB significantly activated the enhancing role of compost in increasing Q_0 values. Of course, the action of compost and bio-compost can be referred to increasing activity of microorganisms leading to solubilizing organic P (**Tisdale *et al* 1993)**. Besides, numerous works have reported that humus accumulation in soils can increase the solubility of phosphorus throughout (1) the formation of phospho- humate complexes, (2) anion replacement of the phosphate by the humate ions, and (3) the coating of phosphate fixing sites (sesquioxides and $CaCO_3$ particles) by humus to form a protective coverage and thus reduce the phosphorus fixing capacity of the soil. Of course, superiority of bio-compost could be partly referred to activating soil microorganisms to lead to decreasing pH in the soil micro-environment, and subsequently enhancing solubility of inorganic P.

Regarding to the effect of growth period, although application of compost and/or PDB continued to positively affect values of Q_0 if compared to control treatment, it decreased significantly as time course progressed. In fact, depression in values of Q_0 encountered as time progressed could be attributed to two main reasons. The first is increasing the depletion of phosphate by growing plants especially in the 15% $CaCO_3$ soil; the second is increasing the chance of fixing the dissolved P particularly in the 31 % $CaCO_3$ calcareous soil. The first suggested reason seemed to be generally more logic since depression rates in Q_0 values, as time progressed, seemed to be higher in the 15 % $CaCO_3$ than in the 31 % $CaCO_3$ calcareous soil.

As the response of P intensity was regarded, values of equilibrium phosphate potentials (EPP) were significantly and negatively responded to application of rice straw compost and/or bio fertilizer to both tested calcareous soils. In this concern, obtained values proved again that the positive role of compost and PDB addition in the intensity of soluble P in soil rhizosphere with using the bio fertilizer was more active. This is true when judgment was carried out to the application of the PDB alone or as combined with application of rice straw compost. In contrast, although application of compost continued to enhance phosphorus status expressed as calculated EPP values, during the whole investigation period, such values increased significantly as the growth time progressed indicating more precipitation of soluble phosphates in calcareous soils particularly in the higher $CaCO_3$ content one. Of course, the presence of $CaCO_3$ in soil is responsible for decreasing phosphorus activity and the greater the time of contact of phosphate with soil phase, the greater the fixation of phosphorus in soil (**Lindsay, 1979 and Tisdale *et al* 1993)**.

Values of phosphorus buffering capacity (PBC) were also activated in both tested calcareous soils as responded to application of rice straw compost and/or PDB ; the response was more pronounced at the lower $CaCO_3$ content soil where the superiority cold be easily encountered for PDB application by compost application.

Finally; to make results and conclusion more fruitful, correlations between the P taken up by grown barley plants and different tested parameters describing P availability in both tested calcareous soils were calculated at the end of each growth period irrespective to compost treatments. Obtained coefficients **(Table, 4)** revealed that, for the 15 % $CaCO_3$ soil, parameter of PBC followed by Olsen –P and relatively EPP were superior to predict P uptake by grown plants. Parameter of P quantity (Q_0), however, seemed to be less sensitive, except at relatively short growth seasons, to express P availability in lower CaCO3 content soil. In other words, PBC and Olsen-P could be used with high confidence for predicting P status and controlling P fertilization in lower $CaCO_3$ calcareous soil irrespective of the duration of plant growth season. In this concern, EPP seemed to be valid although with less confidence while Q_0 parameter could only be used in controlling P fertilization for plants having very short growth seasons.

Unfortunately, as the $CaCO_3$ content in soil increased (31 % $CaCO_3$ soil), all indicated parameters lost their sensitivity to predict available P in such soils. In spite of that, Q_0 parameter proved some sort of validity and could be used only for controlling soil P status when relatively short growth season plants are planned to be cultivated. It may be concluded that the application of rice straw compost and/or bio fertilizer couldn't meet sufficiently or meet hardly P requirements of plants grown on the high $CaCO_3$ soil. So, additional work seemed to be needed to cover this shortage in controlling P fertilization in the high $CaCO_3$ content soil.

Table 4. Correlation coefficients between P uptake by barley plants at successive growth periods and different parameters expressing P availability in the cultivated soils

Growth period	Olsen-P	Q_0	EPP(I_e)	PBC
15 % $CaCO_3$ soil				
1st	0.88 *	0.82 *	0.88 *	0.92 **
2nd	0.88 *	0.72	0.82 *	0.82 *
3rd	0.92 **	0.72	0.82 *	0.92 **
31 % $CaCO_3$ soil				
1st	0.78	0.85 *	0.65	0.70
2nd	0.73	0.58	0.72	0.72
3rd	0.74	0.64	0.78	0.69

* Values are significant at 95 % confidence level
** Values are significant at 99 % confidence level

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