CHALLENGES FACING FOOD PRODUCTION IN UPPER EGYPT: P AMENDMENTS BETWEEN GOVERNMENTAL REGULATIONS AND LOW EFFICIENCY FERTILIZERS

Fahmi, F. M.* and M. H. H. Abbas**
***Soils, Water & Environ. Res. Inst. (SWERI), Agric. Res. Center (ARC), Giza, Egypt**
**** Faculty Agric., Moshtohor, Benha Univ., Egypt.**
⌧Contact address: Benha University, Faculty of Agriculture - Moshtohor, Toukh, Kalyoubia,13736 ,Egypt
Author correspondence: mrhamza_mh@hotmail.co.uk

ABSTRACT

One of the challenges that faces food production recently in upper Egypt is the governmental obligations for applying gypsum to arable lands which contains 50 g P kg^{-1}total P (called phospho-gypsum). Although these soils are not sodic and contain high soil-P residual from the previous soil fertilization for many years. The current research aimed at investigating the effectiveness of using the pH reducing amendment (elemental sulfur) or P-dissolving bacteria (phosphorin) to improve the use efficiency of P from soil and the phospho-gypsum and thus improve the grain yield of maize cultivars SC 3084 and SC 10. Growing plants in the presence of superphosphate fertilizers was taken into consideration for result comparison. The key findings indicate that inoculating maize seeds with phosphorin increased the grain yield production and, at the same time, increased the P-use efficiency. On the other hand, the application of phospho-gypsum caused further significant increases in the grain yield production without any further effect for the co-application of either elemental sulfur or even seed inoculation with phosphorin. Also, the application of superphosphate fertilizers increased significantly the production of grain yield over the increases recorded by application of the phospho-gypsum. However, P-applications reduced drastically P-use efficiencies; accordingly, we can consider the biological approach as efficient and responsive practices for increasing the efficiency of P-utilization by maize plants in soil with high residual soil-P content without further increases in the costs of production; or even soil pollution with contaminants that can be found as impurities in the used amendments.
Keywords: Phosphorin- P-use efficiency- maize-governmental regulations.

INTRODUCTION

Phosphorus is one of the most limiting nutrients for crop production (Bucher, 2007; Lal, 2009). Enriching soil with P amendments has been considered for many years a most appropriate practice for increasing soil productivity from different crops (Cordell *et al*., 2009). Many techniques are followed in this concern including application of easily soluble superphosphate fertilizers (Gaxiola *et al*., 2011), applying rock phosphate with acidifying agents (Trolove *et al*., 1996; Zoysa *et al*., 1998) , besides, inoculating crop seeds with P solubilizing bacteria to increase the efficiency of plants for utilizing P of rock phosphate(Richardson *et al*., 2009). On the other hand, excess fertilizer inputs are associated with high environmental implications (Fageria *et al*., 2008), besides a rapid depletion of phosphate reserves (Weikard and Seyhan, 2009). Therefore, efficient P management guarantees more sustainable soil use in the production of safe food (Hilton *et al*., 2010).

Some countries have regulations to magnify the utility of agricultural lands and minimize soil degradation (Gardner, 1977; Skinner *et al*., 2001). However some of these regulations should be considered more carefully as some soil amendments might adversely affect soil productivity in the long run (Zhu *et al.*, 2004; Schwab *et al.*, 2007). One of the important challenges that face crop production in upper Egypt is the governmental obligations for applying gypsum amendment to the arable lands. Such materials include gypsum with rock phosphate, which contains 50g P kg^{-1} total P (called phospho-gypsum). Many superphosphate fertilizers available in the Egyptian market are of low quality (low solubility in soil). Such challenges made the farmers depend mainly on the total P reserved from previous soil applications in crop production.

The most important parts of maize plants are grains (Li, 2009), yet the other plant residues could be recycled in soil either in the form of compost or through the organic manures of the fed animals (Mutsamba *et al*., 2012). It is therefore important to manage P-resources to maximize crop production. In this concern, grain yield and P use efficiency were used by Fageria and Baligar (1999) as dual parameters to evaluate practices that maximize the effectiveness of P treatments, which they classified as "efficient and responsive", "efficient and nonresponsive", "non-efficient and responsive", and "non-efficient and nonresponsive".

The current study aimed at investigating the effectiveness of using the phospho-gypsum, phospho-gypsum with or without the elemental sulfur as a pH agent and P-dissolving bacteria on increasing P use efficiency from soil for maize growing.

MATERIALS AND METHODS

Materials

A representative composite soil sample collected from the 30-cm surface of the field of the experiment (Sho village, Abnob, Assuit Governorate, Upper Egypt), was air dried, sieved to pass through a 2-mm sieve and analyzed for physical and chemical properties (Page *et al.*, 1982; Klute, 1986). Properties of the soil are shown in Table 1.

The governmental phospho-gypsum contained $CaSO_4.2H_2O$ (850 g kg^{-1}) and 50 g P kg^{-1}. Elemental sulfur was supplied by El-Help Company, Egypt and its purity is about 80%. Bio-fertilization was done using P-dissolving bacteria "*Bacillus megaterium*", supplied by the Soils, Water & Environment Research. Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt. It is marketed under the trade name of "Phosphorin"; a material of organic compost-like peaty substance. Bio-fertilization was conducted by through mixing of seeds with Arabic gum solution 15 %, as an adhesive agent. Maize cultivars used in the experiment are Single cross hybrid 10 (yellow maize, supplied by Agricultural Research Center, Egypt) and single cross hybride 3084 (white maize, supplied by Pioneer company, Egypt).

Table 1. Physical and chemical properties of the soil of the study

Parameter	Value
Coarse sand	4.2 %
Fine sand	7.4 %
Silt	20.3 %
Clay	68.1 %
Textural class	Clay
EC	2.1 dS m^{-1}
pH	7.6
$CaCO_3$	8.9 g kg^{-1}
Organic matter content	18.5 g kg^{-1}
ESP	2.15
AB-DTPA- P	3.1 mg kg^{-1}
Total P	1960.0 mg kg^{-1}

The field experiment

A field experiment assessing different P-fertilization treatments for the two maize cultizers was conducted during 2010. The design was a split-plot; the main plots were assigned to maize cultivars; the sub-plots were assigned to the fertilization treatments. There were 6 fertilization treatments involving the use of sulfur (S), bio-fertilization (Bio), phospho-gypsum (PG) and soluble ordinary super-phosphate (OP). Treatments were as follows: T_1(non-fertilized), T_2 (Bio-fertilization), T_3 (PG), T_4(Bio-fertilization+ PG), T_5 (S+ PG) and T_6 (OP). Application rate of P for T_3, T_4, T_5 and T_6 was 40 kg P ha^{-1}. Sulfur was applied at 120 kg ha^{-1}. Nitrogen was applied at 240 kg N ha^{-1} as urea fertilizer. At physiological maturity, grain yield was recorded. Samples of maize were collected for analysis.

Soil and water analyses

The collected plant materials i.e. grain and shoot samples were oven dried at 70˚ C for 48h and ground to pass through a 5mm mill. Plant sample placed in digestion tubes, then a mixture of concentrated sulfuric (H_2SO_4) and perchloric ($HClO_4$) acids (1:1) were added and left overnight. Afterwards digestion was done using a block digester as described by Peterburgski (1968). Soil samples were placed into centrifuge tubes with extracting solution of ammonium bicarbonate-DTPA (AB-DTPA) (1:10 w:v ratio) for analyzing available P (Soltanpour, 1985). The suspension was centrifuged at 3000rpm for 15 min and filtered. AB-DTPA-P in soil extract and total P in the plant digest were determined spectrophotometrically according to the phosphomolybdate-vanadate method as mentioned by Gupta *et al*. (1993) and measure with a spectrophotometer model Jenway 6300 UK.

Data analysis

The obtained data were statistically analyzed using the Minitab 15 statistical software program through analysis of variance (ANOVA) and least significant difference (LSD) at 0.05 probability level. P grain/shoot ratio, a ratio between P concentration in grain to its concentration in shoot, was calculated according to Sanginga *et al*. (2000). P-use efficiency (PUE) was calculated according to Sanford and Mackown (1986) as follows:

$$P - use \cdot efficiency \cdot (PUE) = \frac{Mg \cdot grain \cdot per.hectar}{kg \cdot P \cdot from \cdot soil \cdot (including \cdot amendments)} \times 100$$

RESULTS AND DISCUSSION

Soil analysis reveals that the soil of study is non-saline non-sodic. Accordingly, the value of the governmental phosphor-gypsum could only be discussed on means of P-amendment for the grown maize plants, especially that the used amendment was labeled as rock phosphate.

Effect of the different P-amendments on the total grain yield

Grain yield (Fig. 1) was significantly affected by the studied treatments (P<0.001) and the obtained yield significantly differed between the two cultivars (P=0.026). There was no significant fertilization/cultivar interaction indicating the variations among fertilization treatments were not affected by the cultivar; it also indicates that the differences between the cultivars was not affected by fertilization treatments. Bio-fertilization without applying P-amendment (T_2) recorded 136 and 153 % increases in the grain yield of SC 3084 and SC 10, respectively. Such increases indicate the significance of inoculating maize seeds with P-dissolving bacteria when growing in soils of high total soil P on improving grain yield production of maize plants. Application of phospho-gypsum (T_3) caused increases in grain yield production. However; such increases were not marked and was not influenced by application of either bio-fertilization (T_4) or sulfur (T_5). Although, soil acidification by adding S with PG can increase P uptake by plants (Zhou *et al*., 2009), and that inoculation with P-dissolving bacteria increases availability of P in soil (Zaidi *et al.*, 2009; Kuhad *et al.*, 2011); yet in the present study, P-nutrient seemed not to be the limiting factor for the plant growth with the application of the phospho-gypsum. A reasonable explanation is that application of rock phosphate in high rates to soil might dilute, to some extent, available nutrient contents of the fertile soil layer and therefore probably reduce the amounts of soil nutrients required for maximum grain yield. On the other hand, application of superphosphate fertilizers (T_6) increased grain yield over the increases recorded by the application of the phospho-gypsum. Based on the classification of Fageria and Baligar (1999), T_2 (Bio-fertilization), T_3 (PG), T_4(Bio-fertilization+ PG), T_5 (S+ PG) and T_6 (OP) can be classified, in general, as efficient treatments.

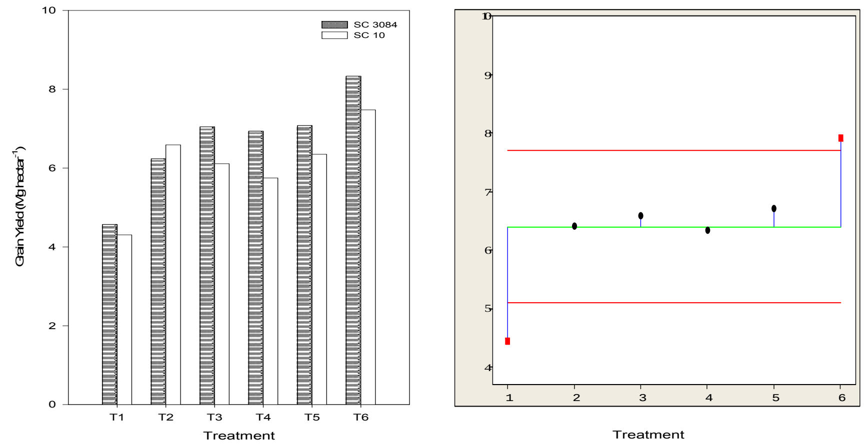

Fig 1. Effect of different fertilization treatments on maize yield (two cultivars). The upper and lower lines around the mean line detects the decision lines of significance.

T_1, T_2, T_3, T_4, T_5 and T_6 denote fertilization with : non-fertilized, Bio-fertilization with *B. megaterium*, phospho-gypsum (PG), Bio-fertilization+ PG, sulfur + PG and superphosphate, respectively.

Effect of fertilization on P-content in straw and grains

P-content in either straw or grains was insignificantly influenced by the different treatments (Fig. 2). P is one of the limiting factors for plant growth because application of P to soil could result in increases in plant growth and grain yield, without further accumulation of P in plant tissue. P use efficiency can be used to assess the efficiency of P utility in soil (Sanginga *et al*., 2000).

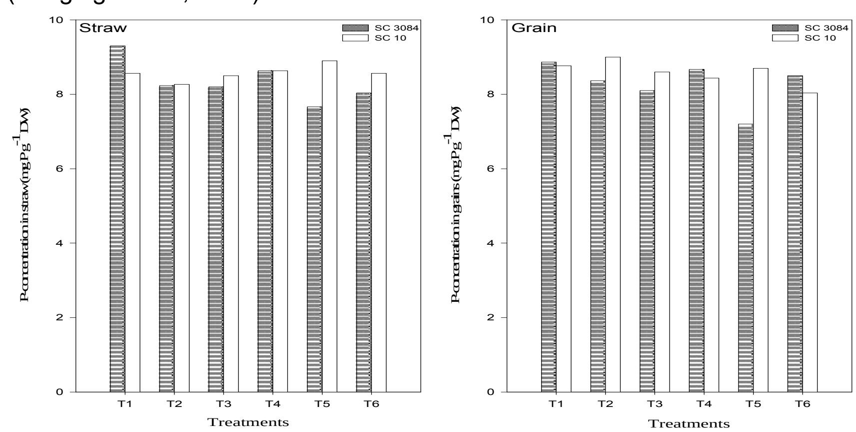

Fig 2. P-content in straw and grain as affected by fertilization treatment.

T_1, T_2, T_3, T_4, T_5 and T_6 denote fertilization with : non-fertilized, Bio-fertilization with *B. megaterium*, phospho-gypsum (PG), Bio-fertilization+ PG, sulfur + PG and superphosphate, respectively.

P-grain/ P-shoot and P-use efficiency as affected by different P-amendments

The results shown in Table 2 reveal that the ratio of P content in grain : P content in shoots remained nearly constant for all treatments ; however, P-use efficiencies were highly influenced by P applications. The highest P-use efficiency was recorded for plants grown in the absence of P amendments i.e. T_1 and T_2. The bio-fertilization treatment increased P-use efficiency noticeably. P-use efficiency decreased drastically with application of P amendments (i.e. superphosphate and phosphor-gypsum) and ranged between 5.78 and 8.99% for SCH 3084 and between 5.92 and 7.99% for SC 10. Accordingly, the biological approach could be considered optimum for increasing P utilization from the previous soil applications and efficient and responsive according to the classification of Sanginga *et al*. (2000). According to Fageria *et al*. (2008), the cost of production of farmers, and the environmental pollution due to excess fertilizer inputs should be taken into consideration during fertilization.

Table 2. P grain/shoot and P-use efficiency as affected by fertilization treatments

Treatment	P grain/shoot			P-use efficiency		
	SC 3084	SC 10	mean	SC 3084	SC 10	mean
T_1	0.95	1.02	0.99	62.14	52.08	57.11
T_2	1.02	1.09	1.05	84.74	79.75	82.24
T_3	0.99	1.01	1.00	7.60	6.53	7.06
T_4	1.00	0.98	0.99	7.48	6.14	6.81
T_5	0.94	0.98	0.96	7.64	6.78	7.21
T_6	1.06	0.94	1.00	8.99	7.99	8.49
mean	0.99	1.005	1.00	29.76	26.54	28.15
$LSD_{(0.05)}$	T:ns	C:ns	T×C:ns	T:4.49	C:2.39	T×C:ns

T_1, T_2, T_3, T_4, T_5 and T_6 denote fertilization with : non-fertilized, Bio-fertilization with *B. megaterium*, phospho-gypsum (PG), Bio-fertilization+ PG, sulfur + PG and superphosphate, respectively.

Effect of the different amendments on available (AB-DTPA extractable) P from soil

Available P was significantly influenced by either of the applied treatments (P=0.001) and the grown cultivar (P=0.02); moreover the interaction between treatments and cultivars were also of significant effects on AB-DTPA-P (P=0.011). Treatments receiving amendments showed greater available P, particularly those of the SC 3084 cultivar. Fig 3 shows that the values of available-P measured at the end of the growing season increased significantly owing to inoculating maize grains (T_2) and such a result is consistence with those obtained by Kuhad *et al*. (2011) and Zaidi *et al*. (2009) who found that inoculating maize seeds with *B. megaterium* var. phosphaticum increased the availability of P in soil. Application of superphosphate or phospho-gypsum increased available-P in soils. Soils have high retention for phosphate and that the application of P-fertilizers is followed by rapid fixation in less available forms (Frossard *et al*., 2011). Thus, behavior of the superphosphate and phospho-gypsum amendments in soil could be subject to the same condition in the long run. Application of phospho-gypsum or phosphate fertilizers might cause considerable changes in total P rather than available P , and this might shift the equilibrium of P in soil to more easily soluble fractions and thus increased P availability in soil temporarily. An application of elemental sulfur or inoculating plants with *B. megaterium* slightly increased available -P in soil for plants amended with low grade rock phosphate. However their behavior seemed to be confusing between the two cultivars.

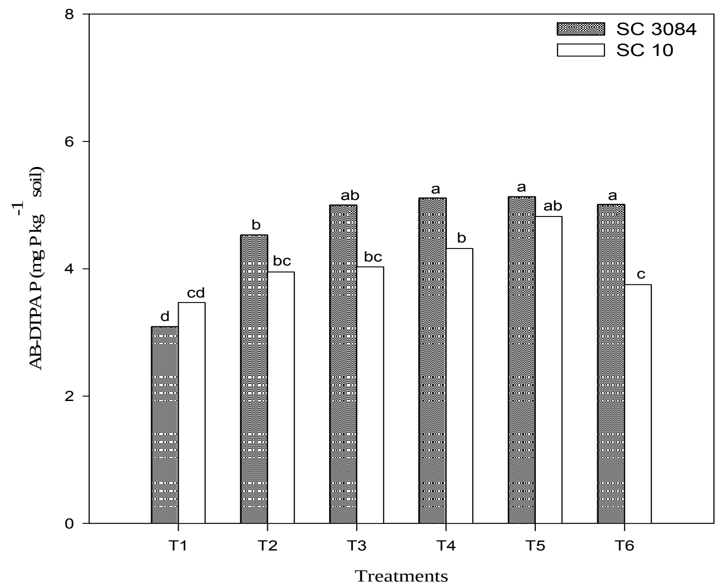

Fig 3. AB-DTPA-P in soil as affected by fertilization treatments.
T_1, T_2, T_3, T_4, T_5 and T_6 denote fertilization with : non-fertilized, Bio-fertilization with *B. megaterium*, phospho-gypsum (PG), Bio-fertilization+ PG, sulfur + PG and superphosphate, respectively.

Effect on P uptake by maize grains

Analysis of variance reveals that both cultivars and the applied treatments influenced significantly P uptake by plants (P= 0.017 and <0.001, respectively) (Fig. 4).The highest P uptake was recorded in maize grains that received superphosphate. The phospho-gypsum treatments i.e T_2, T_3 and T_4 increased P uptake by maize grains; however such increases were nor marked with or without *B. megaterium* or sulfur. Such results indicate that better management for the soil resources might be considered rather than high applications of P to soil.

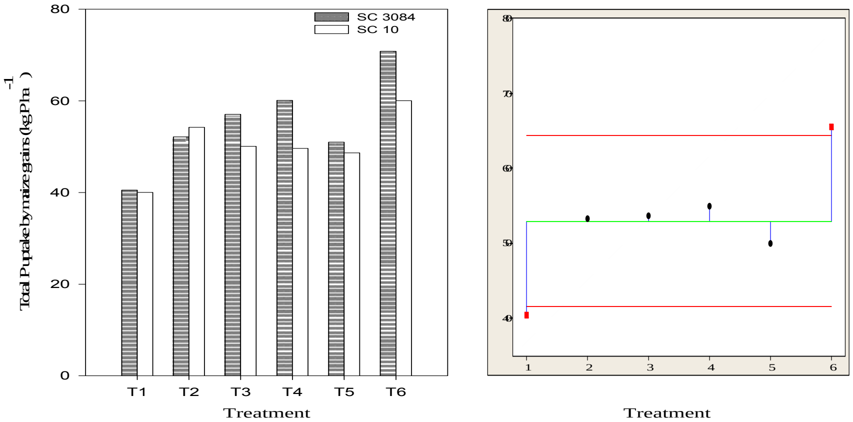

Fig 4. P uptake by maize grains as affected by fertilization treatments.
T_1, T_2, T_3, T_4, T_5 and T_6 denote fertilization with : non-fertilized, Bio-fertilization with *B. megaterium*, phospho-gypsum (PG), Bio-fertilization+ PG, sulfur + PG and superphosphate, respectively.

In conclusion, application of high rates of phospho-gypsum to fulfill the plant requirements from P-nutrient might dilute the available nutrient contents in the fertile soil surface and thus might limit plant growth. Besides, it might also be a source of further contamination of soils with the impurities found in these amendments. The governmental regulations in upper Egypt, concerning the additions of phospho-gypsum seemed efficient but non-responsive for maize plants grown in soils of high residual soil P content from previous applications and alternatively, the biological approach could be considered the optimum for increasing soil-P utilization (efficient and responsive).

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التحديات التي تواجه إنتاج الغذاء في مصر العليا: الإضافات الفوسفاتية ما بين التشريعات الحكومية و المخصبات منخفضة الكفاءة

[١]فايز مرقص فهمي و [٢]محمد حسن حمزة عباس
[1]معهد بحث الأراضي والمياه والبيئة- المركز القومي للبحوث-الجيزة-مصر
[2]كلية الزراعة بمشتهر- جامعة بنها-مصر
عنوان المراسلة:mrhamza_mh@hotmail.co.uk (محمد عباس)

تعتبر التنظيمات الحكومية أحيانا معوقات يمكن أن تؤثر سلبا علي انتاج الغذاء في مصر مثل الدفع الحكومي بالمزارعين لاستخدام رواسب حكومية والمسماه بالصخر الفوسفاتي وإضافتها إلي الأراضي الزراعية والموجودة في محافظة اسيوط بجنوب مصر وهذه الرواسب لا تتعدي نسبة الفوسفور بها ٠.٥% ويمثل الجبس الزرعي أغلب تكوينها بالرغم من كون هذه الأراضي غير صودية ومن ناحية أخري تحتوي هذه الأراضي علي تركيزات مرتفعة من الفوسفور الكلي نتيجة إضافة كميات كبيرة من الأسمدة الفوسفاتية إلي هذه الأراضي لسنوات طويلة وبالتالي تهدف هذه الدراسة إلي التحقق من استخدام بعض المعاملات والتي يمكن أن تزيد من استفادة المحصول النامي(صنفي ذرة هجين فردي ١٠ وهجين فردي ٣٠٤٨) من مثل هذه الرواسب لتحقيق أعلي محصول حبوب وتتمثل هذه العاملات في الكبريت العنصري (كمخفض لرقم حموضة التربة) بالإضافة إلي الفوسفورين (بكتريا مذيبة للفوسفور) وقد استخدم سماد السوبرفوسفات كمرجع تقاس علي أساسه النتائج المتحصل عليها وقد أوضحت النتائج أن التلقيح بالفوسفورين أحدث تحسنا في كفاءة استخدام النبات للفوسفور بالإضافة إلي زيادة في كل كمية محصول الحبوب الناتج، ومن الجدير بالمشاهدة أن إضافة الرواسب الحكومية قد أحدثت زيادة في كمية الحبوب الناتجة دون وجود تأثير معنوي للمحسنات المضافة مع الرواسب الحكومية (الكبريت أو الفوسفورين) علي كمية الحبوب الناتجة، هذا وقد تفوق المحصول الناتج عن إضافة السماد الفوسفاتي إلي التربة مقارنة بالمحصول المتحصل عليه في وجود الرواسب الحكومية ولكن يبدو أن جميع معاملات الفوسفات قد أحدثت انخفاضا ملحوظا في كفاءة استخدام النبات للفوسفور وبالتالي يمكن أن نطلق علي المعاملة الحيوية بأنها المعاملة الكفء والفعالة في زيادة كفاءة استخدام الذرة للفوسفور الموجود بالتربة التي تحتوي علي كميات مرتفعة من الفوسفور مع تجنب الزيادات الحادثة في تكاليف الإنتاج و تلافي الملوثات التي يمكن أن تتواجد كشوائب في المخصبات الفوسفاتية المستخدمة.

قام بتحكيم البحث

أ.د / احمد عبد القادر طه	**كلية الزراعة – جامعة المنصورة**
أ.د / على احمد عبد السلام	**كلية الزراعة بمشتهر – جامعة بنها**