



Improvement in phosphorus use efficiency of corn crop by amending the soil with sulfur and farmyard manure

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Abstract

The use of organic manure is proposed to reduce the use of chemical fertilizers, as well as to add sulfur (S) into the soil so that the phosphate use efficiency may be improved by maize crop. This field experiment was conducted during 2014 at Assiut city, Assiut governorate, Egypt to study the effect of sulfur and farmyard manure (FYM) on phosphorus availability, grain yield and phosphorus use efficiency of corn (Zea mays L. cv Single Hybrid 10). Randomized complete block design was followed with three replications. Four treatments viz SP= superphosphate, SP+S = superphosphate +sulfur, SP+FYM = superphosphate +farmyard manure and SP+FYM+S = superphosphate + farmyard manure + sulfur were tested. The soil analysis after corn harvest showed that the Olsen P of the soil improved with applying sulfur or farmyard manure and their mixture in presence of superphosphate. Adding farmyard manure with superphosphate enhanced grain yield of corn plants by 44.6% as well as the application of superphosphate with farmyard manure and sulfur increased the grain yield by 44.2% compared to the SP. The results in this study showed that amending soil by farmyard manure and sulfur with superphosphate improved phosphorus use efficiency in comparison with superphosphate alone.

Keywords: Superphosphate, grain yield, phosphorus uptake, recovery efficiency

Introduction

Egypt is located in the arid and semi-arid regions. Where most soils are considered being alkaline with soil pH greater than 7, calcium is predominant cation which reacts with phosphate ion and converts it into dicalcium and tricalcium phosphate and hydroxyapatite. One of the problems in alkaline soils when adding phosphate fertilizers is that the soluble phosphate turns to insoluble compounds of low availability to plants (Brady and Weil, 1999). Generally, the arid and semi-arid regions are poor in the organic matter content because of high temperature and low rainfall. Therefore we have to make up the shortfall in organic material by adding organic fertilizer. The application of manure is widely practiced to increase the productivity of soils that contains inadequate levels of organic carbon. The organic fertilizers applied to the soil enhanced soil fertility which release nutrients, maintain aggregate stability and permeability of the soil as well as improve biological activity in the soil (Adediran *et al.*, 2005; Edmeades, 2003). The utilization of organic manures in soil fertilization caused the reduction of the chemical phosphorus fertilizers use. In some countries such as Switzerland, chemical phosphorus fertilizers import decreased by 66% because of using organic manures (Frossard *et al.*, 2009). The addition of organic manures with inorganic phosphate fertilizer was led to increasing the availability and solubility of applied phosphate in the soil

and improving the soil productivity (Agbenin and Igboke, 2006). Also, (Garg and Bahl 2008) reported that the addition of organic manures to soil increased Olsen P due to the mineralization of organic manures. *Thiobacillus* bacteria contribute in the biological oxidation of sulfur producing sulphuric acid which leads to dissolving phosphorus from rock phosphate (Bhatti and Yawar, 2010). Corn (*Zea mays* L.) is the third most important crop in the world after wheat and rice. It is also one of the major cereal crops in Egypt, so it has importance to human and animal feeding. Increasing levels of sulfur up to 60 kg S ha⁻¹ significantly enhanced the grain yield of maize (Khan *et al.*, 2006). The objectives of this study are to investigate the effect of sulfur and farmyard manure application on phosphorus availability, phosphorus use efficiency by corn plants and grain yield of corn.

Materials and Methods

Field experiment

This study was carried out during 2014 season at Assiut city, Assiut governorate to examine the effect of sulfur and farmyard manure on phosphorus use efficiency by corn plants (*Zea mays* L. cv Single Hybrid 10). The physical and chemical properties of the soil under study are presented in (Table 1). The experiment was designed as a randomized complete block with four treatments and three replications. These treatments were SP= superphosphate, SP+S =

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superphosphate+sulfur, SP+FYM= superphosphate+farmyard manure and SP+FYM+S = superphosphate + farmyard manure + sulfur. The superphosphate (15% P₂O₅), sulfur and farmyard manure were applied at level of 240 kg ha⁻¹, 476 kg ha⁻¹ and 20 t ha⁻¹, respectively. The potassium fertilizer was applied in one dose of 120 kg K₂SO₄ ha⁻¹. The additions of superphosphate fertilizer, elemental sulfur, farmyard manure and potassium fertilizer were before one week from cultivation and added through broadcast method. The elemental sulfur treatments were inoculated with *Thiobacillus* bacteria to motivate oxidation of elementals, were added in liquid form. The experimental unit area was 11.2 m² (4 x 2.8 m) with three rows per plot and the space between the rows was 0.75 m. The level of corn was 24 kg ha⁻¹ and corn grains were sown on June 5th 2014. Grains were sown in holes at space of 30 cm between each of them. After the germination the plants were thinned to one plant in hill. The nitrogen fertilizer was added to soil at level 286 kg N ha⁻¹ as Urea (46.5%) and applied in two doses after 14 and 42 days from sowing. Corn plants were harvested after 110 days from planting and grain yield was recorded. The weight of grain yield was estimated for each plot separately. Soil samples were taken from each plot after the harvest for phosphorus analysis.

Soil and plant analysis

The particle size distribution of this soil was determined by the pipette method (Jackson, 1973). Moreover, the organic carbon (OC) was determined by the Walkley–Black dichromate oxidation method (Jackson, 1973). Soil pH was determined with glass electrode in a 1:1 (soil: water) suspension and the electrical conductivity (EC) was measured of 1:2.5 soil: water extract by an electrical conductivity meter (Baruah and Barthakur, 1997). Calcium carbonate (CaCO₃) was estimated using a volumetric calcium carbonate calcimeter (Jackson, 1973). Exchangeable cations were measured with the ammonium acetate replacing method (Baruah and Barthakur, 1997). Olsen P was extracted using 0.5 M NaHCO₃ at pH 8.5 according to Olsen et al. (1954). Total phosphorus in shoot and grain of corn plants has been appreciated by the digestion of the samples with a 2:1 of HNO₃:HClO₄ acid mixture (Morais and Rabelo, 1986). Phosphorus in the extracts was measured colorimetrically by the chlorostannous phosphomolybdic acid method in sulphuric acid system (Jackson, 1973).

Calculation of phosphorus uptake and use efficiency by corn plants

Phosphorus uptake and use efficiency by corn plants (*Zea mays* L.) were calculated as follows according to (Baligar et al., 2001; Dobermann, 2005; Hussein, 2009):

$$\text{phosphorus uptake } \left(\frac{\text{kg}}{\text{ha}} \right) =$$

$$\frac{\text{P concentration (mg/kg) in plant part (dry matter)} \times \text{Yield (kg/ha)}}{1000000}$$

Partial factor productivity of applied phosphorus (PFP_P) or phosphorus use efficiency (PUE)

$$\text{PFP}_P = \frac{\left(\text{Grain yield at applied P} \frac{\text{kg}}{\text{ha}} \right)}{\left(\text{Amount of phosphorus applied, kg} \frac{\text{P}_2\text{O}_5}{\text{ha}} \right)} =$$

$$\text{kg grain/kg P}_2\text{O}_5$$

Crop recovery efficiency of applied phosphorus (RE_P)

$$\text{RE}_P =$$

$$\frac{\left(\text{Total P uptake at applied P} \frac{\text{kg}}{\text{ha}} - \text{Total P uptake at control or no P} \frac{\text{kg}}{\text{ha}} \right)}{\left(\text{Amount of phosphorus fertilizer P, kg} \frac{\text{P}_2\text{O}_5}{\text{ha}} \right)} =$$

$$\text{kg/kg P}_2\text{O}_5$$

Where: increase of phosphorus uptake (kg) / applied P₂O₅ (kg)

Statistical analysis

Data collected were analyzed statistically using MSTAT program and the least significant difference (LSD) was used to compare treatment means at $p \leq 0.05$ level of significance (Steel and Torrie, 1982).

Results

Phosphorus availability (Olsen P)

In the present study, the application of sulfur and farmyard manure in presence of superphosphate to the clay soil caused significant increases in the available phosphorus after harvesting corn plants compared to adding superphosphate alone treatment (Table 2). The available phosphorus increased from 12.4 mg kg⁻¹ when the superphosphate was added alone to 22.5 mg kg⁻¹ using sulfur and farmyard manure in the presence of superphosphate.

Grain yield and total phosphorus uptake of corn

A significant increase in the grain yield of corn was recorded as a result of applying farmyard manure and sulfur with inorganic P fertilizer, in compare to that of the superphosphate alone (Table 2). Adding superphosphate with farmyard manure enhanced the grain yield from 4003.3 with SP alone treatment to 5790.2 kg ha⁻¹. However, superphosphate applied with farmyard manure and sulfur increased the grain yield from 4003.3 to 5774.6 kg ha⁻¹. Thus, the additions of farmyard manure with sulfur, or each one individually in the presence of superphosphate caused significant increases in the total phosphorus uptake by corn plants compared to the superphosphate alone treatment (Table 2). The total phosphorus uptake enhanced from 20.5



kg ha⁻¹ with using superphosphate alone treatment to 30.4 kg ha⁻¹ at the addition of farmyard manure with superphosphate as well as the superphosphate application

with farmyard manure and sulfur raised the total phosphorus uptake from 20.5 to 29.1 kg ha⁻¹.

Table 1: Characteristics of the soil and farmyard manure under study

| Soil | |
|---|------------|
| Property | Value |
| Clay (g kg ⁻¹) | 454.0 |
| Silt (g kg ⁻¹) | 484.9 |
| Fine sand (g kg ⁻¹) | 30.8 |
| Coarse sand (g kg ⁻¹) | 30.3 |
| Texture | Silty clay |
| Organic carbon (g kg ⁻¹) | 8.64 |
| CaCO ₃ (g kg ⁻¹) | 12.5 |
| EC _(1:2.5) (dS m ⁻¹) | 0.44 |
| pH _(1:1) | 7.64 |
| Soluble Cations in soil extract (1:2.5) | |
| Ca (cmol _c kg ⁻¹) | 0.5 |
| Mg (cmol _c kg ⁻¹) | 0.28 |
| Na (cmol _c kg ⁻¹) | 0.52 |
| K (cmol _c kg ⁻¹) | 0.03 |
| Exchangeable Cations | |
| Ca (cmol _c kg ⁻¹) | 58.88 |
| Mg (cmol _c kg ⁻¹) | 17.33 |
| Na (cmol _c kg ⁻¹) | 1.3 |
| K (cmol _c kg ⁻¹) | 1.58 |
| Available phosphorus (mg kg ⁻¹) | 9.03 |
| Farmyard manure | |
| Organic carbon (g kg ⁻¹) | 128.5 |
| Total N (g kg ⁻¹) | 4.6 |
| Total P (g kg ⁻¹) | 3 |
| Total K (g kg ⁻¹) | 11 |

Table 2: Olsen P, grain yield of corn, total phosphorus uptake (TPU), partial factor productivity of applied phosphorus (PFP_P), and crop recovery efficiency of applied phosphorus (RE_P) fertilized with sulfur and farmyard manure

| Treatment* | Olsen P (mg kg ⁻¹) | Grain yield (kg ha ⁻¹) | TPU (kg ha ⁻¹) | PFP _P kg/kg P ₂ O ₅ | RE _P kg/kg |
|---------------------------|--------------------------------|------------------------------------|----------------------------|--|-----------------------|
| SP | 12.4 | 4003.3 | 20.5 | 111.2 | 0.04 |
| SP+S | 14.5 | 4919.6 | 24.9 | 136.7 | 0.16 |
| SP+FYM | 20.9 | 5790.2 | 30.4 | 160.9 | 0.31 |
| SP+FYM+S | 22.5 | 5774.6 | 29.1 | 160.4 | 0.28 |
| LSD_{0.05} | 5.89 | 763.6 | 4.23 | 21.20 | 0.109 |

SP= superphosphate, SP+S = sulfur + superphosphate, SP+FYM = farmyard manure + superphosphate
 SP+FYM+S = sulfur + farmyard manure + superphosphate



Partial factor productivity and crop recovery efficiency of applied phosphorus

The results in this study showed that the amendment through farmyard manure and sulfur with superphosphate improved the partial factor productivity of applied phosphorus (PFP_P) or phosphorus use efficiency in comparison with superphosphate alone (Table 2). PFP_P was increased from 111.2 kg of corn grain/kg of P₂O₅ applied for superphosphate treatment to 160.9 and 160.4 kg of corn grain /kg of P₂O₅ for superphosphate + farmyard manure and superphosphate + farmyard manure + sulfur, respectively. It has been well documented that sulfur and farmyard manure applications with superphosphate caused significant increases in the crop recovery efficiency of applied phosphorus (RE_P). Increasing in the RE_P was noticed from 0.04 kg P uptake/kg applied P₂O₅ at SP to 0.31 and 0.28 kg P uptake/kg applied P₂O₅ for SP+FYM and SP+FYM+S treatments, respectively (Table 2).

Discussion

Effect of sulfur and farmyard manure on Olsen P

In this study, the application of sulfur and farmyard manure with superphosphate to the soil resulted in an increase in Olsen P by 81.4% compared to superphosphate treatment. Therefore, these treatments resulted in increases in the soil available phosphorus in the order of SP+FYM+S>SP+FYM>SP+S>SP. The concentration of available phosphorus increases because of the applications of manure with phosphate fertilizer (Zhihui *et al.*, 2016). The phosphorus availability is enhanced as a result of the decomposition of organic manure which releases nutrients such as phosphorus (Galvez-Sola *et al.*, 2010) as well as lowering the soil pH due to sulfur and FYM addition. Applying sulfur with triple superphosphate was reported to show significantly higher available-P than using triple superphosphate alone in alkaline high-Ca soils may be because the addition of elemental sulfur produces sulfuric acid that is created by microbial oxidation of sulfur (DeLuca, 1989). The combined application of organic manure and chemical fertilizers also could increase the availability of soil phosphorus (Ding *et al.*, 2016).

Effect of sulfur, farmyard manure and their mixture on corn plant parameters

Compared to the superphosphate treatment, additions of SP+FYM, SP+FYM+S and SP+S treatments displayed increases in the grain yield of 44.6, 44.2 and 22.9%, respectively. Effectiveness of these treatments on the grain yield increase was in the order of SP+FYM>SP+FYM+S>SP+S>SP (Figure 1). Applications of

farmyard manure with triple superphosphate were found to exhibit a significant higher grain yield than adding triple superphosphate alone (Aye *et al.*, 2009). Moreover, Rasool *et al.* (2008) indicated significant increases in the grain yield of corn due to the combined application of FYM and superphosphate. Also, the grain yield of corn increased with applying sulfur with inorganic fertilizers (Kihara and Njoroge, 2013). The increment of the grain yield may be attributed to the increases in the phosphorus availability with adding organic matter to the soil that improves the biological, physical and chemical soil properties which enhance plant growth and soil productivity (Zhao *et al.*, 2009). Relative to the superphosphate treatment, SP+FYM, SP+FYM+S and SP+S increased total phosphorus uptake by 48.5, 42.2 and 21.5%, respectively. Effectiveness of the treatments in increasing the total phosphorus uptake by corn plants using the investigated treatments was in the order of SP+FYM>SP+FYM+S> SP+S>SP (Fig. 1). These may be a result of the increase in the P availability of the soil and its absorption by plants. The uptake of phosphorus by corn plants increased with FYM and inorganic fertilizers additions over the control treatment (Rasool *et al.*, 2008). Increases in the phosphorus uptake by corn roots and shoots were observed with increasing the phosphorus availability in the soil (Fageria and Baligar, 1997).

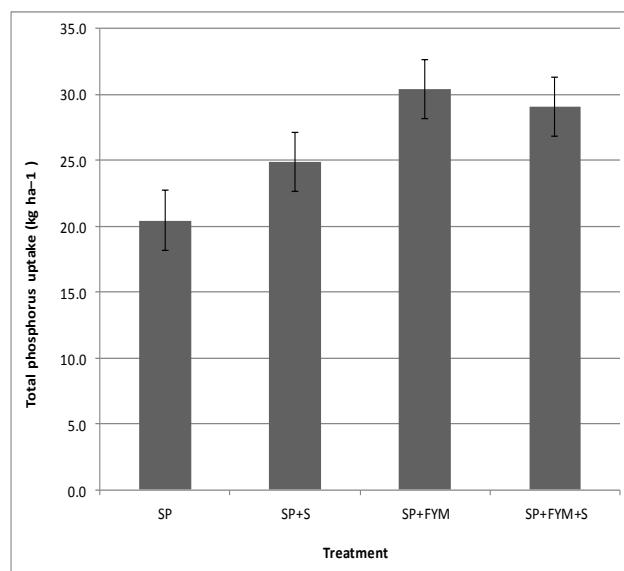


Figure 1: Changes of total phosphorus uptake by corn under amendment by sulfur and farmyard manure

Sulfur, farmyard manure and their mixture application with superphosphate increased the PFP_P by 22.9, 44.7 and 44.2%, respectively, relative to SP alone treatment.

Therefore, the treatments used in this investigation showed increases in the PFP_P in the order of $SP+FYM > SP+FYM+S > SP+S > SP$ (Fig. 2). The increment of phosphorus use efficiency of corn plants may be due increase in the phosphorus availability of the soil (Fageria and Baligar, 1997). The highest value of RE_P was recorded for farmyard manure with superphosphate treatment. The tested treatments can be ranked with respect of RE_P increment in the order of $SP+FYM > SP+FYM+S > SP+S > SP$.

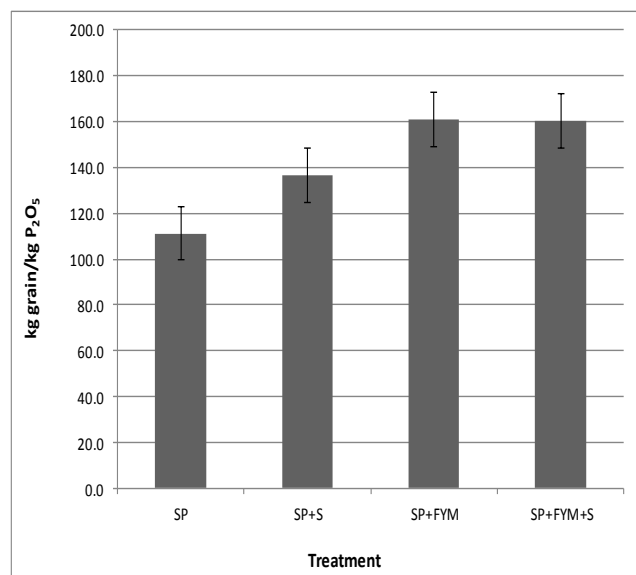


Figure 2: Partial factor productivity of applied phosphorus (PFP_P) affected by sulfur and farmyard manure amendments

Conclusion

In the current study, the application of sulfur and farmyard manure in the presence of superphosphate showed an improvement of the soil productivity by enhancing the bioavailability of phosphorus, grain yield of corn, total phosphorus uptake and use efficiency of phosphorus by corn plants. We recommend fertilizing the soil via sulfur and farmyard manure, this would be conducive to reduce the use of chemical fertilizers. This is considered one of the most important strategies of sustainable agriculture.

Acknowledgments

The author offers sincere thanks and appreciation to Prof. Dr. M.A. El-Desoky, Professor of Soil Sciences, Department of Soils and Water, Faculty of Agriculture, Assiut University, Egypt, for his linguistic correction of this manuscript.

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