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Maize dry matter yield and P uptake as influenced by rock phosphate and single super phosphate treated with farm manure

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Abstract

The availability of soluble P fertilizers at affordable prices has become a myth in Pakistan. One alternative under consideration is the use of locally available rock phosphate (RP) which requires dissolution of P from apatite before its use. The main aim of this study was to assess the availability of P from RP amended with farm manure (FM). Locally available rock phosphate and single superphosphate (SSP) as P_2O_5 were applied at 0+100, 25+75, 50+50, 75+25 and 100+0 %, respectively, with and without farm manure (10 tons ha^{-1}) in addition to the treatment receiving recommended rate of N and K at 150 and 60 kg ha^{-1} in the form of urea and sulphate of potash, respectively. Farm manure application had a significant positive effect on plant growth, yield, P in leaf tissue and uptake of maize in all the treatments. The treatment receiving 25+75% RP and SSP along with 10 tons ha^{-1} FM produced maximum shoot dry matter yield (30 g pot^{-1}), P content (0.31%) and uptake (0.10 g pot^{-1}) followed by treatment having 50+50 RP and SSP . It may be concluded that RP integrated with SSP and FM increased maize growth, dry matter, leaf P content and uptake so, it can be adapted as an alternative strategy to get improved yield of maize in resource poor country like Pakistan.

Key words: *Rock phosphate, farm manure, phosphorus, uptake*

Introduction

Low availability of phosphorus is a common problem in calcareous soils mainly because of its precipitation with Ca and adsorption to $CaCO_3$ (Rahmatullah *et al*., 1994) and Fe and Al oxides (Memon *et al*., 2011). More than 80% soils of Pakistan are deficient in Olsen P (Memon, 2005). Reversing soil depletion, the availability of phosphate fertilizers at reasonable prices is necessary. The rise in soluble P fertilizer prices has developed interest in the use of rock phosphate (White *et al*., 1999; McLay *et al*., 2000; Akintokun *et al*., 2003; Odiete *et al*., 2005). However, due to its low solubility in alkaline calcareous soils, the direct application of rock phosphate has not been effective (Ghosh, 1999) as compared to the acidic soils.

Rock phosphate (RP) is a type of sedimentary rock having P in apatite form with no water soluble P. It is used as a basic P source for commercial P fertilizer production. Major RP reserves of the country are found in lagarban region of Hazara division positioned in the North East. According to Memon (2005), it contains average 25.8% P_2O_5 along with 6% MgO. With enormous livestock population, Pakistan is rich in farm manure. About 50% animal waste is used as fuel and other 50% is not utilized (FAO, 2004).

Plants require soluble portion of P, hence, it is obligatory that the apatite P present in RP be converted into water soluble P. In acid soils, RP is soluble to some extent owing to the presence of hydrogen ions and, therefore, its use is common in these soils (Vitosh, 1990). Whereas, the low concentration of hydrogen ions in alkaline soils hold back the P solubility process and rock phosphate is not effective unless adequate hydrogen ions are made available. Studies show that P solubility increases as the organic matter content increases (Khattak, 1996). The decomposed organic matter liberate organic acids such as humic acid, which lower soil pH as a result of calcium and magnesium ion chelation process and boost the availability of P from RP (Sagoe *et al*., 1998; Van Straaten, 2002; Savini *et al*., 2006; Ali *et al.,* 2012).

Single super phosphate (SSP) is very common source of P used by farmer community and an ample amount of work is done in this regard. Its effectiveness as sole application is proved by the highest total biomass in soybean (Sharma *et al*., 2002) maize (Akande *et al*., 2010), chickpea (Srividya *et al*., 2009) and cowpea (Akande *et al*., 2010) compared with RP. However, some studies indicated better response of integrated use of RP with chemical P fertilizer sources namely MAP, DAP, SSP and TSP reporting better response, whereas, in some cases it is other way around (Bolan *et al*., 1990; Sanyal and De Datta, 1991;

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Hafeez *et al*., 2010). The combined use of organic and inorganic fertilizers improves the efficiency of both sources and helps in substitution of costly chemical input (Hussain and Ahmed, 2000). This study has been, therefore, conducted to assess the best combination of RP and SSP treated with FM using maize as a test crop.

Materials and Methods

Pot experiment

A pot experiment was conducted at the Department of Soil Science, Sindh Agriculture University Tandojam to study the effect of RP and SSP along with FM on dry matter yield and P uptake in maize. A surface soil (0-15 cm depth) in bulk was collected from Latif Experimental Farm Tandojam, dried and ground to pass through 2 mm sieve for pot experiment. The experiment was laid out in completely randomized design (CRD) with eleven treatments and three replications. The treatments were factorial combination of RP and SSP as P_2O_5 (0+100, 25+75, 50+50, 75+25 and 100+0 %) with 0 and 10 tons ha^{-1} FM along with one treatment of recommended N and K at 150 and 60 kg ha^{-1} in the form of urea and sulphate of potash (SOP), respectively. Ten seeds per pot were sown and irrigated as required by the crop. The crop was harvested after 6 weeks. Growth and yield parameters were recorded. The plants were dried in shade for one day and then oven dried at 65 to 68 ^{o}C till constant weight was obtained. Dry matter yield was recorded for each treatment and the oven-dried plants were ground and analyzed for total P content. The P uptake was calculated as a product of P concentration and dry matter. Analysis of variance was performed for plant height, shoot dry matter, P concentration in plant tissue and P uptake by maize plant using the Statistix 8.1. All pair wise comparisons of means of the data were obtained by using Tukey's HSD test at $p < 0.05$.

Soil and plant analyses

The experimental soil was analyzed for particle size distribution by Bouyoucos hydrometer method (Bouyoucos, 1962), electrical conductivity and pH in 1:5 soil-water extract using EC meter and pH meter, respectively, organic matter by Walkley-Black method (Jackson, 1969) and calcium carbonate by acid neutralization method (Kanwar and Chopra, 1959). The available P in soil was extracted by sodium bicarbonate as given by Olsen (Olsen *et al*., 1954) and the amount of P in extracts was quantified by using the method of Murphy and Riley (1962). Phosphorus in leaf tissue was determined by first digesting the sample in an acid mixture ($HClO_4$:HNO_3 - 1:5), followed by P analysis on spectrophotometer by vanadomolybdo-phosphoric acid yellow colour method (Cottenie, 1980).

Results

Soil parameters

The particle size distribution showed that soil contained 26.5% sand, 40.0% silt and 33.5% clay having a clay loam textural class. The chemical characteristics of soil showed that soil was medium alkaline in reaction (7.6-8.2) (Ankerman and Richard, 1989) with pH 7.70, non-saline (<2 dS m^{-1}) with EC 0.35 dS m^{-1}, moderately calcareous (10-15%) (Jackson, 1969) with 12.70% $CaCO_3$ content, low in organic matter (<0.86%) (FAO, 1980) with 0.56% organic matter and low in available P (5-10 mg kg^{-1}) (Olsen *et al*., 1954) with 6.12 mg kg^{-1} Olsen P.

Plant parameters

Plant height

Plant height of maize ranged between 32.00 and 60.50 cm with an average value of 43.13 cm (Table 1). The effect of RP and SSP with and without FM was highly significant ($p \leq 0.01$) on plant height (Table 2 and Figure 1). The maximum plant height (55.27 cm) was observed in treatment with recommended dose of NPK along with FM at 10 t ha^{-1} and minimum of 36.30 cm in treatment 100% RP along with N and K fertilizers at recommended rates. Statistically, treatment NPK+FM was non-significant ($p \leq 0.05$) to the treatment where recommended NPK fertilizer was applied and was significant with all other treatments. The data showed an increased plant height due to SSP and further increase in growth with the application of FM.

Shoot dry matter yield

The shoot dry matter yield of maize ranged between 17.50 and 33.50 g pot^{-1} with an average value of 23.74 g pot^{-1} (Table 1). The effect of RP and SSP with and without FM was highly significant ($p \leq 0.01$) on shoot dry matter yield. The highest dry matter yield of 30.33 g pot^{-1} was observed in treatment applied with RP and SSP (25+75%) along with 10 tons ha^{-1} FM and minimum of 18.33 g pot^{-1} in control (Figure 2). Statistically, the dry matter yield of treatments receiving recommended NPK+FYM and rock phosphate and SSP (50+50, 75+25 and 100+0)+FYM was at par to the treatment RP and SSP (25+75%)+FYM achieving maximum shoot dry matter yield.

Phosphorus concentration in plant tissue

The P content of maize plant tissue ranged between 0.18 and 0.35 % with an average value of 0.25% (Table 1). The effect of RP and SSP with and without FM was highly significant ($p \leq 0.01$) on P concentration in maize shoot. The highest P concentration of 0.311% was observed in treatment with RP and SSP (25+75%) along with 10 tons

ha^{-1} FM and minimum of 0.195% in control where N and K were applied at recommended rates (Figure 3). Statistically, RP and SSP (25+75%) was statistically ($p \leq 0.05$) similar to treatments NPK, NPK+FM, 25+75+0+NK, 50+50+FM+NK, 75+25+FM+NK and 100+0+FM+NK. Whereas, treatments RP and SSP (50+50, 75+25 and 100+0%) without FM were significantly different from RP and SSP (25+75%) but similar to each other.

Table 1: Mean, range, standard deviation and coefficient of variability of the pot experiment data

Parameter	Mean	Range	SD	Coefficient of variability
Plant height (cm)	43.13	32.00-60.00	5.77	13.38
Shoot dry matter yield (g pot^{-1})	23.74	17.70-33.50	3.60	15.15
Phosphorus concentration in plant tissue (%)	0.25	0.18-0.35	0.04	17.32
Phosphorus uptake (g pot^{-1})	0.06	0.03-0.10	0.02	29.35

Table 2: F value and probability of the pot experiment data

Parameter	F value	Probability
Plant height (cm)	11.32	0.0000
Shoot dry matter yield (g pot^{-1})	7.70	0.0001
Phosphorus concentration in plant tissue (%)	5.91	0.0004
Phosphorus uptake (g pot^{-1})	20.57	0.0000

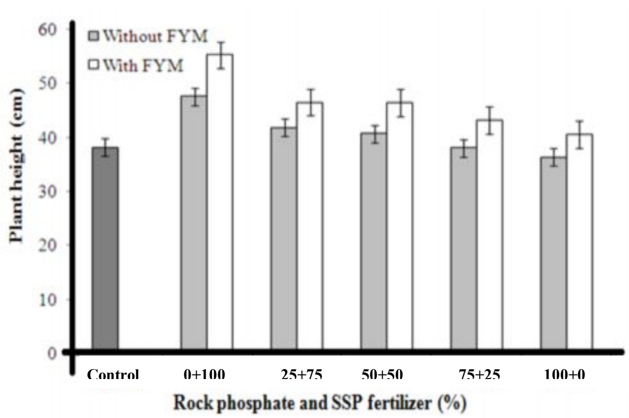

Figure 1: Effect of rock phosphate and SSP treated with FM on plant height of maize

Phosphorus uptake

The P uptake of maize ranged between 0.03 and 0.10 g pot^{-1} with an average value of 0.06 g pot^{-1} (Table 1). The effect of RP and SSP with and without FM was highly significant ($p \leq 0.01$) on P uptake (Figure 4). The highest P uptake of 0.095 g pot^{-1} was observed in treatment applied with RP and SSP (25+75%) along with 10 tons ha^{-1} FM and minimum of 0.035 g pot^{-1} in control (NK) (Fig. 4). Statistically, RP and SSP (25+75%) was significantly different ($p \leq 0.05$) from all other treatments except where recommend NPK and FM was applied.

Discussion

The effect of RP along with SSP and FM on yield and yield parameters of maize was organically positive. Similar results were reported by Patil *et al.* (2011). The chickpea was grown on clayey soil with pH 7.90 and available P 18.90 kg ha^{-1}. Although, they additionally used phosphorus solubilizing bacteria (PSB) in treatments but the effect of FM was prominent in treatment with a plant height of 35.73 cm with 200 kg ha^{-1} RP. Khan *et al.* (1999) found maximum maize plant height of 175.8 cm in the treatment where P was applied at 120 kg ha^{-1}. However, they did not use any FM. Whereas in a field experiment on chickpea conducted by Basir *et al.* (2008) showed that out of four P levels (0, 30, 60, 90 kg P_2O_5 ha^{-1}) maximum plant height was 94.7 cm in treatment having 60 kg P_2O_5 ha^{-1} and in FM applied treatments, maximum plant height was 90.4 cm where 10 tons of FM was applied, however, the effect of FM on plant height was non-significant in all other treatments receiving 5, 10 and 15 tons of FM.

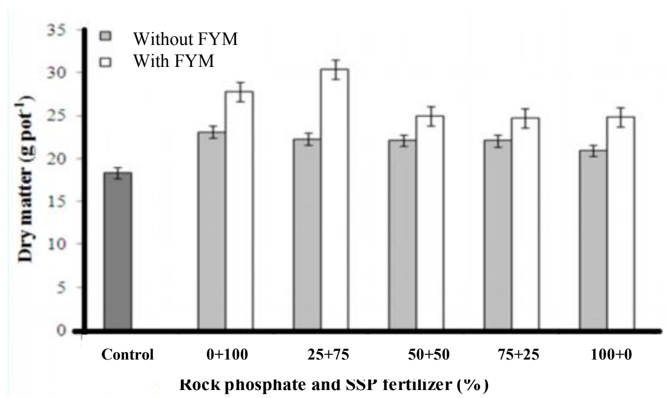

Figure 2: Effect of rock phosphate and SSP treated with FM on dry matter yield of maize

The dry matter yield (30.33 g pot^{-1}), P concentration (0.311%) and P uptake (0.095 g pot^{-1}) was maximum in treatment where RP and SSP were applied as 25+75%. Whereas the minimum values for dry matter and P concentration were obtained in control (NK) treatments as 18.33 g pot^{-1} and 0.195%, respectively. In case of P uptake, the minimum value of 38.04 g pot^{-1} was obtained in treatment receiving RP and SSP as 75+25, but were statistically non significant with control. All three parameters; dry matter, P concentration and uptake followed a decline with the increasing RP and decreasing SSP application in FM control treatments. However, all were statistically non significant, which shows that in no FM applied treatments, the ratio of RP and SSP did not have any significant effects on dry matter, P concentration and P uptake. The trend was different when rock phosphate + SSP were combined with FM. There was notable increase in dry matter yield, P concentration and P uptake with maximum values as 30.33 g pot^{-1}, 0.311% and 0.095 g pot^{-1}, respectively, in treatment having RP and SSP as 25+75% but were statistically similar to RP and SSP 50+50%.

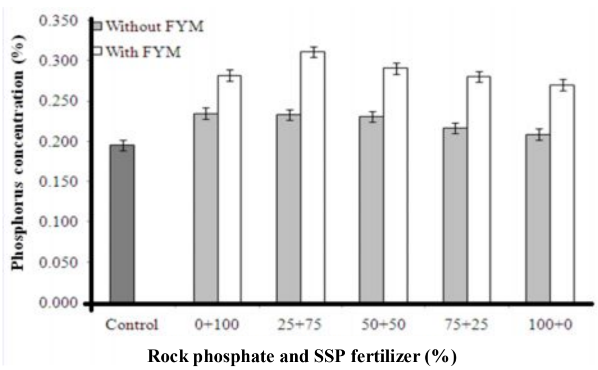

Figure 3: Effect of rock phosphate and SSP treated with FM on phosphorus concentration of maize

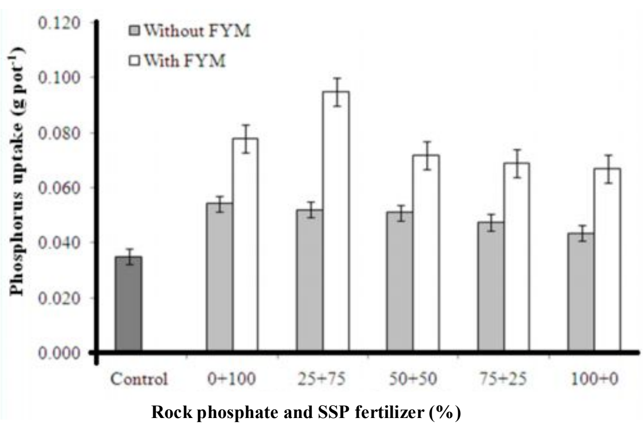

Figure 4: Effect of rock phosphate and SSP treated with FM on phosphorus uptake of maize

The treatment receiving 50+50 RP and SSP was similar to treatments receiving recommended NPK with and without FM with regard to plant height and P concentration. Similar results were reported by Chandrashekara *et al.* (2000) who reported 14% increase in fodder yields of maize when recommended rates of chemical fertilizer NPK (150-75-37.5 kg ha^{-1}) along with 10 t ha^{-1} FM were used as compared to this study where 21% increase in dry matter yield and 21% P concentration in plant tissue of maize over recommended doze of NPK. The results of Anthony and Akinrinde (2009) reported that cassava, maize and melon performed better when RP, organic and mineral fertilizer were applied in combination.

Conclusion

The application of RP along with FM was effective in increasing the plant height, shoot dry matter yield, P concentration and uptake in maize as SSP. It is concluded that the application of RP along with FM can be used as an alternate source of SSP. Similarly, the combined application of RP and SSP performed better than the individual application of the two with the recommended percent of RP and SSP as 50+50.

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