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Biophos Influence on P Availability from Rockphosphate Applied to Rice (*Oryza sativa* L.) With Various Amendments

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ABSTRACT

A greenhouse experiment was conducted to study the agronomic effectiveness of local rock phosphate with Biophos (PSM: Phosphorus Solubilizing Microorganisms) inoculation in conjunction with organic and inorganic amendments on rice yield and P–uptake. Rock phosphate (1.3 g kg^{-1} of soil) was applied to all the pots including control. Green manure and FYM (5% on dry weight basis) and Ca and Al @ 50 mg kg^{-1} of soil as gypsum and aluminum sulfate were added to the respective pots. Application of rock phosphate with PSM inoculation having FYM and green manure out yielded significantly followed by rock phosphate alone, while inorganic amendments showed a feeble response. Rock phosphate application alongwith green manure plus PSM increased 41% paddy yield closely followed by 39% increase in the case of rock phosphate alone under PSM inoculation. Rock phosphate with FYM produced 17% more yield than that of control (without PSM). With PSM inoculation, maximum P-uptake was observed where rock phosphate was applied with green manure followed by FYM. Sole application of rock phosphate with PSM inoculated treatment again performed better than that of gypsum and aluminum sulfate.

Key Words: Rock phosphate; Biophos (PSM); Green manure; FYM; Gypsum; Aluminum sulfate; Rice yield

INTRODUCTION

Phosphorus is found in soil, plant and in microorganisms in a number of organic and inorganic compounds. It is second only to nitrogen as an inorganic nutrient required by both plants and microorganisms, its major physiological role being in certain essential steps in the accumulation and release of energy during cellular metabolisms. This element may be added to soil in the form of chemical fertilizers, or it may be incorporated as leaf litter, plant residues or animal remains. Thus phosphorus occupies a critical position both in plant growth and in the biology of soil.

Rock phosphate is being considered as another phosphorus source for reversing soil fertility depletion (Ghosal *et al*., 1998; White *et al*., 1999). Although, on one hand, insoluble organic compounds of phosphorus are largely unavailable to plants, on the other hand many microorganisms can bring the phosphate into solution (Prosenjit *et al*., 1999; GuangLong *et al*., 1999). This attribute is apparently not rare since one-tenth to one-half of the bacterial isolates tested usually are capable of solubilizing calcium phosphate and counts of bacteria solubilizing phosphates may range from 10^2 to 10^5 per gram of agricultural soil. Such bacteria are often especially abundant on root surfaces (Nakayama *et al*., 1998). Many phosphate dissolving microorganisms in the vicinity of roots may appreciably enhance phosphate assimilation by higher plants (Manna & Ganguly, 1998; Rajkhowa *et al*., 1999).

The aim of Phosphorus Solubilizing Microorganisms (PSM) inoculation technology is to increase the efficiency of applied chemical fertilizers. By adopting the best method, source of application and utilization other than chemical fertilizers such as organic manures, biofertilizers, crop residues etc can meet part of the nutrient needs of crops in a cropping system (Khalil, 1995; Raju & Reddy, 1999; Sultan & Khalil, 1999). The organic and other bio sources of plant nutrients not only supply necessary nutrients but by positive interaction with chemical fertilizers they also increase their efficiency and thereby reduce environmental hazards (NFDC, 1988). Keeping this in view, the present investigation was undertaken to find the best combination of various amendments as well as Biophos inoculum for enhancing agronomic effectiveness of local rock phosphate.

MATERIALS AND METHODS

A greenhouse study was conducted at National Agricultural Research Centre, Islamabad to investigate the agronomic effectiveness of local rock phosphate with various organic and inorganic amendments with Biophos (PSM i.e., Phosphorus Solubilizing Microorganisms: a self prepared inoculum) inoculated and uninoculated conditions. The rice genotype Basmati–385 was grown during the growth season 2000 with the following treatments according to tetra–replicated completely randomized design (factorial):

T1 = Control
T2 = FYM (5% on dry weight basis)
T3 = Green manure (5% on dry weight basis)
T4 = Ca (50 mg kg^{-1} of soil) as gypsum
T5 = Al (50 mg kg^{-1} of soil) as aluminum sulfate

Overall, 30 glazed pots (30 cm x 25 cm) were filled with 6 kg air dried and ground clay loam soil (pH_s = 7.9; OM = 1.4%; $CaCO_3$ = 1.2%; available P = 4.03 mg kg^{-1};

exchangeable Fe = 25.9 mg kg^{-1}). Each treatment was well mixed with soil of the respective pots before filling. Kakul rock phosphate (P_2O_5 = 24%; CaO =39.5; Fe_2O_3 = 2.25%) @ 1.3 g kg^{-1} of soil was applied to all the pots including control. These five treatments were repeated thrice under both inoculated with Biophos as well as uninoculated treatments. A basal dose of K @ 100 mg kg^{-1} of soil (in 4 splits) in addition to 10 mg kg^{-1} of soil, Zn, Cu and Mn as $ZnSO_4$, $CuSO_4$, $MnSO_4$, respectively was applied to all the treatments. Iron @ 20 mg kg^{-1} of soil as $FeSO_4$ and 1.0 mg kg^{-1} of soil $H_3B_3$was also applied to all the treatments at the time of seedling transplanting. Nitrogen @ 200 mg kg^{-1} of soil as urea was applied in three splits, i.e., at seedling transplanting, tillering and panicle initiation stage.

Six, 30–days old seedlings were transplanted to each pot. Seedlings for inoculated treatments were treated with Biophos (PSM) by dipping the roots in a Biophos solution containing 10^9 CFU mL^{-1}. After plants establishment, thinning was done to three healthy plants. Tap water (EC = 0.4 dS m^{-1}; SAR = 1.3 mmol L^{-1} & RSC = 0.7) was applied throughout the growth period. Necessary plant protection measures were done whenever required for a good crop stand. At maturity, the crop was harvested to collect the yields. Dried and ground plant materials from each treatment were analyzed for P concentration to calculate P–uptake. The data thus obtained were analyzed statistically following ANOVA technique (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Results revealed from the study (Table I) that yield of rice genotype Basmati 385 was significantly increased in response to various amendments and Biophos (PSM) inoculation except in case of gypsum and aluminum sulfate application where yield was significantly lower than other treatments as well as than uninoculated gypsum treatment. It might be due to the formation of insoluble inorganic compounds of phosphorus because of calcium sulfate and aluminum sulfate. Thus lesser yield in these treatments is attributed to P fixation in the form of aluminum phosphate and calcium phosphate. Moreover, under inoculated condition, during the decomposition, the increase in microbial abundance puts a great demand on the phosphate supply. Consequently, if the phosphorus is deficient in the carbonaceous residue, the microbial assimilation of available phosphate may depress the crop yield. Sauerbeck and Johnen (1977), Coleman *et al*. (1983) and Salim *et al*. (1989) have discussed similar results.

Under uninoculated environment, FYM and gypsum treatments with rock phosphate produced higher yield than rest of the treatments and was statistically similar to that of yields obtained from FYM, green manure and rock phosphate alone treated pots under Biophos inoculation. A comparison of treatments with and without Biophos addition showed 41% increase in grain yield when green manure was added alongwith Biophos and 17% when FYM was applied with Biophos inoculation. Biophos inoculation added with rock phosphate, i.e., without any amendment produced 39% increase as compared to the respective rock phosphate treatment. Similar conclusions have also been reported by Pany *et al*. (1998), Ghosal *et al*. (1998) and White *et al*. (1999).

Table I. Effect of Biophos inoculation, organic and inorganic amendments on rice growth and yield (g pot^{-1}) (Average of four repeats)

Treatments	Grain yield		Straw yield		↑ in grain yield due to PSM
	– PSM	+ PSM	– PSM	+ PSM	
T1	9.30 c	13.10 b	41.70 c	38.70 d	39%
T2	12.80 b	15.00 a	48.70 ab	40.40 c	17%
T3	9.80 c	13.90 ab	47.20 b	49.70 a	41%
T4	13.60 b	10.10 c	47.50 b	39.70 d	–26%
T5	9.70 c	9.80 c	46.60 b	35.40 e	00%
Mean	11.04 B	12.38 A			

Values followed by same letter(s) are similar statistically at p=0.01

P–Uptake. The data depicted in Table II demonstrate P–uptake by rice crop grown under inoculated and uninoculated soil condition. Maximum P–uptake (114.44 mg pot^{-1}) was observed with the application of green manure plus rock phosphate and Biophos inoculation than rest of the treatments while under uninoculated soil condition, it was maximum with FYM plus rock phosphate. These results indicate that organic and inorganic acids produced by phosphorus solubilizing bacteria converted $Ca_3(PO_4)_2$ to di and monobasic phosphates with net result of an enhanced availability of the element to plants. Moreover, it is speculated that certain bacteria that liberate hydrogen sulfide that reacts with phosphate compounds and liberate phosphate might have made phosphorus more available for plant uptake. Similar conclusions have also been reported by Coleman *et al.* (1983), NFDC (1988), Mongia *et al.* (1998), GuangLong *et al.* (1999), and Raju and Reddy (1999).

Table II. Effect of Biophos inoculation on P–uptake (mg pot^{-1}) by rice grown with rock phosphate and various organic and inorganic amendments (Average of four repeats)

Treatments	P–Uptake		Mean
	– PSM	+ PSM	
T1	42.24 g	80.74 d	61.49 d
T2	87.35 c	98.90 b	93.13 a
T3	65.56 e	114.44 a	90.00 ab
T4	78.11 d	64.01 e	71.01 c
T5	64.44 e	49.28 f	56.86 e
Mean	67.54 B	81.47 A	

Values followed by same letter(s) are similar statistically at p=0.01

As far as, data obtained from uninoculated treatments, higher P-uptake was found in the case of FYM application. This may be due to the mixture prepared with soil or manure, elemental sulfur and rock phosphate; as the sulfur is oxidizing to sulfuric acid by microorganisms, there is a parallel increase in acidity and a net release of soluble phosphate that is easily assimilated by the plants. In flooded soil, the iron in insoluble ferric sulfates may be reduced, a process leading to the formation of soluble iron with a concomitant release of phosphate into solution. Such increases in the availability of phosphorus on flooding may explain why rice cultivated under water often has more P-uptake. Gerretsen (1948), Asea *et al*. (1988) and Vendan and Subramanium (2000) have documented similar findings.

CONCLUSION

Present study emphasizes the need of focusing on application of local rock phosphate, a cheep source of phosphorus, alongwith green manure and/or farmyard manure as well as Biophos (PSM) inoculation to enhance the crop yields. Although, the requirement of phosphorus for rice crop is not so high but still further studies on rock phosphate rates, method, time of application and manuring of amendments for optimum yield are needed under natural environments.

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