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Biological Mining of Soil Reserve Phosphorus in Lowland Rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment entitled "Biological mining of soil reserve phosphorus in lowland rice (*Oryza sativa* L.)" during *kharif* 2009-10 was conducted on sandy clay loam soils of the Agricultural College Farm, Bapatla. Inoculation of PSB recorded the highest grain and straw yields at each level of P application, however, it was on a par with other biological treatments. The maximum P uptake was recorded with application of 60 kg P_2O_5 ha^{-1} (P_3) and it was significantly superior to rest of the P levels. Soil inoculation of PSB recorded significantly the maximum P uptake over other biological treatments, but remained comparable with greenmanuring *in-situ* (T_3).The maximum Apparent Phosphorus Recovery (APR) and Phosphorus Use Efficiency (PUE) was recorded with inoculation of PSB along with 20 kg P_2O_5 ha^{-1}.

Key words : APR, Available P, Biological mining, Greenmanure, PSB,PUE, Rice, VAM.

Rice, like any other cereal, requires a considerable quantity of phosphorus for vigorous growth and grain yield. Though the availability of phosphorus is more in flooded soils compared to uplands, the recovery of applied phosphorus and P-use efficiency are poor in case of cereal crops. Indian soils are generally very poor in available P. The fixation of P by soils has been considered the important reason for the low recovery of applied phosphatic fertilizer. The phosphorus fixation runs to nearly 80 per cent of the applied phosphorus and remains unutilized by current crop. This calls for more efficient management of phosphorus fertilizers. Besides, the recent escalation of prices of conventional phosphatic fertilizers like SSP and DAP is necessitating the farmers to search for alternative ways of increasing efficiency. The soil microorganisms which are associated with plant roots in its immediate environment play a key role in the uptake of P by the plant. The rhizosphere microflora can therefore be manipulated to allow crops to grow with lesser fertilizer without impairing soil fertility. Keeping these facts in view, present investigation was undertaken to findout the efficiency of biofertilizers.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* season of 2009-2010 at the Agricultural College Farm, Bapatla. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen, high in available phosphorus and potassium. The experimental treatments consisting of 4 levels of phosphorus (P_0- no phosphorus, P_1- 20 kg P_2O_5 ha^{-1}, P_2- 40 kg P_2O_5 ha^{-1} and P_3-60 kg P_2O_5 ha^{-1}) and four biological/organic treatments (T_1- PSB @ 5 kg ha^{-1}, T_2-VAM @10 kg ha^{-1}, T_3- greenmanuring *in-situ* and T_0-no inoculation) were replicated three times in randomized block design with factorial concept. PSB @ 5 kg ha^{-1} and VAM @ 10 kg ha^{-1} were mixed separately with vermicompost and were applied in respective treatments at the time of transplanting. Recommended dose of nitrogen was applied @ 120 kg ha^{-1} in the form of urea in three splits ($_{1/2}$ as basal + ¼ at tillering + ¼ at panicle initiation stage) and potassium applied @ 40 kg K_2O ha^{-1} as basal through muriate of potash. Phosphorus was applied as basal in the form of single superphosphate as per the treatments. The rice variety BPT-5204 (Sambamahsuri) was raised by following all other recommended cultural practices. Observations on yield and yield attributing characters *viz*. plant height, drymatter accumulation, productive tillers m^{-2}, filled grains per panicle were recorded in five randomly selected plants for each plot. The data was analyzed statistically by adopting the standard procedures described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Drymatter accumulation, yield attributes and yield

Drymatter accumulation significantly increased with each increase in level of phosphorus.

Application of 60 kg P_2O_5 ha^{-1} (P_3) recorded significantly higher drymatter accumulation compared to rest of the phosphorus levels. Soil inoculation with PSB (T_1) produced significantly higher drymatter than the other biological sources followed by incorporation of greenmanure which inturn was on par with inoculation with VAM. (Table 1). Addition of organic manures and bio fertilizers decrease the rate of conversion of loosely linked phosphorus into more difficult soluble forms and hence both native and applied phosphorus might freely available to the crop. These results were in line with the findings of Mandal and Pal (2009).

Yield attributes like productive tillers m^{-2} and filled grains per panicle of rice were significantly influenced by application of 60 kg P_2O_5 ha^{-1} over rest of the P levels. Among biological sources, soil inoculation of PSB significantly recorded the maximum number of filled grains per panicle and productive tillers m^{-2} followed by greenmanure incorporation and VAM inoculation. Somani (2007) also stated that CO_2 produced in the rhizosphere by the microorganisms has been reported to be involved in increased P availability to plants which might be the reason for increase in tiller number m^{-2} in the present study. Similar higher number of productive tillers m^{-2} and filled grains per panicle by inoculation with PSB was also reported by Brahmachari *et al*., (2009).

The maximum grain yield recorded with inoculation of PSB at 60 kg P_2O_5 ha^{-1} was found on a par with greenmanure incorporation and VAM inoculation at the same level of P and at 40 kg P_2O_5 ha^{-1}, whereas, straw yield recorded at 60 kg P_2O_5 ha^{-1} along with PSB was the highest and found on a par with greenmanure incorporation and VAM inoculation at the same level of P and at 40 and 20 kg P_2O_5 ha^{-1}. The per cent increase in yield by inoculation with PSB and VAM and incorporation of greenmanure over no inoculation without phosphorus application was 27.2, 24.1 and 26.9 per cent respectively. Application of biofertilizers and organicmanure without phosphorus proved superior to no inoculation alone in increasing grain and straw yields, which might be due to increase in P availability through solubilization of insoluble inorganic phosphate, decomposition of phosphate rich organic compounds and production of plant growth promoting substances (Gaur 1990).

Nutrient Uptake

Phosphorus uptake increased significantly with each increment in P level from P_0 to P_{60}. The maximum P uptake was recorded with application of 60 kg P_2O_5 ha^{-1}(P_3) and it was significantly superior to rest of the P levels. Soil inoculation of PSB recorded significantly the maximum P uptake among the biological treatments which was on a par with greenmanuring *in-situ* (T_3) (Table 2). Phosphorus in the insoluble form is solubilized by the action of organic acids released into the soil due to continuous submergence and decomposition of greenmanure that was applied to the soil. These results are in close agreement with Hundal and Thind (1992).

Phosphorus recovery was higher at lower doses of phosphorus over higher doses. All the biological treatments in combination with 20 kg P_2O_5 ha^{-1} recorded the maximum APR and the lowest APR was recorded with application of 60 kg P_2O_5 ha^{-1} applied along with biological sources. Janaki (2003) reported that decomposition products of greenmanure resulted in increased P availability and thereby increased apparent P recovery.

With increase in phosphorus level from 0 to 60 kg P_2O_5 ha^{-1} a decrease in PUE was observed. Application of phosphorus with addition of biological sources increased PUE at each phosphorus level. Inoculation of PSB recorded higher PUE compared to other biological sources. The maximum PUE was recorded with PSB at 20 kg P_2O_5 ha^{-1} followed by greenmanuring *in-situ* and VAM inoculation. All the biological treatments recorded significantly the highest available P at 60 kg P_2O_5 ha^{-1} over rest of the P levels. however, differences among biological sources were not significant at 40 and 60 kg P_2O_5 ha^{-1} with respect to available P status at maturity. Selvi *et al*., (2003) also found greater P use efficiency at lower dose of P level in rice along with greenleaf manures. Meelu and Moris (1984) also reported that a healthy population of soil greenmanuring improves the physical and microbial conditions of soil and enhances fertilizer use efficiency when applied in conjunction with mineral fertilizer.

It can be concluded that application of phosphorus in combination with biofertilizers and organic manure was superior compared to its application alone. Inoculation of PSB @ 5 kg ha^{-1} along with 60 kg P_2O_5 ha^{-1} was found better over other combinations of biological sources increasing growth, yield and nutrient uptake of rice. Addition of biofertilizers and organicmanures *viz.,* PSB, VAM and greeenmanure along with 40 kg P_2O_5 ha^{-1} produced similar grain yield as compared to that produced through application of 60 kg P_2O_5 ha^{-1} alone and thus resulting in saving of phosphorus up to 35 %.

Table 1. Drymatter accumulation, yield attributes and yield of rice as influenced by phosphorus levels and biological/organic treatments.

Treatments	Drymatter accumulation (kg ha^{-1})	Productive tillers m^{-2}	Filled grains $panicle^{-1}$
Phosphorus levels (kg P_2O_5 ha^{-1})			
P_0 : No phosphorus	9429	367	113
P_1 : 20	11331	395	125
P_2 : 40	12235	403	134
P_3 : 60	13110	416	144
SEm ±	147	5.4	1.8
CD (P=0.05)	425	15	5.1
Biological/organic treatments			
T_0 : No inoculation	10699	374	117
T_1 : PSB @ 5 kg ha^{-1}	12159	411	139
T_2 : VAM @ 10 kg ha^{-1}	11564	396	127
T_3:Greenmanuring *in-situ* (*Dhiancha*)	11682	402	132
SEm ±	147	5.4	1.8
CD (P=0.05)	425	15	5.1
CV %	4.5	4.7	4.7
Interaction (P x T)	NS	NS	NS

NS-Not significant

Table 2. Grain yield of rice as influenced by phosphorus levels and biological/organic treatments.

Treatments	Grain yield (kg ha^{-1})				
	P levels (kg P_2O_5 ha^{-1})				
	P_0	P_{20}	P_{40}	P_{60}	Mean
Biological/organic					
T_0 : No inoculation	3067	3976	4201	4487	3933
T_1 : PSB @ 5 kg ha^{-1}	4214	4264	4604	4817	4475
T_2 : VAM @ 10 kg ha^{-1}	4040	4202	4460	4625	4332
T_3 : Greenmanuring *in-situ* (*Dhiancha*)	4199	4218	4560	4741	4430
Mean	3880	4165	4456	4668	
	SEm ±		CD (P = 0.05)	CV (%)	
P level (P)	61		176	5.0	
Biological/organic treatments (T)	61		176		
Interaction (P x T)	122		391		

Table 3. Straw yield of rice as influenced by phosphorus levels and biological/organic treatments

Treatments	Straw yield (kg ha^{-1})				
	P levels (kg P_2O_5 ha^{-1})				
	P_0	P_{20}	P_{40}	P_{60}	Mean
Biological/organic					
T_0 : No inoculation	4270	5746	6349	6524	5722
T_1 : PSB @ 5 kg ha^{-1}	5698	6363	6500	6756	6329
T_2 : VAM @ 10 kg ha^{-1}	5455	6130	6417	6583	6146
T_3 : Greenmanuring *in-situ* (*Dhiancha*)	5588	6233	6457	6630	6227
Mean	5253	6118	6431	6623	
	SEm ±		**CD (P = 0.05)**	**CV (%)**	
P level (P)	86		249	4.9	
Biological/organic treatments (T)	86		249		
Interaction (P x T)	173		552		

Table 4. Phosphorus uptake, apparent P recovery, P use efficiency and available P as influenced by phosphorus levels and biological/organic treatments.

Treatment	Phosphorus uptake (kg ha^{-1})	*Apparent P recovery	*P use efficiency (%)	*Available P (kg ha^{-1})
Phosphorus levels (kg P_2O_5 ha^{-1})				
P_0 : No phosphorus	7.4	-	-	18.5
P_1 : 20	8.6	26.3	54.8	24.8
P_2 : 40	10.6	23.7	34.7	29.1
P_3 : 60	11.6	19.9	26.6	34.1
SEm ±	0.3	-	-	0.5
CD (P=0.05)	0.8	-	-	1.3
Biological/organic treatments				
T_0 : No inoculation	7.6	14.6	32.5	24.3
T_1 : PSB @ 5 kg ha^{-1}	11.5	32.8	42.5	28.6
T_2 : VAM @ 10 kg ha^{-1}	9.2	20.9	39.2	26.2
T_3 : Greenmanuring *in-situ* (*Dhiancha*)	10.0	24.8	40.9	27.4
SEm ±	0.3	-	-	0.5
CD (P=0.05)	0.8	-	-	1.3
CV %	9.9	-	-	5.8
Interaction (P x T)	NS	-	-	2.9

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