Phosphorus Availability from Mussoorie Rock Phosphate in an Aeric Haplaquept in a Rice-Rice Sequence

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Abstract : *A field experiment conducted at Research Farm, Assam Agricultural University, Jorhat, with different levels of Mussoorie rock phosphate in presence and absence of Aspergillus niger Van Tiegh shows that the amount of phosphorus in soil as extracted by Bray 1 and Bray 2 methods after the harvest of each crop in a rice-rice sequence was significantly affected by the levels of phosphate. Bray 2 method extracted significantly higher amount of available P than did the Bray 1 method. Al-P, Fe-P and organic P contributed to about 97 per cent of the P extracted by Bray 2 method. These three P fractions in the soil combinedly contributed to 94 and 83 per cent of the variations in the P uptake and grain yield of Kharif rice (Monohar sali) respectively in a low land Aeric Haplaquept.* *(**Key words :** P availability, rock phosphate, rice-rice sequence, Haplaquept, regression co-efficient).*

Availability of phosphorus from applied rock phosphate in acid soils has been reported by Khasawaneh and Doll (1978) and Marwah (1989). Some soil microorganisms inhabiting the rhizosphere zone of various plant species possess the ability to dissolve relatively insoluble phosphate and render it available to the plants (Barthakur 1978; Darmwal *et al.* 1989). In view of this, it is essential to evaluate the use of indigenous rock phosphate (cheap source of phosphorus) in acid soils of Assam.

MATERIAL AND METHODS

Field experiment was conducted at Research farm of Assam Agricultural University, Jorhat. Soils, of the study area belong to fine loamy, mixed hyperthermic family of Aeric Haplaquepts. The soils have light olive brown (2.5 Y 5/4), sandy clay loam and moderately acidic A horizon and olive brown (2.5 Y 4/4) to brownish yellow (10 YR 6/6), sandy loam to clay loam and slightly acidic B horizons. The profile characteristics of soils is given in Table 1. Treatments consisted of four levels of phosphate (40, 80, 120 and 160 kg P_2O_5 ha^{-1} as Mussoorie rock phosphate (MRP) with and without inoculation of *Aspergillus niger* Van Tiegh (phosphate dissolving fungus). A treatment with 40 kg P_2O_5 ha^{-1} as single superphosphate (SSP), was also included in the study as a standard. Treatments were randomised in four replications with plots of 5m x 3m size cultivated to rice : Pusa-2-21 (in summer) and Manohar Sali (in *Kharif*) in a sequence.

Calculated amount of MRP (100 mesh), containing total P_2O_5 (20%), citrate soluble (5.2%), and CaO (45%) as per treatments was taken in a plastic bucket and mixed with fresh rice gruel (containing 83% moisture, 55.7% starch, 39.7% total soluble sugar, 0.867% total N, 0.735% total P_2O_5 and 0.028% total K_2O on dry wt. basis) in the ratio of 1:1 and inoculated with *Aspergillus niger* Van Tiegh and incubated at room temperature (max. 25.4^{0}C; min. 16.3^{0}C). The rice gruel was used to provide carbon source to the growth of microbes.

Treatments were applied one month before the transplanting of summer (1st week of April to 1st week of July) rice (Pusa 2-21) followed by *Kharif* (1st week of August to 1st week of December) rice (Manohar Sali). No phosphorus was applied to *Kharif* rice. Nitrogen and potash were applied @ 80 and 40 kg ha^{-1} in the form of urea and muriate of potash respectively, to both the crops. After the harvest of each crop, soil samples were analysed for available P (Bray & Kurtz 1945); total, inorganic, organic P (Mehta *et al.* 1954) as described by Jackson (1973)

TABLE 1. Characteristics of the soils

Horizon (depth) cm	Sand	Silt	Clay	O.C	pH	CEC Cmol(+) kg^{-1}	Base Sat.	Bray 1 P (ppm)	Bray 2 P (ppm)
	-----	(%)	-----						
Apg (0-14)	56.7	19.2	24.1	1.3	4.7	5.6	38.6	4.9	5.6
B21g (14-21)	42.8	23.9	33.3	0.9	5.8	10.2	31.8	-	-
B22 (21-68)	49.8	20.8	29.4	0.7	6.1	6.2	55.0	-	-
B3 (68-115)	69.0	12.5	18.5	0.1	5.7	4.2	66.2	-	-

TABLE 2. Different P fractions (ppm) in the soil after harvest of crops

Treatment		After harvest of summer rice					After harvest of kharif rice				
		Inorganic P	Organic P	Al-P	Fe-P	Ca-P	Inorganic P	Organic P	Al-P	Fe-P	Ca-P
I_0	P_{40}	99	49	14	54	19	75	48	14	46	16
	P_{80}	115	60	17	51	17	95	56	16	49	18
	P_{120}	120	78	21	56	26	105	73	22	53	18
	P_{160}	134	78	20	60	22	128	80	19	54	24
	Mean	117	66	18	55	21	101	64	18	51	19
I_1	P_{40}	103	56	18	50	17	78	48	18	48	17
	P_{80}	114	73	14	55	19	92	62	18	49	13
	P_{120}	113	88	20	56	20	101	86	19	49	18
	P_{160}	130	104	21	57	24	123	88	20	52	23
	Mean	104	80	18	54	20	99	71	19	50	18
Mean	P_{40}	101	53	16	52	18	77	48	16	47	16
Mean	P_{80}	114	66	16	53	18	94	59	17	49	16
Mean	P_{120}	116	83	20	56	23	103	80	20	51	18
Mean	P_{160}	132	91	20	58	23	125	84	19	53	24
Standard	SSP_{40}	106	53	16	53	20	92	48	14	44	20
C.C. at 5% for											
Treatment		N.S.	17	NS	NS	NS	NS	29	NS	5	5
Levels of P		N.S.	12	NS	NS	4	NS	20	NS	4	4
Inoculation		N.S.	8	NS	NS	NS	NS	NS	NS	NS	NS

N.S. = not significant * values in the paranthesis represent % of total P and Al-P, Fe-P and Ca-P as per procedure of Chang and Jackson (1957).

RESULTS AND DISCUSSION

Results (Table 2) showed that inorganic P, Al-P, Fe-P and Ca-P content in the soil after the harvest of summer rice were not significantly affected by different treatments. However, Ca-P content significantly increased at 120 and 160 kg P_2O_5 ha^{-1} over 80 kg P_2O_5 ha^{-1} application. On the other hand, the variation in organic P, Fe-P and Ca-P fractions in soil after the harvest of second (*kharif*) rice was significantly affected by different phosphate treatments. Results reveal that Fe-P content in the soil increased at 120 and 160 kg P_2O_5 ha^{-1} of non-inoculated MRP over the standard treatment. Application of 160 kg P_2O_5 ha^{-1} as MRP could significantly increase the Fe-P and Ca-P content in the soil over 40 kg P_2O_5 ha^{-1} level in this form. Fe-P constituted a major part of inorganic P fraction in soil after harvest of each rice. This was followed by Ca-P and Al-P fractions. Appreciable amount of organic P was also observed after the harvest of each crop. Inoculation of MRP with *Aspergillus niger* Van Tiegh significantly increased the organic P content in the soil after harvest of first rice. But this effect was not significant after the harvest of second rice. The results, therefore, indicate that a considerable amount of applied rock phosphate got transformed into organic P fraction due to immobilization by soil microorganisms and the process was enhanced by the inoculated test fungus. During the growing period of second rice, a substantial portion of organic P was mineralized releasing the available phosphorus for the growth of the crop.

Results (Table 3) showed that the available P in soil after the harvest of each crop was significantly affected by different phosphate treatments only when extracted by Bray 2 method. However, the effect was significant only between 40 kg and 160 kg P_2O_5 ha^{-1}. The levels of MRP significantly affected the available P contents in the soil as extracted by Bray 1 and Bray 2 methods. Application of MRP @ 120 and 160 kg P_2O_5 ha^{-1} significantly increased the available P after the harvest of both crops except Bray 1 P after the harvest of second (*kharif*) rice where it was significant at 160 kgh P_2O_5 ha^{-1} over all the levels. Mussoorie rock phosphate maintained a higher amount of available P in the soil after the harvest of each crop as compared to the equivalent level of single superphosphate . Mandal and Khan (1972) also reported higher amount of available phosphorus under rock phosphate treatment than that of the single superphosphate treatment in an acid lowland rice soil under waterlogged conditions. Inoculation of the rock phosphate with *Aspergillus niger* Van Tiegh could slightly increase the available P content in the soil as extracted by Bray 1 method after the harvest of summer rice only.

The relative performance of the methods in extracting the available P from the soil was studied by calculating Fisher 't' values which showed that the Bray 2 method extracted significantly higher amount of available P than did the Bray 1 method . On the average, Bray 1 soluble P accounted for 3.8 and 3.6 per cent of the total P in the soil after harvest of summer and Kharif rice, respectively, whereas the Bray 2 soluble P accounted for 5.1 and 5.5 per cent of the total P in the soil after the harvest of summer and kharif rice respectively.

Correlation coefficients between available P and various P fractions in the soil (Table 4) were worked out so as to find out the relative contribution of each P fractions towards the available phosphorus. The available P correlated significantly and positively with Al-P and Fe-P in the soil after harvest of each crop. This finding suggests that Al-P and Fe-P contributed mostly to the available P content in the soil. Several workers (Smith 1965 and Zubriski 1971) have also reported that Al-P is an important source of available phosphorus to different crops. Singh and Bahaman (1976) observed that an increase in the available P content under waterlogged conditions is mainly due to increase in Fe-P which is also corroborated in the present study.

TABLE 3. Available P (ppm) in the soil after harvest of crops

Treatments		After harvest of 1st crop (summer rice)				After harvest of 2nd crop (kharif rice)			
		Bray's 1 P		Bray's 2 P		Bray's 1 P		Bray's 2 P	
I_0	P_{40}	5.9	(4.1)*	8.9	(6.1)	3.2	(2.5)	6.8	(5.5)
	P_{80}	6.1	(3.5)	9.8	(5.6)	5.6	(3.7)	9.3	(6.1)
	P_{120}	7.1	(3.6)	12.9	(6.5)	8.0	(4.5)	10.3	(5.8)
	P_{160}	8.5	(4.1)	14.8	(7.1)	8.5	(4.1)	12.0	(5.8)
	Mean	6.9	(3.8)	11.6	(6.3)	6.3	(3.7)	9.6	(5.8)
I_1	P_{40}	6.8	(4.3)	7.9	(5.0)	4.7	(3.7)	6.6	(5.2)
	P_{80}	6.1	(3.3)	8.5	(4.6)	6.4	(4.2)	8.5	(5.5)
	P_{120}	8.2	(4.1)	8.5	(4.3)	5.9	(3.1)	10.7	(5.7)
	P_{160}	7.9	(3.4)	11.2	(4.8)	6.1	(2.9)	10.9	(5.2)
	Mean	7.2	(3.8)	9.0	(4.7)	5.8	(3.5)	9.2	(5.4)
Mean	P_{40}	6.3	(4.1)	8.4	(5.5)	3.3	(2.7)	6.7	(5.4)
Mean	P_{80}	6.1	(3.4)	9.1	(5.1)	6.0	(3.9)	8.9	(5.8)
Mean	P_{120}	7.7	(3.9)	10.4	(5.3)	7.0	(3.8)	10.5	(5.7)
Mean	P_{160}	8.2	(3.7)	13.0	(5.9)	7.3	(3.5)	11.5	(5.5)
Standard	SSP_{40}	6.1	(3.9)	6.2	(3.9)	5.2	(3.7)	6.2	(4.4)
C.D. at 5% for									
Treatment		N.S.		4.6		NS		3.7	
Levels of P		N.S.		3.2		2.2*		2.6	
Inoculation		N.S.		NS		NS		NS	

N S. = Not significant: * Values in the paranthesis represent % of total P.

Multiple regression equations and coefficients of determination (Table 4) showed that Al-P and Fe-P combinedly contributed to about 86 per cent and 58 per cent of the variations in the Bray 1 and Bray 2 P respectively after the harvest of first crop (summer rice). However, the contribution to second crop (*kharif* rice) was about 64.3 and 81.1 per cent. Inclusion of organic P (x_4) in the regression equation improved the predictability of the Bray 2 P to about 97 per cent. However, such improvement was not observed in case of Bray 1 P. This suggests that the Bray 2 P represent a better index for available P content in the soil after the harvest of the second crop in a rice-rice sequence under lowland conditions.

Correlation studies (Table 4) showed that the phosphorus uptake as well as the grain yield of the kharif rice was positively and significantly correlated with Al-P, Fe-P, organic P, inorganic P and total P in the soil. These phosphorus fractions in the soil combinedly contributed to 97 and 83 per cent of the availability in P uptake and grain yield respectively. But the Al-P, Fe-P and organic P conbinedly contributed to 94 and 83 per cent of the variations in the P uptake and grain yield of the kharif rice respectively. This finding suggests that the Al-P, Fe-P and organic P fractions are the major sources of available phos

TABLE 4. Simple correlation coefficients and regression equations of differnt P-forms in soil with Bray P, uptake and yields

Dependent variables	Simple correlation coefficients (r)				
	Al-P X_1	Fe-P X_2	Ca-P X_3	Org-P X_4	Inorg-P X_5
After harvest of summer crop					
Bray 1 P	0.827**	0.729*	0.518	0.767*	0.723*
Bray 2 P	0.597	0.684*	0.643	0.496	0.825*
After harvest of kharif crop					
Bray 1 P	0.717*	0.798*	0.460	0.652	0.802*
Bray 2 P	0.707*	0.895*	0.541	0.920*	0.884*
P forms after 1st rice % yield of 2nd rice crop					
P uptake	0.734*	0.817**	0.628	0.931**	0.717*
Grain yield	0.682*	0.803**	0.575	0.839**	0.791*

Regression equations (After summer rice crop)

Bray 1 P $= -5.563 + 0.240 X_1 + 0.515 X_2$ ($R^2 = 0.859$)

Bray 1 P $= -5.892 + 0.248 X_1 + 0.157 X_2 - 0.002 X_4$ ($R^2 = 0.860$)

Bray 1 P $= -5.991 + 0.260 X_1 + 0.174 X_2 - 0.001 X_4 - 0.010 X_5$ ($R^2 = 0.864$)

Bray 2 P $= -20.883 + 0.365 X_1 + 0.441 X_2$ ($R^2 = 0.583$)

Bray 2 P $= -30.522 + 0.613 X_1 + 0.625 X_2 - 0.069 X_4$ ($R^2 = 0.650$)

Bray 2 P $= -28.733 + 0.396 X_1 + 0.335 X_2 - 0.099 X_4 + 0.175 X_5$ ($R^2 = 0.828$)

Regression equations (after kharif rice crop)

Bray 1 P $= -12.455 + 0.085 X_1 + 0.338 X_2$ ($R^2 = 0.643$)

Bray 1 P $= -11.840 + 0.074 X_1 + 0.332 X_2 - 0.006 X_4$ ($R^2 = 0.645$)

Bray 1 P $= -5.191 + 0.336 X_1 + 0.007 X_2 - 0.055 X_4 + 0.084 X_5$ ($R^2 = 0.794$)

Bray 2 P $= -22.433 - 0.145 X_1 + 0.683 X_2$ ($R^2 = 0.811$)

Bray 2 P $= -14.390 - 0.292 X_1 + 0.466 X_2 + 0.083 X_4$ ($R^2 = 0.968$)

Bray 2 P $= -14.390 - 0.305 X_1 + 0.482 X_2 + 0.084 X_4 - 0.004 X_5$ ($R^2 = 0.969$)

Regression equations (P forms of first rice crop and yield uptake of 2nd rice crop

P uptake $= -8.631 + 0.198 X_1 + 0.228 X_2$ ($R^2 = 0.851$)

P uptake $= -3.797 + 0.073 X_1 + 0.131 X_2 + 0.035 X_4$ ($R^2 = 0.940$)

P uptake $= -4.117 + 0.112 X_1 + 0.183 X_2 + 0.040 X_4 - 0.031 X_5$ ($R^2 = 0.972$)

Grain Yield $= - 3.084 + 0.283 X_1 + 0.366 X_2$ ($R^2 = 0.788$)

Grain yield $= 1.946 + 0.153 X_1 + 0.270 X_2 + 0.036 X_4$ ($R^2 = 0.825$)

Grain yield $= 2.083 + 0.137 X_1 + 0.248 X_2 + 0.034 X_4 + 0.013 X_5$ ($R^2 = 0.827$)

* Significant at 5% level of probability ** Significant at 1% level of probability

phorus to the kharif rice in a rice-rice sequence in an Aeric Haplaquept under waterlogged condition.

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