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TRANSFORMATION OF ORGANIC AND INORGANIC PHOSPHOROUS IN RELATION TO P UPTAKE IN CALCAREOUS SOILS

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ABSTRACT

A field experiment was conducted during kharif season in 2005 to assess the impact of long-term application of different organic amendments and different doses of inorganic fertilizer on P fraction like saloid-P, Al-P, Fe-P, Ca-P, dissolved organic P, humic matter P, microbial biomass P, available P, organic P and inorganic P and their ultimate effect on P availability, P-uptake and yield of rice (34th crop) in rice-wheat cropping sequence. The present investigation was undertaken from a long-term experiment running since Rabi 1988-89 in calcareous soil at RAU, Pusa farm in split plot design having doses of inorganic fertilizer in main plot and organic amendments in sub plots. Incorporation of organics and inorganics progressively enhanced the crop yield, P-uptake and P-status in post harvest soils. The grain and straw yield of rice increased significantly with increasing levels of NPK fertilizers. However, the yield at 150% NPK was at par with 100% NPK. The increase in yield due to conjoint application of organics can be presented in the following order: compost + crop residue > compost > crop residue > no manure. The application of compost (10 tha^{-1}) + crop residue (100%) could save approximately 50 per cent of the recommended dose of NPK. Over and above, the effect of organics and inorganics individually and their conjoint use enhanced crop yield and nutrient uptake by crop.

Key words : Transformation, organic and inorganic phosphorous, calcareous soils

The rice-wheat cropping system is one of the dominant cropping system under a wide range of management practices in Indo-Gangetic plains of South Asia (Singh and Singh, 2001). The productivity of this intensive agricultural production system spread over 12 million ha in India, Pakistan, Nepal and Bangladesh (Huke and Hulke, 1992), varies mainly due to variations in soil types, climate and water management etc. The present population growth rate of 1.8 percent is estimated to create a shortfall of 20 million tons of cereal grains by the year 2020 (Singh and Singh, 2001). The rice – wheat cropping system being an exhaustive feeder crops and having a yield up to 7 t ha^{-1} of rice and 4 t ha^{-1} of wheat respectively removes more than 300 kg ha^{-1} nitrogen, 30 kg ha^{-1} phosphorous and 300 kg ha^{-1} of potassium from soil. Therefore, under these conditions, only efficient fertilizer use may produce healthy plants that will be less vulnerable to pests, diseases, and lodging. Further, optimal crop management here requires farmer's knowledge of matching inputs to crop production needs (Pingali *et al.* 1995). As per FAO report, the extent of calcareous soils are at 800 million hectares worldwide (Land, FAO and Plant Nutrition Management, 2000). The efficiency of P fertilizers in calcareous soil is observed as generally very low because phosphorus applied to the soil reacts with $CaCO_3$ to form ultimately, the hydroxyl apatite. In soils from Bihar, P- fixation ranged between 25-90% of the applied phosphorous within 120 days of application (Gupta, 1965). Beside this, over use or improper use of nutrient's inputs is highly damaging to crop and the environments because excess nitrate pollutes not only the soil and groundwater but also to the produce itself. Nitrous oxide, thus released from denitrification of nitrates pollutes the air. Therefore, to minimize health risks, new methods or products must be developed to increase nutrient use efficiency. Efficient fertilizer use will not only minimize water pollution by nitrates and phosphates but also will reduce accumulation of free nitrates in food. Even with the recommended rate of fertilization of this system, a negative balance of the primary nutrients still exists, particularly for nitrogen and potassium. The system infact is now showing signs of fatigue and is no longer exhibiting increased production with increase in input use.

In the present study on the P uptake mechanisms of crop, it is important to identify the P forms present in soil and there dynamic processes which effect the availability of P to the plants. Chang and Jackson (1957) developed a fractionation method, which separates inorganic P into aluminum (Al)$^{-}$, iron (Fe)$^{-}$, and calcium (Ca) $^{-}$ bound P, respectively.

MATERIALS AND METHODS

Location, Climate and field experiment : The 34^{th} crop rice (*Oryza sativa* cv. Rajshree) during Kharif-2005 was selected under a "Long term experiment on crop residue management" running in calcareous soils since 1988-89 at Research farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (India). The site is located at 25.9^0 N latitude, 85.67^0 E longitudes and at an altitude of 52.0 meter above the mean sea level and falls in the sub-humid sub-tropical climatic zone. The average annual rainfall is about 1400 mm and about 90% of its received during the monsoon season. Temperature was highest in May (38.4 ^{0}C) and lowest in January (4.3 ^{0}C).

Compost @ 10 t ha^{-1} and/or crop residues of previous crop to the respective alone or in combination with different levels of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) *i.e.* 0, 50, 100 and 150% of the recommended dose of fertilizers (120:60:40) are being applied since 1988-89. In rice, the N, P and K were applied through urea, single super phosphate and muriate of potash in each crop under rice-wheat cropping sequence in split plot design with three replications. In main-plot, No NPK, 50% recommended dose of NPK, 100% recommended dose of NPK and 150% recommended dose of NPK, hereby referred as M_0, M_1, M_2, and M_3, respectively. In sub-plot no compost/crop residue, compost @ 10 t ha^{-1}, 100% of crop residue produced and compost @ 10 t ha^{-1} with 100% of crop residue produced, were hereby referred as S_0, S_1, S_2, and S_3, respectively, were applied in the form of 16 treatment combinations. The net experimental areas were 480 m^2 with net plot size of 10 m^2 (2.5 m× 4m). Half dose of N and full dose of P and K were applied at the time of rice transplanting and remaining half dose of N was applied as top dressing in two equal splits i.e. one at tillering and other at panicle initiation stage. Application of compost was done one month prior to transplanting of rice seedling whereas, crop residues were incorporated in soil just after threshing of crop. The initial properties of soil, collected during 1988-89 are presented in Table-1.

Sample preparation and analysis : Surface soil (0-15cm) was drawn after harvest of rice crop was drawn with stainless steel tube auger. The soils were air dried and ground to pass through a 2-mm stainless steel sieve.

Organic P in soil was fractionated to the timely organic P by using method given by Kalbitz *et al.* (2000) while microbial biomass P was extracted by the method given by Brookes *et al.* (1982), however, humic matter P was determined by the modified methodology given by (Kononova, 1966 and Jackson, 1973).

Grain and straw samples of rice were drawn from each treatment plot after recording the yields. Each plant sample was washed in acidified detergent solution and finally rinsed three times in deionized water. These samples were dried at 65^0C. These samples were pulverized and digested in di-acid (9:4 v/v) of nitric acid (HNO_3)/ perchloric acid ($HClO_4$). After digestion, volume of digests was made up to 50 ml using distilled water. The phosphorous was determined colorimetrically by using vanadomolybdate yellow colour method (Jackson, 1973).

Table-1 : Physical and chemical properties of initial soil.

Sl. No.	Soil Properties	Value
1.	pH (1:2, soil : water)	8.5
2.	EC (dSm^{-1})	0.36
3.	Textural class	Sandy Loan
	Sand (%)	58.72
	Silt (%)	29.05
	Clay (%)	12.23
4.	Free $CaCO_3$ (%)	32.05
5.	Organic Carbon (%)	0.50
6.	Available N (kg ha^{-1})	236.1
7.	Available P_2O_5 (kg ha^{-1})	19.7
8.	Available K_2O (kg ha^{-1})	100.0
9.	Total P (%)	0.048

Calculations and statistical analysis : Uptake of P by rice grain and straw were calculated by multiplying the P contents of grain and straw respectively with their respective yield.

The experimental data were analyzed by Fisher's method of analysis of variance. All statistical analysis was done with help of computer (EC-micro-32 model).

RESULTS AND DISCUSSION

Rice yield : Different levels of fertilizers, organics and their interactions showed significant increase in grain and straw yield of rice (Table-2). The grain yield of rice varied from 7.0 to 45.6 q ha^{-1} with application of different levels of fertilizers and organics. Increase in levels of NPK enhanced the grain yield from 14.3 q ha^{-1} (M_0) to 42.5 q ha^{-1} (M_3) indicated 110, 176 and 197

Table-2 : Influence of organic and inorganic fertilizers on yield of rice (34th crop) under rice-wheat cropping system in calcareous soil.

Inorganic fertilizer levels	Grain Yield (q/ha^{-1})					Straw Yield (q/ha^{-1})				
	Organic sources					Organic sources				
	No Organics	Compost @ 10tha^{-1}	Crop residues	Compost + Crop residues	Mean	No Organics	Compost @ 10t ha^{-1}	Crop residues	Compost + Crop residues	Mean
No NPK	7.02	14.75	14.94	20.57	14.32	13.83	32.35	29.42	40.53	29.03
50% NPK	22.42	30.50	30.73	36.48	30.03	44.17	60.09	60.54	71.86	59.16
100% NPK	36.05	39.88	38.32	43.99	39.56	71.01	78.89	71.72	86.60	81.91
150% NPK	39.63	42.37	42.34	45.57	42.48	77.87	83.47	83.41	89.77	83.63
Mean	26.28	31.88	31.58	36.65		51.72	63.70	61.27	72.20	
Sources	S.Em.±		CD(P=0.05)			S.Em.±		CD(P=0.05)		
Fertilizer (F)	0.86		3.00			2.86		9.91		
Manure (M)	0.54		1.57			3.04		8.87		
F x M	1.28		3.99			5.99		18.24		

Table-3 : Influence of organic and inorganic fertilizers on P-content of rice (34th crop) under rice-wheat cropping system in calcareous soil.

Inorganic fertilizer levels	P-content (%) of rice grain					P-content (%) of rice straw				
	Organic sources					Organic sources				
	No Organics	Compost @ 10t ha-1	Crop residues	Compost + Crop residues	Mean	No Organics	Compost @ 10t ha-1	Crop residues	Compost + Crop residues	Mean
No NPK	0.182	0.223	0.216	0.237	0.215	0.050	0.098	0.056	0.103	0.077
50% NPK	0.224	0.243	0.232	0.258	0.239	0.056	0.102	0.083	0.113	0.089
100% NPK	0.242	0.268	0.256	0.278	0.261	0.079	0.114	0.098	0.126	0.104
150% NPK	0.265	0.273	0.271	0.286	0.274	0.090	0.120	0.106	0.132	0.112
Mean	0.228	0.252	0.244	0.265		0.069	0.109	0.086	0.119	
Sources	S.Em.±		CD(P=0.05)			S.Em.±		CD(P=0.05)		
Fertilizer (F)	0.006		0.020			0.002		0.007		
Manure (M)	0.004		0.013			0.002		0.005		
F x M	0.009		NS			0.004		0.011		

Table-4 : Influence of organic and inorganic fertilizers on P uptake by rice (34th crop) under rice-wheat cropping system in calcareous soil.

Inorganic fertilizer levels	P uptake (kg ha^{-1}) by rice grain					P uptake (kg ha^{-1}) by rice straw					Total P uptake (kg ha^{-1}) by rice crop				
		Organic sources					Organic sources					Organic sources			
	No Organics	Compost @ 10t ha^{-1}	Crop residues	Compost + Crop residues	Mean	No Organics	Compost @ 10t ha^{-1}	Crop residues	Compost + Crop residues	Mean	No Organics	Compost @ 10t ha^{-1}	Crop residues	Compost + Crop residues	Mean
No NPK	1.28	3.29	3.23	4.81	3.17	0.67	3.17	1.64	4.17	2.41	1.95	6.46	4.87	9.05	5.58
50% NPK	5.02	7.41	7.13	9.41	7.24	2.47	6.12	5.02	8.12	5.43	7.49	13.53	12.15	17.53	12.68
100% NPK	8.72	10.69	9.81	12.23	10.36	5.60	8.99	7.02	10.91	8.13	14.32	19.68	16.83	23.14	18.49
150% NPK	10.50	11.57	11.47	13.03	11.64	7.00	10.01	8.84	11.84	9.42	17.50	21.58	20.31	24.87	21.07
Mean	6.38	8.24	7.91	9.89		3.94	7.07	5.63	8.76		10.32	15.31	13.54	18.65	
Sources		S. Em. ±		CD (P=0.05)			S. Em. ±		CD (P=0.05)			S. Em. ±		CD (P=0.05)	
Fertilizer(F)		0.17		0.60			0.14		0.47			0.31		1.07	
Manure (M)		0.16		0.47			0.12		0.36			0.28		0.82	
F x M		0.33		NS			0.25		0.78			0.58		NS	

percent with application of 50, 100 and 150 percent NPK application over no NPK (M_0), respectively. Incorporation of organic sources significantly increased the grain yield from 26.3 q ha^{-1} (S_0) to 36.7 q ha^{-1} (S_3). Among different organic treatments, the increase in g rain yield over control (N_0) was 21.3, 20.2 and 39.5 per cent with the application of compost (M_1), crop residue (M_2) and compost with crop residue (M_3), respectively.

Phosphorous content and uptake : The P content in rice grain ranged from 0.182 to 0.286 per cent as influenced by different treatment combinations (Table 3). Application of graded does on NPK fertilizers significantly increased the P content in rice grain over control (M_0) and varied from 0.215 percent (M_0) to 0.274 percent (M_3). But the highest P content in the treatment, M_3, was not significant over the treatment, M_2. Similarly, the application of organic sources significantly influenced the P content in rice grain. The maximum P content (0.265 percent) was recorded in treatment. S_3, while, minimum (0.228 per cent) in treatment with no manure (S_0).

The P content in rice straw (Table-3) increased significantly with the application of graded doses of fertilizers. It ranged from 0.077 per cent under no NPK treatment to 0.112 Per cent in 150% NPK treatment.

Similarly, application of different organic sources had a significant positive influence on the P-content of rice straw over no manure. The highest P-content in rice straw was recorded with compost +crop residue treatment (0.119%) followed by compost (0.109%), crop residue (0.086%) and no manure (0.069%).

The interaction effect of organic and inorganic fertilizers on P-content of rice straw was found significant. Among different treatment combinations, it varied from 0.050% under control plot to 0.132% under 150%NPK + compost + crop residue combination. At each level of fertilizer dose, the maximum P-content in rice straw was recorded with compost + crop residue. While, in the absence of organic sources, P-content in rice straw varied from 0.050%under control to 0.090% under 150% NPK. The increase in P-content of rice crop may be due to higher available P in soil with combined effect of inorganic fertilizer and organic sources.

P-uptake by Rice (34th crop) : The data on P-uptake by rice crop are presented in table-4 and depicted in fig.-3 perusal of the data indicate the significant increase in P-uptake by rice with increasing levels of fertilizer doses. With the increase in fertilizer doses, P-uptake increased to the tune of 127.2, 231.4 and 277.6 per cent over no NPK treatment (5.58 kg ha^{-1}), at 50, 100 and 150% NPK, respectively. The maximum P-uptake was recorded with 150% NPK (21.07 kg ha^{-1}) followed by 100 percent NPK (18.49 kg ha^{-1}), 50 percent NPK (12.68 kg ha^{-1}).

The impact of various organic treatments with regard to P-uptake by rice followed the order: compost + crop residue (18.65 kg ha^{-1}) > compost (15.31 kg ha^{-1}) > crop residue (13.54 kg ha^{-1}). The per cent increase in P-uptake was 48.4, 31.2 and 80.7 percent over no manure treatment with compost, crop residue and compost+ crop residue treatments, respectively. It might be possible that organic matter addition in soil might have enhanced the uptake of applied as well as native P by the crops through its influence on solubility and availability of P in the soil.

The interaction effects of organic manures and inorganic fertilizers on total P-uptake by rice were found to be statistically non-significant. The P-uptake among different treatment combination varied from 1.95 kg ha^{-1} (absolute control) to 24.87 kg ha^{-1} (150% NPK + compost + crop residue combination). At each level of fertilizer, compost + crop residue treatment proved superior over other organic treatments. Similar results were also reported by Dahiya *et al.* (1980), Maskina *et al.* (1985) and Pandey (2003), respectively.

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