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FORMS OF PHOSPHORUS IN RICE-WHEAT GROWING SOILS OF INDO-GANGETIC ALLUVIUM PLAINS OF BIHAR

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ABSTRACT

*The status of various phosphorus fractions in soils of Patna (Bihar) was studied in relation to soil properties. The results revealed that the amounts of different forms of phosphorus i.e. soluble-P (saloid-P), Al-phosphate (Al-P), iron phosphate (Fe-P), calcium phosphate (Ca-P), reductant soluble phosphate (RS-P), occluded Al-Fe-P (Occluded-P) and organic-P ranged from: 29.4 to 36.4, 12.3 to 16.1, 7.5 to 9.7, 89.0 to 98.1, 15.2 to 22.1, 16.9 to 22.5 and 116.8 to 165.7 mg kg^{-1}, respectively. Among the inorganic P fractions, Ca-P was the major contributor to the availability of phosphorus. Significant correlation coefficients showed that the Olsen-P had a positive correlation with saloid P, Al-P, occluded P, total P and organic P. The pH had positive correlation with saloid P (r = 0.18), Fe P (r = 0.17) and EC had with all forms of phosphorus except occluded P. Significant positive correlation was observed between organic carbon with occluded P (r = 0.27**) and close relationship was observed between available P and total P (r = 0.33**) and organic carbon (r = 0.32**). It was found that the soil was fairly rich in total P reserve but the available P status was medium.*

***Key words*:** Phosphorus fractions, rice-wheat, soils

INTRODUCTION

Phosphorus is considered as second most limiting nutrient for crop growth, production and quality. Phosphorus in soil is present in three forms: P dissolved in the soil (soil solution P), organic P and inorganic P. Inorganic form is predominant form of soil P, constituting 20-80% of the total P in the surface layer. Phosphorus transformation in plants involves various complex microbiological, chemical and biological processes. Mainly it is the inorganic P fractions, which is related to the phosphate nutrition to the plants.The principal organic P compounds present in soil are: (i) inositol phosphate, (ii) phospholipids, (iii) nucleic acids and (iv) other unidentified esters and phosphoproteins. The soil inorganic P includes various forms like soluble P, Al-P, Fe-P, reductant soluble-P and Ca-P. Since, these forms of phosphorus have different solubilities, the availability and uptake depends upon their amount in the soil. The forms of phosphorus are influenced by soil characteristics such as soil reaction, EC, organic matter content, (Singh *et al.,* 2014). Calcium-P is present as discrete particles, whereas, Al-P and Fe-P occur as films and / or adsorbed on clay or silt particles. The occluded-P consists of Fe-P and Al-P fractions surrounded by an inert coat of another material that prevents the reaction of these phosphates with the soil solution (Singh and Sharma, 2007). Reductant soluble forms occur with an inert material that may be partially or totally dissolved under anaerobic condition. Strong acid soils, usually highly weathered, are dominant in Al-P, Fe-P and RS-P. Neutral and slightly acid soils usually contain all five fractions in comparable amounts. Alkaline and calcareous soils are often dominant in Ca-P. Only 10-30% of the freshly applied P fertilizer is utilized by crop plants and rest gets fixed. Chemical fractionations of soil inorganic P provides a method for identifying the predominate individual forms of inorganic P in soils as well as to know the fate of added P fertilizer and its potential availability and mobility in soils. Therefore, the objectives of this study were to evaluate; (i) the status of inorganic P fractions and (ii) the relationship between inorganic P fractionation and selected soil properties in surface soil of Indo-gangetic alluvium in Bihar.

MATERIALS AND METHODS

The study area (25°33´43▪ N latitude and 84°52´12▪ E longitude) is located at Patna district, Bihar falling in the region of Indo-gangetic alluvium plains. The area has sub-tropical climate falling in agro-climatic zone III. The study area has annual temperature ranges from 37.1ºC to

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7.8ºC and an average annual rainfall of the area is 1100-1200 mm which is good for the cereal crops. Surface soil samples from 75 locations were collected from rice-wheat growing soils of Indo gangetic alluvium zone of Bihar. The collected soil samples were air-dried and passed through 2mm sieve for different laboratory analysis. Soil samples were analysed for pH, EC, organic carbon (Jackson, 1973) and available P (Olsen *et al.,,* 1954). Total P was determined by H_2SO_4: Se digestion method (Houba *et al.,,* 1988) while other forms of phosphorus were determined by the sequential phosphorus extraction procedure, originally developed by Chang and Jackson method (1957) modified by Corey and Peterson (1966). Total inorganic phosphorus was estimated by addition of all the inorganic P fractions and organic phosphorus was determined by subtracting the value of total inorganic phosphorus from the corresponding value of total phosphorus.

RESULTS AND DISCUSSION

Chemical characteristics

All the soils were neutral to alkaline in reaction having a pH range of 6.9 to 8.7 which may be due to the calcareous nature of the soils. The organic carbon content ranged from 4.4 to 6.8 g kg^{-1} with a mean value of 5.6 g kg^{-1} showing low to medium in organic carbon content which may be due to high temperature prevailing in the area responsible for rapid decomposition of organic carbon. The electrical conductivity (EC) ranged from 2.04 to 3.22 dSm^{-1} with an average value of 2.63 dSm^{-1} indicating high soluble salt content (Table 1).

Table 1: Physico-Chemical properties of soils of Indo-Gangetic alluvium plains of Bihar

Location (villages)	pH	EC (dSm^{-1})	Organic C (g kg^{-1})	Av. P (kg ha^{-1})
Pali	8.0	2.82	5.7	10.4
Dumri	7.6	2.76	5.8	13.9
Madhupura	7.3	3.03	6.3	12.2
Painal	6.9	3.07	5.2	17.2
Banwanpur	7.0	3.11	6.2	14.6
Methapur	7.2	3.13	4.6	13.2
Milki	7.2	3.07	5.3	12.3
Narayanpur	7.5	2.91	6.3	12.4
Ramnagar	7.6	2.50	5.4	12.4
Khedarpur	7.2	2.66	6.7	13.3
Mustafapur	7.5	3.06	6.4	12.8
Sadisopur	7.4	2.50	6.7	13.8
Bahpura	7.8	2.82	6.7	12.7
Maner	7.6	2.04	6.6	12.7
Neuri	8.7	3.22	6.7	14.3
SD±	3.0	0.60	0.07	1.8
C.V. (%)	40	21.12	11.6	13.8

Forms of phosphorus

Total P: The total P in the soils of Indo Gangatic plains of Bihar ranged from 311.7 to 391.1 mg kg^{-1} with a mean value of 327.6 mg kg^{-1}. The wide variation in total P content of these soils seems to be caused by variations in their physic-chemical properties.The highest value (391.1 mg kg^{-1}) of total P was found in Dumri village whereas lowest value (311.6 mg kg^{-1}) in Madhupura (Table 2). This might be attributed to the higher clay content of the soil. Similar results were found Lungmuana *et al.,* (2012) in red and lateritic zone of West Bengal.

Available P: The available phosphorus content in these soils varied from 10.4 to 17.2 kg ha^{-1} with a mean range of 13.8 kg ha^{-1} (Table 1). The highest value (17.2 kg ha^{-1}) was found in Painal whereas lowest value (10.4 kg ha^{-1}) in Pali village. The standard deviation value of the available phosphorus content of the soil was 1.83. The low availability of P could be due to its high fixation rate. Among the soil samples collected, all samples were medium range in available phosphorus content. These findings were in accordance with the results reported by Laxminarayana (2007) and Trivedi *et al.,* (2010) in some soils of Mizorum and Madhya Pradesh, respectively.

Saloid P: The saloid bound-P in soils of the region ranged from 29.4 to 36.4 mg kg^{-1} with a mean value of 32.9 mg kg^{-1}. The highest value (36.4 mg kg^{-1}) of saloid -P was found in Banwanpur village whereas lowest value (25.4 mg kg^{-1}) in Khedarpur (Table 2). The high amount of saloid bound-P in the surface soil could be due to the slow transformation of soluble forms of P added into relatively less soluble forms with progress of time. Similar result was also found by Singh and Sharma (2007) in the surface soils of agro ecological zones of Panjab.

Alunimium P: The Al-P in these soils ranged from 12.3 to 16.1 mg kg^{-1} with a mean value of 14.2 mg kg^{-1} (Table 2). The lower content of Al-P in such soil seems to accompany strong weathering in the tropics under well drained condition. Similar result was found by Trivedi *et al.,* (1997).

Iron P: The Fe-P in the soils of the region ranged from 7.5 to 9.7 mg kg^{-1} with a mean value of 8.6 mg kg^{-1}. The highest value (9.7 mg kg^{-1}) of Fe-P was found in Narsayanpur village and lowest value (7.5 mg kg^{-1}) in Painal (Table 2). The amounts of Fe and Al bound P can be ascribed to the presence of sesquioxides which might have transformed a portion of added P in these forms. Similar results were found by Singh and Sharma (2007) in soils of Punjab.

Table 2: Forms of Phophorus (mg kg^{-1}) in soils of Indo-Gangetic alluvium plains of Bihar

Location (villages)	Saloid P	Al-P	Fe-P	Ca-P	RS-P	Occluded P	Inorganic P	Total P	Organic P
Pali	32.1	13.6	9.1	95.6	19.9	16.9	187.1	303.9	116.8
Dumri	31.9	14.1	8.2	95.4	15.2	18.7	183.4	391.1	135.7
Madhupura	35.1	16.1	9.1	89.0	15.4	17.0	181.8	311.6	129.8
Painal	35.0	14.6	7.5	92.8	17.8	20.2	188.0	339.2	151.1
Banwanpur	36.4	13.0	8.2	97.9	21.6	20.0	199.3	333.8	134.5
Methapur	29.8	14.7	8.6	89.6	19.3	19.0	180.9	345.7	164.8
Milki	32.1	13.2	7.7	93.6	17.6	18.9	183.2	333.3	150.0
Narayanpur	29.5	12.9	9.7	94.2	16.9	20.6	183.8	331.5	147.6
Ramnagar	30.3	13.4	8.6	98.1	18.4	18.6	188.9	331.9	143.0
Khedarpur	29.4	13.8	8.9	93.2	20.7	22.2	188.2	317.4	129.2
Mustafapur	34.1	12.3	9.1	94.0	22.1	22.5	193.9	335.4	141.3
Sadisopur	34.6	13.1	8.1	90.8	17.3	20.5	184.5	350.2	165.7
Bahpura	33.7	13.1	7.6	96.2	20.2	19.9	191.1	309.8	118.6
Maner	32.2	13.4	7.6	92.0	19.2	19.3	183.8	328.5	144.7
Neuri	33.3	14.1	8.8	91.9	18.9	19.7	186.7	322.9	131.1
SD±	3.1	1.4	1.0	4.1	2.4	1.99	6.2	23.9	24.6
C.V. (%)	10.1	10.1	11.4	4.4	12.8	10.1	3.3	7.3	17.5

Calcium P: The Ca P in these soils ranged from 89.0 to 98.1 mg kg^{-1} with a mean value of 93.6 mg kg^{-1}. The lowest value (89.0 mg kg^{-1}) of Ca-P was found in Madhupura village and highest value (98.1 mg kg^{-1}) in Ramnagar. Dominance of Ca-P over other inorganic P forms can be supported that the area comprised of recent alluvium rich in silt and clay content with high CEC and exchangeable cations. Similar results were found by Trivedi (2010) in the soils of grid region of Madhya Pradesh and Singh *et al.,* (2014) in soils of Agra region of Uttar Pradesh.

Reductant soluble P: The reductant soluble P in the soils of the region ranged from 15.2 to 22.1 mg kg^{-1} with a mean value of 18.7 mg kg^{-1}. The highest value (22.1 mg kg^{-1}) of reductant soluble P was found in Mustafapur village and lowest value (15.2 mg kg^{-1}) in Dumri. Amount of reductant soluble P in the surface soils could be attributed to the weathering of the soils. Since, its recently formed aluvium hence low reductant soluble P range is found. Similar results were found by Kalivanan and Sudhir (2012) in the soils of Tamil Nadu, Karnataka, Gujarat and Andhra Pradesh.

Occluded P: The occluded Al-Fe-P in the soils of the region ranged from 16.9 to 22.5 mg kg^{-1} with a mean value of 19.6 mg kg^{-1}. The highest value (22.5 mg kg^{-1}) of occluded P was noted in Mustafapur village whereas lowest value (16.9 mg kg^{-1}) of occluded P was found in Pali. Amount of occluded Al-Fe-P in the surface soils

could be attributed to the weathering of the soils. Since, its recently formed aluvium hence low occluded Al-Fe-P range is found. Similar results were found by Lungmuana *et al.,* (2012) in red and lateritic zone of West Bengal.

Organic P: The Organic P in these soils ranged from 116.8 to 165.7 mg kg^{-1} with a mean value of 165.7 mg kg^{-1}. The highest value (165.7 mg kg^{-1}) of organic P was found in Sadisopur village whereas lowest value (116.8 mg kg^{-1}) of organic P was found in Pali. Its content mainly depends on the amount of organic matter added to the soils. It also depends on the distribution of clay content and total-P in the soil. Similar results were found Lungmuana *et al.,* (2012) in red and lateritic zone of West Bengal.

Correlation studies

In order to assess the influence of soil properties on various forms of P, coefficients of correlation were worked out (table 3 and 4). The pH was positively correlated with saloid P (r = 0.18), Fe-P (r = 0.17) and Ca P (r = 0.05) and reductant P (r = 0.02) and negatively with Al P (r = -0.10), occluded P (r = -0.16), inorganic P (r = -0.09), and total P (r = -0.16), and organic P (r = -0.15). Similar positive and negative correlation was found between RS-P and pH by Lungmuana *et al.,* (2012) in soils of West Bengal. The dominance of Al-P in contributing towards availability of P has also been reported by Kalaivanan and Sudhir (2012) and Laxminarayana (2007). The EC was positively correlated with all forms of P except occluded P (r = - 0.03). Similar positive relationships were found with all forms of form of phosphorus by Lungmuana *et al.,* (2012) in soils Terai zone of West Bengal.The organic carbon showed a positive significantly correlation with occluded P (r = 0.27*) and negative one with organic P (r =-0.24*). The positive correlation was found between organic carbon and saloid P (r = 0.15), Fe P (r = 0.16), reductant-P (r = 0.12) and inorganic P (r = 0.17) and negative ones with Al P (r = -0.10), Ca P (r = - 0.0.05) and total P (r = -0.20). Similar results were found by Trivedi *et al.,* (2012) and Dharumarajan *et al.,* (2014).

Table 3: Correlation coefficients among various forms of phosphorus

	pH	EC	OC	Avai. P
Saloid-P	0.18	0.14	0.15	0.13
Al-P	-0.1	0.08	-0.1	0.58
Fe-P	0.17	0.02	0.16	-0.29**
Ca-P	0.05	0.07	-0.05	-0.09
Red -P	0.02	0.12	0.12	-0.02
Occ-P	-0.16	-0.03	0.27*	0.18
Inorg. P	-0.09	0.18	0.17	0.92
Total P	-0.16	0.05	-0.2	0.33**
Org. P	-0.15	0.02	-0.24*	0.32**

''represents significant at 0.05 level '**' significant at 0.01 level*

The available P showed positive correlation with total P (r = 0.33**) and organic P (r = 0.32**) and negative one with Fe P (r = -0.29**). The positive correlation was found between available P and saloid P (r = 0.13), Al P (r = 0.58), occuluded P (r = 0.18) and inorganic P (r = 0.92) and negative one with Ca P (r = -0.09) and reductant-P (r = - 0.02). Similar relationships among all the form of P were also reported by Singh *et al.,* (2014).

Table 4: Correlation coefficients among various forms of phosphours

	Saloid-P	Al-P	Fe-P	Ca-P	RS-P	Occ-P	Inorg. P	Total P
Saloid-P	1							
Al-P	-0.11	1						
Fe-P	-0.22	0.13	1					
Ca-P	0.04	0.04**	-0.26*	1				
Red-P	0.11	-0.31**	0.003	0.23*				
Occ-P	0.03	-0.41**	0.03	0.04	0.32**	1		
Inorg. P	0.50**	-0.34**	-0.10	0.68*	0.63**	0.39**	1	
Total P	-0.06	-0.06	-0.09	0.05	0.02	0.09	0.01	1
Org. P	-0.19	0.03	-0.07	-0.11	-0.13	-0.01	-0.22*	0.96**

From the study, it may be concluded that among the inorganic P fractions Ca-P was the major contributor to the availability of phosphorus. The soil was fairly rich in total P reserve but the available P status was medium. Inorganic soil P fractions had relationship with different physico-chemical properties. Farmers are suggested to adopt adequate P-fertilization as epr the requirement of the crop(s) towards optimizing agricultural production of the rice-wheat cropping system generally practiced in the area.

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