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Distribution of Inorganic Phosphorus Fractions in Soils of Bobbili Mandal, Vizianagaram District, Andhra Pradesh

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An investigation was carried out to estimate the distribution and relative proportion of phosphorus fractions in soils of Bobbili mandal, Vizianagaram district. The soil samples (0-25 cm) from 50 representative locations covering Bobbili mandal were collected and were analysed for the distribution of inorganic phosphorus fractions. Based on elevations and drainage, the study area was divided into three physiographic units viz., uplands, midlands and lowlands. The inorganic phosphorus fractions were in the order of Ca-P > Fe-P > Al-P > saloid-P. Among different phosphorus fractions, the saloid-P, Al-P, Fe-P and Ca-P ranged from 1.25 to 12.50, 1.50 to 45.00, 10.50 to 71.50 and 17.00 to 170.50 mg kg^{-1}, respectively while the total-P varied from 172 to 752 mg kg^{-1}. The contribution of saloid-P, Al-P, Fe-P and Ca-P towards total-P ranged from 0.75 to 1.70, 2.55 to 7.31, 6.70 to 10.78 and 11.16 to 25.88 per cent, respectively.

(***Key words :*** *Inorganic phosphorus fractions, Saloid-P, Al-P, Fe-P, Ca-P, Total-P*)

Phosphorus plays a key role in crop production. It is the nutrient, which records high residual efficiency. The application of P through manures and fertilizers for years would build up the soil reserves due to the fixation of appreciable portions of the applied phosphorus into forms of low solubility. The active forms of P in soils viz., saloid-P, Al-P, Fe-P and Ca-P provide useful information for evaluating the phosphorus supplying capacity of soils. Various forms of P are interrelated and contribute to the pool of plant - available P according to their physico-chemical properties such as composition, solubility, surface area, age, etc. The fixation of phosphorus in relatively unavailable forms differs from soil to soil and is closely related to soil pH. The objective of the present study was to investigate the relative abundance of various inorganic P fractions so as to understand the behavior of P in upland, midland and lowland situations.

MATERIAL AND METHODS

The study area lies between 18°34′ and 18°56′ North latitude and 83° 22′ and 83° 36′ East longitude with elevation varying from 107-178 m above the mean sea level. The annual precipitation was 1037 mm, the mean annual maximum and minimum temperatures were 39.02°C and 29.04°C, respectively. The drainage pattern is sub-dendritic with ephemeral streams going from West to East. River Vegavathi forms the southern boundary of the study area. The soils of the study area were divided into three physiographic units *viz*., uplands, midlands and lowlands based on elevations and drainage. Surface (0-25 cm) samples collected from fifty representative locations of three physiographic units were processed and taken up for analysis.

The texture of the soils was determined by Bouyoucos hydrometer method (Piper, 1966), pH was determined in 1:2.5 soil : water suspension using pH meter. Organic carbon content was estimated by Walkley and Black method (Jackson, 1973) whereas, cation exchange capacity was estimated as per the procedure outlined by Bower *et al*. (1952) and the amount of free calcium carbonate was analysed by following the procedure outlined by Hesse (1971). The available phosphorus was extracted by using Olsen's extractant (0.5 M $NaHCO_3$ of pH 8.5) as described by Olsen *et al*. (1954) and the phosphorus in the extract was determined by Murphy and Riley (1962) method using ascorbic acid as the reducing agent using spectrophotometer.

The inorganic phosphorus fractions *viz*., saloid-P, Fe-P, Al-P and Ca-P were estimated by following the sequential extraction procedure as given by Kovar and Pierzynski (2009). Total phosphorus in the soils was determined by perchloric acid digestion method as described by Jackson (1973).

RESULTS AND DISCUSSIONS

The soils of the study area were sandy loam to clay in texture (12.20 - 56.80 %), strongly acidic to moderately alkaline in reaction with values varying from

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5.3 to 8.4. The soils were low to high in organic carbon (0.11 - 0.76%) and low to high in available phosphorus (18.46 - 92.97 kg ha^{-1}). Calcium carbonate content varied from nil to 5.20 per cent and cation exchange capacity ranged from 9.22 to 42.60 cmol (p^+) kg^{-1} (Table 1). The distribution of inorganic phosphorus fractions viz., saloid-P, Al-P, Fe-P, Ca-P and total- P in the surface soils of Bobbili mandal are presented in the Table 2. The distribution pattern of different inorganic P fractions in the present study was found to be in the order of Ca-P > Al-P > Fe-P > saloid- P, which were in conformity with the observations of Laxminarayana and Rajagopal (2002) in rice growing soils representing eight districts of Andhra Pradesh.

Saloid - P

The saloid -P ranged from 1.25 to 12.50 mg kg^{-1} with a mean of 4.91 mg kg^{-1}. Saloid bound P was the least among the fractions in different soil types. The low concentrations of saloid-P in soils might be due to transformation of soluble P forms into less soluble forms with time (Sarkar *et al*., 2013). The relatively higher content of saloid P in some soils may be due to addition of P through fertilizers and manures (Viswanatha and Doddamani, 1991). The applied P may remain available in the saloid bound or loosely bound fraction over a shorter interval of fertilization.

On ageing, this fraction will be fixed and become unavailable (Srivastava and Pathak, 1968; Patiram and Mukhopadhyay, 2008).

Saloid P content of the soils was significantly and positively correlated with Fe-P (0.333**) and Ca-P (0.361**) (Table 3). The saloid P, though recorded maximum values in coarse textured soils within a physiographic unit, it registered a positive relation with clay (0.276*) and in turn with CEC (0.276*). Similar positive correlation (r = 0.189) between saloid-P and clay was observed by Sacheti and Saxena (1973) in clay soils of Rajasthan. The combined influence of clay and organic colloids might have helped in retention of loosely bound P in soils. The variation in saloid - P amongst different soils can be ascribed to the variation in clay, organic carbon and available P content of the soils (Singh and Sharma, 2007).

Aluminium - P

The aluminium P in the soils varied from 1.50 to 45.00 mg kg^{-1} with a mean of 17.18 mg kg^{-1}. The low Al-P suggests that the capacity of the soils to supply phosphorus is very limited. Relatively higher Al-P contents were recorded in lowlands which ranged from 7.00 to 45.00 mg kg^{-1} with a mean value of 24.95 mg kg^{-1} followed by midlands ranging from 4.00 to 40.00 mg kg^{-1} with a mean of 15.14 mg kg^{-1} and uplands ranging from 1.50 to 26.00 mg kg^{-1} with a mean value of 10.11 mg kg^{-1}. Similar findings earlier were reported by Lungmuana *et al*. (2012) and Sarkar *et al*. (2013). The Al- P was positively and significantly correlated with CEC (r = 0.407**), Ca-P (0.506**), clay (0.326**), organic

Table 1. *Selected soil properties of different landforms*

S. No	Soil properties	UPLANDS		MIDLANDS		LOWLANDS	
		Range	Mean	Range	Mean	Range	Mean
1	Clay (%)	12.20-41.70	28.44	16.60-46.70	32.24	36.80-56.80	50.12
2	pH	5.3-8.2	7.1	5.9-8.4	7.5	7.3-8.4	7.92
3	Organic carbon (%)	0.11-0.66	0.35	0.12-0.54	0.34	0.29-0.76	0.46
4	$CaCO_3$ (%)	Nil-3.20	0.32	Nil-0.46	0.77	Nil-5.20	1.82
5	CEC (cmol (p+) kg^{-1})	9.22-28.54	19.96	13.05-34.52	21.08	21.10-42.60	35.25
6	Available P_2O_5 (kg ha^{-1})	18.46-62.63	43.33	26.16-92.97	46.67	29.75-87.17	53.88

Table 2. *Distribution of inorganic phosphorus fractions (mg kg^{-1}) of soils in different landforms*

S. No	Soil properties	UPLANDS		MIDLANDS		LOWLANDS	
		Range	Mean	Range	Mean	Range	Mean
1	Saloid-P	1.38-5.02	2.73	1.25-9.50	4.98	1.88-12.50	6.30
2	Aluminium-p	1.50-26.00	10.11	4.00-40.00	15.14	7.00-45.00	24.95
3	Iron-P	13.75-44.25	27.07	10.50-66.00	33.29	11.25-71.50	37.66
4	Calcium-P	18.00-89.00	45.38	17.00-142.50	73.33	51.00-170.50	112.89
5	Total-P	192-460	310.91	172-752	356	248-720	489

Table 3. *Correlation between different phosphorus fractions and soil parameters*

	Saloid- P	Al- P	Fe-P	Ca -P	Total- P	pH	$CaCO_3$	OC	P_2O_5	Clay %	CEC
Saloid- P	1.000										
Al-P	0.183	1.000									
Fe-P	0.333**	0.004	1.000								
Ca-P	0.361**	0.506**	0.291	1.000							
Total- P	0.110	0.470**	0.438**	0.657**	1.000						
pH	0.228	0.232	-0.100	0.559**	0.188	1.000					
$CaCO_3$	0.070	0.295	-0.501	0.313**	0.101	0.490	1.000				
Organic carbon	0.110	0.341**	0.078	0.507**	0.348**	0.285	0.121	1.000			
Available P_2O_5	0.105	0.407**	0.378**	0.527	0.525**	0.182	0.045	0.262	1.000		
Clay	0.276**	0.326**	0.124	0.670**	0.467**	0.597	0.306	0.375	0.324	1.000	
CEC	0.276**	0.407	0.085	0.708	0.510	0.620	0.431	0.398	0.303	0.883	1.000

**Significant at 1% level

Table 4. *Contribution (%) of different inorganic phosphorus fractions to total-P in different landforms*

S. No		UPLANDS		MIDLANDS		LOWLANDS	
		Range	Mean	Range	Mean	Range	Mean
1	Saloid-P	0.30-1.95	1.00	0.18-3.02	1.59	0.29-2.52	1.37
2	Aluminium-p	0.78-10.08	3.27	1.05-15.50	4.53	1.78-8.82	5.08
3	Iron-P	5.29-12.50	8.86	3.33-18.97	9.87	2.83-14.92	7.98
4	Calcium-P	6.98-25.96	14.40	5.90-41.90	21.44	14.01-38.06	23.75

carbon (0.341**) and available P (0.407**) of soils. The results were in confirmation with the findings of Chakravarthy and Barua (1987) and Puranik *et al.* (1995).

Iron - P

The iron P in the soils ranged from 10.50 to 71.50 mg kg^{-1} with a mean value of 33.32 mg kg^{-1}. The magnitude of Fe-P is largely dependent on the distribution of finer fractions in soil (Puranik *et al.*, 1995). Fe-P also followed similar trend to that of Al-P with maximum mean value (37.66) recorded by lowlands followed by midlands (33.29 mg kg^{-1}) and uplands (27.07 mg kg^{-1}). Similar findings were observed by Patgiri and Dutta (1993) in tea growing soils of Nagaon district of Assam.

Olsen P showed significant positive correlation with Al-P (r = 0.407**) and Fe-P (r = 0.378**). Similar finding were reported by Debnath and Mandal (1982). Significant positive correlation of Fe-P with total P (r = 0.438**) was also reported by Chakravarthy and Barua (1987) in hill soils of Assam. Organic carbon exhibited a significant positive correlation with Al-P and Fe-P (0.341** and 0.078) indicating the dependence of the fractions on organic matter content of soil, which acts as a source of P on mineralization. The results are in close conformity with the findings of Jaggi (1991) in some representative soils of Himachal Pradesh and Tripathi and Dwivedi (1993) in central alluvial soils of Uttar Pradesh. A higher level of Fe-P was also ascribed to iron rich parent material. Higher Fe-P content in lowlands may be attributed to deep prolonged weathering due to longer wet period as a result of lower topographic situation which might have brought about the transformation of Ca-P to Fe-P (Singh *et al.*, 2003).

Calcium -P

The calcium-P in the soils varied from 17.00 to 170.50 mg kg^{-1} with a mean of 79.84 mg kg^{-1}. In uplands the Ca-P varied from 18.00 to 89.00 mg kg^{-1}, in midlands soils it varied from 17.00 to 142.50 mg kg^{-1} while, in lowlands the Ca-P ranged between 51.00 and 170.50 mg kg^{-1}. Overall high Ca-P was observed in lowlands which registered a mean value of 112.89 mg kg^{-1}. Continuous application of high doses of P-fertilizers like diammonium phosphate for a longer period of time might have led to accumulation of more Ca-P (Laxminarayana and Rajagopal, 2002). Dominance of Ca-P among the inorganic P fractions in several soils is well expected in view of their origin from calcareous parent material (alluvium) and alkaline reaction together with high saturation of the exchange complex (Mishra, 1994).

Table 5. *Distribution of inorganic phosphorus fractions (mg kg^{-1}) of soils related to texture in different landforms*

S. No.	Textural class	No. of samples	Saloid-P		Aluminium-P		Iron-P		Calcium-P		Total-P	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
UPLANDS												
1	sc	5	1.63-2.50	2.18	1.50-15.50	8.40	13.75-44.25	27.70	27.75-81.00	52.39	192-398	316.80
2	scl	2	1.38-2.25	1.82	9.00-17.50	11.75	24.50-33.50	29.00	38.25-89.00	63.63	400-460	430.00
3	sl	4	3.00-5.02	3.88	1.50-26.00	10.69	19.25-29.25	25.31	18.00-36.25	27.50	192-288	244.00
MIDLANDS												
1	sc	13	1.25-7.50	4.94	4.00-35.00	11.65	14.25-66.00	35.15	27.25-142.50	83.11	172-752	366.60
2	scl	6	2.75-5.25	4.33	5.75-40.00	22.91	10.50-54.50	29.54	33.50-105.50	72.80	216-462	323.30
3	sl	4	2.50-9.50	6.06	7.50-17.75	13.06	19.25-44.50	37.68	17.00-58.50	42.31	288-454	372.00
LOWLANDS												
1	c	12	1.88-12.50	5.64	7.00-45.00	26.52	11.25-69.00	35.14	90.00-170.50	121.95	248-720	491.60
2	sc	4	5.00-8.60	6.71	7.00-40.00	20.25	18.00-71.50	45.18	51.00-120.75	85.68	364-636	480.00

sl - sandy loam sc - sandy clay, scl - sandy clay loam c - clay

A positive significant relationship of calcium bound P with clay (r = 0.670**) and soil pH (r = 0.559**) clearly exhibited the influence of these parameters on the abundance of calcium bound P. Calcium phosphate become more soluble as soil pH decreases, hence they tend to dissolve in acid soils. The findings are in conformity with those observed earlier by Singh and Sharma (2007). Significant positive correlation observed between Ca-P and calcium carbonate content (r = 0.313**) emphasizes its role in distribution of Ca-P. This might possibly be due to more precipitation of calcium bound phosphorus under the influence of organic chemicals and active microflora by the interaction of soluble phosphates and calcium. Calcium bound phosphorus with organic carbon relationship (r = 0.507**) can be explained on the basis of solubilization of more calcium under the influence of organic matter which may react with soluble phosphates to produce calcium phosphates (Sacheti and Saxena, 1973).

Total - P

The total P in the soils ranged from 172 to 752 mg kg^{-1} with a mean of 389 mg kg^{-1}. The total-P content ranged from 192 to 460, 172 to 752 and 248 to 720 mg kg^{-1}, respectively in uplands, midlands and lowlands. The total P in the soil indicates the P reserves, which might eventually be available to plants in course of time (Lungmuana *et al*., 2012). The soils derived from the parent materials rich in P, contain higher amount of total P. The total P content is generally highest in soils developed on granite gneiss (Tiwari, 2012). The higher content of total P in surface layers may be attributed to continuous addition of fertilizer and manure to this layer (Viswanatha and Doddamani, 1991). The amount of total P in soils is governed by the amount of clay and organic matter (Williams and Saunders, 1956).

The correlation analysis revealed that total P had significant positive correlation with clay (r = 0.467**) and organic carbon (r = 0.348**) indicating that the soils containing higher amount of clay and organic matter are characterized by greater retention of phosphorus. The observations were in conformity with the finding of Bhatai and Deo (1988). Total-P also correlated significantly and positively (r = 0.525**) with available P. similar correlation was noticed by Patgiri and Dutta (1993). Higher amount of available P in surface layers and significant positive correlation of available P with total P and Fe-P indicated the dependence upon the release of P from these fractions (Chakravarthy and Barua, 1987). Total-P showed a significant positive correlation with Ca-P (r = 0.657**).

The contribution of saloid-P, Al-P, Fe-P and Ca-P towards total-P ranged from 0.75 to 1.70, 2.55 to7.31, 6.70 to 10.78 and 11.16 to 25.88 per cent, respectively (Table 4). In each land form higher contribution of saloid-P was observed in coarse textured soils indicating lesser fixation of P in these soils. Overall contribution of different inorganic fractions towards total P was in the order of Ca-P > Fe-P > Al-P > saloid-P in all textural groups of all physiographic units. On the whole the active forms of inorganic phosphorus viz. saloid-P, Al-P, Fe-P and Ca-P (Hedley *et al*., 1982) constituted to 135.25 mg kg^{-1} and contributed 35.50 per cent to the total P. Similar contribution by active forms towards total P was reported by Lungmuana *et al.* (2012).

Phosphorus fractions (mg kg^{-1}) of soils related to texture in different landforms

Critical observation of data in the Table 5 relating the P-fractions to soil texture in different land forms revealed that the saloid-P was more in coarse textured soils compared to fine textured soils within a physiographic unit. However, variations in saloid-P within a given texture could be due to variable P-application rates as well as P retention capacity of soil minerals. Further observation of data indicated high mean values of Al-P in sandy clay loams of uplands and midlands soils while in lowlands, clay soils recorded higher Al-P. The highest average Fe -P was observed in sandy clay texture of lowlands. In general, no particular trend was observed in Fe-P. The average Ca-P values were maximum in fine textured soils of lowlands and midlands soils, whereas in uplands the sandy clay loams recorded higher Ca-P over sandy clays. Such variation could be ascribed to the type of minerals, soil reaction, clay content and organic carbon content.

The wide range of variation in inorganic P fractions observed in the soils might be a result of variability in the composition of parent materials and weathering coupled with fertilizer application (Mishra, 1994). All forms generally existed in all soils, but Al-P and Fe-P fractions were more abundant in acid soils and Ca-P dominated in neutral to alkaline soils. Various forms of P are interrelated and contribute to the pool of plant - available P depending upon the physico-chemical properties of soils.

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