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Distribution of Inorganic Phosphorus Fractions in Varying Phosphorus Levels of Soils

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Abstract
In Present study, Phosphorus factions in representative agricultural soils belonging to three soil P levels, low-P, medium-P, and high-P, soils collected from Ranga Reddy district, Hyderabad, Telangana. Results revealed that in low phosphorus soil the order of phosphorus fixation is Ca-P>Al-P>Fe-P>Saloid-P with a mean values of 37.32, 11.64, 10.58, 7.58, mg kg^{-1} and in medium phosphorus soils the order of phosphorus fixation from (M1-M2), Ca-P>Fe-P>Al-P>Saloid-P, (M3-M10) Ca-P>Al-P>Fe-P>Saloid-P with a mean value of 73.27, 30.31, 27.92, 13.55 mg/kg, and in high phosphorus soils showed that the order of phosphorus fixation is Ca-P>Al-P>Fe-P>Saloid-P, with a mean values of 94.53, 34.13, 30.41, 17.08mg/kg. The mean contribution of saloid P to total P was 11.46%, 9.26% and 9.69% in low, medium and high phosphorus status soils respectively. Mean Al- P contribution to total P in low, medium and high phosphorus soils is as follows 17.36%, 20.77% and 19.40%. and The extent of Ca- P contribution to total phosphorus was 55.44%, 50.34% and 53.71% under soil studied. Among all the P fractions, the Al-P and Fe-P fractions contributed very little to the total P compared to the Ca-P. This could be mainly due to the fact that the solubility of Al-P and Fe-P, decreased with increase in pH**,** forming insoluble iron and aluminium phosphates, resulting in their reduced activity.

Keywords: Low P soils, Medium P soils, High P soils, Phosphorus

1. Introduction
Phosphorus is essential element for plant growth as well as an important in the development process of Agricultural crops. The application of phosphorus to each crop in a rotation and low recovery of added phosphorus has been found to result in its significant build up in soils. (Song *et al*., 2007) [16]. The availability of soil phosphorus to plant depends on the replenishment of labile phosphorus from other phosphorus fractions (Nwoke *et al*., 2004) [5].
The total phosphorus level of soil is not only low but also P compounds are mostly unavailable for plant uptake. The concentration of P in the soil solution (intensity) and capacity of the soil to supply phosphorus to the soil solution are important factors affecting P availability. As the basic raw material rock phosphate available in the country is only 10 percent in India is not self-sufficient in meeting the requirement of phosphorus therefore, depends on import for the balance of 90 percent. (Chandarakala. 2014) [2].
Phosphorus, like any other plant nutrient, is present in soil in two major components i.e. organic and inorganic. Organic P, which mainly confined to the surface layer, is mineralized into inorganic forms. But the plants mainly depend on inorganic P forms for their P requirements. Saloid-P, Al-P, Fe-P and Ca-P fractions are the main source of P supply to the plants. The relative proportion of different forms of inorganic phosphorus depends on various soil characteristics like pH, organic carbon, CaCO3, CEC and texture (Jaggi, 1991, Singh *et al*. 2005) [4, 13]. Knowledge of forms of phosphorus and their relationship with these soil characteristics is very useful in assessing phosphorus nutrition of plants.
The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, occluded and organic-P governs the response to applied P (Singh *et al*., 2003) [15]. It is therefore important to consider both organic and inorganic P fractions for soil phosphorus fertility evaluation. It can serve as an indicator for proper nutrient management Shen *et al*., (2004) [12] concluded that fractions of phosphorus can provide effective approach for investigating soil phosphorus availability and

phosphorus inter conversion among soil P fractions from different P pools. Hence a study was undertaken to know the distribution of P fractions in different (low, medium, and high) phosphorus soil.

2. Materials and Methods

One hundred forty soil samples were collected in and around Ranga Reddy district, Hyderabad, Telangana state in the present investigation. Soils samples were dried and sieved through 2mm sieve and stored for chemical analysis. These soils were initially tested for available P using Olsen extractant as per the standard procedures to find out the status of available P. Based on status of available P 10-low, 10-medium, 10-high, (Total-30) soil samples were employed in the present investigation. Fractionation of soil phosphorus was carried out for selected 30 soils by the Chang and Jackson (1957) [3] as modified by Peterson and Corey (1966) [10] and available P by Olsen *et al*., (1954) [7].

2.1 Determinations of phosphorus fractions

The procedure of Chang and Jackson (1957) [3] as modified by Peterson and Corey (1966) [10] was followed for fractionation of soil phosphorus. The sequence of Saloid-P, Al-P, Fe-P, and Ca-P from each sample. The soils extractant for various fractions in sequence were as follow:

The phosphorus content in the extracts was determined by developing blue color using ascorbic acid method of Watanabe and Olsen (1965) and the intensity of blue color was measured at 660 nm in a Spectrophotometer and fractions were expressed in mg kg^{-1}soil.

2.1.1 Saloid – P (mg kg^{-1})

Saloid – P was extracted by shaking 1.0 g of soil with 50 ml of 1 *N* NH_4Cl for half an hour. It was then centrifuged at 2000 rpm for 10 minutes and supernatant was decanted. In this supernatant solution phosphorus was determined.

2.1.2 Al – P (mg kg^{-1})

The residue left after the extraction of saloid – P was shaken for one hour with 50 ml of 0.5 *N* NH_4F (pH 8.2), centrifuged at 2000 rpm for 10 minutes and decanted. Phosphorus in this extract was determined.

2.1.3 Fe – P (mg kg^{-1})

The residue left after the extraction of Al – P was washed twice with saturated NaCl solution (25 ml each time) to remove excess NH_4F and the washed solution was removed by centrifugation and decanting the supernatant. The washed soil was then shaken with 50 ml of 0.1 *N* NaOH for 17 hrs and centrifuged at 2400 rpm and decanted to this decanted solution, 5 drops of concentrated H_2SO_4 was added and it was filtered through 0.5 g activated charcoal. Fe-bound – P was determined in the filtrate and expressed as mg P kg^{-1}.

2.1.4 Ca – P (mg kg^{-1})

The residue left after the extraction was washed twice with saturated NaCl solution (25 ml each time) by centrifugation and decantation and discarded the decanted solution. The washed soil was then shaken with 50 ml of 0.25 *M* H_2SO_4 for 1 hr and centrifuged. The P in the decanted solution was determined and expressed in mg kg^{-1}.

Saloid-P extracted by 1N NH_4Cl
Al-P extracted by 0.5N NH_4F buffered at pH -8.2
Fe-P extracted by 0.1M NaOH
Ca-P extracted by 0.5N H_2SO_4

In each fraction take 5ml extract in 25ml of volumetric flask for determination after dilution shake the content and add 4ml reagent mixture (Ascorbic acid) the contents of flasks were shaken well and diluted to the mark. Colour intensity was measured in spectrophotometer within 10 minutes after setting the instrument to 100 reading of transmittance with blank prepared. The amount of phosphorus was calculated as Pin Kg ha^{-1}.

3. Results and Discussion

3.1.1 Saloid -P

Saloid –P represent the loosely bound P and most readily available form of phosphorus. It was of lowest concentration among inorganic phosphorus fractions under study. (Table-1) The overall saloid P content varied from 4.94 to 20.37 mg kg^{-1}. Variation of saloid P may be attributed to Variation in the available phosphorus content in these soils (Devra *et al*., 2014) [11]. The minimum amount of saloid P (4.94 mg kg^{-1}) was registered in low phosphorus status and it extended up to 9.39 mg kg^{-1} with a mean of 7.58 mg kg^{-1} while in case of medium phosphorus status soils it was ranging from 10.68 to 16.62 mg kg^{-1} with an average value of 13.55 mg kg^{-1}. It was varied from 14.5 mg kg^{-1} to 20.37 mg kg^{-1} in high phosphorus status soils with a mean of 17.08 mg kg^{-1}. As the phosphorus status increased from low to high correspondingly there was increase in its content. The mean contribution of saloid P to total P was 11.46%, 9.26% and 9.69% in low, medium and high phosphorus status soils respectively.

3.1.2Al- P and Fe – P

The Fe P and Al-Pare the fractions of P associated with the amorphous oxy hydroxide surfaces and the crystalline Fe & Al oxides. In neutral and alkaline soils phosphorus sequestration promote to Ca- P rather than Fe P and Al-P thus these fractions are less in these soils. Similar findings were noticed by Beura *et al.*, (2019) [1].

The data indicated that Al- P concentration was wavering from 7.72 to 15.44 mg kg^{-1} with a mean of 11.64 mg kg^{-1} in low phosphorus status soils. (Table-1) In medium phosphorus status soils the Al- P content was ranging from 23.82 to 34.64 mg kg^{-1} with an average of 30.31 mg kg^{-1} while in high phosphorus status soils its mean was 34.13 mg kg^{-1} and ranged from 29.42 to 37.83 mg kg^{-1}. Similar to saloid P the concentration of Al- P also increased as the available phosphorus status increased from low to high. Mean Al- P contribution to total P in low, medium and high phosphorus soils is as follows 17.36%, 20.77% and 19.40%.

The highest mean value of Fe- P (30.41 mg kg^{-1}) was registered in high phosphorus status soils which varied content from 24.51 to 34.69 and the lowest mean value of 10.58 mg kg^{-1} was observed in low phosphorus status soils with a range of 6.48 to 14.61 mg kg^{-1}. The medium phosphorus status soils have ranged Fe-P from 22.54 to 28.89 mg kg^{-1} with a mean 19.16 mg kg^{-1}. The extent of contribution by mean Fe- P to total P in various phosphorus status soils are 15.74%, 19.16% and 17.20%.

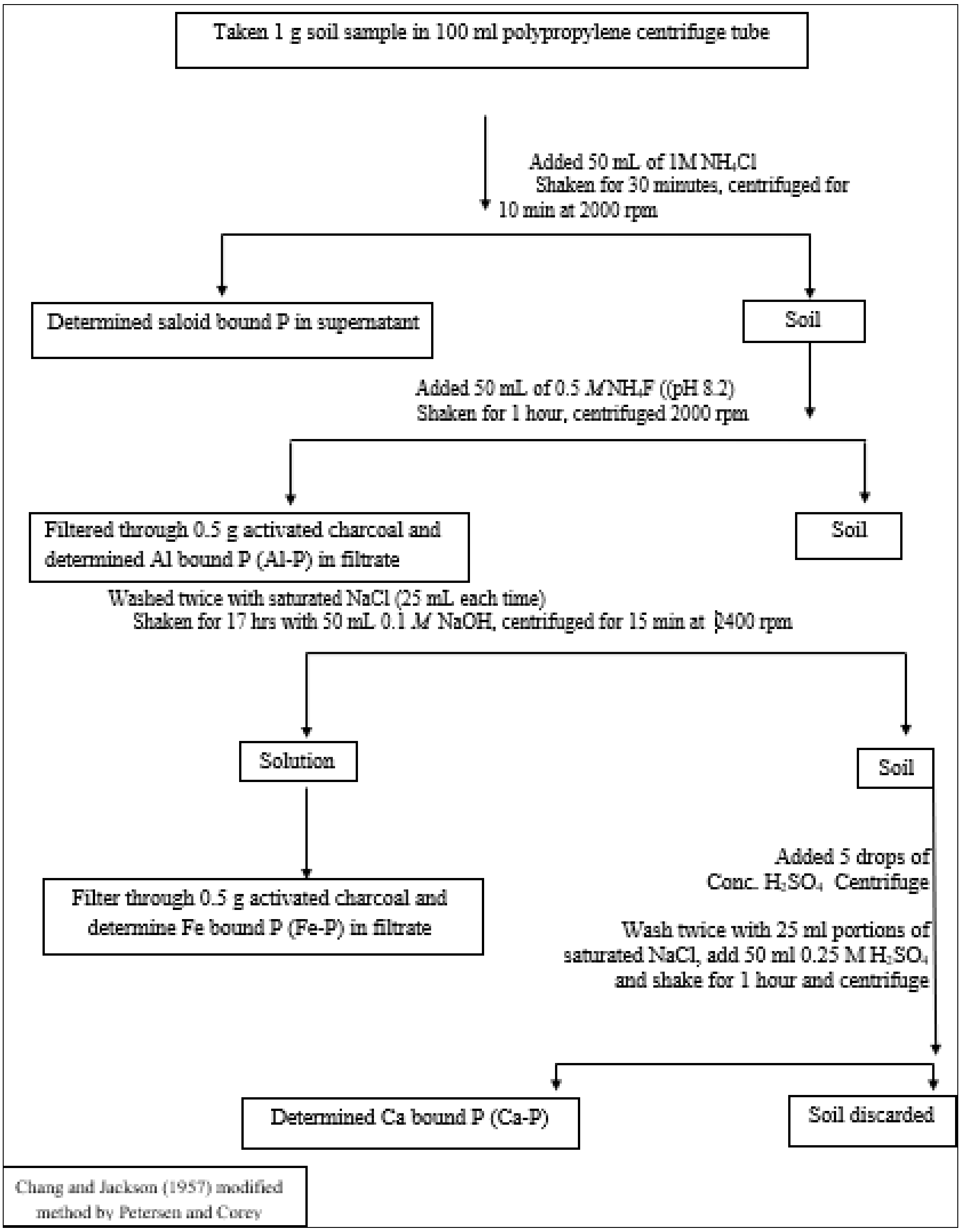


Fig 1: P fractions flow chart with sequential extraction procedure

3.1.3Ca –P

Among all fractions studied Ca –P concentration was the highest irrespective phosphorus status of soils (fig-2).It was the dominant fraction of P in alkaline soils and highest proportion of P in stable inorganic form. Phosphorus adsorption and precipitation with Ca represents a more stable pool than the labile and Fe & Al bound fractions (Beura *et al.*, (2019) [1]. The major variations in Ca – P distributions in between different soils were presented in the table 4.2. The maximum content of Ca-P was observed as 109.61 mg kg^{-1} and minimum content recorded was 26.84 mg kg^{-1} with varied range across P status soils.

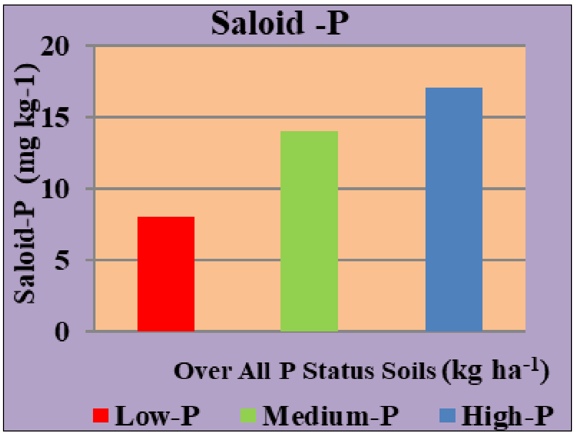
In high phosphorus status soils, the average Ca –P content recorded was 94.53 mg kg^{-1} with an array of 82.54 mg kg^{-1}to109.61 mg kg^{-1}. (Table-1) The lowest mean concentration of Ca – P (37.32 mg kg^{-1}) was noticed in low phosphorus status soils and the range was 26.84 to 50.49 mg kg^{-1}. The overall Ca P content varied from 62.28 to 82.26 mg kg^{-1} in medium phosphorus status soils with a mean 73.27 mg kg^{-1}. The contribution towards total phosphorus by calcium phosphorus was highest among all phosphorus fractions. The extent of Ca- P contribution to total phosphorus was 55.44%, 50.34% and 53.71% under soil studied.

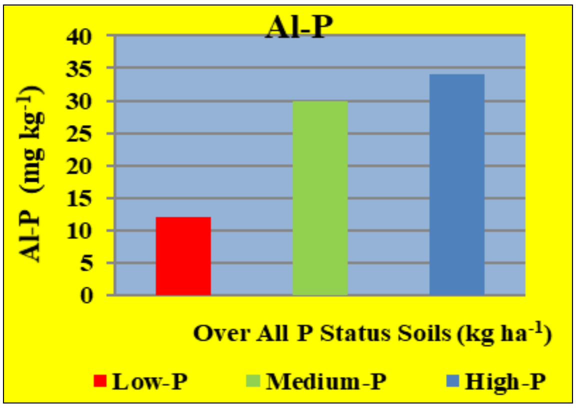
From the above study it clearly indicated that there was increase in Saloid-P, Al-P, Fe-P and Ca-P when the P fertility was increased from low to high. The contents of various inorganic fractions of P (saloid-P, Al-P, Fe-P, and Ca-P) were higher in high phosphorus status soils than those of low phosphorus status soils. A notable trend recorded was Ca – P > Al – P > Fe-P > Saloid –P irrespective of available phosphorus status in soils. The mean contributions by different fractions towards total P has shown similar trend as above. The above trend indicates that Fe-P content lower than the Ca- P and Al-P which might be due to higher activity of Ca^{2+} and Al^{3+} over Fe^{3+} in the soils. The above findings are in agreement with the results of Patagundi *et al.*, (1996) [8], Singh *et al.*, (2010) [14] and Patidar *et al.*, (2019) [9].

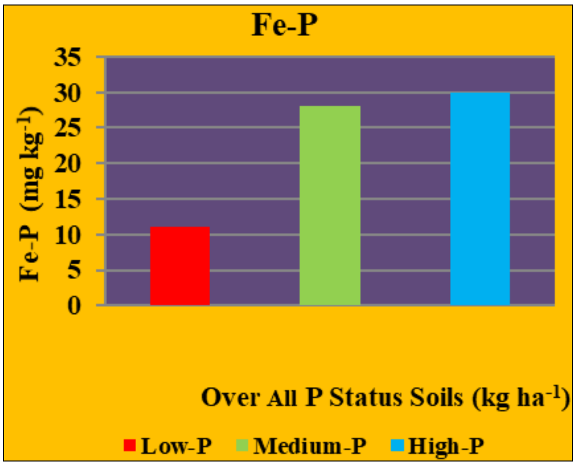
Among all the P fractions, the Al-P and Fe-P fractions contributed very little to the total P compared to the Ca-P. This could be mainly due to the fact that the solubility of Al-P and Fe-P, decreased with increase in pH**,** forming insoluble iron and aluminium phosphates, resulting in their reduced activity. Al-P was more than Fe-P. This increased p content in different inorganic phosphorus fractions with increase in soil fertility may be due to buildup of phosphate in soil which got transformed into different inorganic – P fractions (Singh *et al*.2010) [14].

Table 1: Inorganic fractions P fractions (mg kg^{-1}) in Varying Phosphorus levels of soils under investigation

S. No.	Category	Olsen-P_2O_5 (kg/ha)	P fractions (mg kg^{-1})			
			Saloid - P	Al - P	Fe – P	Ca – P
	LOW P SOILS					
1	L_1	8	4.94	7.72	6.48	26.84
2	L_2	12	6.78	9.13	8.56	27.28
3	L_3	14	7.25	10.04	9.22	28.46
4	L_4	16	6.12	10.36	9.67	30.51
5	L_5	18	8.13	11.83	10.24	33.6
6	L_6	19	9.39	9.87	8.46	44.12
7	L_7	20	7.99	12.67	11.18	43.78
8	L_8	22	9.28	14.07	13.24	42.43
9	L_9	23	7.83	15.27	14.17	45.67
10	L_{10}	24	8.13	15.44	14.61	50.49
		Mean	7.58	11.64	10.58	37.32
	Medium P Soils					
1	M_1	30	10.68	23.82	22.54	62.28
2	M_2	35	11.76	26.36	24.63	67.32
3	M_3	38	11.21	28.51	27.47	69.44
4	M_4	42	13.73	29.13	26.31	70.18
5	M_5	49	12.64	31.42	28.56	75.21
6	M_6	50	12.89	30.47	29.23	81.39
7	M_7	52	14.27	32.69	28.62	74.13
8	M_8	56	16.52	33.23	30.48	78.55
9	M_9	57	15.14	32.86	31.45	79.02
10	M_{10}	59	16.62	34.64	29.89	82.26
		Mean	**13.55**	**30.31**	**27.92**	**73.27**
	HIGH P SOILS					
1	H_1	60	14.5	29.42	24.51	82.54
2	H_2	65	15.42	28.37	23.86	84.93
3	H_3	77	14.67	32.58	26.21	82.07
4	H_4	84	16.48	30.62	29.06	86.68
5	H_5	90	15.24	34.71	26.77	90.92
6	H_6	114	17.44	33.42	35.52	104.11
7	H_7	135	18.83	36.83	34.64	97.96
8	H_8	152	18.24	38.12	35.88	100.84
9	H_9	166	19.59	39.35	32.94	105.63
10	H_{10}	178	20.37	37.83	34.69	109.61
		Mean	17.08	34.13	30.41	94.53







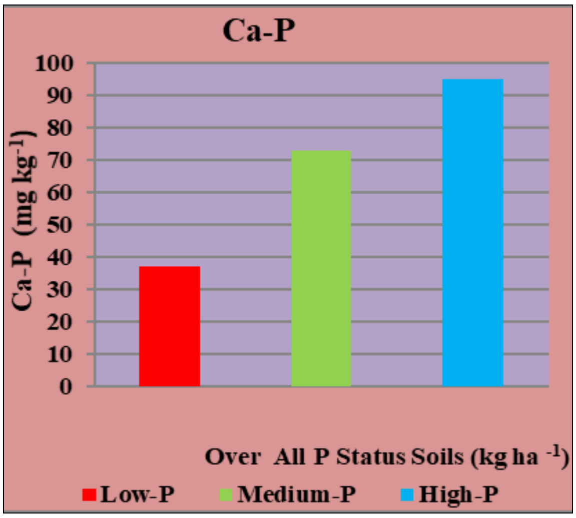


Fig 2: Different inorganic phosphorus fractions in varying Phosphorus level soils

4. **Conclusion**

From the above study it was clearly conclude that there was increase in Saloid-P, Al-P, Fe-P and Ca-P when the P fertility was increased from low to high. The contents of various inorganic fractions of P (saloid-P, Al-P, Fe-P, and Ca-P) were higher in high phosphorus status soils than those of low phosphorus status soils. A notable trend recorded was Ca – P > Al – P > Fe-P > Saloid –P irrespective of available phosphorus status in soils. The mean contributions by different fractions towards total P has shown similar trend as above. The above trend indicates that Fe-P content lower than the Ca- P and Al-P which might be due to higher activity of Ca^{2+} and Al^{3+} over Fe^{3+} in the soils.

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