

Fractionation of different Inorganic Pools of Phosphorus in Vertisols with different Organic Sources

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ABSTRACT: An experiment was carried out in the laboratory of Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur. In this study through incubation study in lab, soil samples were pre incubated at 25°C for 1 week prior to actual incubation to stabilize the microbial activity. There were three Rock Phosphates of origin Jhabua, Udaipur-I, Udaipur-II and eleven treatments including the control and soils were analysed for phosphorus inorganic pool fractions. The aim of this study was to investigate the composition of Phosphorus (P) forms in vertisols with different organic sources and to identify the factors affecting the P forms in these soils for the purpose of reducing the fertilizer risks. Soil P was sequentially extracted by NH₄Cl, NH₄F and H₂SO₄, and inorganic (Pi) P in each fraction were determined. Initially when analyzed it was found Ca-P>Res P>Al-P>Fe-P>Saloid-P and percent contribution was 30.71>26.91>16.29>10.60>8.18 respectively may be due to the alkaline nature of the soil. After incubation with rock phosphates, the dominance of different inorganic P fractions in followed the order: Ca-P>Fe-P >Al-P>Saloid-P. The incubation experiment showed a positive impact of the organic acids and FYM in their ability to release P from all the RP sources. Among the various treatments, FYM@ 5 tonne ha⁻¹ has maximum contribution in Saloid (13.34 kg ha⁻¹), Fe-P (29.65 kg ha⁻¹), Al-P (19.29 kg ha⁻¹) and Ca-P (40.82 kg ha⁻¹) fraction.

Keywords: Fractionation, P Pools, Rock phosphate, saloid P, soil, FYM.

INTRODUCTION

Soil phosphorus (P) is one of the most important nutrients after nitrogen controlling plant root proliferation and biomass growth in tropical agroecosystems where highly weathered soils exist. These soils are rich in P but limit the availability in occluded form (Nishigaki *et al.*, 2018). Soil characteristics affect the P bioavailability and stability. Excess accumulation of P in soils can hamper the availability and increase losses through runoff (Yan *et al.*, 2020). P seasonal utilization efficiency is just 15-20% (Dwivedi *et al.*, 2017) which is obviously very

low in India resulting in high accumulations in soil and lower availability. The dominant form of P in soils depends on the parent material and the soil physicochemical properties. Calcium (Ca) P as primary minerals is the most dominant form at the beginning of soil formation when the soils are young, and after subsequent weathering the P released is transformed into less-labile pools associated with the (Al) and (Fe) hydroxides. Therefore, Al-P and Fe-P are the main P forms in highly weathered soils of tropical areas, while Ca-P is the dominant form in younger soils. Furthermore, the use of chemical fertilisers like superphosphate may increase the amount of Ca-P in

surface soils on arable fields (Wright 2009). Organic matter in soil also enhances P availability by blocking the Al and Fe fixation sites in soil complexes. Labile, inorganic, and organic fractions of P pools give an indication of the stability of P in soil.

The solubility of phosphorus is greatest between pH 4.5 and 7, and the dominant species are then H_2PO_4^- . When the pH is outside the range of greatest solubility, phosphorus will form insoluble precipitates with available iron/ aluminium and calcium/fluoride respectively. At low pH aluminium iron becomes soluble, and the concentration of these cations in soil solution increases. If there are large enough amounts of orthophosphate in the solution, the soil water may become supersaturated with regards to the solubility product of AlPO_4 and FePO_4 , and precipitate phosphate out of the solution. At pH above the region of greatest solubility calcium carbonate becomes soluble, and form $\text{Ca}_3(\text{PO}_4)_2$ precipitates with phosphate. The availability of P depends on the soil pH as it governs the occurrence and abundance of those metal cations that are prone to precipitate with P ions in the soil solution, namely Ca, Fe and Al. Hence, in neutral to alkaline soils, P ions rather precipitate as dicalcium or octa calcium phosphates, hydroxyl apatite and eventually least soluble apatites (Hinsinger, 2011). The aim of the study was to extract the P forms soil using the sequential extraction method, and to identify the factors responsible to the formation of P pools in soils.

Moreover, evaluating Olsen-P and P fractions can predict the bioavailability of P fractions by giving quantitative information on the dynamic process of the P replenishing ability (Yan *et al.*, 2020).

MATERIAL AND METHODS

Rock phosphate. Three rock phosphates (RP) were used for the study, out of which two Udaipur grade I with 26% P_2O_5 and II with 27.48% P_2O_5 were used and one is from Jhabua (M.P) with 11.68% P_2O_5 . Udaipur RP (URP) was obtained from Rajasthan State Mines and Minerals Ltd, Udaipur, Rajasthan, India; and Jhabua RP (JRP) was obtained from Jhabua, M.P., India. All the three RPs were used for the incubation study.

Analysis of physico-chemical properties of soil of study area

Available Phosphorus. The available P in soil was extracted using the Olsen's reagent (0.5 M NaHCO_3) (Olsen *et al.*, 1954) for the neutral soil. The P content in the extracts was determined using the ascorbic acid blue colour method (Watanabe and Olsen, 1965). The intensity of the blue color developed was determined by a spectrophotometer at 660 nm wavelength.

Fractionation of Inorganic P. Soil inorganic P was fractionated into various fractions by modified P fractionation scheme by Kuo (1996). The procedure is depicted through the flow chart (Fig. 1).

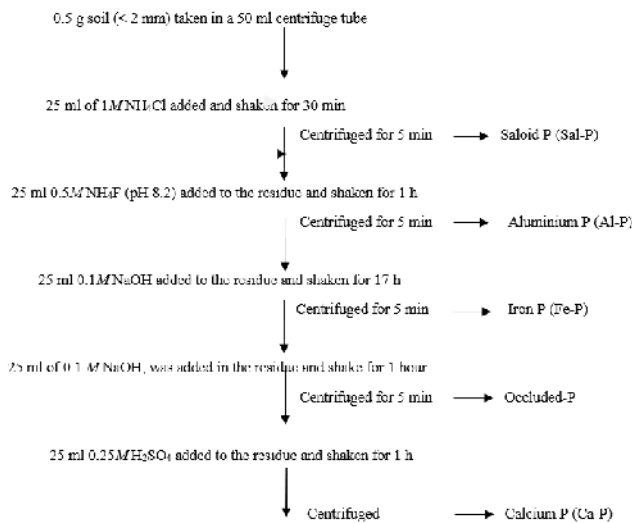


Fig. 1. Flow chart showing the fractionation scheme for inorganic P.

Saloid means loosely-bound P, occluded P means P occluded in Fe/ Al oxides while residual P means P from the soil residue remaining after the last acid extraction which was digested with $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2$ at 360°C (Soremia *et al.*, 2017). All the inorganic P

fractions was determined as per the ascorbic acid blue colour method as described above. The maximum colour intensity developed after 10 min and was measured using a spectrophotometer at 660 nm wavelength.

Table 1: Initial physico-chemical properties and fractions.

Soil properties	
Latitude	N-23013'02.4"
Longitude	E-79056'40.7"
pH	8.28
EC (dSm ⁻¹)	0.20
OC (gkg ⁻¹)	5.10
CaCO ₃ (gkg ⁻¹)	45
CEC [cmol (p+) kg ⁻¹]	58.75
Clay (%)	52.33
Olsen-P (Kg ha ⁻¹)	30.36
Saloid-P	10.5(8.18%)
Al-P	20.9(16.29%)
Fe-P	13.6(10.60%)
Ca-P	39.4(30.71%)
Res-P	34.4(26.81%)

The fractions of P i.e., Saloid-P, Al-P, Fe-P and Ca-P were analyzed in soils. Results showed the P pools in abundance. From analysis of soil result was: Ca-P> Res

P> Al-P> Fe-P> Saloid-P which value was 39.4>34.4>20.9>13.6>10.5 kg ha⁻¹ and percent contribution 30.71> 26.91> 16.29> 10.60> 8.18 of total-P, respectively.

RESULTS AND DISCUSSION

Among the various forms, Ca-P fraction was dominant fraction in the soil which ranged from 40.41 to 42.61 kgha⁻¹, Compared to other P fractions Saloid-P was present in a small quantity which ranged from 11.02 to 13.81 kgha⁻¹, the contribution of Fe-P in phosphorus fractions is about 29.28 to 31.48 kgha⁻¹ followed by Al-P which ranged from 17.78 to 19.86 kgha⁻¹. The dominance of different inorganic P fractions in soil followed the order: Ca-P> Fe-P > Al-P> Saloid-P. Among the various treatments, FYM has maximum contribution in Saloid (13.34 kg ha⁻¹), Al-P (19.29 kg ha⁻¹), Fe-P (29.65 kg ha⁻¹) and Ca-P (40.82 kg ha⁻¹) fraction.

Table 2: Distribution of phosphorus pools under different treatments.

Treatment	P Pools (kg ha ⁻¹)			
	Saliod	Al-P	Fe-P	Ca-P
S-JRP	11.02	17.78	29.28	40.31
S- URP-I	12.18	18.71	30.33	41.76
S- URP-II	13.81	19.86	31.48	42.61
SEM±	0.115	0.105	0.126	0.191
CD at 5%	0.325	0.294	0.354	0.538
Treatments				
T1-RDF (control)	9.74	14.96	27.85	36.70
T2- PSB @ 1 ml/100 g soil	11.45	17.39	27.91	38.56
T3- Cow urine @ 1ml/100 g soil	11.76	17.00	28.25	38.57
T4- FYM @ 5 tones ha ⁻¹	13.34	19.29	29.65	40.82
T5- Zeolite @ 1g kg ⁻¹ soil	11.79	18.29	28.95	39.30
T6- Gluconic acid @20 mM	12.46	17.29	28.27	38.22
T7- Oxalic acid @ 0.5 M	11.69	17.60	28.65	38.84
T8- Citric acid @ 2 mg/L	12.40	17.33	28.06	38.37
T9- Ammonium Sulphate+zeolite	12.48	17.09	28.40	39.26
T10- Zeolite+gluconic acid	10.57	17.64	27.92	37.99
T11- Ammonium sulphate @20 kgha ⁻¹	10.21	18.68	29.24	37.34
SEM±	0.383	0.347	0.418	0.634
CD at 5%	1.078	0.976	1.175	1.785

Effect of RPs and organics on P pools in soils at the end of incubation experiment. The data pertaining to distribution of different pools of phosphorus is given in Table 2. The alkaline nature (soil reaction) of soils tends to precipitate the available phosphorus as Ca-P and least as saloid-P similarly reported by Sarkar (2002). Similar findings were reported by Kanwar and Garewal (1990), they reported that the Ca-P fraction increased with addition of P fertilizer as well as increase in pH, on ageing Ca-P increased up to 15-30 day. The result is in conformity with findings of Chang and Tomar (2007), Trivedi *et al.* (2010). The dominance of different inorganic P fractions in soils followed the order: Ca-P> Fe-P > Al-P> Saloid-P.

Among the various treatments, FYM has maximum contribution in Saloid, Fe P, Al P and Ca P fraction. The content of the Ca-P ranks highest which was an indication of the fact that Ca-P form contributed to the major source of P in black soil as reported by Garg and Milkha (2010).

The organic fraction generally constitutes 20-80% of P in surface horizon (Brady and Weil, 2002). The process of soluble phosphate anion being bound with soil constituent so, that they become insoluble and unavailable to the plants. Several mechanisms like precipitation, dissolution, adsorption-desorption, immobilization and mineralization reactions occurred (Kanwar and Reddy, 2003). Variation in P fraction is

the pedogenic manifestation (Walker and Syres 1976), stage of soil development (Smeck 1976) and age of soil. As the soil mature the Ca-P gets transformed into Al-P and sesquioxide bond phosphorus with maturity of soils. Changes in the P pools in soils are significantly affected by soil type. In general, total P content is low in strongly weathered soils orders and high in young soil.

In acid soils among the different forms of P, Fe-P dominates. In India Alfisols with pH ranging from 5.5 to 6.8 the order of soil P distribution was Fe-P > Ca-P > Al-P. The presence of clay, Al, Fe and sesquioxides is responsible for fixation of applied P (Doddamani and Seshagiri Rao, 1996). The availabilities of P also depend on soil pH, type of clay minerals, Fe, Al hydroxides and calcium carbonates (Kaistha *et al.* 1997).

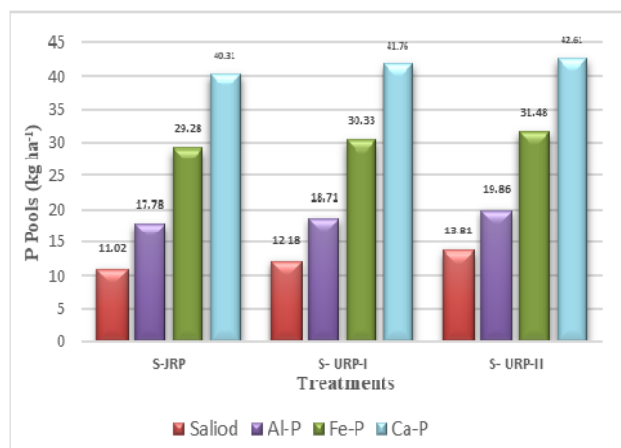


Fig. 2. Distribution of P pools under different RP's.

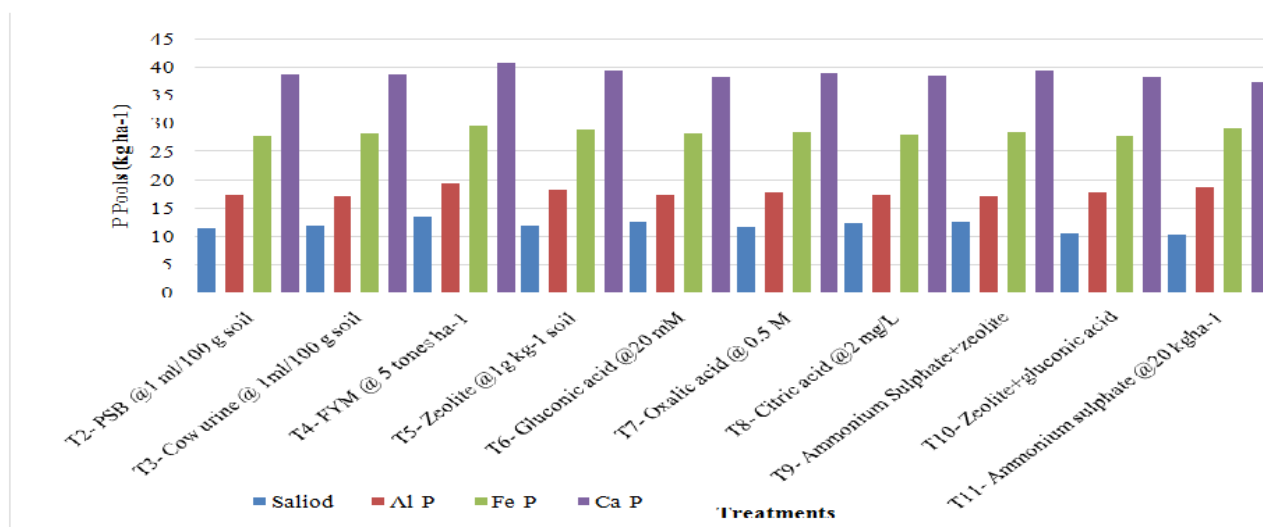


Fig. 3. Distribution of P pools under different Treatments.

Therefore the response of phosphorus in different soils varies and the crop response varies. But, in case of slightly acidic soils, applied phosphorus gradually reacts with Fe and Al compounds present in the soil and consequently, gets transformed into relatively insoluble compounds (variscite and strengite), which are hardly available to plants. Reddy *et al.* (2000) reported that the Vertisols of Bhopal of which about 18% is tied-up in organic form. Sarkar (2002) concluded that the saloid-P was very low in comparison to all other forms of inorganic soil P and varied from 1.5 to 2.8 mg kg⁻¹ which might be due to high P-fixing capacity of chotanagpur plateau soils. Lakshminarayana (2007) suggested that minimum amount of P is in the saloid fraction (S-P), whereas maximum amount is in reductant soluble form (RS-P) in the soil and such high values may be attributed to the acidic to neutral soil reaction and high content of Fe₂O₃. Sarkar *et al.* (2014) revealed that the mean relative abundance followed the order: RS-P > Fe-P > occluded-P > Ca-P > Al-P > S-P.

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The soil is fairly rich in total P reserve but the available P status is low, the overall contribution of the inorganic soil P fractions to the total soil P is 57.75%. Singh *et al.* (2015) indicated that the release of P in alluvial and black soil was of higher degree of magnitude than that of red soil. Thakur *et al.* (1975) observed that in rice culture at Jabalpur (Madhya Pradesh), the Fe-P fraction formed the major portion of native inorganic soil P fractions, Al-P Fe-P and Ca-P fractions increased with the addition of P fertilizers. Goswami and Sahrawat, (1982.) indicated that Ca-P was the dominant form followed by Fe-P with very low amount of Al-P.

CONCLUSION

In general, all Pi fractions increased. After the application of rock phosphate, the content of the Ca-P is increased this was an indication of the fact that RPs contains a major source of Ca-P. Furthermore, the dominance of different inorganic P fractions in soils followed the order: Ca-P > Fe-P > Al-P > Saloid-P.

Among the various treatments, FYM has maximum contribution in Saloid, Fe P, Al P and Ca P fraction as it contains high amount of P and helped in releasing P by blocking Al and Fe hydroxide complex sites. Hence by evaluating the various Pi fractions of P in soil accordingly fertilizer recommendations should be given and RPs can be a reliable source of P when applied with organic sources.

Conflict of Interest. None.

REFERENCES

- Brady, N. C., & Weil, R. R. (2000). The Nature and properties of Soils. 13th Ed. Prentice Hall, New Jersey: 609–610 pp.
- Chang, T., & Tomar, N. K. (2007). Effect of soil properties on the kinetics of phosphate desorption in some arid, semiarid and dry sub humid soils of North West India. *Journal of Indian Society of Soil Science*, 55: 30-35.
- Doddamani, V. S., & Rao, T. S. (1996). *Mysore Journal of Agriculture Science*, 23: 18.
- Dwivedi, B., Singh, V., Shekhawat, K., Meena M. C., & Dey, A. (2017). Enhancing Use Efficiency of Phosphorus and Potassium under Different Cropping Systems of India. *Indian Journal of Fertilizers*, 13(8), pp.20-41.
- Garg, A. K., & Milkha, S. A. (2010). Effect of long-term fertilizer management and crop rotation on accumulation and downward movement of phosphorous in semi-arid subtropical irrigated soil. *Communication in Soil Science and Plant Anatomy*, 41: 848-864.
- Goswami, N. N., & Sahrawat, K. L. (1982). Nutrient transformations in soils - Macronutrients. Transformation of the 12th International Congress of Soil Science, *Soil Research in India. New Delhi (India) 1(1)*: 123-145.
- Hinsinger, P., Brauman, A., Devau, N., Gérard, F., Jourdan, C., Laclau, J. P., & Plassard, C. (2011). Acquisition of phosphorus and other poorly mobile nutrients by roots. Where do plant nutrition, models fail. *Plant and Soil*, 29: 348.
- Kaistha, B. P., Sharma, P. K., & Sharma, R. P. (1997). Influence of soil components on phosphorus fixing capacity of some Alfisols in Himachal Pradesh. *Journal of Indian Society of Soil Science*, 4: 261-264.
- Kanwar, J. S., & Reddy, D. D. (2003). Phosphorus fixation and management in Indian soils, First edition, IARI, Krishi Anusandhan Bhavan, New Delhi 30-40.
- Kanwar, J. S. & Grewal, J. S. 1960. Phosphate fixation in Punjab soils, 8: 211-18.
- Kuo, S. (1996). Phosphorus. In Sparks, D.L., Ed. Methods of Soil Analysis, 3rd edition Part 3. *Soil Science Society of America*, Madison, WI. pp. 869–920.
- Lakshminarayana, K. (2007). Distribution of inorganic phosphorus fractions and critical limit of available P in rice soils of Mizoram. *Journal of the Indian Society of Soil Science*, 55: 481-487.
- Nishigaki, T., Sugihara, S., Kobayashid, K., Hashimotoe, Y., Kilasaraf, M., Tanakac, H., Watanabea, T., & Funakawaa, S. (2018). Fractionation of phosphorus in soils with different geological and soil physicochemical properties in southern Tanzania. *Soil Science and Plant Nutrition*, 64(30): 291-299.
- Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean L. A. (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. *U.S. Department of Agriculture Circular 939*, USDA, Washington, DC.
- Reddy, D. D., Rao, S. A., & Rupa, T. R. (2000). Effect of continuous use of cattle manure and fertilizer phosphorus on crop yields and soil organic phosphorus in a Vertisol. *Bioresource Technology*, 75: 113-18.
- Sarkar, D. (2002). Soil resource information for meeting challenges of land degradation: a case study in Chotanagpur Plateau region. *Journal of Indian Society of Soil Science*, 50: 413-437.
- Sarkar, D., Haldar, A., & Mandal, D. (2014). Forms of phosphorus in relation to soil maturity along a topo sequence under hot, dry, subhumid agro-ecological subregion of West Bengal. *Journal of Indian Society of Soil Science* 62(1): 29-37.
- Singh, H. K., Singh, S., & Singh, D. K. (2015). Release pattern of available phosphorus and Sulphur at constant moisture regime in different soils. *Journal of Indian Society of Soil Science*, 63(2): 288-231.
- Smeck, N. E. (1976). Phosphorus: an indication of pedogenic weathering process. *Soil Science*, 115, 199-206.
- Soremia, A. O., Adetunja, M. T., Azeeza, J. O., Adejuyigbea, C. O., & Bodundeb, J. G. (2017). Speciation and dynamics of phosphorus in some organically amended soils of southwestern Nigeria. *Chemical Speciation & bioavailability*, 29(1): 42–53.
- Thakur, R. S., Bisen, D. C., & Dubey, S. M. (1975). Transformations of applied phosphorus under waterlogged conditions in rice culture. *Journal of Indian Society of Soil Science*, 13: 423-27.
- Trivedi, S. K., Tomar, R. A. S., Tomar, P. S., & Gupta, N. (2010). Vertical distribution of different forms of phosphorus in alluvial soils of arid region of Madhya Pradesh. *Journal of Indian Society of Soil Science*, 58: 86-90.
- Walker, T. W., & Syres, J. K. (1976). Fate of phosphorus during pedogenesis. *Geoderma*, 15: 1-19.
- Watanabe, F. S., Olsen, S. R., & Cole, C. V. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Circular of U.S. Department Agriculture*, 39: 1-9.
- Wright, A. (2009). Soil phosphorus stocks and distribution in chemical fractions for long-term sugarcane, pasture, turfgrass, and forest systems in Florida. *Nutrient Cycling Agroecosystems*, 83: 223–231.
- Yan, X., Yang, W., Chen, X., Wang, M., Wang, W., Ye, D., & Wu, L. (2020). Soil Phosphorus Pools, Bioavailability and Environmental Risk in Response to the Phosphorus Supply in the Red Soil of Southern China. *International journal of environmental research and public health*, 17(20), 73-84.

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