Study of different phosphorus fractions and their relationship with soil properties under major cropping systems in Y.S.R. Kadapa district, A.P.

GK Surya Krishna, T Giridhara Krishna, V Munaswamy and Y Reddi Ramu

DOI: https://doi.org/10.22271/chemi.2020.v8.i11.8326

Abstract
Phosphorus fractionation study in soils of Y.S.R. Kadapa district, A.P., was studied in relation to soil properties in which 5 soil samples collected from each major cropping system were analysed for different physico-chemical properties and different P fractions. The sequential distribution of different forms of P under major cropping systems in surface soils followed the order: Ca-P > Fe-P > Al-P > Sal-P (Fallow-Bengalgram), Al-P > Ca-P > Sal-P > Fe-P (Sunflower-Sesame), Ca-P > Fe-P > Al-P > Sal-P (Paddy-Paddy), Ca-P > Al-P > Fe-P > Sal-P (Groundnut monocropping), Al-P > Fe-P > Ca-P > Sal-P (Groundnut-Groundnut). Soil reaction (pH) showed positive and significant correlation with other forms of P (r = 0.413*), available P showed positive and significant correlation with Al-P (r = 0.893**), Fe-P (r = 0.823**), Ca-P (r = 0.766**) and total-P (r = 0.651**). Al-P showed positive and significant correlation with Fe-P (r = 0.916**), Ca-P (r = 0.473*) and total-P (r = 0.554**) whereas Fe-P showed significant and positive correlation with Ca-P (r = 0.543**) and total-P (r = 0.643**). Ca-P showed positive and significant correlation with total-P (r = 0.705**), total-P showed positive and significant relation with other forms of P (r = 0.790**).

Keywords: P fractions, soil properties, correlation, cropping systems

Introduction
Phosphorus is an essential element for plant growth. Therefore, maintenance of an adequate amount of soil P through application of inorganic and/or organic P is critical for the sustainability of cropping systems. Inorganic phosphorus fractionations have been widely used to interpret native inorganic P status and the applied P to soils. Phosphorus use efficiency in agricultural systems is very low, with only 10-20% of fertilizer P used by crops (Johnston and Syers, 2009). Typically fertilizer P is converted to less soluble forms due to reactions with aluminum (Al) and/or iron (Fe) in acid soils and with calcium in neutral to alkaline soils (Soffe 2003; Mitran et al., 2016), which are usually insoluble under aerobic or upland condition (De-Datta, 1981). The distribution of different forms of phosphorus and their relationship with each other as well as with different soil properties is useful to understand the capacity of soil to supply phosphorus to plants.

Materials and methods
Five soil samples from each cropping system (Fallow-Bengalgram, Sunflower-Sesame, Paddy-Paddy, Groundnut monocropping, Groundnut-Groundnut) at 0-15cm depth were collected from calcareous soils of Y.S.R. Kadapa district of southern zone of A.P. The processed soil samples (<2mm) were analysed for pH, EC and free CaCO3 by adopting standard procedures (Table 1 and 2). Total P in soil was determined using 60% perchloric acid digestion method as suggested by Jackson (1973). The original fractionation procedure for different forms of inorganic P viz., saloid-P, Fe-P, Al-P and Ca-P proposed by Kovar and Pierzynski (2009) and available P2O5 by Olsen et al., (1954) were followed. The other P forms were computed by deducting the estimated forms viz., Saloid-P, Al-P, Fe-P and Ca-P from total-P. The other forms include Org-P, RS-P, Ocll-P, etc., Simple correlation coefficients between soil properties and fractions of P were computed by standard statistical methods.
Results and discussion
The data on Soil texture, Physico-chemical properties, fractionation of soil phosphorus and correlation coefficients (r) between soil properties and P forms are given in Tables 1, 2, 3 and 4, respectively.

Physico-chemical properties of soil
In calcareous soils of Y.S.R. Kadapa district, the pH of surface soils ranged from 7.64 in paddy-paddy system to 8.81 in groundnut monocropping system with a mean value of 7.82 and 8.36, respectively (Table 2). It was revealed from Table 4 that, pH showed significant positive correlation with other forms of P (r= 0.413*), while it was positive and non-significant with Al-P (0.015) and total-P (0.316). Fe-P showed a negative non-significant relation with pH wherein increase in pH associated with decrease in P content (Jaggi, 1991) [8] was observed.

The electrical conductivity measured was non-saline and below the critical limits. The EC of surface soils ranged from 0.007 dS m-1 in fallow-bengalgram cropping system to 0.117 dS m-1 in paddy-paddy cropping system with a mean value of 0.014 and 0.097 dS m-1, respectively (Table 2). It was revealed from Table 4 that, EC showed significant positive correlation with Fe-P (r= 0.476*) and Ca-P (r= 0.650*), positive and non-significant with Al-P and total-P.

The free CaCO3 ranged from 4.5% in groundnut-groundnut cropping system to 15.5% in groundnut monocropping system with a mean value of 6.1% and 11.8%, respectively (Table 2). It was revealed from Table 4 that, free CaCO3 showed positively significantly correlated with Ca-P (r= 0.526**) emphasizes its role in distribution of Ca-P. Similar results were reported by Kothandaraman and Krishnamoorthy (1977) [9] in calcareous soils, Deobhatia and Deopal (1988) [5], Viswanath and Doddamani (1991) [10], Sharma and Tripathi (1992) [15], Devra et al. (2014) [10] and Bhavsar et al. (2018) [3].

The available P2O5 of surface soils ranged from 31.99 kg ha-1 in fallow-bengalgram system to 253.72 kg ha-1 in groundnut monocropping system with a mean value of 34.80 kg ha-1 and 182.41 kg ha-1, respectively (Table 2). The results revealed that (Table 4) available P2O5 showed positive significant correlation with Al-P (r= 0.893**), Fe-P (r= 0.823**) and total-P (r= 0.766**) and total-P (r= 0.651**). It may indicate the dependence upon the release of P from these fractions.

Similar results were reported by Chakravarthy and Baruwa (1987) [4], Lungmuana et al. (2012) [11] and Anjali and Dhananjaya (2017) [2] with total-P and Fe-P.

Inorganic P fractions
Saloid-P
The saloid-P of surface soils ranged from 3.20 mg kg-1 in fallow-bengalgram system to 27.95 mg kg-1 in sunflower-sesame system with a mean value of 4.23 mg kg-1 and 23.01 mg kg-1, respectively (Table 3). Saloid-P was the least among the fractions under all the major cropping systems. The lowest saloid-P content might be due to transformation of soluble P forms into less soluble forms with time (Sarkar et al., 2013) [14].

The correlation analysis revealed that, saloid-P showed negative and non-significant correlation with all the P fractions, positive and non-significant relation with Al-P (Table 4).

Al-P
The data on Al-P in soil under different cropping systems is presented in (Table 3). The Al-P of surface soils varied from 23.36 mg kg-1 in fallow-bengalgram system to 100.32 mg kg-1 in groundnut monocropping sequence with a mean value of 27.93 mg kg-1 and 80.82 mg kg-1, respectively. The results revealed that (Table 4) Al-P showed positive and significant correlation with Fe-P (r= 0.916**), Ca-P (r= 0.473*) and total-P (r= 0.554**). This indicates the dynamic equilibrium existing in the soil. Similar results were reported by Majumdar et al. (2004) [12] in acid alfisols of Meghalaya, Lungmuana et al. (2012) [11] in rice growing areas of red and lateritic soils and Anjali and Dhananjaya (2017) [2], Abolfazil et al. (2012) [5] in calcareous soils with Fe-P and Ca-P.

Fe-P
The data indicate that Fe-P (Table 3) of surface soils varied from 20.25 mg kg-1 in Sunflower-Sesame system to 91.87 mg kg-1 in groundnut-groundnut cropping sequence with a mean value of 21.94 mg kg-1 and 69.82 mg kg-1, respectively. It was observed that, Fe-P showed significant positive correlation with Ca-P (r= 0.543**) and total-P (r= 0.643**) (Table 4). Similar results were reported by Majumdar et al. (2004) [12] and Anjali and Dhananjaya (2017) [2].

Ca-P
The Ca-P of surface soils varied from 16.94 mg kg-1 in groundnut-groundnut monocropping system to 156.43 mg kg-1 in groundnut monocropping system with a mean value of 23.91 mg kg-1 and 118.55 mg kg-1, respectively (Table 3). The high Ca-P content in groundnut monocropping could be attributed to high soil CaCO3 content indicating greater availability of Ca-P in calcareous soil.

It was observed from Table 3 that Ca-P was the predominant form of soil phosphorus, and had positive and significant correlation with total-P (r= 0.705**). Such correlation suggests that these P fractions are in dynamic equilibrium with total-P in soils. Similar results were reported by Majumdar et al. (2004) [12], Lungmuana et al. (2012) [11] in rice growing areas of red and lateritic soils and Anjali and Dhananjaya (2017) [2].

Total-P
The total-P content indicates the reserves of this element in the soil. The data regarding total-P presented in (Table 3). The total-P of surface soils varied from 120.85 mg kg-1 in sunflower-sesame system to 607.81 mg kg-1 to groundnut monocropping sequence with a mean value of 157.46 mg kg-1 and 434.35 mg kg-1, respectively.

The results revealed that total-P (Table 4) showed positive and significant relation with Al-P (r= 0.544**), Fe-P (r= 0.643**) and Ca-P (r= 0.705**), other forms of P (r= 0.790**). These indicate that these fractions are dependent on total-P. Similar results reported by Lungmuana et al. (2012) [11] in rice growing areas of red and lateritic soils, Anjali and Dhananjaya (2017) [2] and Majumdar et al. (2004) [12] with Al-P, Fe-P and Ca-P.

Other forms of P
The other P forms were computed by deducting the estimated forms viz., Saloid-P, Al-P, Fe-P and Ca-P from total-P. The other forms of P of surface soils varied from 20.73 mg kg-1 in sunflower-sesame system to 432.7 mg kg-1 in fallow-bengalgram system with a mean value of 47.77 mg kg-1 and 228.55 mg kg-1, respectively (Table 3). The other forms of P showed significant and positive correlation with Total-P (0.790*), positive and non-significant with other P forms.
except with saloid-P where it shows negative and non-significant relation (Table 3).

**Conclusion**

The present study indicates that different cropping systems have an overwhelming influence on P dynamics. Ca-P was the dominant fraction in all the cropping systems except in Sunflower-Sesame and Groundnut-Groundnut cropping systems where Al-P was the dominant P fraction. Soil pH showed positive and significant correlation with other forms of P. Available P₂O₅ showed positive and significant correlation with Al-P, Fe-P, Ca-P and total-P. Al-P showed positive and significant correlation with Fe-P, Ca-P and total-P, whereas Fe-P showed significant and positive correlation with Ca-P and total-P. Ca-P showed positive and significant correlation with total-P, total-P showed positive and significant relation with other forms of P.

**Table 1**: Per cent textural separates and textural class under different cropping systems in Y.S.R. Kadapa district

| S. No. | Cropping Systems       | Sand (%) | Silt (%) | Clay (%) | Textural class |
|--------|------------------------|----------|----------|----------|----------------|
| 1      | Fallow-Bengalgram      | 41.12    | 21.53    | 31.25    | cl             |
| 2      | Sunflower-Sesame       | 74.68    | 13.58    | 11.74    | sl             |
| 3      | Paddy-Paddy            | 40.25    | 21.88    | 37.87    | cl             |
| 4      | Groundnut monocropping | 55.75    | 20.68    | 26.57    | scl            |
| 5      | Groundnut-Groundnut    | 52.14    | 33.65    | 14.21    | sl             |

c1 = clay, s1 = sandy loam, sc1 = sandy clay, sl = sandy loam

**Table 2**: Physico-chemical properties of calcaereous soils under different cropping systems in Y.S.R. Kadapa district

| S. No. | Cropping system       | pH        | EC (dSm⁻¹) | CaCO₃ (%) | Available P₂O₅ (kg ha⁻¹) |
|--------|-----------------------|-----------|------------|-----------|--------------------------|
| 1      | Fallow-Bengalgram     | 8.22-8.45 | 0.007-0.018 | 5-11 (7.2) | 31.99-36.69 (34.8)       |
| 2      | Sunflower-Sesame      | 7.85-8.07 | 0.014-0.059 | 5-8.5 (7)  | 34.81-50.27 (41.47)      |
| 3      | Paddy-Paddy           | 7.64-7.95 | 0.072-0.117 | 6-15 (9.5) | 99.28-146.61 (118.42)    |
| 4      | Groundnut monocropping| 8.15-8.81 | 0.049-0.079 | 10.5-15.5 (11.8) | 128.33-253.72 (182.41) |
| 5      | Groundnut-Groundnut   | 7.88-8.51 | 0.008-0.085 | 4.5-7.5 (6.1) | 49.01-138.97 (92.04)     |

**Note**: Figures in parentheses indicate the mean value.

**Table 3**: Distribution of different forms of P (mg kg⁻¹) under major cropping systems in calcaereous soils of Y.S.R. Kadapa district

| S. No. | Cropping system       | Sal-P    | Al-P     | Fe-P     | Ca-P     | Total-P   | Other P forms |
|--------|-----------------------|----------|----------|----------|----------|-----------|---------------|
| 1      | Fallow-Bengalgram     | 3.2-5.57 | 23.36-33.44 | 29.98-36.16 | 42.28-78.93 | 212.9-586.79 | 113.34-432.7 (228.55) |
| 2      | Sunflower-Sesame      | 19.71-27.95 | 31.61-42.28 | 20.25-23.21 | 27.22-29.54 | 120.85-237.91 | 15.65-114.74 (47.77) |
| 3      | Paddy-Paddy           | 3.62-7.82 | 54.63-75.03 | 61.89-80.61 | 79.67-120.02 | 342.58-359.18 | 349.89 (80.14-142.77 (109.62) |
| 4      | Groundnut monocropping| 10.16-24.8 | 69.45-100.32 | 60.85-91.57 | 101.8-156.43 | 333.9-607.8 | 96.5-234.39 (151.58) |
| 5      | Groundnut-Groundnut   | 11.56-16.09 | 55.71-99.18 | 53.91-98.7 | 16.94-30.52 | 255.51-364.01 | 116.11-159.54 (130.54) |

**Note**: Figures in parentheses indicate the mean value.

**Table 4**: Correlation coefficient between soil properties and forms of phosphorus (mg kg⁻¹) under different cropping systems in calcaereous soils of Y.S.R. Kadapa district

|           | pH        | EC         | CaCO₃%     | Available P₂O₅ | Sal-P    | Al-P     | Fe-P     | Ca-P     | Total-P | Other P forms |
|-----------|-----------|------------|------------|----------------|----------|----------|----------|----------|---------|---------------|
| Avail-P₂O₅| 0.141**   | 0.530**    | 0.445**    | 1              | 0.015    | 0.363    | 0.250    | 0.893**   | 0.187   | 1              |
| Sal-P     | -0.235    | -0.186     | -0.119     | 0.088          | 1        | 1        | 1        | 1        | 1       | 1              |
| Al-P      | 0.015     | 0.363      | 0.250      | 0.893**        | 0.187    | 1        | 1        | 1        | 1       | 1              |
| Fe-P      | -0.025    | 0.476**    | 0.241      | 0.823**        | -0.144   | 0.916**  | 1        | 1        | 1       | 1              |
| Ca-P      | 0.136     | 0.650**    | 0.526**    | 0.766**        | -0.266   | 0.473*   | 0.543*** | 1        | 1       | 1              |
| Total-P   | 0.316     | 0.255      | 0.307      | 0.651**        | -0.283   | 0.554**  | 0.643**  | 0.705**  | 1       | 1              |
| Other P forms | 0.413*    | -0.170     | 0.057      | 0.077          | -0.378   | 0.019    | 0.142    | 0.264    | 0.790** | 1              |

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

**References**

1. Abolfazil F, Forghani A, Norouzi M. Effects of phosphorus and organic fertilizers on phosphorus fractions in submerged soil. Journal of Soil Science and Plant Nutrition. 2012; 12(2):349-362.
2. Anjali MC, Dhananjaya BC. Correlation between P fractions, P fractions with yield and yield attributes, soil properties and nutrient uptake by groundnut (Arachis hypogaea L.). Research Journal of Agricultural Sciences. 2017; 8(1):242-245.
3. Bhavsar MS, Ghagare RB, Shinde SN. Study of different phosphorus fractions and their relationship with soil properties in Agricultural Botany Research Farm, Nagpur, India. International Journal of Current Microbiology and Applied Sciences. 2018; 7(1):1130-1137.
4. Chakravarthy DN, Barua JP. Phosphorus status of the hill soils of Assam. Indian Journal of Agricultural Chemistry. 1987; 22(2):131-139.
5. Deobhatia KS, Deopal. Phosphorus distribution in cultivated and eroded alluvial soil in Kanpur district of
Uttar Pradesh. Indian Journal of Agricultural Chemistry. 1988; 21:207-213.

6. Devra P, Yadav SR, Gulati IJ. Distribution of different phosphorus fractions and their relationship with soil properties in Western plain of Rajasthan. Agropedology. 2014; 24(01):20-28.

7. Jackson, M.L. Soil Chemical Analysis. Prentice Hall of India Private Ltd., New Delhi, 1973, 134-182.

8. Jaggi RC. Inorganic Phosphate fractions as related to soil properties in some representative soils of Himachal Pradesh. 1991; 39(3):567-568.

9. Kothandaraman GV, Krishnamoorthy KK. Distribution of inorganic phosphorus fractions in Tamil Nadu soil. Madras Agricultural Journal. 1977; 64:516-521.

10. Kovar JL, Pierzynski GM. Methods of Analysis for Soils, Sediments, Residuals and Waters, Second edition, Virginia Tech University, 2009, 50-53.

11. Lungmuana, Ghosh SK, Patra PK. Distribution of different forms of phosphorus in surface soils of rice growing areas of red and laterite zone of West Bengal. Journal of the Indian Society of Soil Science. 2012; 60(3):204-207.

12. Majumdar B, Venkatesh MS, Kumar K, Patiram. Effect of different farming systems on phosphorus fractions in an acid alfisols of Meghalaya. Journal of the Indian Society of Soil Science. 2004; 52(1):29-34.

13. Olsen SR, Cole CV, Frank SW, Dean LA. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. United States Department of Agriculture Circular, 1954, 939.

14. Sarkar D, Mandal D, Haldar A. Distribution and forms of phosphorus in some red soils of Chotanagpur plateau, West Bengal. Agropedology. 2013; 23(2):93-99.

15. Sharma PK, Tripathi BR. Fractions of phosphorus from acid hill soils of North-West India. Journal of the Indian Society of Soil Science. 1992; 40:59-65.

16. Viswanatha J, Doddamani VS. Distribution of phosphorus fractions in some vertisols. Journal of the Indian Society of Soil Science. 1991; 39:441-445.