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

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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_2O_5 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 aluminium (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 $CaCO_3$ 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) [10] and available P_2O_5 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, Occl-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 dSm^{-1} in fallow-bengalgram cropping system to 0.117 dSm^{-1} in paddy-paddy cropping sequence with a mean value of 0.014 and 0.097 dSm^{-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 $CaCO_3$ 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 $CaCO_3$ 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) [16], Sharma and Tripathi (1992) [15], Devra *et al.* (2014) [6] and Bhavsar *et al.* (2018) [3].

The available P_2O_5 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 P_2O_5 showed positive significant correlation with Al-P (r= 0.893**), Fe-P (r= 0.823**), Ca-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 Barua (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) [1] 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 $CaCO_3$ 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 P_2O_5 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

cl= clay, sl= sandy loam, scl= sandy clay, sl= sandy loam

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

S. No.	Cropping system	pH	EC (dSm^{-1})	$CaCO_3$ (%)	Available P_2O_5 ($kg\ ha^{-1}$)
1	Fallow-Bengalgram	8.22-8.45 (8.33)	0.007-0.018 (0.014)	5-11 (7.2)	31.99-36.69 (34.8)
2	Sunflower-Sesame	7.85-8.07 (7.91)	0.014-0.059 (0.03)	5-8.5 (7)	34.81-50.27 (41.47)
3	Paddy-Paddy	7.64-7.95 (7.82)	0.072-0.117 (0.097)	6-15 (9.5)	99.28-146.61 (118.42)
4	Groundnut monocropping	8.15-8.81 (8.36)	0.049-0.079 (0.066)	10.5-15.5 (11.8)	128.33-253.72 (182.41)
5	Groundnut-Groundnut	7.88-8.51 (8.09)	0.008-0.085 (0.025)	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 calcareous 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 (4.23)	23.36-33.44 (27.93)	29.98-36.16 (32.79)	42.28-78.93 (55.89)	212.9-586.79 (349.39)	113.34-432.7 (228.55)
2	Sunflower-Sesame	19.71-27.95 (23.01)	31.61-42.28 (36.53)	20.25-23.21 (21.94)	27.22-29.54 (28.20)	120.85-237.91 (157.46)	15.65-114.74 (47.77)
3	Paddy-Paddy	3.62-7.82 (6.18)	54.63-75.03 (61.85)	61.89-80.61 (68.77)	79.67-120.02 (103.47)	342.58-359.18 (349.89)	80.14-142.77 (109.62)
4	Groundnut monocropping	10.16-24.8 (13.99)	69.45-100.32 (80.82)	60.85-91.57 (69.35)	101.8-156.43 (118.55)	333.9-607.8 (434.35)	96.5-234.39 (151.58)
5	Groundnut-Groundnut	11.56-16.09 (13.96)	55.71-99.18 (73.55)	53-91.87 (69.82)	16.94-30.52 (23.91)	255.51-364.01 (311.71)	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 calcareous soils of Y.S.R. Kadapa district

	pH	EC	$CaCO_3$%	Avail-P_2O_5	Sal-P	Al-P	Fe-P	Ca-P	Total-P	Other P forms
Avail-P_2O_5	0.141	0.530**	0.445*	1						
Sal-P	-0.235	-0.186	-0.119	0.088	1					
Al-P	0.015	0.363	0.250	0.893**	0.187	1				
Fe-P	-0.025	0.476*	0.241	0.823**	-0.144	0.916**	1			
Ca-P	0.136	0.650**	0.526**	0.766**	-0.266	0.473*	0.543**	1		
Total-P	0.316	0.255	0.307	0.651**	-0.283	0.554**	0.643**	0.705**	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)

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