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Study of Different Phosphorus Fractions and their Relationship with Soil Properties in Agricultural Botany Research Farm, Nagpur, India

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A B S T R A C T

Phosphorus fractionation study in soils of Agricultural Botany Research Farm, Nagpur were studied in relation to soil properties in which10 surface (0-15 cm depth) and 10 subsurface (15-30 cm depth) soil samples collected from studied area were analysed for different physical, chemical properties and different P fractions. Majority of the soils of the study area clayey in nature, neutral to moderately alkaline in reaction, Soil organic carbon was moderate to moderately high in soils, EC values for these soils within safe limit, the free lime content indicating that these soils are moderately calcareous in nature. The available phosphorus content of the soils showed low to moderately high in category. Occluded P had significant positive correlation with sand. Fe-P and Reduct-P had negative significant relation with silt and Ca-P had significant positive correlation. Saloid –P, Al-P, Reduct-P, Org-P and Total-P had significant positive correlation with clay. No one phosphorus form gave significant positive correlation with pH and E.C. Available P was significant positively correlated with Total-P, Organic-P, Ca-P. Organic carbon had significant positive correlation with Total-P, Organic-P, Fe-P, Ca-P. Clay was significant positively correlated with saloid-P, Al-P, Ca-P, Red-P, Organic-P, and Total-P. Silt was significant negatively correlated with Saloid-P, Fe-P, Red-P and positively correlated with Ca-P. Total P and Organic P had significant positive correlation with all the fractions except Occl-P was not showed significant relation with Total-P. All the forms of inorganic P were highly significant and positively correlated with each other except Al-P and Occl-P.

Introduction

Phosphorus in soil present in organic and inorganic forms. Only 10 to 30 per cent of the freshly applied phosphate is utilized by crop plants and rest goes into the formation of different P compounds of varying solubility which later serve as potential source of P for plants (Kanwar, 1976).

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. Keeping in view the scanty information in this respect on soils of Agricultural Botany Research farm, Nagpur, the present investigation was undertaken.

Materials and Methods

Ten surface (0-15 cm) and ten subsurface (15-30 cm) soil samples collected from Agricultural Botany Research Farm, Nagpur were used for the study. The processed soil samples (<2 mm) were analyzed for pH, EC, Organic carbon, $CaCO_3$, CEC, S and, Silt, Clay and different P fractions by adopting standard procedures (Table 1 and 2). Total P in soil was determined using 60% perchloric acid digestion method as suggested by Piper (1966). The original fractionation procedure for different forms of inorganic P proposed by Peterson and Corey (1966) and available P by Olsen *et al.,* (1954) were used. Organic P was determine as the difference between total P and Inorganic P. Simple correlation coefficient analyses between soil properties and fractions of P were computed by standard statistical methods.

Results and Discussion

Inorganic-P

Saloid-P

In Agricultural Botany Research Farms, Nagpur Saloid-P content of the soils decrease with depth and ranged from 2.1 to 3.7 ppm and accounted on an average about 0.62 per cent of the total P. Sharma and Tripathi (1992) reported that, content of Saloid P on an average 0.8 percent of the total P and 1.6 per cent of the Inorganic P. The variation in Saloid P in the studied area soils can be attributed to the variation in clay, organic carbon and available P content of these soils. Saloid P had significant and positive with clay (r = 0.638**). Similar result was reported in clayey soils of Rajasthan by Sacheti and Saxena (1973). Saloid P had significant and negative relationship with silt (r = -0.746**). It showed significant positive correlation with Org-P (r =0.519**), Total-P (r =0.568**), Red -P (r =0.495*), Fe-P (r =0.503**) and showed significant negative correlation with Ca-P (r = -0.512). The significant positive correlation of Saloid –P with Org-P and Total-P indicate that two forms have profound effect on the content and distribution of Saloid-P, Devra *et al.*, (2014). The higher content of Saloid –P as a result of inorganic fertilization and FYM could be attributed to the transformation of applied P into Saloid-P. The result was agreement with Vishwanath and Doddamani (1991) and Jatav *et al.*, (2010).

Aluminium–P

The distribution of Al-P decreased with sampling depth. This might be due to increase amount of calcium carbonate in the soil with increasing depth. The results corroborate the finding of Gupta and Cornfield (1962).The Al-P varied from 40.56 ppm to 53.15 ppm. It contributed about 10.12 % of total-P. Al-P had significant and positive correlation with clay (r = 0.797**). It also showed significant negative correlation with $CaCO_3$ (r = -604**). Al-P had significant positive correlation with Org-P (r =0.506), Total-P (r = 0.608**).

Iron bound phosphorus (Fe-P)

The Fe-P content shows variations in all samples. According to Table 3, Fe-P content varies between 14.15 ppm to 28.34 ppm. It contributes 4.27 per cent of total P. These results were in accordance with that of Viswanath and Doddamani (1991). Fe-P was found higher in surface soil due to higher organic carbon content, higher amount of calcium carbonate was recorded at higher pH where iron activity was less to precipitate P into Fe, Chandra Bhan and Harishankar (1973), Devra *et al.*, (2014). The high organic carbon content increased the amount of Fe-P in studied area. Silt content showed significant and negative relationship with Fe-P (r = –0.646**). The Organic carbon had significant and positive relationship with Fe-P (r = 0.502**). This might be due to the mineralization of organic –P and conversion into iron fraction due to high biological activity in the soils, Sacheti and Saxena (1973), Jaggi (1991). The high amount of free $CaCO_3$ was found at high pH at which Fe-P activity was less to precipitate P into Fe-P. Similar finding were also reported by Chander Bhan and Harishankar (1973) and Viswanath and Doddamani (1991).

Fe-P showed significant and positive with Saloid-P (r = 0.503**), Red-P (r = 0.725**), Org-P (r =0.448*), Total-P (r =0.507**). Similar result was found by Devra (2014).

Calcium–P

Ca- P was found to be most dominant amongst all the forms of phosphorus. The Ca-P varied from 182.09 ppm to 208.45 ppm and accounted about 41.11 per cent of total P. This might be attributed with finding of Mishra and Ojha (1969) and Viswanath and Doddamani (1991). Ca-p was increased with increasing depth similar result was obtained by Trivedi (2010). Available P showed significant and positively correlated with Ca-P (r = 0.652**). Similar finding is reported by Lungamuana *et al.*, (2012). Being constant with correlation analysis Ca-P had low direct and indirect path coefficient.

The transformation mainly occurred among other Pi fraction. P added to the soil was distributed between labiale and non-labiale pools. Shen *et al.*, (2004) found that, labile P (Ca-P, Al-P) could be readily fixed into non-labiale P (Fe-P, Occl-P and Ca-P) due to the associated with hydrous Fe oxides and calcareous compound in calcareous soil result reported by Wang (2010) significant relationship of Ca-P with available P indicating that these fraction mainly contributed towards available P pool. Ca-P had showed significant positive correlation with silt (r =0.583**), OC (r = 0.499*), $CaCO_3$ (r =0.508**), available P (0.652**).

Ca-P showed significant negative correlation with Saloid-P (r = -0.512**) and Fe-P (r = -0.683), Red-P (r = - 0.548**) and showed significant positive correlation with Occl-P (r =0.510**), Org-P (r =0.573**), Total-P (r =0.498*).The close association of Ca-P with Total-P was due to the dominance of Ca-P in soils. Similar results were also reported by Patgiri and Dutta (1993).

Reductant–P

The Reductant –P varied from 23.99 ppm to 39.13 ppm. It accounted about 6.88 per cent of the total-P. The low value of Red –P was observed in the soil having relatively higher pH and sand content. This might be due to iron and aluminum bound P content and rise in the content of calcium bound P and also Red-P. Red-P had negative significant correlation with pH (r = -0.642**), silt (r = -0.520**).

It showed significant positive correlation with clay (r = 0.494*). Similar finding were observed by Viswanath and Doddamani (1991), Sharma and Tripathi (1992), Trivedi *et al.*, (2010).

Red-P had significant positive correlation with Saloid-P (r = 0.495*), Fe –P (r = 0.725**), Org-P (r =493*), Total-P (r = 0.606**) and showed significant negative correlation with Ca-P (r = -0.548**).Prasad *et al.*, (1986) showed that all the forms of P are correlated with each other.

Occluded-P

The Occluded –P ranged from 14.88 ppm to 25.30 ppm. It accounted about 4.53 per cent of total-P. Similar the results were found by Singh and Omankar (1987).

Table.1 Physical properties of soils in Agricultural Botany Research Farm, Nagpur

Sr. no	Depth (cm)	Particle size distribution (per cent)			Textural class
		Sand %	Silt %	Clay %	
BOT-1(1)	0-15	18.5	19.8	56.90	Clayey
BOT-1(2)	15-30	20.5	20.86	53.75	Clayey
BOT-1(3)	0-15	19.53	24.20	56.27	Clayey
BOT-1(4)	15-30	21.37	25.33	52.20	Clayey
BOT-2(5)	0-15	16.5	22.10	58.56	Clayey
BOT-2(6)	15-30	18.1	23.70	55.00	Clayey
BOT-2(7)	0-15	19.50	23.50	56.32	Clayey
BOT-2(8)	15-30	21.80	21.20	53.20	Clayey
BOT- 3(9)	0-15	20.22	21.53	58.25	Clayey
BOT-3(10)	15-30	21.1	20.5	55.03	Clayey
BOT-3(11)	0-15	17.20	21.6	58.88	Clayey
BOT-3(12)	15-30	19.60	22.3	56.20	Clayey
BOT-4(13)	0-15	18.81	22.40	58.80	Clayey
BOT-4(14)	15-30	20.95	20.55	56.3	Clayey
BOT-4(15)	0-15	20.70	22.50	56.71	Clayey
BOT-4(16)	15-30	21.30	25.20	52.60	Clayey
BOT-5(17)	0-15	18.96	21.07	58.24	Clayey
BOT-5(18)	15-30	19.51	22.46	55.09	Clayey
BOT-5(19)	0-15	20.87	22.75	55.30	Clayey
BOT-5(20)	0-15	22.59	24.17	53.24	Clayey

Table.2 Chemical properties of soils in Agricultural Botany Farm, Nagpur

Sr. no	Depth (cm)	pH (1:2.5)	EC dSm^{-1}	Organic Carbon (%)	$CaCO_3$ (%)	Available Phosphorus (kg ha^{-1})
BOT-1(1)	0-15	7.3	0.24	0.71	4.52	15.21
BOT-1(2)	15-30	7.5	0.25	0.67	4.91	12.30
BOT-1(3)	0-15	7.6	0.31	0.79	4.70	16.25
BOT-1(4)	15-30	7.9	0.38	0.71	5.12	14.01
BOT-2(5)	0-15	7.7	0.40	0.58	3.68	16.60
BOT-2(6)	15-30	7.9	0.42	0.52	4.75	13.15
BOT-2(7)	0-15	7.4	0.26	0.65	4.50	18.17
BOT-2(8)	15-30	7.8	0.31	0.60	5.61	15.10
BOT-3(9)	0-15	7.8	0.33	0.73	4.56	14.11
BOT-3(10)	15-30	8.0	0.39	0.68	5.14	12.15
BOT-3(11)	0-15	7.5	0.36	0.68	4.96	17.20
BOT-3(12)	15-30	8.0	0.38	0.61	5.39	14.35
BOT-4(13)	0-15	7.7	0.35	0.78	4.61	13.18
BOT-4(14)	15-30	8.1	0.40	0.72	5.25	11.23
BOT-4(15)	0-15	7.4	0.30	0.54	4.57	16.33
BOT-4(16)	15-30	7.6	0.34	0.47	5.48	14.18
BOT-5(17)	0-15	7.7	0.35	0.68	3.87	17.21
BOT-5(18)	15-30	7.8	0.37	0.62	4.76	15.36
BOT-5(19)	0-15	7.4	0.36	0.65	4.45	18.30
BOT-5(20)	15-30	7.6	0.39	0.58	4.80	16.19

Table.3 Distribution of soil phosphorus form (ppm) in Agricultural Botany Research Farm, Nagpur

Sr.no	Depth cm	S- P	Al- P	Fe- P	Ca-P	Red-P	Occl-P	Inorg-p	Org-P	Total-P
BOT-1(1)	0-15	3.7	48.38	28.34	182.09	39.13	18.34	319.98	170.6	490.58
BOT-1(2)	15-30	2.8	41.18	25.15	190.03	36.09	21.45	316.7	116.74	433.44
BOT-1(3)	0-15	2.6	47.12	19.34	194.34	32.67	14.88	310.95	184.25	495.20
BOT-1(4)	15-30	2.1	42.15	15.75	203.48	27.45	17.13	308.06	132.3	440.36
BOT-2(5)	0-15	3.4	50.14	15.70	196.14	30.15	15.98	311.51	159.28	480.79
BOT-2(6)	15-30	2.5	42.24	14.53	201.41	23.99	19.12	303.82	89.34	393.16
BOT-2(7)	0-15	3.0	47.20	20.12	198.88	33.56	21.45	324.21	174.02	498.23
BOT-2(8)	15-30	2.9	40.56	16.32	202.47	28.70	25.23	316.18	140.49	456.67
BOT-3(9)	0-15	3.1	48.84	24.36	193.2	31.45	18.45	319.4	162.87	482.27
BOT-3(10)	15-30	3.5	43.26	21.75	200.42	26.75	21.70	317.38	141.79	459.17
BOT-3(11)	0-15	3.6	50.55	23.70	199.34	39.10	22.2	338.59	173.44	512.03
BOT-3(12)	15-30	2.8	43.12	19.34	207.98	35.10	20.34	328.68	127.77	456.45
BOT-4(13)	0-15	3.2	51.15	19.95	196.34	32.16	18.34	321.14	170.59	491.73
BOT-4(14)	15-30	3.0	48.14	15.70	206.44	30.17	21.66	325.11	128.91	454.02
BOT-4(15)	0-15	2.5	53.15	20.18	201.25	30.45	22.45	329.98	143.55	473.53
BOT-4(16)	15-30	2.2	46.67	14.15	208.45	26.47	25.3	319.24	93.22	412.46
BOT-5(17)	0-15	3.0	52.14	22.18	195.89	35.18	21.52	328.91	129.37	458.28
BOT-5(18)	15-30	2.7	45.32	16.17	203.87	32.12	23.5	323.68	96.68	420.36
BOT-5(19)	0-15	2.8	47.12	24.36	201.45	33.06	20.86	327.15	140.29	467.44
BOT-5(20)	15-30	2.3	42.56	21.12	207.13	29.45	24.35	327.41	83.21	410.62

Table.4 Correlation coefficient(r) between forms of phosphorus with physic - Chemical properties of soils in Agricultural Botany Research Farm, Nagpur

Form of P	Sand %	Silt %	Clay %	pH	EC dSm^{-1}	O.C%	$CaCO_3$ %	Available P $kg^{-1}ha$
Saloid-P	-0.266	-0.746**	0.638**	-0.011	0.188	0.363	-0.254	0.017
Al- P	-0.342	-0.173	0.797**	-0.081	0.064	0.198	-0.604**	0.249
Fe- P	-0.006	-0.646**	0.378	-0.353	-0.254	0.502**	-0.330	0.247
Ca –P	0.363	0.583**	-0.443	0.162	0.474	0.499*	0.508**	0.652**
Red-P	-0.319	-0.520**	0.494*	-0.642**	-0.292	0.445	-0.272	0.244
Occl- P	0.605**	-0.044	-0.433	-0.011	0.303	-0.542**	0.469*	-0.128
Inorg.-P	0.160	-0.266	0.335	-0.402	0.234	0.012	-0.036	0.241
Org.- P	-0.354	-0.327	0.638**	-0.170	-0.417	0.651**	-0.305	0.454*
Total- P	-0.322	-0.378	0.706**	-0.261	-0.311	0.597**	-0.330	0.501**

** Significant at 1 per cent level
* Significant at 5 per cent level

Table.5 Correlation coefficient (r) amongst the forms of phosphorus

Forms of P	S-P	Al-P	Fe-P	Ca-P	R-S-P	Occl-P	Org-P	Total-P
S-P	1							
Al-P	0.317	1						
Fe-P	0.503**	0.203	1					
Ca-P	-0.512**	-0.279	-0.683**	1				
R-S-P	0.495*	0.371	0.725**	-0.548**	1			
Occl-P	0.122	0.210	0.164	0.510**	-0.111	1		
Org-P	0.519**	0.506**	0.448*	0.573**	0.493*	0.550**	1	
Total-P	0.568**	0.608**	0.507**	0.498*	0.606**	-0.411	0.968**	1

** Significant at 1 per cent level
* Significant at 5 per cent level

Occl-P had significant and positive correlation with sand (r = 0.605**), $CaCO_3$ (r =469*) and negatively correlated with organic carbon (r = -0.542**). It showed significant positive correlation with Ca-P (r = 510**) and Org-P (r = 0.550**).

Organic–P

The organic P was mainly located in fulvic acid fractions. The soils having high organic matter content generally have high Organic –P. Org-P content in the soils decreased with depth. The Org-P content in the soil varied from 83.21 ppm to 184.25 ppm which contributed about 28.58 per cent of the total-P. Khan and Mandal (1973) reported that, the Org-P constituted 29.82 per cent of the total P. Similar trend was also reported by Kothandarman and Krishnamoorthy (1978). In generally Org-P and its per cent to total P was found to decrease with depth. The decrease of organic phosphorus in soil may be attributed to the decreased of organic matter and organic carbon with depth. Similar trends were recorded by the Kothandaraman and Krishnammorthy (1977), Viswanath and Doddamani (1991). Since all soils were calcareous in nature, organic phosphorus was relatively low.

Org –P had significant positive relationship with OC (r = 651**). It appears that several phosphorus containing organic compounds dominate the soils and on mineralization will be available to crops. Similar observation was recorded by Kothandaraman and Krishanmoorthy (1977) and Viswanath and Doddamani (1991).

Organic P showed significant and positive correlation with available P(r = 0.454*). Availability and forms P in the soil to a large extent are influenced by organic matter application. Some investigations carried out on decomposition of plant and animal residues, revealed that in initial stage of humification, large part of inorganic P gets converted into organic compound but later on when the sources of available energy is exhausted, mineralization of Org-P compound was detected. The increase in the availability P was due to mineralization of Org-P solublization of negative inorganic P and lesser fixation of added P Tomar *et al.,* *(*1984). Org-P showed significant and positive relationship with clay (r = 0.638**). However, organic phosphorus was significantly and positively correlated with Saloid P (0.519**), Al-P (r =0.506**), Fe (r=0.448**), Ca-P (r=0.573**), Red-P (r=493*). Occl-P (r =0.550**), Total-P (r =0.968**). The association between Organic-P and total-P which was evident because of higher correlation value of Organic and Total-P, had been reported by Dongale (1993)

Total-P

The Total P content indicates the reserves of this element in the soil. The total P content in the soils of Agricultural Botany Research Farm, Nagpur varied from 393.16 ppm to 512.03 ppm. The range was quite large which might be due to variation in crop management practices. The total P content in the soils was generally higher in the surface layer than in subsurface layer and decreased with depth. The decreased in total-P content may be due to decrease in organic matter content down to depth of soil. Similar result, also reported by Viswanath and Doddamani (1991) and Dongale (1993). Total-P had significant and positive correlation with clay (r = 0.706**), organic carbon(r = 0.597**), available P (r = 0.501**). Similar results were also reported by Gupta and Lattoo (1999) and Trivedi *et al., (*2010), Agrawal (1987) and Singh *et al.*, (2010) (Table 4 and 5).

Total P was significantly and positively correlated with Saloid P (r =0.568**), Al-P (r =0.608**), Fe-P (r=0.507**), Ca-P (r =0.498*), Red-P (r =0.606**), Org-P (0.968**). The Ca-P was the predominate form of soil phosphorus, and was significantly and positively correlated with total P because of the close association of Ca-P with total-P due to the dominance of Ca-P in soils. Similar results were also reported by Patgiri and Dutta (1993).

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