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Evaluation of phosphorus availability and phosphorus fixation in four different soils orders

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Abstract
A controlled experiment was conducted to study the Phosphorus availability and Phosphorus fixation in four soils orders with contrasting characteristics. The results showed that, available P in the tested soil samples of Vertisols and Aridisols were found to be in high range 23.4 and 27.5 kg ha^{-1} respectively. The available phosphorus in tested soil samples of Inceptisols and Alfisols is found to be in low to medium range. 6.8 and 14.9 kg ha^{-1} respectively. Phosphorus fixation the increase in time and doses of phosphorus the phosphorus fixation also increases. About 80-95% of added phosphorus is fixed in the soils and the maximum fixation was in then Vertisols while the least fixation was observed in Alfisols at all the stages of incubation, although the differences were meagre. Phosphorus fixation was positively correlated with different pools of iron and aluminium compounds whereas, P fixation showed positive significant correlation with amorphous ferri-alumino silicate content.

Keywords: phosphorus availability, phosphorus fixation, alfisol, vertisol, inceptisol, aridisols

Introduction
Availability of P to plant is limited due to fixation as free oxides and hydroxides of aluminium and iron in acid soils and calcium in alkali soils. This is a fact that soluble P compound when added to soil react with various soil components, and are quickly converted to slowly available forms, creating one of the main problems relevant to the maintenance and improvement of soil fertility.

The availabilities of P also depend on soil pH, type of clay minerals, Fe, Al hydroxides and calcium carbonates (Kaistha *et al*., 1997) [10], Therefore the response of phosphorus in different soils varies and the crop response varies. There is an acute deficiency of phosphorus in acid soils which, makes it the most limiting nutrient for crop production in such soils. Under normal conditions, most of the phosphorus added through chemical fertilizers is water soluble and therefore, readily available to plants. But, in case of acid 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 (Brady, 2002) [2].

Phosphorus fixation is a process whereby the readily available forms of P are changed to sparingly soluble ones by reacting with inorganic and organic components of soil. It involves a series of reactions that remove P from the soil solution and render it unavailable for plants. Phosphate fixation reaction occurs rapidly in soil profile. These reactions usually involve dissolved phosphate anions from applied fertilizers forming chemical complexes with metals and minerals that exist in the soil solution and on clay particles. It takes place in soil profiles typically allow only a small fraction (10-20%) of phosphorus in fertilizer to be taken up by plants. A large portion of chemical fertilizers with high P content applied to soil is immobilized rapidly and 80-85% becomes unavailable to plants (Goldstien, 1986) [6]. The presence of clay, Al, Fe and sesquioxides is responsible for fixation of applied P.

P fixation is significantly and positively correlated with clay content of soil. This is due to larger specific surface area of clay associated with higher anion exchange phenomenon. Clay minerals P through co-ordination of phosphate ions on mineral surface by exchange of coordinated H_2O molecules, adsorbed SO_4^{-2} and other anions, displacement of hydroxyl and silicate ions and precipitation by exchangeable Ca^{+2} (Tomar, 2001) [18].

Soil P is finite, non-renewable and limited resource, Phosphate rock is a general term that describes naturally occurring mineral assemblages containing a high concentration of phosphate minerals about 95% of it is used to produce fertilizers, animal feeds and pesticides. India has reserve of 14.7 Mt of high grade rock phosphate and 190 Mt of low grade with an average of 12% P_2O_5.

Out of total India reserve of 217.2 Mt, Rajasthan has the largest reserve of rock phosphate of about 78.8 Mt (Jaggi, 2000) [8].

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) [11].

Material and Methods

The experiment was conducted at the carry out the investigation a laboratory during year 2016 in the lab of Japanese International Cooperation Agency (JICA), College of Agriculture, Indore. Soils of the experimental area: A composite sample of four different soils which belong to different soil orders are randomly collected from four different cities (Nasik, - Banglore-, Indore, -Gwalior). All the possible technical precautions as prescribed for standard soil sampling have been followed. Samples were, air - dried in the shade and grounded by wooden roller, thereafter sieved through 2 mm mesh and stored in polyethylene bags. The soil samples thus obtained were subjected to various chemical analyses to assess the single value of chemical properties of soil. The soil of the experimental site is 1. Soil of Nasik Inceptisols 2. Soil of Bengaluru Alfisols, 3. Black soil of Indore Vertisols, 4. Alluvial soil of Gwalior Aridisols. The experiment was laid out in permanent plot with: 7 treatments comprised of different dosages of P: 1. Control P No phosphorus, 2. - 40 kg P, 3. - 80 kg P, 4.- 120 kg P, 5. - 160 kg P,6. - 200 kg P, 7 -. 400 kg P, Statistical design: completely randomized design, with three replications for each treatment was selected for the study. The surface (0-15 cm) soil samples were collected, ground and passed through 2mm sieve and characterized for physico-chemical properties and mineralogical compositions. The pH in soil water suspension (1:2.5) was measured using combined electrode (glass and calomel) in a digital pH meter. The electrical conductivity was measured in the supernatant liquid of the soil water suspension (1:2.5) with the help of Conductivity Bridge, expressed in dS m^{-1} at 25 ºC. Normal sodium acetate (pH 8.) was used to determine cation exchange capacity of soils. Organic carbon was determined by wet digestion method and mineralizable nitrogen by alkaline - $KMnO_4$ method. Available phosphorus in soil was determined by 0.5 M $NaHCO_3$ (pH 8.5) extraction method for Inceptisol and Vertisol and Bray-Kurtz no 1 method for Alfisol, followed by colour development by ascorbic acid method Available potassium was extracted by 1N neutral NH_4OAc and determined by flame photometer. The sand, silt and clay contents (%) were determined by hydrometer method.

Results and Discussion

Phosphorus availability in different soils

The data presented in Table .1 shows the availability of the phosphorus in different soil samples which is highest in order Aridisols (27.5 kg ha^{-1}) followed by Vertisols (23.4 kg ha^{-1}), Alfisols (14.9 kg ha^{-1}), and Inceptisols (6.8 kg ha^{-1}). Similar finding was reported by Olsen *et al.*, (1954) Dhir *et al*, (1956) Kanwar *et al.*, (1986). Bansal and Sekho (1994) [1]. Jain *et al*., (1997) [9], Singh *et al.*, (2015) [14].

Phosphorus fixation capacity of different soils

The data pertaining to the values of recovered P, Fixed P and fixation capacity of different soil samples under different doses of treatment at different days of incubation are given in the Table 2, it is evident that with increasing the incubation period the amount of fixed P and Fixation capacity of different soils under analysis increased while there was a decrease in recovered P values Recovered - P in the soil order Vertisols ranged from 3.5 - 74.1 kg ha^{-1}, constituted about 36.5 - 325.1 kg ha^{-1} of fixed - P and the fixation capacity ranged from 81.28 - 91.25% on 15th day of incubation, On 30th day of incubation the value of recovered P ranged from 5.1 - 22.3 kg ha-^{1},fixed P 35.1 - 377.7 kg ha^{-1}, fixation capacity 87.25 - 94.43%, On 45th day of incubation the value change from 3.1-27.1 kg ha^{-1}, fixed P 36.9 - 372.9 kg ha $^{-1}$ and fixation capacity varied as 92.16 -93.21% With continuous changes in data the P values on 60th day of incubation were recovered - P 1.5 - 26.6 kg ha^{-1}, fixed P38.5 - 373.4 kg ha^{-1} and fixation capacity 96.17 - 93.5% which we are highly significant with the increasing doses at each treatment level, (Table 2).

Recovered P in the soil order Inceptisols ranged from 3 - 1.7 kg ha^{-1}, constituted about 39.2 - 399.7 kg ha^{-1} of fixed - P and with fixation capacity ranged from 98 - 99.3 % on 15th day of incubation, on 30th day of incubation the value of recovered P ranged from 7 - 12.2 kg ha^{-1}, fixe P 39.3 - 388.6 kg ha^{-1}, fixation capacity 93.4 - 99.26%,on 45th day of incubation it changed as recovered P .7 - 26.6 kg ha^{-1}, fixed P 39.3 - 374.4 kg ha^{-1} and fixation capacity 93.09 - 98.33% with continuous changes in data the P values on 60th day of incubation were recovered P 2.5 - 28.9 kg ha^{-1}, fixed P 37.1 - 371.9.4 kg ha^{-1} and fixation capacity 91.4 - 98.81% which weare are highly significant with the increasing doses at each treatment level as, given in (Table 3).

Recovered P in the soil order Alfisols ranged from 13.1 - 157.4 kg ha^{-1}, constituted about 26.9 - 242.6 kg ha^{-1} of fixed P and with fixation capacity ranged from 68.89 - 69.41 % on 15th day of incubation, On 30th day of incubation the value of recovered P ranged from 11.2-142.2 kg ha^{-1}, fixed P 28.2 - 257.8 kg ha^{-1}, fixation capacity 61.92 - 72.0 %, on 45th day of incubation the value changed as recovered P 1.1 - 12.7 kg ha^{-1}, fixed P 38.9-387.3 kgha^{-1} and fixation capacity 9682 - 99.42 % With continuous changes in data the P values on 60th day of incubation were recovered P .7 - 4.9 kg ha^{-1}, fixed - P 35.9 - 398.7 kg ha $^{-1}$ and fixation capacity 89.83 - 99.67 % which are highly significant with the increasing doses at each treatment (Table 4). Similar finding were reported by Swenson *et al*., (1949). Ellis and Truog (1955) [4] and Hemwall *et al.,* (1957) [7].

Recovered P in the soil order Aridisols ranged from 3.5 - 74.1 kg ha^{-1}, constituted about 36.5 - 325.1 kg ha^{-1} of fixed P and with fixation capacity ranged from 81.28 - 91.25% on 15th day of incubation, On 30th day of incubation the value of recovered P ranged from 5.1 - 22.3 kg ha^{-1},fixed P 35.1 - 377.7 kg ha^{-1}, fixation capacity 87.25 - 94.43%, on 45th day of incubation changed as recovered P 3.1 -27.1 kg ha^{-1}, fixed P 36.9 - 372.9 kg ha^{-1} and fixation capacity 92.16 - 93.21 % With continuous changes in data the P values on 60th day of incubation were recovered P 1.5-26.6 kg ha^{-1}, fixed P 38.5 - 373.4 kg ha-^{1} and fixation capacity 96.17 - 93.5% which weare highly significant with the increasing doses at each treatment level as, given in (Table .5). Similar finding was reported by Ghosal *et al.* (2011) [16].

Conclusion

A composite sample of four different soils which belong to different soil orders weare randomly collected from the experimental field of four different cities. The soil samples thus obtained were subjected to various chemical analyses to assess the available P with the use of Olsen P method Maximum available P was recorded in Aridisols 27.5 Kg ha^{-1}, followed by 23.3 Kg ha^{-1} in Vertisol and lesser values were found in Inceptisol and Alfisol.

The findings of the present investigation concluded that soil P fixation capacity increased with advancement of the days of incubation significantly from 15th day to 60th day. Also P fixation increased with, increase in doses of P. About 80 - 95% of added P was fixed in the soils and the maximum fixation was in Vertisols while the least fixation was observed in Alfisol at all the stages of incubation, although the differences are meager. Maximum recovery of added P was high in the soils of pH less than 7. In Inceptisols and Alfisols.

Table 1: Phosphorus availability in different soils.

Place	Order	Available phosphorus (kgha^{-1})
Indore	Vertisols	23.4
Nasik	Inceptisols	6.8
Bengaluru	Alfisols	14.9
Gwalior	Aridisols	27.5

Table 2: Recovered- P, Fixed-P and P- fixation capacity of Vertisols as influenced by levels of applied P and incubation period.

Treatment	15th Day			30th Day			45th Day			60th Day		
P(Kgha^{-1})	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P- fixation capacity (%)	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. (Kgha-^{1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)
Control P	0	0	0	0	0	0	0	0	0	0	0	0
40 Kg P	3.5	36.5	91.25	4.9	35.1	87.25	3.1	36.9	92.16	1.5	38.5	96.17
80 Kg P	6	74	92.5	4.7	74.7	94.13	4.9	75.1	93.91	3	77	96.2
120 Kg P	7.1	119.9	94.08	3.5	116.5	97.08	5.4	114.6	95.48	12.2	107.8	90
160 Kg P	9.1	150.9	94.31	8.1	151.9	94.94	10.4	149.9	93.7	3.5	156.5	97.78
200 Kg P	11	169	94.5	22.3	177.7	88.85	4.6	195.4	97.69	1.3	198.7	99.36
400 Kg P	74.9	325.1	81.28	22.3	377.7	94.43	27.1	372.9	93.21	26.6	373.4	93.35
	SEm±	2.262	Average	SEm±	2.813	Average	SEm±	1.947	Average	SEm±	3.895	Average
	CD5%	3.981	91.32	CD5%	3.979	92.78	CD5%	3.427	94.4	CD5%	3.895	95.5

Table 3: Recovered- P, Fixed-P and P-fixation capacity of Inceptisols as influenced by levels of applied P and incubation period.

Treatment	15th Day			30th Day			45th Day			60th Day		
P(Kgha^{-1})	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P- fixation capacity (%)	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. (Kgha-^{1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov.Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)
Control P	0	0	0	0	0	0	0	0	0	0	0	0
40 Kg P	0.8	39.2	98	0.7	39.3	98.35	0.7	39.3	98.33	2.5	37.5	93.82
80 Kg P	1.8	78.2	97.75	0.6	79.4	99.26	4	76	94.99	4	76	95.06
120 Kg P	0.1	119.9	99.92	4.7	115.3	96.07	5.5	114.5	95.44	1.4	118.6	98.81
160 Kg P	0.7	159.3	99.54	10.5	149.5	93.41	8.7	151.3	94.57	13.7	146.3	91.41
200 Kg P	1.7	198.3	99.17	12.2	187.8	93.92	8.2	191.8	95.92	20.9	179.1	89.57
400 Kg P	0.3	399.7	99.93	11.4	388.6	97.15	27.6	372.4	93.09	28.8	371.3	92.81
	SEm±	2.758	Average	SEm±	0.571	Average	SEm±	0.508	Average	SEm±	6.509	Average
	$CD_{5\%}$	3.901	99.05	$CD_{5\%}$	1.004	96.36	$CD_{5\%}$	0.894	95.4	$CD_{5\%}$	11.456	93.6

Table 4: Recovered- P, Fixed-P and P-fixation capacity of Alfisols as influenced by levels of applied P and incubation period.

Treatment	15th Day			30th Day			45th Day			60th Day		
P(Kgha^{-1})	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P- fixation capacity (%)	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. (Kgha-^{1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)
Control P	0	0	0	0	0.3	0	0	0	0	0	0	0
40 Kg P	13.1	26.9	67.25	11.2	28.8	72.03	1.1	38.9	97.29	4.1	35.9	89.83
80 Kg P	26.9	53.1	66.33	24.3	55.7	69.63	1.1	78.9	98.58	2.4	77.6	97.04
120 Kg P	37.7	82.3	68.56	41.4	78.6	65.5	0.7	119.3	99.42	0.1	119.9	99.88
160 Kg P	48.9	111.1	69.41	57.9	102.1	63.83	1.1	158.9	99.31	4.9	155.1	96.94
200 Kg P	72.2	127.8	63.89	76.2	123.8	61.92	1.1	198.9	99.47	0.7	199.3	99.67
400 Kg P	157.4	242.6	60.65	142.2	257.8	64.44	12.7	387.3	96.82	1.3	398.7	99.66
	SEm±	0.265	Average	SEm±	0.361	Average	SEm±	0.479	Average	SEm±	0.363	Average
	CD5%	0.466	66.02	CD5%	0.636	66.225	CD5%	0.843	98.5	CD5%	0.639	97.2

Table 5: Recovered- P, Fixed-P and P-fixation capacity of Aridisols as influenced by levels of applied P and incubation period.

Treatment	15th Day			30th Day			45th Day			60th Day		
P(Kgha^{-1})	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P- fixation capacity (%)	Recov. (Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. (Kgha-^{1})	Fixed (Kgha^{-1})	P-fixation capacity (%)	Recov. Kgha^{-1})	Fixed (Kgha^{-1})	P-fixation capacity (%)
Control P	0	0.1	0	0	0	0	0	0	0	0	0	0
40 Kg P	4.8	35.2	88	0.9	39.1	97.69	1.2	38.8	97.01	4.9	35.1	87.67
80 Kg P	10.2	69.8	87.19	1.5	78.5	98.13	0.2	79.8	99.69	5.2	74.8	93.5
120 Kg P	11.6	108.4	90.3	17.7	102.3	85.22	10.1	109.9	91.55	5.2	114.8	95.64

160 Kg P	13.6	146.4	91.5	34.9	125.1	78.17	4.7	155.3	97.06	11	149	93.12
200 Kg P	31.6	168.4	84.18	1.3	198.7	99.34	4.8	195.2	97.61	11.7	188.3	94.15
400 Kg P	78.9	321.1	80.28	5	395	98.75	4.1	395.9	98.98	8.5	391.5	97.88
	SEm±	0.414	Average	SEm±	0.418	Average	SEm±	0.405	Average	SEm±	0.525	Average
	CD5%	0.729	86.91	CD5%	0.737	92.2	CD5%	0.713	97	CD5%	0.924	93.7

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