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Phosphorus adsorption characteristics and isotherms under different land use practices in acidic soils of Nagaland

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Abstract
A research investigation was undertaken in Nagaland University: School of Agricultural Science and Rural Development to estimate the effect of phosphorus adsorption in acidic soils of Nagaland under two land use practices i.e., forest and cultivated soils. Twenty two soil samples were collected from forest and cultivated soils of eleven districts of Nagaland. Effect of soil properties on phosphate adsorption was examined. The soil samples of each soil were equilibrated for 24 hrs at 25±2 ºC with aqueous solution of KH_2PO_4 containing 0-100 µgP mL^{-1} in a (1:20) soil: solution ratio. The amount of phosphorus adsorbed increased and distribution coefficient (Kd) and the percentage of added phosphate adsorbed (Xad) decreased with increasing solution phosphorus concentration. Phosphate adsorption was satisfactorily described by Langmuir and Freundlich equations. Langmuir equation was fitted more in both forest and cultivated soils followed by Freundlich equation. The pH was correlated negatively with constants of Langmuir (b and k) and Freundlich (k_f and 1/n). Aluminium was correlated positively with all the constants of Langmuir and Freundlich isotherm of forest soils. Also, adsorption maxima of Langmuir equation is significantly and positively correlated to clay of cultivated soils. In general forest soils (average 420.19ppm) have higher phosphorus adsorption than (average 383.06ppm) cultivated soil through paired t-Test. The results concluded that effect of land use practices were responsible for varying degree of phosphorus adsorption.

Keywords: Phosphorus adsorption, forest and cultivated soils, Freundlich and Langmuir adsorption isotherms

Introduction
In India, acid soils constitute nearly one-third of the area under cultivation. Acid soils are widely distributed in Himalayan regions, Eastern, North-Eastern and in Southern states under varying climatic and environmental conditions (Panda, 1987) [27]. Soil acidity is one of the major problems in states like Nagaland where 77% of area is under acid soil (Singh and Gupta, 2001) [32] for increasing agricultural productivity of these soils. Phosphorus deficiency is one of the most widespread soil constraints in the acidic soils of Nagaland. These soils are basically low in both total and plant available phosphorus and major portion of the applied fertilizer phosphorus is converted into non available form. It has been reported that in acidic soils only 10-40% of the applied phosphorus is available to the plants (Aulakh and Pasricha, 1999) [2].
Phosphate sorption is a complex reaction between the components of soil and phosphorus source and involves both adsorption and precipitation reactions, the former appears to be dominant over a short period at low phosphorus concentration in soil solution (Mehadi and Taylor, 1998) [25] whereas precipitation at higher concentration for longer period (Lin *et al.*, 1983) [23] The adsorbed and precipitated phosphate serve as a reservoir for regeneration of solution phosphorus, the concentration of which influences the diffusion of phosphate to plant roots and absorption by plants (Barrow,1979; Tomar and Biswas, 1998) [4, 35]. One important nutritional problem of acid soil is phosphorus deficiency, which is linked not only to low available phosphorus content of the soils but also to their capacity to fix fertilizer phosphorus in highly insoluble forms (De Datta, 1991) [16]. The phosphorus adsorption by soil is important because phosphorus equilibrates with soil solution phosphorus which, in turn, is immediate source of phosphorus for plants. Phosphorus adsorption isotherms integrates phosphorus intensity and quantity parameters of soils and these together play an important role in controlling phosphorus flux to the roots of growing plants (Chand *et al.*, 1995) [10].

Soil differ widely in their chemical and physical make up according to geological and geographical location and since no further work has been done in this field relating to phosphorus adsorption in Nagaland and so this study "Effects of Land Use Practices on Phosphorus Adsorption in Acid Soils of Nagaland" was carried out with the objectives to determine physicochemical properties of soil samples and to compare the different types of soil and land use practices on phosphorus adsorption in acid soils of Nagaland.

Materials and methods

Soil sampling and analyses

Twenty two acidic surface (0-15 cm) soil samples from 11 districts of Nagaland of varying chemical properties, two samples from each district, one from forest land and other from cultivated land were collected. The collected soil samples were air-dried, crushed and passed through a 2mm sieve and were analyzed for different physicochemical properties by standard procedure (Jackson, 1973) [21]. The samples were analysed for pH (1:2.5,soil:water suspension), electrical conductivity (EC; 1:2.5, soil:water suspension), clay percentage (Piper, 1966) [29], soil organic carbon (SOC) by Jackson (1973) [21], cation exchange capacity (CEC) by (Chapman, 1965) [14], available N (Subbiah and Asija, 1956) [33], available P (Bray and Kurtz, 1945) [9], available K (Jackson, 1973) [21], extractable Al (Baruah and Barthakur, 1997) [5], extractable Fe (Chen and He, 1985) [15] and Ca (Chang and Bray, 1951) [13].

Phosphorus adsorption studies

Two gram of each soil sample was equilibrated in a 100ml centrifuge tube in duplicate with 20 ml solution of KH_2PO_4 containing 10, 25, 50, 100µg P ml^{-1} for 24 hrs. Two drops of toluene were added to each tube during the equilibration period. The tubes were shaken for one hour and placed in a BOD incubator at 25±2° C. Thereafter, the supernatant liquid was removed after centrifugation at 10,000 rpm for 20 minute. The filtrate in duplicate was analyzed for phosphorus. The amount of phosphorus adsorbed was calculated by depletion technique (Olsen and Watanabe, 1957) [26]. Percentage of the added phosphorus adsorbed (Xad) and distribution co-efficient (Kd) were also calculated.

Evaluation of adsorption data

The distribution co-efficient (Kd) characterizing the distribution of phosphate between solid and solution phase at equilibrium was calculated as:

$$\mathrm{Kd} = \frac{\mathrm{P\ adsorbed}(\mathrm{meq\ g^{-1} soil})}{\mathrm{P\ in\ solution}(\mathrm{meq\ L^{-1}})\ \mathrm{at\ equilibrium}}$$

The percent adsorption of added phosphate (Xad) was calculated from the amount of added in soil through phosphate solutions and the amount of phosphorus adsorbed as:

$$\mathrm{Xad} = \frac{\mathrm{Amount\ adsorbed\ per\ g\ soil}}{\mathrm{Amount\ of\ added\ P\ per\ g\ soil}} \times 100$$

The P adsorption data was fitted to the following adsorption equation:

(i) Langmuir equation

A common form of the conventional Langmuir equation is:

$$\frac{\mathrm{C}}{(\mathrm{x/m})} = \frac{1}{\mathrm{kb}} + \frac{\mathrm{C}}{b}$$

Where, x/m is the amount of phosphorus adsorbed per unit weight of soil (µg P g^{-1} soil): C is equilibrium phosphorus concentration (µg mL^{-1}); k is the constant related to bonding energy (mL g^{-1}); b is phosphorus adsorption maxima (µg P g^{-1}soil). A plot of C/x/m *vs* C should give a straight line from which b (slope^{-1}) and k (slope/intercept) may be obtained.

(ii) Freundlich equation

$$x/m = k_f C^{1/n}$$

Where, k_f and n are constraints and x/m and C have the same meaning as in the Langmuir equations.

Statistical analysis

Correlation coefficient was worked out in order to see whether different characteristics were interrelated to each other using the procedure suggested by Panse and Sukhatme (1961) [28].

Result and discussion

Physico-chemical properties of soils

The pH of the soil of different districts ranged from 3.84 to 5.87 for forest soil and from 3.76 to 6.49 for cultivated soil. On an average, the EC was 0.09 dS m^{-1} and 0.12 dSm^{-1} for forest and cultivated soils in various districts respectively. Forest soils had higher value (1.32%) of organic carbon than the cultivated soils (1.28%) on average basis. The cation exchange capacity of forest soils ranged from 22 to 62 [cmol (P^+) kg^{-1}] and in cultivated soils, the values varied from 17.6 to 48 [cmol (P^+) kg^{-1}]. The forest soil of Nagaland districts had an average of 6.03(%) clay content while cultivated soils had an average of 6.20 (%). The average value of calcium was 0.45 (g kg^{-1}) in forest soils and 0.33 (g kg^{-1}) for cultivated soils of different districts. The average values of available nitrogen was 344.08 (kg ha^{-1}) and 321.86 (kg ha^{-1}), available phosphorus 7.49 kg ha^{-1} and 8.31 kg ha^{-1}, available potassium 212.49 kg ha^{-1} and 191.21kg ha^{-1}, extractable iron 16.82(cmol (P^+) kg^{-1}] and 20.45 (cmol (P^+) kg^{-1}] and extractable aluminium 6.95 [cmol(P^+)kg^{-1}] and 6.22 [cmol (P^+) kg^{-1}] for forest and cultivated soils respectively in different districts of Nagaland.

Phosphate adsorption forest soils

Phosphate adsorption (x/m) by soils increased with increasing the solution phosphorus concentration. The highest amount of phosphate was adsorbed by Tuensang forest soils with the highest rate of applied P (100 µgP g^{-1} soil) and also with an average of 456.54 ppm while lowest was observed in Phek soils with an average of 356.23 ppm (Table No.1). This may be due to the presence of higher amounts of iron and clay in Tuensang soil as compared to Phek soil as phosphorus adsorption is much affected by the type of surface contacted by phosphorus in the soil where amorphous iron and aluminium oxide are most effective P sorbents due to their high specific surface area (Brar and Vig, 1988) [8], it is also affected by the quantity and the mineralogy of the clay fractions (Upadhyay *et al.*, 1993; Tomar, 2000) [37, 36].

The percentage of added phosphate adsorbed (Xad) and distribution coefficient (Kd) decreased with increasing solution phosphorus concentration (Table No.2), thereby indicating that the affinity of aluminium, iron and clay for phosphate decreased with fractional surface coverage by phosphate or with increasing concentration of phosphorus in solution phase. Higher values of Kd are indicative of more efficient removal of phosphate from solution by sorbents (aluminium, iron and clay) due to higher affinity of phosphate for sorbents than for solvent (water). Further, Kd decreased with increasing amount of phosphate aluminium and iron and clay for phosphorus decreased with increasing x/m or fractional surface coverage by phosphate. (Chand and Tomer, 2009) [11-12].

Table 1: Phosphorus adsorption of forest soils

Districts	Solution of P concentration (ppm)				Average
	10	25	50	100	
Tuensang	99.998	249.950	498.400	977.800	456.537
Kohima	99.996	249.650	495.750	857.500	425.724
Kiphire	99.997	249.890	498.200	865.000	428.272
Mokokchung	99.995	249.800	498.500	898.000	436.574
Wokha	99.998	249.890	498.700	947.800	449.197
Peren	99.997	249.450	488.000	697.500	383.736
Zunhaboto	99.978	249.655	493.750	892.600	433.996
Longleng	99.925	249.615	492.700	842.300	421.135
Dimapur	99.929	248.700	482.300	767.550	399.620
Phek	99.220	211.600	375.600	738.500	356.230
Mon	99.670	249.160	488.00	887.700	431.133

Table 2: Initial (C_0) percentage of added phosphorus adsorbed (Xad) and distribution coefficient (Kd) in different forest soils

Districts		Solution P concentration (ppm)			
		10	25	50	100
Tuensang	Xad	99.998	99.980	99.680	97.780
	Kd	49.999	49.898	2.913	0.348
Kohima	Xad	99.996	99.860	99.150	85.750
	Kd	24.999	7.133	1.166	0.060
Kiphire	Xad	99.997	99.956	99.640	86.500
	Kd	33.332	22.717	2.768	0.064
Mokokchung	Xad	99.995	99.920	99.700	89.800
	Kd	19.999	12.490	3.323	0.088
Wokha	Xad	99.998	99.956	99.740	94.780
	Kd	39.999	22.717	3.836	0.182
Peren	Xad	99.997	99.780	97.600	69.750
	Kd	28.570	4.535	0.407	0.023
Zunheboto	Xad	99.978	99.862	98.750	89.260
	Kd	45.445	7.236	0.790	0.083
Longleng	Xad	99.925	99.846	98.540	84.230
	Kd	13.327	6.484	0.675	0.053
Dimapur	Xad	99.929	99.480	96.460	76.755
	Kd	14.075	1.913	0.272	0.033
Phek	Xad	99.220	84.640	75.120	73.850
	Kd	1.272	0.055	0.030	0.028
Mon	Xad	99.670	99.664	97.600	88.770
	Kd	3.020	2.966	0.407	0.079

Phosphate adsorption cultivated soils

Phosphate adsorption (x/m) in cultivated soils also increased with increasing solution P concentration. The highest amount of phosphate was adsorbed by Longleng soils with an average of 457.06 ppm and the lowest amount was observed in Kipheri soil with an average of 293.16 ppm (Table No.3). The possible reason might be due to low pH of Longleng as compared to Kipheri soils for phosphorus sorption which increases with decrease in pH (Wani and Bhat, 2010) [38] and higher amount of clay as compared to Kiphire as sorption is also affected by the quantity and mineralogy of clay fraction (Upadhyay *et al*., 1993; and Tomar, 2000) [37, 36].

The value of distribution coefficient (Kd), which indicates the relative affinity of adsorbate to adsorbent and solvent, is a measure of the extent to which an iron is removed from the solution by the soil. The Kd values, in general, decreased with increasing amount of phosphorus added. Kd value was highest (49.99) in Kohima and Zunheboto soil of 10 ppm concentration solution while lowest value (0.01) was obtained in Mon and Kiphire soil of 100 ppm concentration solution (Table No. 4). Also it was found that the value of Xad decreased with increase in concentration of added phosphorus in all soils due to decrease in affinity of soil for phosphorus with fractional surface coverage by phosphorus. The highest value (99.98 %) was observed in Kohima, Tuensang and Zunheboto of 100 ppm concentration solution and lowest value (43.3%) was found in Kiphire soil of 100 ppm concentration solution (Wani and Bhat, 2010) [38].

Table 3: Phosphorus adsorption of cultivated soils

Districts	Solution of P concentration (ppm)				Average
	10	25	50	100	
Tunsang	99.98	249.49	466.00	771.50	396.74
Kohima	99.98	249.25	494.95	746.60	397.70
Kiphire	99.55	248.77	391.30	433.00	293.16
Mokochung	99.94	249.15	486.50	801.00	409.15
Wokha	99.95	249.75	492.50	848.00	422.55
Peren	99.58	228.50	437.40	615.50	345.25
Zunheboto	99.98	249.21	493.70	966.10	452.25
Longleng	99.974	249.49	497.79	980.97	457.06
Dimapur	99.18	207.30	362.60	624.00	323.27
Phek	99.97	249.21	478.00	699.60	381.69
Mon	99.97	248.00	440.20	551.00	334.79

Table 4: Initial (C_0) percentage of added phosphorus adsorbed (Xad) and distribution coefficient (Kd) in different cultivated soils

Districts		Solution P concentration (ppm)			
		10	25	50	100
Kohima	Xad	99.98	99.70	98.99	74.66
	Kd	49.99	3.32	0.98	0.03
Dimapur	Xad	99.18	82.92	72.52	62.40
	Kd	1.20	0.05	0.03	0.02
Phek	Xad	99.97	99.68	95.60	69.96
	Kd	31.24	3.15	0.22	0.02
Peren	Xad	99.58	91.40	87.48	61.55
	Kd	2.37	0.11	0.07	0.02
Tuensang	Xad	99.98	99.80	93.20	77.15
	Kd	39.99	4.89	0.14	0.03
Longleng	Xad	99.97	99.80	99.56	98.10
	Kd	38.45	4.89	2.25	0.52
Mon	Xad	99.97	99.20	88.04	55.10
	Kd	33.32	1.24	0.07	0.01
Wokha	Xad	99.95	99.90	98.50	84.80
	Kd	19.22	9.99	0.66	0.06
Zunheboto	Xad	99.98	99.68	98.74	96.61
	Kd	49.99	3.14	0.78	0.28
Mokokchung	Xad	99.94	99.66	97.30	80.10
	Kd	16.38	2.93	0.36	0.04
Kiphire	Xad	99.55	99.51	78.26	43.30
	Kd	2.21	1.99	0.04	0.01

Adsorption isotherms and their correlation with soil properties

Adsorption isotherm equations (Langmuir and Freundlich) have been used worldwide to characterise the phosphorus status of soils (Shailaja and Sahrawat 1990; Anghinoni *et al*., 1996; Bikram and Das, 2007) [31, 1, 6]. The adsorption data of phosphate were fitted in Langmuir and freundlich equations to predict the behaviour of phosphate adsorbed by soils. Adsorption data were plotted according to linear form of Langmuir equation {C *vs* C/ (x/m)}and Freundlich equation (log C *vs* Log x/m) for eleven soil sample each for cultivated and forest soils. Langmuir and Freundlich equations gave a good fit for phosphorus adsorption data in the present study (Anghnoni *et al*., 1996) [1], Quang *et al*., (1996) [30] and Thakur *et al*., (2004) [34].

A) Langmuir equation

The Langmuir equation was linearly correlated with r> 0.73 indicating apparent high conformity of adsorption data to the Langmuir isotherm. The correlation coefficient of Langmuir adsorption equation (Table No.5) varied for forest and cultivated soils. The phosphorus adsorption maxima and constant related with bonding energy for forest and cultivated soils (Table No.6) had an average value of k = 8.12mL g^{-1} & b = 873.32 µg g^{-1} for forest soils and k = 3.05mL g^{-1} & b = 757.79 µg g^{-1} for cultivated soils. There was an exponential inverse relationship between b and k parameters for soils (Balluax and Peaslee, 1975) [3]. The bonding energy 'k' and 'b' was calculated from the slope and intercept values obtained from regression of the Langmuir equation.

In forest soils, 'k' was non-significantly correlated with soil properties (Table No.8) which indicated that the bonding energy constant is a site characteristic and is independent of the fractional composition of the soil (Haysom 1974), 'b'was negatively significant with pH (r = -0.67, P=0.05) and calcium (r = -0.62, P=0.05).

The non-significant correlations of organic carbon, CEC and clay with adsorption maxima may be attributed to the negative correlation of clay with organic carbon because the organic carbon and CEC were positively correlated (Chand and Tomar, 2009) [11-12]. A Positive and non-significant correlation of extractable aluminium with adsorption maxima and non-significant correlations of iron with all the constants of Langmuir and Freundlich were found due to counteracting effect of pH, because of its negative correlation with Extractable aluminium and iron (Freese *et al.*, 1995, and Majumdar *et al.*, 2005) [17, 24]. Inverse relation between pH and adsorption maxima was observed in forest soils.

Whereas, in cultivated soils (Table No. 8) 'k' was positively significant correlated with iron (r = 0.78) and pH was negative and significantly correlated (r = -0.66), other values were non-significant. The phosphorus adsorption maxima was positively significant with clay (r = 0.64) (Hoseini and Taleshmikaiel, 2013) [19] and negatively correlated with pH, this might be due to (i) decrease in pH which increase the electrostatic potential of the sorption plane and (ii) the dissolution of the sorption plane and release of soluble iron and aluminium hydrous oxide with further reduction in soil pH (Bohn *et al*., 1985) [7].

B) Freundlich equation

The correlation coefficient of freundlich equation (Table No.5) significantly differed for forest and cultivated soils.b The constants k and 1/n of Freundlich equation (Table No.7) ranged from 193.59 to 825.30 µg g^{-1} and 0.21 to 0.34 mL g^{-1} for forest soils respectively whereas for cultivated soils, 180.80 to 785.80 µg g^{-1} and 0.17 to 0.35 mL g^{-1} respectively, showing that soils differed in their adsorption characteristics. The k_f is dependent on the solution phosphorus concentration (Kuo & Lotse, 1974) [22] due to which value of k_f varied from soil to soil (Hussain *et al.,* 2003) [20]. The k_f negatively correlated with pH and positively non-significant with clay, available potassium, extractable iron & aluminium while the 1/n positively non-significant with EC, CEC, organic carbon available phosphorus & potassium, and extractable aluminium and negatively non-significant with extractable iron in forest soils (Table No. 8). On the other hand, in cultivated soils the (Table No.8) 1/n was positively significant with clay (r = 0.67, P = 0.05) and positively non-significant with EC, CEC, available nitrogen &phosphorus, also negatively non-significant with pH, calcium, organic carbon and available potassium and extractable iron and aluminium. The k_f was positively correlated with EC, CEC, clay, organic carbon, available nitrogen and phosphorus, negatively significant with pH (r = -0.71, P = 0.05,) and negatively non-significant with extractable aluminium, potassium and Calcium. Yuan and Lucas (1982) also found non-significant correlation between either the adsorption maxima or the slope term of the linear Freundlich equation and aluminium and iron individually or combined together.

Table 5: Correlation coefficients (r) of various adsorption equations for forest and cultivated soils

Districts	Langmuir adsorption isotherm (r)		Freundlich adsorption isotherm (r)	
	Forest	Cultivated	Forest	Cultivated
Kohima	0.99981**	0.99997**	0.86270**	0.95743**
Dimapur	0.99909**	0.98813**	0.99302**	0.95714**
Phek	0.88270**	0.99951**	0.93742**	0.98936**
Peren	0.99987**	0.99611**	0.97943**	0.97925**
Tuensang	0.99781**	0.99508**	-0.32070	0.99304**
Longleng	0.99954**	0.99506**	0.98515**	0.99778**
Mon	0.99677**	0.99948**	0.99085**	0.99013**
Wokha	0.99981**	0.99949**	-0.17440	0.98641**
Zunheboto	0.99900**	0.98507**	0.99648**	0.99326**
Mokokchung	0.99995**	0.99924**	0.19647	0.97736**
Kipheri	0.99996**	0.99981**	0.28000	0.92551**

**=significant at 0.01 level of probability

Table 6: Constants of Langmuir isotherms for forest and cultivated soils

Districts	Forest soil		Cultivated soil	
	Langmuir b (µg g^{-1})	Langmuir k (mL g^{-1})	Langmuir b (µg g^{-1})	Langmuir k (mL g^{-1})
Kohima	865.81	6.99	750.60	7.10
Dimapur	781.13	2.18	699.01	0.14
Phek	839.72	0.13	707.00	2.55
Peren	702.10	4.72	649.80	0.42
Tuensang	1002.30	15.97	788.70	1.34
Longleng	853.48	4.48	1046.40	7.16
Mon	922.97	1.98	556.20	1.75
Wokha	957.87	17.56	859.00	4.67
Zunheboto	908.13	4.88	1029.30	3.41
Mokokchung	904.22	14.02	814.50	2.70
Kiphire	868.85	16.37	435.20	2.27
Average	873.32	8.12	757.79	3.05

Table 7: Constants of Freundlich isotherms in forest and cultivated soils

Districts	Forest soil		Cultivated soil	
	Fruendlich k_f (µg g^{-1})	Fruendlich 1/n (mL g^{-1})	Freundlich k_f (µg g^{-1})	Freundlich (1/n)(mL g^{-1})
Kohima	505.81	0.26	435.40	0.22
Dimapur	380.85	0.25	180.80	0.28
Phek	193.59	0.31	374.90	0.21
Peren	395.36	0.21	226.70	0.27
Tuensang	825.30	0.29	392.90	0.21
Longleng	465.11	0.26	785.80	0.35
Mon	426.55	0.34	302.60	0.18
Wokha	701.98	0.28	480.40	0.25
Zunheboto	525.37	0.26	602.20	0.30
Mokokchung	584.43	0.27	412.40	0.26
Kiphire	560.52	0.23	241.20	0.17
Average	505.90	0.27	403.21	0.25

Table 8: Correlation of soil properties with Langmuir and freundlich isotherm constants for forest and cultivated soils

Soil Properties	Forest soil				Cultivated soil			
	Langmuir		Freundlich		Langmuir		Freundlich	
	b	k	k_f	(1/n)	b	k	k_f	(1/n)
pH	-0.67*	-0.33	-0.55	-0.29	-0.56	-0.66*	-0.71*	-0.18
EC	0.08	-0.52	-0.56	0.57	0.26	-0.04	0.31	0.06
CEC	0.20	-0.28	-0.08	0.18	0.37	0.44	0.50	0.46
Clay	0.07	-0.13	0.08	-0.19	0.64*	0.28	0.43	0.67*
Organic carbon	0.51	-0.08	-0.02	0.50	0.27	0.07	0.23	-0.15
Calcium	-0.62*	-0.18	-0.18	-0.52	-0.60	-0.13	-0.31	-0.47
Available N	0.13	-0.20	0.07	-0.13	0.52	0.03	0.42	0.43
Available P	0.24	-0.15	-0.01	0.32	0.05	0.19	0.31	0.19
Available K	0.38	0.00	0.12	0.13	0.05	-0.37	-0.17	-0.10
Extractable Fe	0.22	0.19	0.20	-0.11	0.18	0.78**	0.11	-0.11
Extractable Al	0.32	0.46	0.37	0.04	0.05	0.03	-0.01	-0.11

**= significant at 0.01 level of probability;
*= significant at 0.05 level of probability; while others are non-significant

Conclusion

From the findings of present investigation, it can be concluded that the different soils of Nagaland are acidic in nature which affects the phosphorus availability to plants due to phosphorus fixation, as acids soils have higher amount of extractable aluminium and iron there by higher adsorption capacity and thus need phosphorus management in order to reduce phosphorus deficiency in plants. The phosphorus adsorption was found more in forest soil than compared to cultivated through paired t-test. This might be due to higher in extractable aluminium and lower in pH in forest soils as compared to cultivated soils.

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