Int.J.Curr.Microbiol.App.Sci (2020) *9*(5): 2354-2360

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 5 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.905.268

A Study on Phosphorus Fixation Capacity in *Ultisol* Soil Order of North-Eastern India

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Keywords

Ultisol, Phosphorus fixation capacity, Phosphorus use efficiency, Phosphatic fertilizers

Article Info

Accepted:
18 April 2020
Available Online:
10 May 2020

A B S T R A C T

The availability of native phosphorus (P) in Northeast Indian *Ultisols*, one of the dominant agricultural soils in the region, is relatively low. Given that crop production in North Eastern region is dominated by low external input practices, native P remains important to plant P nutrition in many locations. A laboratory experiment was conducted in the College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya. The surface soil samples of 3 soil profiles were used in the study representing the soil order *Ultisol*. The physical and chemical attributes of the 3 profile soils along with the ability of the profiles to fix phosphorus (P) were determined in this investigation. The order *Ultisol* comprised of 3 profiles *viz.*, P1, P2 and P3 representing North-West-1 Jorhat (Assam), Mokokchung (Nagaland) and North-West-2Jorhat (Assam), respectively. Results from the incubation experiment (Plevels 0, 25, 50, 100, 200, 300,400, 500, 600, 700 and 800 ppm for 24 h) indicated that phosphorus fixation capacity (PFC) (µg P g^{-1} soil) ranged from 103 to 577 for the soil profiles of *Ultisol*. The maximum PFC was obtained at the P application dose (µg g^{-1} soil) for Mokokchung (Nagaland) at 600.The higher percent P fixed was in order of Mokokchung, Nagaland (96.1) >North-West-2Jorhat, Assam (84.3)>North-West-1Jorhat, Assam (51.4). The bulk density (BD), maximum water holding capacity (MWHC) and clay content ranged from 0.95 to 1.16 g cc^{-1}, 36.0 to 54.9% and 10 to 55%, respectively among the three soil profiles. The content of soil organic carbon (SOC), soil available nitrogen, phosphorus and potassium (Avl.N, Avl.P and Avl.K, respectively) ranged from 1.0 to 2.0%, 176 to 216 kg ha^{-1}, 7.6 to 62.1 kg $ha^{-1}$and 108 to 205 kg ha^{-1}, respectively. Soil pH, exchangeable aluminium (Ex.Al), readily soluble aluminium (RS.Al), exchangeable calcium+magnesium (Ex.Ca+Mg) and base saturation (BS) ranged from 4.2 to 4.5, 0.46 to 2.81meq $100g^{-1}$ soil, 34.6 to 384 mg kg^{-1} soil, 1.7 to 2.10meq $100g^{-1}$ soil, 16.2 to 30.2%, respectively. The soils of Mokokchung (Nagaland) showed the highest percentage of P fixation andNorth-West-1Jorhat (Assam), the least among the three profiles. It is utmost important to enhance the phosphorus use efficiency of these soils, which can be accomplished with the application of phosphatic fertilizers judiciously as the P reserves are depleting rapidly.

Introduction

Ultisols are a group of soil order which occur sporadically in a global band that lies almost completely between latitudes of 40"N and40"S. They are prominent in the areas located in the south- eastern United States, northeastern Australia, southwest China, east central Africa, the islands of south-east Asia, and the northeast India. Of the earth's total land mass area, about 5.6 percent (730 million hectares) area is *Ultisols* (Soil Geography Unit, 1972). *Ultisols* are often characterized by highly weathered soils having low phosphorus (P) stocks and high capacity for P fixation (Roy *et al.,* 2016).These soils are rich in iron and aluminum oxides that fix P added in fertilizers before it can be utilized by the crops (Palm *et al.,* 2007; Syers *et al.*, 2008).These soils have low levels of chemical soil fertility, often caused by low levels of available phosphorus (P) (Buresh *et al.,* 1997; Sanchez, 2002). Furthermore, *Ultisol* soils are able to fix large quantities of fertilizer P, which is considered a main factor lowering the recovery of fertilizer P by plants. The low P status of these soils is in sharp contrast to the situation in some areas of the western world where as a result of repeated application of animal manure and P fertilizers, soils have become P saturated. Despite the often large P retention capacity of soils, excessive applications of P may lead to P leaching to ground- and surface-waters and may contribute to eutrophication of surface waters (Smil, 2000).

The North Eastern region (NER) of India has the largest landmass of acid soils, followed by the neighbouring states of West Bengal, Bihar and Orissa. It is estimated that approximately 91% soils are acidic, and nearly 65% soils are suffering from strong acidity (pH < 5.5) in NE India (Sharma *et al.,* 2006).

The causes of low P-use efficiency (PUE) in highly weathered humid sub-tropical soils of NE India are Al and Fe induced P deficiency (Sharma *et al.*, 2006). The process of P fixation accelerates the problem leading to low PUE in these soils. Since, there lies spatial variability of P availability in soils, single blanket recommendation is not appropriate, instead site-specific nutrient management is the need of the hour.

Materials and Methods

The representative soil profiles of the order *Ultisol* of NE India considered in this study were from different locations *viz*. North-West-1Jorhat, Assam (P1); Mokokchung, Nagaland; (P2) and North-West-2Jorhat, Assam (P3). The soil samples from surface layers (0-15 cm depth) were collected for laboratory analysis and some basic physico-chemical properties (Soil texture, soil colour, pH, SOC, Available. N, P, K, Exchangeable Ca and Mg, Readily soluble Al, CEC, Exchangeable aluminum, Base saturation) of the soils were determined (Fig. 1).

An amount of 5 g soil was taken in each conical flask (capacity 100 ml). The graded levels of P (0, 25, 50, 100, 200,300, 400, 500, 600,700 and 800 mg P_2O_5 kg^{-1} soil) were imposed to each profile soil maintaining 3 replicate flasks. Immediately after addition of P levels, 25 ml of 0.01 M $CaCl_2$solution was added to each conical flask and these flasks were incubated for 24 h in a gyratory shaker at rpm 120.

After incubation, soil suspension was filtered through Whatman filter paper no. 42 and then the concentration of P in the clears upernatant was determined using stannous chloride blue colour method. The percent P fixed was calculated by dividing fixed P amount with added P amount and multiplying it with 100. The formula used to calculate percent P fixed is given below:

$$\%\ P\ fixed = \frac{Fixed\ P}{Added\ P} \times 100$$

Quantity of fixed P = (Quantity of P applied – Quantity of P in solution – Quantity of solution P in blank)

Statistical analysis

Univariate statistics were performed using SPSS v12.0 (Statistical Packages for Social Science Inc., Chicago, IL, USA). Means were tested at a significant level of P≤0.05using Tukey's HSD test for multiple pair-wise comparisons among means.

Results and Discussion

Physico-chemical properties of the profiles

The colour of the soils in dry conditions ranged from light olive brown to yellowish brown *viz.*, 2.5Y 5/4 to 10YR 5/4 and under moist conditions ranged from olive brown to dark brown *viz.*, 2.5 Y 4/4 to 10YR 3/3. The sand content varied from 35 to 85% and clay content ranged from 10 to 55%. The maximum clay content was 55% in P2 and minimum was 10% in P3. The values of silt content varied from 5-10%. The rapid fixation of P by clay minerals is attributed to its reaction with readily available Fe and AI in soils (Tening *et al.*, 2013; Goundar *et al.*, 2014). The texture varied from loamy sand to clay. The values of BD ranged from 0.95 to 1.16 g cc^{-1} among the 3 profiles and the highest was found in P3. The water holding capacity ranged from 36.0% in P3 to a maximum of 54.9% in P2. Among all the 3 profiles, P3 had the least capacity to hold water.

Soil pH values ranged from 4.22 to 4.56 that are from extremely acidic to very strongly acidic. The pH of P3profile soil was the highest and P1 soil was the lowest among *Ultisols*. Most soils of the tropics (predominantly *Ultisols*) are acidic in nature due to high rainfall and high weathering that lead to basic cations removal from the soil. In such soils, acidic cations such as Al and Fe predominate, and depending on soil pH, they fix the applied inorganic P (Adnan *et al.*, 2003). The PFC of soils increased with decrease in soil pH, which was evident from the significant negative correlation (r= -0.58**) between soil pH and PFC in this study. The similar relationship between PFC and soil pH was previously noticed (Kanwar and Grewal, 1990; Naidu *et al.*, 1990). Soil organic carbon varied from 1.0%- 2.0%. The content of SOC was the highest (2.0%) for P2 and the least (1.0%) was for P3. The highest percent SOC may be due to the clayey nature of soil from P2. The content of soil Avl.N ranged from 176 kg ha^{-1} to 216 kg ha^{-1} and P2 contained maximum Avl.N and minimum was for P3 soil. The content of Avl.P varied from 7.6 kg ha^{-1} to 62.1 kg ha^{-1}. The highest P was found in P1 soils and the lowest in P3 soils. The P2 soil contained maximum Avl.K (205 kg ha^{-1}) and the minimum content (108 kg ha^{-1}) for P3 soils. The P3 had the least amount of Avl.K among all the profiles. Exchangeable alumina (Ex. Al) ranged from 0.46 meq 100^{-1}g to 2.81 meq 100^{-1}g. The P3 soil had the highest amount and P1 had the least amount of Ex.Al. The higher content of readily soluble alumina was due to low soil pH of the soil. The P2 soils contained the highest amount of readily soluble alumina (384 mg kg^{-1}) and the lowest (34.6 mg kg^{-1}) was P4 soil. In addition to very low soil pH, the high amount of Ex.Al (41.4 to 253 mg kg^{-1} soil) and RS.Al (34.6 to 384 mg kg^{-1} soil) might be the responsible factor for higher PFC values. The content of DTPA-Fe varied from 20.3 mg kg^{-1} to 24.5 mg kg^{-1}.The content of Exch.Ca+Mg ranged from 1.7 meq 100^{-1}g soil to 2.1 meq 100^{-1}g soil. The values of CEC ranged from 6.6 to 14.2 cmol kg^{-1} and the percent BS ranged from 16.2% to 30.2% for the 3 soil profiles belonging to *Ultisol*. Higher values of BS was in P3 due to high CEC and high amount of Ex.Ca+Mg and low BS values was in P2due to low amount of Ex.Ca+Mg (Table 1)**.**

Soil profiles and their phosphate fixation capacity

The values of maximum quantity of applied P fixed and % P fixed ranged from 102.8 to 576.7 µg P g^{-1} soil and 51.4 to 96.1%, respectively for *Ultisol* profiles P1, P2 and P3 (Fig. 2). The P dose at which maximum PFC value obtained for P1, P2 and P3 profiles were 200, 600 and 400 µg P g^{-1} soil, respectively (Fig. 2).

Table.1 Physico-chemical properties of surface soils of the three profiles of *Ultisol*

Profile		P1	P2	P3
Soil colour	Dry	2.5 YR 6/4	10 YR 5/4	2.5 Y 5/4
	Moist	2.5 Y 4/4	7.5 YR 3/4	10 YR 3/3
Coarse sand (%)		14.7	3.85	11.85
Fine sand (%)		65.3	31.15	73.15
Silt (%)		5	10	5
Clay (%)		15	55	10
Textural Class		sandy loam	clay	loamy sand
BD (g cc^{-1})		1.14±0.005e	0.95±0.005b	1.16±0.011ef
MWHC (%)		36.3±0.88abc	54.9±0.404e	36.0±0.69abc
FC (%)		26.3±0.12bc	41.2±0.29g	27.0±0.52c
pH		4.22±0.058a	4.33±0.036a	4.56±0.066bc
SOC (%)		1.20±0.057bc	2.00±0.288e	1.00±0.057ab
Avl.N (kg ha^{-1})		210±4.9cd	216.30±4.0d	176±5.7b
Avl.P (kg ha^{-1})		62.1±0.55g	9.20±0.529bc	7.60±0.321ab
Avl.K (kg ha^{-1})		195±2.06c	205±4.0cd	108±1.334cd
DTPA-Fe (mg kg^{-1} soil)		21.20±1.86a	24.46±2.08ab	20.26±0.58a
Ex.Al (meq 100 $^{-1}$ soil)		0.46±0.022d	1.06±0.030e	2.81±0.100f
RS.Al (mg kg^{-1} soil)		34.6±1.73a	384±5.8e	318±5.7c
Ex.Ca+Mg [cmol (P^+) kg^{-1} soil]		2.10±0.231a	1.80±0.115a	1.70±0.0578a
CEC [cmol (P^+) kg^{-1} soil]		8.90±0.923ab	14.2±1.27cd	6.60±0.058a
BS (%)		28.9±1.70bc	16.2±1.13a	30.2±2.86bc

Values ± means, n = 3; Within a column (parameter) values followed by different letters are statistically significant as determined by one-way ANOVA incorporating Tukey's HSD test for multiple pair-wise comparisons among means. BD – bulk density, MWHC – maximum water holding capacity, FC– field capacity, SOC – soil organic carbon, Avl.N – soil available N, Avl.P – soil available P, Avl.K – soil available K, DTPA-Fe – soil available Fe, Ex.Al – exchangeable aluminium, RSA – readily soluble aluminium, Ex.Ca+Mg – exchangeable ca+Mg, CEC – cation exchange capacity and BS – base saturation.

Table.2 The maximum quantity of applied P fixed at the P dose where the highest % P fixed in soils of the three profiles

Profile	Soil order	Maximum quantity of applied P fixed (µg P g^{-1} soil)	P fixed (%)	P dose at which max. PFC point achieved (µg P g^{-1} soil)
P1	*Ultisol*	102.8±3.1b	51.4	200
P2		576.7±4.6i	96.1	600
P3		337.0±4.0f	84.3	400

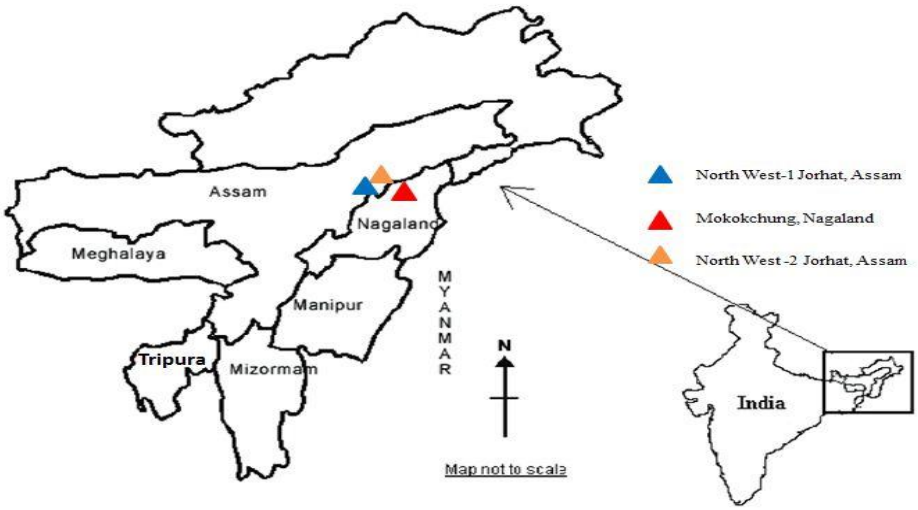

Fig.1 Sampling locations of the study area

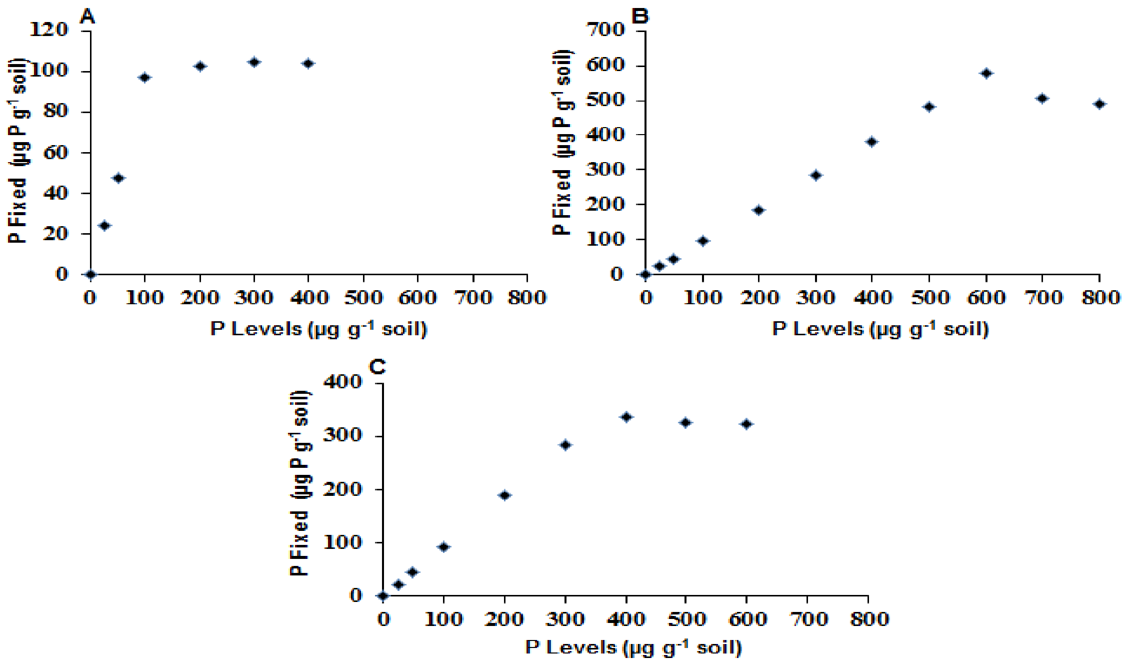

Fig.2 Phosphate fixation capacity curves of *Ultisols* representing 3 soil profiles (A) Profile 1, (B) Profile 2 and (C) Profile 3

Ultisols are expected to show a high affinity for P since they are dominated by oxyhydroxides and kaolinite in soil. Our findings indicated that *Ultisol* order had the highest PFC which ranged from 103 to 577 µg P g^{-1} soil and % P fixed ranged from 85.1 to 96.1. In past, Syers *et al.,* (1971) reported such higher PFC of highly weathered soils such as *Oxisols* and *Ultisols.* The relatively lesser quantity of applied P fixed (103 µg P g^{-1} soil) and lesser % P fixed (51.4) by P1 soil in comparison to that in soils of P2 and P3 was an exception. The possible reason was that the Profile 1 falls within a commercial Tea garden (located in North West-1, Jorhat) where inorganic fertilizers were applied regularly since last 50 years that lead to accumulation of P in soil which might partially saturated the P fixation sites and as a result higher content of soil Avl.P content (Table 2).

Because of build-up of inorganic P pools which could satisfy the P adsorption sites of clay minerals and Al and Fe oxides and hydroxides in P1 soils, the PFC was found lower (only 102 µg g^{-1} soil) as compared to the range (337 to 576 µg g^{-1} so) for P2 and P3 soils. This justification could be further supported by higher soil Avl.P content (62.1 kg ha^{-1}) for P1 soil as against the range of soil Avl.P content (7.6 to 9.2 kg ha^{-1}) for P2 and P3 soil. The accumulation of P due to continuous application of inorganic P fertilizers in peach orchard under humid subtropics of Eastern Himalayas was recently report by Surchand-Singh *et al.,* (2017). So, it can be mentioned that the right dose of P with suitable management practices (liming with organic manures) may offset the P deficiency or toxicity problem in acid soils of tropics and subtropics (Franklin, 2012).

Out of three soil profiles, Mokokchung (Nagaland) possess very high PFC and North-West-1Jorhat (Assam), possesses relatively the lowest PFC.

The higher percent P fixed was in the order of Mokokchung, Nagaland (96.1) >North-West-2Jorhat, Assam (84.3)>North-West-1Jorhat, Assam (51.4). For agricultural practice, the low-input strategy is recommended. Frequent applications at modest rates are more effective than less frequent applications at higher rates.

So, the PFC findings of this study calls for an urgent need to correct the existing blanket recommended dose of phosphatic fertilizer. There is a need for formulation of suitable nutrient management practice that can improve the status of these soil attributes so as to reduce the PFC and enhancing the PUE of soil. Findings of this investigation revealed the fundamental understanding on PFC of *Ultisol* of NE India and based on which efficient P management practice needs to be formulated and tested for effectiveness against the existing blanket recommendation of phosphatic fertilizer.

Acknowledgements

The laboratory facility provided by the School of Natural Resource Management, College of Post Graduate studies in Agricultural Sciences, Umiam under Central Agricultural University, Imphal for carrying out soil analysis for the present study is duly acknowledged.

References

Adnan, A., Mavinic, D.S., and Koch, F.A., 2003. Pilot-scale study of phosphorus recovery through struvite crystallization-examining to process feasibility. J. Environ. Eng. Sci., 2: 315–24.

Buresh, R.J., Smithson, P.C., Hellums, D.T., 1997. Building soil phosphorus capital in Africa. In: Buresh, R.J., Sanchez, P.A. (Eds.), Replenishing Soil Fertility in Africa. SSSA Special

Publication, Madison, WI, USA, pp. 111–149.
Franklin, O.N., 2012. Ameliorating soil acidity in Ghana: A concise review of approaches. J. Sci. Technol., 2: 1-9.
Goundar, M.S., Morrison, R.J., and Togamana, C., 2014. Phosphorus requirements of some selected soil types in the Fiji sugarcanebelt. South Pacific J. Nat. Applied Sci., 32 (1): 1-10.
Kanwar, J.S., and Grewal, J., 1990. Phosphorus fixation in Indian soils. Second edition. Indian Council of Agricultural Research, New Delhi, India.
Naidu, R., Syers, J.K., Tillman, R.W., and Kirkman, J.H., 1990. Effect of liming on phosphate soption by acid soils. Soil Sci., 41: 163 -175.
Palm, C., Sanchez, P., Ahamed, S., Awiti, A., 2007. Soils: a contemporary perspective. Annu. Rev. Environ. Resour. 32, 99–129.
Roy, E.D., Richards, P.D., Martinelli, L.A., Della Coletta, L., Machado Lins, S.R., Ferraz Vazquez, F., Willig, E., Spera, S., Van Wey, L.K., Porder, S., 2016. The phosphorus cost of agricultural intensification in the tropics. Nat. Plants 2, 16043.
Sanchez, P.A., 2002. Soil fertility and hunger in Africa. Science. 295, 2019–2020.
Sharma, P.D., Baruah, T.C., Maji, A.K., and Patiram, 2006. Management of acid soils of NEH Region. Indian Council of Agricultural Research, KrishiAnusandhanBhavan, Pusa Campus, New Delhi, pp. 45-60.
Smil, V., 2000. Phosphorus in the environment: natural flows and human interferences. Ann. Rev. Energy Environ. 25, 53–88.
Soil Geography Unit, 1972. Soils ofthe World. Map. USDA Soil Conservation Service, Washington, D.C.
Surchand-Singh K., Hazarika S., Thakuria D., Bordoloi L.J., and Deka B.C., 2017. Long-term management impact on soil quality under Peach (*Prunis persica* L.) orchard in humid subtropics of Eastern Himalayas. J. Indian Soc. Soil Sci., 65(4): 401-409.
Syers, J.K., Evans, T.D., Williams, D.H., and Murdock, J.T., 1971. Phosphate sorption parameters of representative soils from Rio Grande do sul, Brazil. Soil Sci., 112: 267-275.
Syers, J.K., Johnston, A.E., Curtin, D., 2008. Efficiency of soil and fertilizer phosphorus use: Reconciling changing concepts of soil phosphorus behavior with agronomic information. FAO Fertilizer and Plant Nutrition Bulletin. Food and Agriculture Organization of the United Nations, pp. 18.
Tening, A.S., Foba-Tendo, J.N., Yakum-Ntaw, S.Y., and Tchuenteu, F., 2013. Phosphorus fixing capacity of a volcanic soil on the slope of mount Cameroon. Agric. Biol. J. N. Am., 4(3): 166-174.

How to cite this article:

Bidisha Borpatragohain, Dwipendra Thakuria, Samarendra Hazarika, Ashish Rai, Rashmi Priyadarshi and Subhra Sahoo. 2020. A Study on Phosphorus Fixation Capacity in *Ultisol* Soil Order of North-Eastern India. *Int.J.Curr.Microbiol.App.Sci.* 9(05): 2354-2360.
doi: https://doi.org/10.20546/ijcmas.2020.905.268