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Forms and status of phosphorus in acid soils of Kakching district, Manipur (India)

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Abstract
Twenty soil samples were collected from different locations of Kakching district, Manipur for this experiment. All the investigated soil samples were acidic in nature with a mean value pH 4.98. There was wide variation of organic carbon content with a mean value of 16.76 g kg^{-1}. The mean EC, Cation exchange capacity, available nitrogen, available potassium were 0.22 dSm^{-1}, 14.01 [cmol(P+)kg^{-} '], 212.66 kg ha^{-1}, 114.75 kg ha^{-1}, respectively. For the soil studied the amount of inorganic P fractions was in the order: Red-P> Fe-P> Al-P>Occl-P>Ca-P>Sal-P. Al-P and Fe-P were negatively correlated with pH (r = -0.446*) and (r=-0.447*) respectively. Saloid P was positively correlated with E.C. (r =0.512*) and CEC (r=0.456*) along with Red-P (r =0.555*). Occl-P was negatively correlated with available potassium (r = -0.505*) and positively and significantly correlated pH (r=0.583**)and CEC (r=0.577**). Ca-P was positively and significantly correlated with E.C (r = 0.523*), sand fraction (r=0.500*), clay fraction (r = 0.583**) and CEC (r = 0.605**). Sal-P was positively correlated with Ca-P and negatively correlated with Org-P (r=0.520* and -0.547*). Fe-P was positively correlated with Tot-P (r=0.540*) and Red-P with Ca-P (r=0.628**). Finally, the Tot-P was positively correlated with Org-P (r=0.882**).

Keywords: P fractions, soil properties, correlation, acid soil

1. Introduction
Phosphorus is referred to as the "king-pin" in Indian agriculture and also as "energy currency" of the plants. It is one of the three primary nutrients and the second most important element after nitrogen for growth and development of every plants. Phosphorus aids in plant growth by enabling photosynthesis (energy transformation), building nucleic acids, proteins and enzyme, facilitating root growth, strengthening stems and stalks and also improving flower formation and seed production. Phosphorus is taken up from the soil solution by plant roots principally as primary orthophosphate ions ($H_2PO_4^-$, pH- 6.5) and to a lesser extent as secondary orthophosphate ions (HPO_4^{2-}, pH- 7.2). Phosphorus is important for pollination and pollen germination. It also helps in potassium ion translocation, stomatal opening as well it is essential for translocation of sugar. The North-East Region of India has geographical area of 26.3 million hectares and almost 85% of the soils are moderate to strongly acidic. Phosphorus deficiency is the main limiting factor for crop production in acidic soils and therefore, requires the application of phosphatic fertilizers for optimum plant growth and production of food and fibre. An increase in organic phosphorus content decreases the net mineralization but C: P ratio of < 200 enhances organic phosphorus mineralization. The two major forms in which phosphorus is available in the soil are inorganic and organic forms. Indian soils are generally contains 44 to 3580 mg kg^{-1} of total P (Suresh Kumar, 1999) [20] and traces to 2160 mg kg^{-1} of organic P. The organic P can be seen mostly as humus and many other organic materials. The inorganic P occurs in fixed forms or combinations with various forms of AI, Fe, Mg, Ca and other elements mostly unsuitable and unavailable to the plants. Inorganic P (Pi) is the most dominant form of soil P, which constitutes 20-80% of the total P in surface layer (Tomar, 2003). The inorganic phosphorus fraction in soil has been categorized into readily soluble and insoluble categories. 94-99% of the total P is constituted by the insoluble fractions which are not readily available to the plants. This fractions are mostly attached to Fe and Al in acid soils and to Ca in slightly acidic to alkaline soils.

2. Materials and Methods
Surface soil samples (0-15cm) for Investigation were collected from rice cultivated farmer fields of Kakching District of Manipur.

Soil samples collected from different locations of the districts were collected which were dried under shade and further ground in mortar and pestle and passed through 2 mm sieve. These samples were subjected for further analysis for correlation with physico-chemical characteristic. The pH (1:2.5 suspension) and EC (1:2 suspension) were determined as outlined by Jackson, 1973 [10], CEC (Borah *et al*., 1987), organic carbon (Walkley and Black, 1934) [23], available nitrogen (Subbiah and Asija, 1956) [19], available potassium (Jackson, 1973) [10], calcium and magnesium (Chopra and Kanwar, 1976) [3] and soil texture (Mechanical analysis, N.B.S.S. and LUP) for each location was calculated**.** Total phosphorus content of soil sample was determined by Wet digestion method (Jackson, 1973) [10].

3. Results and Discussion

Table 1. denotes the physic-chemical properties of the soils from different locations. According to the particle size analysis, mean clay percentage was found to be 56.95%, mean sand percentage was found to be 17.69 and mean silt percentage was found to be 25.37%. The results showed that the mean values of all physico-chemical properties were found to be 4.98 for pH, 0.22 dSm^{-1} for EC, 14.01 [cmol (p^{+}) kg^{-1}] for CEC, 16.76 g kg^{-1} for organic carbon, 212.66 kg ha^{-1} for available nitrogen, 114.75 kg ha^{-1} for available potassium, 2.81 [cmol (p^{+}) kg^{-1}] and 1.86 [cmol (p^{+}) kg^{-1}] for calcium and magnesium, respectively.

3.1 Inorganic Phosphorus

3.1.1 Saloid phosphorus (Sal-P)

The saloid P content in the soils varied from 4.50 to 15.00 ppm. The average value of saloid P was 7.90 ppm of the studied soils. Saloid P was highly and significantly correlated (Table 3) with E.C (r =0.512*) and C.E.C (r=0.456*) (Malakar *et al*., 2015) [16]. Sal-P was positively and significantly correlated with Ca-P (r=0.520*) and negatively correlated with Org-P (-0.547*).

3.1.2 Aluminium phosphorus (Al-P)

Al-P content in the soils studied was ranged from 25.00 ppm to 85.00 ppm. The mean value of AI-P was 53.10 ppm. Al-P content was and negatively and significantly correlated (Table 3) with pH (r = -0.446*) and positively significantly correlated with CEC (r = 0.699**).

3.1.3 Iron phosphorus (Fe-P)

Fe-P in the soils studied ranged from 40.50 ppm to 112.50 ppm with a mean of 76.26 ppm. Fe-P content was negatively and significantly correlated (Table 3) with pH (r= -0.447*).

3.1.4 Reductant Soluble phosphorus (Red-P)

Red-P in the studied soils ranged from 51.25 ppm to 110.00 ppm with a mean value of 80.00 ppm. Red-P was positively significantly correlated with CEC (r =0.555*). A positive and highly significant correlation existed between Red-P and Ca-P (0.628**).

3.1.5 Occluded phosphorus (Occl-P)

Occl-P content in the soil varied from 10.65 ppm to 33.83 ppm average value of Occl-P was 22.02 ppm. Occl-P was negatively and significantly correlated (Table 3) with available potassium (r = -0.505*) and positively and significantly correlated pH (r=0.583**) and CEC (r=0.577**).

3.1.6 Calcium phosphorus (Ca-P)

Amount of Ca-P ranged from 9.23 ppm to 33.20 ppm with a mean value of 21.60 ppm. Ca-P was positively and significantly correlated (Table 4.3) with E.C (r = 0.523* Fig. 11), sand fraction (r=0.500*), clay fraction (r = 0.583**) and CEC (r = 0.605**).

3.2 Organic Phosphorus

The organic-P content in the soil was found in the range from 205.00 ppm to 495.00 ppm with a mean value of 295.38 ppm.

3.3 Total Phosphorus

The total phosphorus content of the soils happened to range from 452.00 to 768.26 ppm. Tot-P was found highly significant with Org-P (r=0.882**)

3.4 Tables

Table 1: Physico-chemical properties of the experimental soil

Soil properties	Range	Mean
pH	4.58 - 5.67	4.98
EC (dSm^{-1})	0.14 - 0.31	0.22
CEC [cmol (p^{+}) kg^{-1}]	9.00 - 19.00	14.01
Org C (g kg^{-1})	10.55 - 26.60	16.76
Available N (kg ha^{-1})	75.26 - 305.50	212.66
Available K (kg ha^{-1})	49.63 - 160.50	114.75
Ca [cmol (p^{+}) kg^{-1}]	1.25 - 4.40	2.81
Mg [cmol (p^{+}) kg^{-1}]	0.15 - 4.30	1.86
Sand (%)	6.20 - 50.92	17.69
Silt (%)	8.18 - 42.50	25.37
Clay (%)	19.79 - 83.12	56.95

Table 2: Concentration of different Pfractons in the soils

Soil No.	ppm							
	Saloid-P	Al-P	Iron-P	Red-P	Occl-P	Ca-P	Org-P	Total-P
1	6.50	68.25	97.13	68.50	21.00	19.07	350.00	630.45
2	1.35	53.83	103.38	59.25	33.83	21.62	495.00	768.26
3	6.24	41.90	89.45	54.35	23.70	12.67	425.00	653.31
4	7.35	55.00	87.50	88.80	20.40	26.28	212.50	497.83
5	6.75	40.10	80.65	97.00	25.10	25.06	325.00	599.66
6	5.33	32.73	76.00	81.00	23.30	22.70	262.50	503.56
7	10.00	42.50	50.45	91.00	19.80	26.45	240.00	480.20
8	12.33	45.50	77.50	75.50	23.85	24.50	245.00	504.18
9	2.48	34.95	70.80	67.00	16.38	9.23	317.50	518.34
10	5.50	43.60	84.65	65.85	19.80	16.25	241.00	476.65
11	10.00	81.50	112.50	98.75	10.65	18.53	312.50	644.43
12	7.00	49.52	67.52	87.50	12.50	15.84	288.00	527.88
13	6.53	76.53	82.20	79.00	24.28	22.83	233.50	524.87

14	12.25	47.50	86.95	51.25	30.05	19.00	205.00	452.00
15	4.50	25.00	40.50	69.00	25.80	21.00	310.00	495.80
16	8.25	61.00	77.25	110.00	19.45	27.50	327.50	630.95
17	15.00	60.00	67.50	95.65	27.05	30.00	240.00	535.20
18	9.80	62.50	45.20	69.30	22.42	14.70	257.50	481.42
19	13.50	85.00	80.00	90.00	18.07	33.20	295.00	614.77
20	7.25	55.00	48.00	101.30	23.00	25.50	325.00	585.05
Mean	7.90	53.10	76.26	80.00	22.02	21.60	295.38	556.24

Table 3: Simple correlation co-efficient between the different forms of phosphorus and soil Properties

Sl. No.		Sal-P	Al-P	Fe-P	Red-P	Occl-P	Ca-P	Org-P	Tot-P
1	pH	-0.065	-0.446*	-0.447*	-0.131	0.583**	0.183	0.201	0.277
2	E.C.	0.512*	0.13	0.211	0.318	-0.091	0.523*	-0.174	-0.134
3	0.C.	-0.068	0.083	0.213	0.365	-0.309	-0.046	0.252	0.224
4	Av. N	-0.119	0.012	0.077	0.168	-0.315	-0.137	0.158	0.174
5	Av. K	-0.022	0.040	-0.301	0.237	-0.505*	-0.139	-0.018	0.831**
6	Sand	-0.04	0.189	-0.189	0.294	-0.16	0.500*	-0.211	0.442
7	Silt	0.104	-0.277	-0.137	-0.331	-0.306	-0.144	-0.295	0.272
8	Clay	-0.032	0.023	0.229	-0.026	-0.063	0.583**	0.344	0.079
9	Ca	0.017	0.025	-0.017	0.018	-0.233	-0.053	0.240	0.251
10	Mg	-0.029	0.053	0.469*	-0.216	0.112	-0.105	0.196	0.257
11	C.E.C.	0.456*	0.699**	0.185	0.555*	0.577**	0.605**	0.164	0.092

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Table 4: Simple correlation co-efficient among the different forms of phosphorus

Sl. No.	Forms	Saloid-P	Al-P	Iron-P	Red-P	Occl-P	Ca-P	Org-P	Total-P
1	Saloid-P	1							
2	Al-P	0.436	1						
3	Iron-P	-0.090	0.394	1					
4	Red-P	0.326	0.337	-0.157	1				
5	Occl-P	-0.079	-0.275	-0.040	-0.436	1			
6	Ca-P	0.520*	0.334	-0.083	0.628**	0.194	1		
7	Org-P	-0.547*	-0.025	0.307	-0.193	0.198	-0.218	1	
8	Total-P	-0.272	0.365	0.540*	0.097	0.098	0.095	0.882**	1

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

4. Conclusion

The studied soils were found to have availability of different inorganic forms of phosphorus in the order Red-P> Fe-P> Al-P>Occl-P>Ca-P>Sal-P. Red-P was found to have maximum amount of inorganic phosphorus among the other fractions whereas, Sal-P was to constitute lowest fraction of inorganic phosphorus.

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