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Fertility status and forms of acidity in soils of Phek district of Nagaland in relation to land use systems

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ABSTRACT

A study was conducted to evaluate some important physico-chemical properties, fertility status and forms of acidity of the cultivated and forest soils of Phek district of Nagaland. For this purpose, ninety soil samples (45 each from cultivated and forest land use system) were collected from fifteen locations of the district. The results revealed that the soils were strong to moderate acidic in reaction and soils of cultivated land use were more acidic. The soils denoted quite low CEC, but soils of forest land use showed more CEC than that of soils of cultivated land use. A wide variation in sand, silt and clay contents were observed. But almost same quantity of soil separates were reported in both cultivated and forest soils. The soils were high in organic carbon, medium in available N and K, low in available P and low to medium in available S. Nutrient index for organic carbon, N, P, K and S of the soils under cultivated and forest land use were 3.00 and 3.00, 2.00 and 2.00, 1.23 and 1.50, 2.00 and 2.00 and 1.16 and 1.82, respectively. Higher amounts of organic carbon, available N, P, K and S were reported in forest soils. Total potential acidity of the soils was quite high and accounted severe acidity problem in these soils and ranged from 7.1 to 15.7 and 7.4 to 15.5 cmol(P^+)kg^{-1} in cultivated and forest soils, respectively. The extractable acidity, pH dependent acidity, exchangeable acidity, exchangeable aluminium and exchangeable hydrogen contributed 32.2, 82.6, 17.8, 13.0 and 4.8% in cultivated land use system and 31.6, 84.1, 15.2, 10.3 and 4.9% in forest land use system to total potential acidity, respectively. Quantum of acidity components was high in cultivated soils. Available N, P, K and S had significant positive correlation with organic carbon. Available P had significant positive correlation with soil pH, available K with CEC and clay and available S with CEC of the soils. Significant negative correlation existed between forms of acidity and soil pH. Most of the components of acidity were significantly and positively correlated with CEC in cultivated soils.

Key words: Cultivated and forest land use systems, physico-chemical properties, fertility status, forms of soil acidity, Phek district

INTRODUCTION

Different land use patterns play a vital role in governing the soil characteristics, nutrient dynamics and soil fertility. Soils under particular land use system for long period may affect physic-chemical properties which may modify fertility status and nutrient availability to plants (Tsanglao *et al.*, 2014). Soils are formed by various soil forming factors, *viz.* parent material, relief, climate, organisms and time. Since different climatic zones have wide meteorological variation, soils also differ according to these variations. Knowledge of fertility status of the soil and their interrelationship with physical and chemical properties is helpful in understanding the inherent capacity of soil to supply essential nutrients for plants. Nutrients availability in soils is affected by their distribution and other physico-chemical properties of soils. **L**and degradation is prevalent in various forms throughout the world and country of which the most outstanding problem in agriculture is soil acidity. About 40% of the total cultivated area in India is affected by acidity (Kant, 2009). Soil acidity is among the important environmental factors which can influence plant growth, and can seriously limit crop growth and production. Problem of soil acidity is acute in hilly states like Nagaland and recognized as an important agricultural problem (Mishra, 2004)**.** Therefore, assessment of physic-chemical properties, fertility status and nature of acidity of the soils under important land use patterns has significant importance in soil health management strategies for future generations. Therefore, a study was conducted to generate information on physicochemical properties, fertility status and nature of acidity of soils of the Phek district of

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Nagaland under cultivated and forest agro-ecosystem.

MATERIALS AND METHODS

Description of Study Area

Phek district is in the eastern part of Nagaland sharing the international boundary with Myanmar around 100 km long. It has an area of 2026 km^2, lying at an altitude of about 1524 m above sea level. It lies at 25.66^0 N latitude and 94.50^0 E longitudes. The average rainfall of the district is 200 – 250 cm. The average mean temperature is 25 – 30^0 C during summer and the temperature fall even to around 0^0C during peak winter in some place. In winter season occasionally the district enjoys snow falling also. Physiographically, district is covered with hills, high ridges, deep gorges and narrow valleys. The landscape is mostly covered with closed to open broadleaved evergreen or semi-deciduous forests. Major crops of the district are rice, maize, soybean, beans, cabbage, potato, cucurbits etc. Fertilizer consumption in Nagaland during 2012-13 was 5.7 kg ha^{-1}(N 2.9, P 1.8 and K 1.0 kg ha^{-1}) and generally crops survive on inherent soil fertility (Anonymous, 2013). About 80% area of the district is covered by forest.

Present study was conducted during 2014-15 to study various characteristics of soils under cultivated and forest land use systems. Ninety surface soil samples (0-15 cm), representing cultivated and forest soils (45 from each category) were collected from 15 villages of the Phek district of Nagaland**.** Three villages from each block were selected for soil sampling and all five blocks of the district were covered to represent entire district in the sampling. Three soil samples from cultivated land use and three samples from forest land use were collected from different locations of each village. Collected soil samples were analyzed for pH, CEC (Chapmam, 1965), sand, silt, clay contents and different forms of soil acidity following standard methods as described by Baruah and Barthakur (1997). Organic carbon, available N and available K were analyzed using standard methods (Jackson, 1973). For available P, soil samples were extracted with Bray P-1 extractant (Bray and Kurtz, 1945) and phosphorus content in soil extract was determined as described by Jackson (1973). Available sulphur was estimated by turbidimetric method (Chesnin and Yien, 1951). Simple correlation coefficient was calculated to correlate physico-chemical characteristics of soils with available nutrients and different forms of soil acidity. Nutrient index was calculated using the formula suggested by Biswas and Mukherjee (1994).

RESULTS AND DISCUSSION

Physico-chemical Properties

Irrespective of land use pattern, the pH value of soils of Phek district varied from 4.15 to 5.74 indicating that soils are acidic in reaction (Table 1). The pH value of cultivated and forest soils varied from 4.15 to 5.56 and 4.17 to 5.74 with mean values of 4.84 and 5.10, respectively. The soils under cultivated land use showed less pH value as compared to forest soils. This might be due to high exchangeable Al^{3+} and H^+ ions in the cultivated soils. Similar findings have also been reported by Sharma *et al.*, (2015). Cation exchange capacity (CEC) of the soils ranged from 6.46 to 12.20 and 8.53 to 13.00 cmol(p^+)kg^{-1} with an average of 9.53 and 11.10 cmol(p^+)$kg^{-1}$for cultivated and forest soils, respectively indicating the soils under both land uses were low in CEC. Comparatively high CEC was observed in the forest soils. Possible explanation for these results is that higher organic matter content in the forest soils might be cause of higher CEC. Low CEC of these soils might be ascribed due to presence of low CEC clay minerals *viz;* kaolinite and illite dominantly in the soils of North Eastern states of India (Dey and Sehgal, 1997). Low CEC values of the soils of Nagaland have also been reported by Patton *et al.* (2007). Wide variations in soil separates were observed in the soils of the Phek. Sand, silt and clay contents of the cultivated soils ranged from 41.8 to 54.0, 20.9 to 29.4 and 18.9 to 33.0% with averages of 45.8, 25.0 and 29.2%, respectively. While sand, silt and clay contents in the forest soils varied from 41.2 to 53.8, 22.7 to 28.9 and 21.3 to 31.5% with averages of 45.4, 26.0 and 28.4%, respectively. A very few variations in sand, silt and clay contents were noticed in cultivated and forest soils.

Table 1: Physico-chemical properties and available nutrient status of cultivated and forest soils

Sampling site	pH		CEC [cmol(P^+)kg^{-1}]		Sand (%)		Silt (%)		Clay (%)		OC (g kg^{-1}))		Available nutrients (kg ha^{-1})							
													N		P		K		S	
	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
Akhegwo	.497	5.52	9.33	9.93	46.2	42.4	20.9	26.1	32.9	31.5	14.7	23.9	305.4	450.7	9.2	11.2	205.3	197.8	23.7	27.1
Lephori	5.49	4.17	7.60	9.13	41.8	46.1	25.0	24.8	33.0	29.0	18.6	24.5	348.4	370.6	11.8	10.3	182.9	238.9	12.0	26.1
Meluri	4.82	5.15	10.00	10.73	41.8	45.8	29.4	24.7	28.7	28.6	12.5	14.8	305.4	450.7	9.4	11.0	177.3	218.4	19.1	21.6
Kami	5.40	5.55	7.20	9.33	54.6	53.8	27.1	24.9	18.9	21.3	14.2	15.1	309.6	363.7	10.0	13.8	179.7	182.9	17.3	20.4
Pfutseromi	4.82	5.17	8.67	10.47	47.0	41.9	24.8	27.6	28.2	0.5	14.1	16.9	374.0	432.3	8.5	10.3	186.6	231.4	16.5	18.6
Zuketsa	4.66	4.81	11.73	12.60	49.0	47.8	24.2	22.7	26.7	30.3	12.7	25.7	345.7	385.5	7.4	8.0	233.3	253.8	26.5	33.1
Losami	4.47	4.68	12.13	12.53	46.6	41.2	25.0	27.7	28.1	30.6	15.7	21.1	337.3	403.8	7.4	7.4	207.2	248.2	21.6	31.9
Lozaphuhu	4.68	5.05	11.06	13.00	42.9	47.2	27.6	25.5	29.4	27.3	14.1	16.9	373.7	430.9	8.0	9.7	175.4	233.3	14.0	24.9
Phek	4.97	5.05	8.13	12.00	43.3	42.2	26.6	28.9	30.1	28.9	15.0	17.4	354.3	409.0	8.6	8.5	164.2	237.0	17.3	31.2
Khetsami	4.15	4.75	12.20	12.27	44.5	43.6	24.3	27.9	31.2	28.6	14.6	18.2	309.8	353.8	7.7	10.6	192.2	225.8	22.5	25.8
Sathazu	4.62	5.43	11.93	11.93	46.0	49.6	22.6	24.7	31.4	25.7	12.6	24.6	349.3	380.5	8.3	10.6	220.2	225.8	24.1	23.1
Sekruzu	4.34	5.18	11.13	11.47	45.7	45.3	24.1	24.3	30.1	30.3	16.1	20.8	367.2	437.2	8.5	10.6	246.4	220.2	23.1	24.4
Laruri	4.87	4.90	6.46	12.33	47.8	45.8	22.4	25.8	29.6	28.3	13.9	15.1	346.8	400.8	9.2	9.4	179.2	254.2	12.5	30.7
Waziho	4.84	5.31	8.06	8.53	45.0	44.2	27.8	26.6	27.1	28.4	15.6	21.6	365.3	419.3	11.9	12.8	186.6	184.8	15.8	18.6
Zhipu	5.56	5.74	7.40	10.27	44.9	44.3	22.7	28.1	32.4	27.3	18.2	24.7	359.5	402.1	10.4	11.0	192.2	212.8	19.7	21.3
Minimum	4.15	4.17	6.46	8.53	41.8	41.2	20.9	22.7	18.9	21.3	12.5	14.8	305.4	353.8	7.4	7.4	164.2	182.9	12.0	18.6
Maximum	5.56	5.74	12.20	13.00	54.0	53.8	29.4	28.9	33.0	31.5	18.6	25.7	374.0	450.7	11.9	13.8	246.4	254.2	26.5	33.1
Average	4.84	5.10	9.53	11.10	45.8	45.4	25.0	26.0	29.2	28.4	14.8	20.1	343.4	406.1	9.1	10.3	195.2	224.3	19.0	25.2
Nutrient index											3.00	3.00	2.00	2.00	1.23	1.50	2.00	2.00	1.16	1.82
Nutrient index class											H	H	M	M	L	M	M	M	L	M

CS = Cultivated soils, FS = Forest soils, H = High = M = Medium, L = Low

Fertility Status

The soils under different land use patterns had wide variation in soil organic carbon (SOC) content (Table 1). Irrespective of land use systems, the organic carbon content of the soils ranged from 12.5 to 25.7 g kg^{-1} indicating high organic carbon status of the soils. Nutrient index value for SOC of the soils of both land use systems was 3.00. The SOC content ranged from 12.5 to 18.6 g kg^{-1} and 14.8 to 25.7 g kg^{-1} with averages of 14.8 and 20.1 g kg^{-1} in cultivated and forest soils, respectively. The agronomic practices such as tilling of the soils and crop removal during harvest might be decreased SOM level in cultivated soils. Furthermore, tillage activities aerate the soil and accelerate the breakup of organic residues by stimulating micro organism activity in the soil ultimately promotes SOM decomposition. Forest ecosystem tended to promote SOC accumulation possibly due to addition of huge quantity of forest litter to the soils. Wide variation in SOC content of the soils under different land use systems has also been reported by Sharma (2013). Available N and P contents of cultivated and forest soils varied from 305.4 to 374.0, 353.8 to 450.7 and 7.4 to 11.9 and 7.4 to 13.8 kg ha^{-1}, with mean values of 343.4, 406.1, 9.1 and 10.3 kg ha^{-1}, respectively. Irrespective of land use systems the soils of all sites belong to medium category of available nitrogen with a nutrient index value 2.00 for both cultivated and forest land use. Despite high in organic carbon, medium available N content might be due to low rate of N mineralization under climatic condition and soil environment of Nagaland. Soils have low amount of available P in both land uses with a nutrient index of 1.23 and 1.50. Forest soils contained higher amounts of available N and P in comparison to cultivated soils which might be due to higher organic carbon status in forest soils. Available K content in the soils under cultivated land use varied from 164.2 to 246.4 kg ha^{-1} and in forest soils it ranged from 182.9 to 254.2 kg ha^{-1}. Mean values of K for cultivated and forest soils were recorded 195.2 and 224.3 kg ha^{-1}, respectively. Irrespective of land use pattern, the soils of Phek district fell under medium class with regard to available K with nutrient index of 2.00.

Table 2: Forms of acidity of cultivated and forest soils

Sampling site	Soil acidity components (cmol kg^{-1})											
	Total potential acidity		Extractable acidity		pH- dependent acidity		Exchangeable acidity		Exchangeable Al^{3+}		Exchangeable H^{+}	
	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
Akhegwo	13.4	8.7	4.38	2.59	10.9	7.8	2.50	0.95	1.87	0.45	0.62	0.50
Lephori	8.9	15.5	2.84	4.54	8.1	11.7	0.83	3.87	0.41	3.25	0.41	0.62
Meluri	14.2	10.9	4.75	3.80	11.1	9.5	3.12	1.37	1.95	0.87	1.17	0.50
Kami	7.1	8.1	2.26	2.99	6.6	7.3	0.58	0.75	0.37	0.41	0.20	0.31
Pfutseromi	11.9	10.0	4.11	3.02	10.1	9.0	1.79	1.00	1.33	0.49	0.46	0.50
Zuketsa	13.2	12.7	4.54	4.25	10.6	10.7	2.62	2.08	1.99	1.62	0.62	0.46
Losami	15.0	14.0	4.68	4.46	11.9	11.4	3.12	2.62	2.12	1.37	1.00	1.25
Lozaphuhu	13.3	11.5	4.55	3.96	11.2	9.8	2.16	1.66	1.62	1.16	0.54	0.49
Phek	13.1	10.7	3.90	3.21	11.4	9.2	1.66	1.50	1.33	1.12	0.33	0.37
Khetsami	15.7	13.7	4.98	3.69	11.9	11.4	3.74	2.29	2.87	1.37	0.87	0.91
Sathazu	12.2	7.4	4.41	2.17	10.1	6.6	2.08	0.83	1.62	0.41	0.46	0.41
Sekruzu	13.4	10.5	4.58	3.62	10.3	9.2	3.08	1.29	2.16	0.74	0.91	0.54
Laruri	15.0	12.9	5.02	3.96	12.4	10.6	2.62	2.29	2.20	1.79	0.41	0.50
Waziho	14.2	10.5	4.47	2.84	11.7	8.9	2.50	1.66	1.99	1.24	0.50	0.41
Zhipu	10.3	11.7	3.84	4.41	8.7	10.1	1.62	1.66	0.91	1.16	0.71	0.49
Minimum	7.1	7.4	2.26	2.17	6.6	6.6	0.58	0.75	0.37	0.41	0.20	0.31
Maximum	15.7	15.5	5.02	4.54	12.4	11.7	3.74	3.87	2.87	3.25	1.17	1.25
Average	12.7	11.3	4.22	3.57	10.5	9.5	2.27	1.72	1.65	1.16	0.61	0.55

CS - Cultivated soils, FS - Forest soils

These results are in accordance with those of Rajkonwar *et al.* (2016). Available sulphur status of cultivated and forest soils varied from 12.0 to 26.5 and 18.6 to 33.1 kg ha^{-1} in the soils under forest. Average S status of the soils under cultivated and forest land use was 19.0 and 25.2 kg ha^{-1}, respectively. Cultivated and forest soils of the district fell under low and medium class with regard to available S with nutrient index of 1.16 and 1.82, respectively.

Possible reason of low nutrient status in cultivated soils is wide gap between addition and removal of nutrients which might be the cause of nutrient mining from the soils. Available N had significant positive correlation with organic carbon and CEC and negative correlation with soil pH (Table 3). Available P had significant negative correlation with CEC and positive correlation with SOC and pH of the soils. Positive correlations indicated that organic matter is good source of available P in these soils and soil reaction (pH) governs the availability of phosphorus. Available potassium had significant positive correlation with organic carbon, CEC and clay content of soils and negative with pH of the soils under forest land use. Available sulphur had significant positive correlation with organic carbon and CEC and negative with pH of the soils under forest land use systems. These correlations indicated that soil pH, CEC, organic carbon as well as clay content govern nutrient availability in these soils. These results are in agreement with those of Somasundaram *et al.* (2009) and Tsanglao *et al.* (2014).

Forms of Soil Acidity

Wide was reported in total potential acidity status of the soils under different land use (Table 2). Irrespective of land use pattern, total potential acidity of the soils varied from 7.1 to 15.7 cmol (p^+) kg^{-1}. Total potential acidity of cultivated and forest soils ranged from 7.1 to 15.7 and 7.4 to 15.5 cmol (p^+) kg^{-1} with an average of 12.7 and 11.3 cmol $(p^+)kg^{-1}$, respectively. Total potential acidity was higher in cultivated soils than that of forest soils. Total potential acidity had significant positive correlation with organic carbon in forest soils and significant negative correlation with pH of the soils. Extractable acidity varied from 2.26 to 5.02 and 2.17 to 4.54 cmol$(p^+)kg^{-1}$ in the cultivated and forest soils with mean values of 4.22 and 3.57 cmol$(p^+)kg^{-1}$, respectively. Contribution of extractable acidity toward total potential acidity was 33.2 and 31.6% in the variation soils under cultivated and forest land use, respectively. Exchangeable Al^{3+} and H^+ contributed 39.1, 14.4 and 32.5, 15.4% in the soils of cultivated and forest land use, respectively to extractable acidity. Exchangeable Al^{3+} might have major constituent of extractable acidity. The pH-dependent acidity in cultivated and forest soils ranged from 6.6 to 12.4 and 6.6 to 11.7 cmol (p^+) kg^{-1}, respectively. Average value of pH-dependent acidity was reported in tune of 10.5 and 9.5 cmol (p^+) kg^{-1}, respectively for cultivated and forest soils. Contribution of pH-dependent acidity to total potential acidity was 82.6 and 84.1% in the soils under cultivated and forest land use, respectively. Exchangeable acidity of cultivated and forest soils varied from 0.58 to 3.74 and 0.75 to 3.87 cmol (p^+) kg^{-1} with average values of 2.27 and 1.72 cmol (p^+) kg^{-1}, respectively. Contribution of exchangeable acidity towards total potential acidity was recorded 17.8 and 15.2%, respectively in cultivated and forest soils. Exchangeable Al^{3+} and H^+ contributed 72.6, 26.8% and 67.4 and 32.0% to exchangeable acidity under cultivated and forest soils, respectively. Reasonable exchangeable acidity in these soils may be due to presence of exchangeable Al^{3+} and H^+ in high quantities which might have contributed to exchangeable acidity (Laxminarayana, 2010).

Table 3: Correlation coefficient between various soil properties

Soil properties	pH		CEC		OC		Clay	
	CS	FS	CS	FS	CS	FS	CS	FS
Ext-A	-0.76**	-0.57*	0.52*	0.26	0.48	0.47	-0.21	0.25
PDA	-0.69**	-0.77**	0.36	0.28	0.36	0.55*	-0.26	0.36
TPA	-0.78**	-0.83**	0.48	0.22	0.47	0.53*	-0.25	0.31
Ex-Al	-0.87**	-0.81**	0.59*	0.43	0.59*	0.41	-0.25	0.09
Ex-H	-0.57*	-0.51*	0.57*	0.34	0.42	0.29	-0.04	0.39
Ex-A	-0.84**	-0.86**	0.64**	0.07	0.59*	0.44	-0.21	0.19
S	-0.47	-0.52*	0.69**	0.64**	0.75**	0.73**	0.01	0.32
K	-0.45	-0.67**	0.59*	0.73**	0.52*	0.94**	0.55*	0.60*
P	0.71**	0.55*	-0.73**	-0.75**	0.90**	0.86**	0.30	-0.36
N	-0.55*	-0.50	0.79**	0.63*	0.83**	0.78**	0.05	0.18

**Significant at 5% level; ** Significant at 1% level*

CS - Cultivated soils, FL - Forest soils, Ext-A – Extractable acidity, PDA- pH-dependent acidity, TPA- Total potential acidity, Ex-Al - Exchangeable aluminium, Ex- H - Exchangeable hydrogen, Ex-A – Exchangeable acidity

Exchangeable Al^{3+} and H^+ contents of the cultivated soils varied from 0.37 to 2.87 and 0.20 to1.17 cmol (p^+) kg^{-1}, respectively. However these ions were recorded in the range of 0.41 to 3.25 and 0.31 to 1.25 cmol (p^+) kg^{-1}, respectively in the forest soils. Average Al^{3+} and H^+ contents of the cultivated and forest soils were 1.65 and 1.16 and 0.61 and 0.55 cmol (p^+) kg^{-1}, respectively. Exchangeable aluminium and hydrogen ions constituted 13.0 and 4.8% in cultivated soils and 10.3 and 4.9% in forest soils to total potential acidity, respectively. All forms of soil acidity had significant negative correlation soil pH. Extractable acidity, exchangeable acidity and exchangeable Al^{3+} and H^+ ions had significant positive correlation with CEC of the soils under cultivated land use. Exchangeable Al^{3+} of cultivated soils, pH-dependent and total potential acidity of forest soils had significant positive correlation with organic carbon of the soils. These results are similar to the findings of Rahman and Karak (2001).

From the present study, it may be concluded that the soils of Phek district of Nagaland were high in organic carbon, medium in available N and K and low to medium in available S. The CEC of the soils was quite low. Organic carbon and available nutrients were high in the forest soils. Higher values of different component of soil acidity were recognized in the cultivated soils. The soils of studied area have major problem of acidity and to improve soil fertility and crop yield, application of lime and growing of acidity tolerant crops along with tolerant varieties are essential.

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