Original Research Article

Distribution study of the different forms of soil acidity components and available nutrients in Upper Brahmaputra Valley Zone (UBVZ) of Assam

ABSTRACT

Soil acidity is a major constraint that affect crop growth and production in larger aspect. In order to study the different forms of soil acidity components in relation to the soil properties 14 georeferenced soil samples were collected from Jorhat and Sibsagar district of Assam. The soils of UBVZ of Assam were highly to moderately acidic (pH range 4.27 to 5.34) with sandy loam to silty clay loam in texture and high content of organic carbon ranged from 0.72 to 2.59%. The exchangeable (Ex.) Ca and Mg value ranged from 1.40-2.64 cmol(p+)/kg and 0.7-2.0 cmol(p+)/kg, respectively with CEC from 7.8 to 14.2 cmol(p+)/kg and BS from 25.03 to 43.76%. Correlation between soil physico-chemical properties and soil acidity components revealed that OC had positive correlation with total acidity (r=0.638*) and exchange acidity (r=0.551*) while BS% had negative significant correlation with total acidity (r=-0.540*). Exchangeable calcium was significantly correlated with total acidity (r=-0.751**), exchange acidity (r=-0.610*) and exchangeable H+ (r=-0.557*) while Ex Mg had significant negative correlation with exchangeable H+ (r=-0.596*). Deficiency of various nutrients in soil can hinder the yield productive prospects in future. So, we must think of the holistic approach to meet the present need of the nutrients.

Keywords: Soil, acidity, nutrients and components

1. INTRODUCTION

Soil acidity is an important constraint in agriculture production. It is a natural process occurred due to heavy rainfall and leaching of cations like calcium, potassium and magnesium. Acidic parent materials and decomposition of organic matter also leads to formation of acidic condition in soil. Acceleration of acidification is caused by acid forming fertilizers usage, disturbance of soil structure and cultivation of high yielding crops (Fageria and Baligar, 2008). Due to these factors acid soils are generally poor in nutrient content. In strongly to moderately acidic soils, plant growth and crop yield are hampered to a large extent (Bhat et al. 2010). Higher soil acidity leads to decline in productive potential of the soils.

Soil acidity is a major agricultural problem affecting productivity worldwide (Borgohain et al., 2019). The strengths of soil acidity and its influences on fertility and productivity are further embellished by the present need for over exploitation of land for food security (Devi et al., 2023). In India, soil acidity affects approximately 1/3 rd of arable land (Mandal, 1997) and out of 245 million hectare of cultivated land, acidic soils occupy nearly 49 Mha area, which occupy nearly 34% of the total cropped area of the country (Maji et al., 2012; Devi at al., 2023). It was recorded that 26 Mha had pH below 5.5 and 23 Mha had pH between 5.6 and 6.5 out of 49 million hectare of acidic soil in India (Panda, 1979).

North- eastern region of India covered about 21 million hectares of acid soils. The region occupies with nearly 65 per cent of the lands which are in extreme forms of soil acidity with pH of < 5.5 (Sharma and Singh, 2002; Devi et al., 2023)) constituting a major areas under acid soils. Approximately 15 Mha of land area of the north-eastern region is acidic with pH varying from strongly acidic to slightly acidic (pH 4.0-6.3) and with pH below 5.5 occupying 54% of the acid soils in the country (Bhatt et al., 2014; Devi et al., 2023)). In the context of Assam, more than 60 per cent of the land was affected by soil acidity problem, thereby affecting crops in many ways and its effects were mostly indirect through its influence on chemical factors such as aluminium and manganese toxicity calcium, phosphorus and magnesium deficiency and microbiological process.

Soil acidity marks a tremendous impact on soil chemical and biological properties besides regulating nutrient accessibility and aluminium toxicity (Lavelle et al., 1995). So, amelioration of soil acidity through liming is the best strategy for improving efficiency and productivity of acid pretentious soil. Soil acidity is usually defined in terms of different forms of soil acidity components viz., total acidity, exchange acidity exchangeable aluminium, etc. The different form of these acidity components and their proportion in soil regulates fixation of nutrients and extent of lime requirement. Precise information of the soil physico-chemical properties and indication of the different forms of acidity components assist in understanding as well as management of acid soils. In light to this information, attempt has been made to study the different soil physico-chemical properties, characterized acidity components and correlates their relationship among them.

2. MATERIALS AND METHODS

2.1 SOIL SAMPLE COLLECTION

The studied soil samples were collected from Jorhat and Sibsagar districts of UBVZ of Assam. A total of 14 Geo referenced surface soil (0-15 cm) samples were collected. Analysis of the different soil properties for the illustration of the key features of soil were done by the standard procedures.

2.2 PROCESSING OF SOIL SAMPLES

The collected soil samples were grinned using wooden mortar and pestle and mixed uniformly. It was then aired dried in shade and sieved with 2 mm sieve and thereafter packed in zipped polythene bags with proper labelling.

2.2 ANALYSIS OF SOIL SAMPLES

The particle size distribution of the soil samples were determined by International Pipette Method (ISSS, 1966). Soil moisture at field capacity (0.3 bars) was determined using Pressure plate and pressure membrane apparatus. The collected soil samples were then analysed for pH, EC, CEC and K2O using standard procedures as described by Jackson (1973). The collected soil samples were analysed for available nitrogen (Subbiah and Asija, 1956), available P2O5 (Bray and Kurtz, 1973), neutral ammonium acetate extractable K2O (Jackson, 1973), organic carbon (Walkley and Black, 1934), and Lime requirement (LR) by Shoemaker, McLean and Pratt (SMP) Method (1961). The exchangeable calcium and magnesium were estimated by Versene Titration Method (Barrow and Simpson, 1962). Percentage Base Saturation (PBS) was determined by using the following formula:

$$\text{Percent Base Saturation (PBS)} = (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})/CEC * 100\%.$$

Acidity components of the soils were determined as per the procedure outlined by Baruah and Barthakur (1997). Soil acidity components were characterized as follows: total acidity was determined by 1N NaOAc solution. The exchange acidity and exchangeable Al were extracted by 1N KCl solution and determined by titration of 0.1N NaOH using phenolphthalein as indictor and by back titration after acidification with 40g/L NaF with 0.1N HCl solution respectively. Exchangeable H+ was determined by subtracting exchangeable Al from exchangeable acidity i.e.

$$\text{Exchangeable } H^{+} = \text{Exchangeable acidity} - \text{Exchangeable Al}.$$

2.4 STATISTICAL INTERPRETATION

Simple correlation study between different forms of acidity and physico-chemical characteristics of soil and with soil available nutrients were computed following standard statistical procedures and methods.

3. RESULTS AND DISCUSSION

Physico-chemical properties of the soils

The data of physico-chemical properties of the soils collected from the Upper Brahmaputra Valley Zone (UBVZ) of Assam is presented in the table 1. Texture of the soils of UBVZ region of Assam were loamy sand, sandy loam, loam and silty clay loam (Table 1). Sand, silt and clay fraction of soil varies from 14.22 to 75.85, 10.00 to 61.90 and 4.90 to 29.70 per cent, respectively with mean values of sand, silt and clay were 53.75, 25.34 and 16.24 per cent, respectively. Moisture content of the soil at field capacity (0.3 bars) at varied from 16.08 to 32.79 per cent with the mean value of 21.79 per cent (Table 1).

The pH of the soil varied from highly acidic to strongly acidic in reaction ranging from 4.27 to 5.34 with a mean value of 4.96. The electrical conductivity (EC) of the soils varied from 0.49 to 2.01 dS/m. The organic carbon content of the soils ranged from 0.72 to 2.59 per cent with mean value of 1.61 per cent of organic carbon (Table 1).

Data of exchangeable bases in the soils of UBVZ of Assam are presented in Table 1. The calcium was the dominant exchangeable basic cation of the soils and it ranged from 1.40 to 2.64 cmol(p+)/kg with the mean value of 2.11 cmol(p+)/kg. The range of exchangeable magnesium, exchangeable sodium and exchangeable potassium content of the soils were from 0.70 to 2.00 cmol(p+)/kg, 0.11 to 0.79 cmol(p+)/kg and 0.05 to 0.11 cmol(p+)/kg, respectively. The mean value of these basic cations viz., Ca, Mg, Na and K were 2.11, 1.39, 0.25 and 0.09 cmol(p+)/kg, respectively. The base saturation (BS) of the soils varied from 25.03 to 43.76 percent with the mean value of 35.77 per cent. The Cation

Exchange Capacity (CEC) of soils of the UBVZ of Assam varied from 7.80 to 14.20 cmol(p+)/kg and their mean value was 10.99 cmol(p+)/kg. The range and mean of Lime Requirement (LR) of the soils were 0.56 to 11.42 t/ha and 7.52 t/ha, respectively (Table 1).

Magnitude of lime requirements in soils of UBVZ of Assam ranged from 0.56 to 11.42 t/ha with mean value of 7.42 t/ha (Table 1). Report available in acid soils of Assam revealed that LR of the soils varied with clay content, CEC and pH of the soil (Borah and Nath, 1980). Reports also revealed that in acid soils of Assam LR of the soils not only governed pH alone but by the combined influence of soil pH, exchange acidity and exchangeable Al (Halder and Mandal, 1985). Significant positive correlation of LR of the soils of UBVZ of Assam was also observed with clay content (r= 0.535*) in the present investigation (Table 3).

Available Macronutrients

Available nitrogen (N) status in the soil of UBVZ of Assam ranged from low to medium with its content ranging from 100.80 to 260.22 kg/ha as shown in table 2. The N-content of the soils depend on factors like soil type, soil pH, climate vegetation, fertilizer management etc. Among these, climate seemed to have most striking effect on organic carbon content in soils of Brahmaputra valley (Chakravarty et al., 1978) which in turn determine N- content of these soils.

Available phosphorus (P2O5) content of the soils of UBVZ of Assam varied from low 12.73 kg/ha to medium 29.80 kg/ha (Table 2). Hence available P2O5 status of these soils can be considered as low. In acid soils of Assam fixation of both native and applied P is generally considered as its low availability in these soils (Baruah et al., 2011). High positive correlation existed between available P (Bray'I) and Al-P and Fe-P indicated that these factors mostly contribute to availability of P in acid soils of Assam (Dey and Bhattacharyya, 1996).

The exchangeable potassium (K2O) content of the soil of UBVZ of Assam varied from 40.86 kg/ha to 90.01 kg/ha which was low in status (Table 2). The type and nature of soils were most important factors affecting soil K2O status through fixation and release of K in the soil (Barua et al., 2011). Fixation of K was also found to correlate positively with clay fractions of soil but the correlation was not significant with silt and sand fractions suggesting K fixation in soils was related to the clay fractions of the soils (Table 5).

The secondary nutrients exchangeable calcium (Ca) and exchangeable magnesium (Mg) varied from 1.40 to 2.64 and 0.70 to 2.00 cmol(p+)/kg respectively (Table 1). The calcium was the dominant exchangeable basic cation followed by exchangeable Mg of the soils of the soils of UBVZ of Assam. Similar observations were also reported by Gangopadhyay et al. (2016) in tea growing soils of Assam. In acid soils of India Ca saturation of exchange complex generally varied from 20 to 40 per cent. Total CaO and MgO of this acid were low (0.1 to 1.0 % and 0.23 to 1.2 %, respectively). Therefore management of acid soils involved use of liming material (Pasricha and Sarkar, 2009).

The correlation found in soils of UBVZ of Assam between forms of soil acidity and exchangeable Ca and Mg content of the soils was mostly negative which also indicates that with increase in soil acidity in any form resulted in decrease of Ca and Mg content of these soils (Table 5). However, correlations between total acidity, exchange acidity and exchangeable H+ and exchangeable Ca were statistically significant with r values -0.751**, -0.610* and -0.557*, respectively. The exchangeable Mg content of the soils had significant negative correlations with exchangeable H+ (r = -0.596*) only (Table 5).

Forms of soil acidity

Total acidity

The findings of acidity components of the soils of UBVZ of Assam are presented in Table 2. The results on forms of acidity revealed that total acidity varied from 1.38 to 3.75 cmol(p+)/kg with the mean value of 2.41cmol(p+)/kg in soils of UBVZ of Assam. It was the most dominant forms of acidity in soils of UBVZ of Assam (Table 2). The correlation study of the different forms of soil acidity with soil physico-chemical properties are shown in table 4. In soils of UBVZ of Assam significant positive correlation of total acidity (r=0.638*) was found with OC and its correlation with BS% was significant and negative (r= -0.540*) (Table 4).

Exchange acidity

The exchange acidity of the soils had a varied from 0.88 to 2.63 cmol(p+)/kg and its mean value was 1.87 cmol(p+)/kg as shown in table 2. The OC content of the soils is correlated positively and significantly with exchange acidity (r=0.551*). Lime requirement of the soil showed positive correlation with exchange acidity (0.081) even though not significant. However, there is negative correlation between exchange acidity with pH, CEC, clay content and base saturation per cent of the soils (Table 4).

Exchangeable Aluminium & Exchangeable Hydrogen

The exchangeable aluminium and the exchangeable hydrogen of the soils varied from 0.63 to 1.50 cmol(p+)/kg and 0.10 to 1.48 cmol(p+)/kg, respectively and the mean exchangeable Al and exchangeable H of the soils of UBVZ of Assam were 1.05 and 0.82 cmol(p+)/kg, respectively (Table 2). Similar observations on forms of acidity in acid soils of Assam were also made by Dhananjaya and Ananthanarayana (2010); Sahoo et al. (2010); Reza et al. (2012) and Gangopadhyay et al. (2016). Badole et al. (2015) and Sangtam (2017) reported significant negative correlations of all forms of acidity with pH (H_2O) in acid soils. However, in the soils of UBVZ of Assam though forms of acidity correlate negatively with pH it was not significant (Table 4).

Table 1. Physico-chemical characteristics of the soils of UBVZ of Assam

Soil . No	pH	EC	OC (%)	% sand	% silt	% clay	CEC (cmol(p+)/kg)	B.S %	M.C (%)	LR (t/ha)	Ca (cmol(p+)/kg)	Mg (cmol(p+)/kg)
1	5.08	0.72	1.23	75.85	19.30	4.90	9.60	43.76	19.82	0.56	2.20	1.80
2	4.98	0.80	2.16	69.02	22.30	15.30	13.11	35.19	19.53	6.56	2.07	2.00
3	4.79	0.90	0.78	56.16	31.60	17.50	13.80	30.53	18.83	11.42	2.13	1.90
4	4.27	0.67	0.93	65.00	15.00	20.00	9.64	40.34	20.80	7.78	2.16	0.86
5	5.16	0.97	1.41	70.00	10.00	20.00	11.09	33.47	18.56	2.92	1.88	1.62
6	4.75	0.96	1.80	39.33	34.90	17.20	12.50	33.50	26.69	8.99	2.20	1.80

7	4.94	0.49	2.59	14.22	61.90	26.70	11.23	25.03	21.15	11.42	1.40	1.10
8	5.25	0.90	0.72	65.80	18.10	8.38	9.80	43.63	16.81	7.78	2.60	1.40
9	4.63	2.01	2.34	56.29	17.33	5.70	8.90	40.61	32.79	10.21	2.20	1.20
10	4.82	1.27	2.19	30.09	27.00	22.30	7.80	41.10	18.35	8.99	2.30	0.70
11	5.04	1.08	1.98	87.41	8.70	9.30	11.30	29.62	24.88	4.13	1.70	1.09
12	5.26	0.84	1.54	23.85	39.00	29.70	14.20	30.92	26.11	11.42	2.64	1.40
13	5.34	1.11	1.53	29.49	34.37	17.13	12.50	29.51	24.67	7.78	2.10	1.20
14	5.13	0.84	1.32	69.95	15.30	13.20	8.50	43.65	16.08	5.35	2.00	1.40
Mean	**4.96**	**0.97**	**1.61**	**53.75**	**25.34**	**16.24**	**10.99**	**35.77**	**21.79**	**7.52**	**2.11**	**1.39**
Range	**4.27-5.34**	**0.49-2.01**	**0.72-2.59**	**14.22-87.41**	**10.00-61.90**	**4.90-29.70**	**7.80-14.20**	**25.03-43.76**	**16.08-32.79**	**0.56-11.42**	**1.40-2.64**	**0.70-2.00**

Table 2. Different forms of soil acidity components (Total Acidity, Exchange Acidity, Exchangeable Aluminium & Exchangeable Hydrogen) and available nutrients (Nitrogen, phosphorus and potassium) in soil of UBVZ of Assam

Sample no.	Total Acidity	Exchange Acidity	Exchangeable Aluminium	Exchangeable Hydrogen	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
1	2.13	1.25	0.88	0.38	102.23	22.30	61.02
2	2.75	2.25	1.50	0.75	170.30	20.80	69.87
3	2.75	1.88	1.38	0.50	162.21	23.40	40.86
4	2.25	2.13	0.63	1.50	100.80	29.80	70.03
5	1.88	1.75	1.13	0.63	150.24	24.30	89.84
6	2.25	1.13	0.75	0.38	152.51	14.83	76.82
7	3.75	2.25	1.00	1.25	260.22	17.86	90.01
8	1.38	0.88	0.78	0.10	220.19	27.42	83.17
9	3.00	2.63	1.25	1.38	210.50	23.40	78.76
10	2.13	2.00	1.25	0.75	223.90	20.55	76.07
11	3.63	2.63	1.15	1.48	240.10	12.73	78.71
12	1.88	1.38	0.75	0.63	211.20	16.35	83.06

13	2.00	1.88	1.13	0.75	225.21	24.55	89.24
14	2.00	2.13	1.13	1.00	219.50	14.42	83.60
Mean	**2.41**	**1.87**	**1.05**	**0.82**	**189.22**	**20.91**	**76.50**
Range	**1.38-3.75**	**0.88-2.63**	**0.63-1.50**	**0.10-1.50**	**100.80-260.22**	**12.73-29.80**	**40.86-90.01**

Table 3. Correlation coefficient among Lime Requirement (LR) and physico-chemical properties of the soils

Parameters	**Physico-chemical properties of the soils**					
	pH (H_2O)	**OC**	**Clay**	**EC**	**CEC**	**BS**
Lime Requirement	-0.271	0.211	0.535*	0.150	0.315	-0.378

*Significant at 0.05% level of significance

Table 4. Correlation coefficient among soil acidity components and soil physical and chemical properties

Parameters	**Physico-chemical properties**					
	pH (H2O)	**O.C**	**CEC**	**Clay**	**BS%**	**LR**
Total Acidity	-0.319	0.638*	0.127	0.0004	-0.540*	0.199
Exchange Acidity	-0.355	0.551*	-0.176	-0.030	-0.224	0.081
Exchangeable Aluminium	0.090	0.374	0.071	-0.150	0.006	-0.160
Exchangeable Hydrogen	-0.488	0.451	-0.258	-0.052	-0.161	0.096

*Significant at 0.05% per cent level.

N=14, df=12 , $*P_{0.05}$=0.532, $**P_{0.01}$= 0.661

Table 5. Correlation coefficient among soil acidity components and macronutrients

Parameters	**Available Macronutrients**				
	N	**P**	**K**	**Ca**	**Mg**
Total Acidity	0.314	-0.386	-0.106	-0.751**	-0.129

Exchange Acidity	0.310	-0.165	-0.042	-0.610*	-0.388
Exchangeable Aluminium	0.273	-0.119	-0.237	-0.319	0.210
Exchangeable Hydrogen	0.217	-0.131	-0.191	-0.557*	-0.596*

*Significant at 0.05% per cent level

Conclusion

The exclusive study of the soil samples collected from Upper Brahmaputra valley zone of Assam showed a variable trend. The different soil parameters and its allocated nutrients help in retaining crop growth and its quality and ultimately crop yield. An amalgamation of different soil properties render the soil its optimum soil health status and maintain balance crop nutrition in environment. The different soil acidity components viz. total acidity, exchange acidity, exchangeable aluminium and exchangeable hydrogen showed fickle contribution in acidic soils. The total and exchange acidity showed a significant positive correlation with OC while exhibited significant negative correlation with BS% and exchangeable calcium. Among the different soil acidity components, exchangeable hydrogen showed significant negative correlation with exchangeable magnesium. Deficiency of various nutrients in soil can hinder the yield productive prospects in future. The overall study not only supports the farmers in boosting their farming knowledge but at the same time render their rational ability towards fertilizers amendments for a sustainable environment.

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