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NATURE OF ACIDITY IN SOME SOILS OF RED AND LATERITIC BELT OF WEST BENGAL

Manik Chandra Kundu[1]

ABSTRACT

Twenty four acid soil samples were collected during May, 2011 from western part of Bankura district representing part of red and lateritic belt of West Bengal and Alfisols soil order were analysed to characterise their nature of acidity in relation to some soil physico-chemical properties. The total acidity (TA), hydrolytic acidity (HA) and exchange acidity (EA) were ranged from 1.08-2.27, 0.83-1.64, 0.14-0.65 cmol (p^+) kg^{-1} with the mean values of 1.58, 1.21 and 0.37 cmol (p^+) kg^{-1} respectively. On an average, the contribution of electrostatically bound aluminium (Al^{3+}) and hydrogen (H^+) to exchange acidity varied from 54.53-96.67 and 3.3-45.47 per cent with the mean values of 65.69 and 34.31 per cent respectively. All these forms of acidity showed significant positive correlations with organic C content in soil but negative correlations with soil reaction (pHw and pHca). They also showed significant positive correlations with each other. Results implied wide variation in different forms of soil acidity and their significant correlations with each other and also with different soil properties.

(Key words: Red and lateritic soil, Alfisols, forms of acidity, soil properties)

INTRODUCTION

The degree of soil acidity is known to exert an adverse effect on crop growth by influencing nutrient availability and microbial activity. It is one of the major factors that restrict crop growth in large areas of the world (Shainberg *et al.,* 1989). Soil acidity also has effect on the survival and growth of important microbes such as *Rhizobium* bacteria and aluminium toxicity restricts roots growth and reduces the yield of crops grown on acid soils (Mallik and Rai, 2013). In West Bengal, acidic soils constitute about 2.2 M ha distributed from northern foot-hill soils (Entisols) to Western red and laterite soils (Alfisols) up to southern coastal acidic sulfate soils (Chand and Mandal, 2000). In red and lateritic zone of West Bengal, India, soil acidity poses a serious problem for crop production. In this red and lateritic belt main reasons for formation of acid soil are moderate to high rainfall, high temperature, hilly topography and also acidic parent materials. The sources of soil acidity include mainly the exchangeable hydrogen (H^+) and aluminium (Al^{3+}), iron (Fe) and Al oxides, clay and organic matter (Panda *et al.,* 2009). In general, these soils are very poor in fertility status and plant growth is hampered to a large extent in strongly to moderately acidic soils. The proportion of different forms of acidities in such acid soils determines their nutrient holding capacities and lime requirement values. Knowledge of forms of acidity, therefore, helps in the management of acid soils. The objective of the study was to determine: (i) the different forms of acidity, (ii) interrelationship between various forms of acidity and selected soil properties.

MATERIALS AND METHODS

Description of the sampling sites

Soil sampling was done in May, 2011 from the western part of Bankura district (Ranibandh, Khatra, Hirbandh, Indpur, Chhatna, Saltora blocks) which represents a part of the Red and Lateritic belt of West Bengal. Bankura district is situated between 22°38¹ and 23°38¹ N latitude and between 86°36¹ and 87°46¹ E longitude occupying an area of 6,788 square kilometres (2,621 sq miles). Soils of this red and lateritic belt of West Bengal were formed on the Chotanagpur Plateau (granite gneiss landscape) with gently sloping to undulating plain situated at 100-120 m from mean sea level. The annual rainfall of this zone varies from 1200 to 1400 mm with maximum and minimum temperatures of 26.5-41.0 and 11.0-25.5 °C, respectively. Soils are mostly acidic in nature due to the presence of oxides of iron and aluminum. The fertility status is also very low. The soil is light and porous in nature with low organic matter and low water holding capacity. The major constraints of the soil are soil acidity, extensive runoff and erosion leading to poor soil fertility, shallow depth, low organic carbon content, low available phosphorus, and highly leached coarse-textured soils with deficiency of micronutrients like zinc and boron.

Soil sampling and analysis

Twenty four soil samples were collected (0-0.20 m depth) in May, 2011 from Ranibandh, Khatra, Hirbandh, Indpur, Chhatna, Saltora blocks of Bankura district representing part of the red and lateritic zone of West Bengal, India and also representing soil order of Alfisols. After collection they were air-dried, powdered and sieved through

1. Asstt. Professor of Soil Science, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati University, Sriniketan, Birbhum-731 236, West Bengal, India. Corresponding author: mckundu@rediffmail.com.

2 mm nylon sieve and analysed for pH_w (1:2.5::soil:water), pH_{ca} (1:2.5::soil:0.1M $CaCl_2$ solution), organic C (Walkley and Black, 1934), Clay (hydrometer method) and different forms of acidity viz., total acidity, exchange acidity, hydrolytic acidity, and electrostatically bound H^+ (EBH^+) and Al^{3+} ($EBAl^{3+}$). Total acidity and exchange acidity of the soils were determined by extracting the soils with 1.0 M sodium acetate (pH 8.2) (Kappen 1934) and 1.0 M KCl (McLean 1965) respectively and subsequently titrating with standard NaOH using phenolphthalein as an indicator. Electrostatically bound Al ($EBAl^{3+}$) was determined in 1.0 M KCl extract by titrating with 0.1 N hydrogen chloride (HCl) after adding sodium fluoride (NaF). The difference between exchange acidity and $EBAl^{3+}$ represent the electrostatically bound H^+ (EBH^+). The difference between total acidity and exchange acidity was designated as hydrolytic acidity (Peech *et al.,* 1962).

Statistical analyses

Range, mean and standard deviation of studied soil parameters and different forms of acidity and Pearson's correlation coefficient among the forms of acidities and also with different soil properties were established following standard statistical methods, using Windows-based SPSS (20.0).

RESULTS AND DISCUSSION

Soil characteristics

Some important characteristics of soils are presented in table 1. All the studied soils were acidic in nature with mean pH values of 5.38 (pH_w) and 4.55 (pH_{ca}) (Table 1). Lower values of pH_{ca} than pH_w in all the soil samples explained that the soils were negatively charged and with low base saturation. Almost all the soils were low in organic carbon (0.17 to 0.45% with the mean value of 0.29%) due to rapid oxidation of organic matter in the study area because of high temperature of 40-45^{0}C during peak summer months. The clay content of the soils was ranged from 19.2 - 30.3% with mean value of 24.39%.

Nature of soil acidity

Range and mean values of different forms of acidities of the studied soil are presented in table 2. The total acidity (TA) of the soils was varied from 1.08-2.27 cmol (p^+) kg^{-1} with mean value of 1.58 cmol (p^+) kg^{-1} (Table 2). Similarly the hydrolytic acidity (HA) and exchange acidity (EA) were varied from 0.83 to 1.64 and 0.14 to 0.65 cmol (p^+) kg^{-1} with the mean values of 1.21 and 0.37 cmol (p^+) kg^{-1}. Badole *et al.* (2015) while studying the liming influences forms of acidity in soils belonging to different orders under subtropical India observed that total acidity of the Alfisols of West Bengal was ranged from 0.85 to 1.98 with the mean value of 1.44 cmol (p+) kg^{-1}. Badole *et al.* (2015) also observed that hydrolytic acidity (HA) of the some soil of Alfisols order of West Bengal was varied from 0.80 to 1.75 with the mean value of 1.31 cmol (p^+) kg^{-1}.

The contribution of exchange acidity (EA) to total acidity (TA) was very low ranging from 12.17 to 28.80 per cent with mean value of 22.67 per cent. However, the contribution of hydrolytic acidity (HA) to total acidity (TA) was very high ranging from 71.20 to 87.83 per cent with mean value of 77.33 per cent. A relatively low contribution of EA towards total acidities had also been reported by Das *et al.* (1991) in red-lateritic and terai soils and Chand and Mandal (2000) in Entisols, Alfisols and Inceptisols of West Bengal. Similar low contribution (8.5%) of EA to total acidity (TA) was also reported by Badole *et al.* (2015) in their study.

The exchange acidity (EA) includes the exchangeable H^+ and Al^{3+} held at the permanent charge sites of the soil exchange complex (McLean 1965). Electrostatically bound aluminium and hydrogen ions were ranged from 0.09 to 0.38 and 0.01 to 0.27 cmol (p^+) kg^{-1} with the mean values of 0.24 and 0.13 cmol (p^+) kg^{-1} respectively. Badole *et al.* (2015) also observed that electrostatically bound H^+ of the some acidic soils of Alfisols order of West Bengal was varied from 0.03 to 0.10 with the mean value of 0.06 cmol (p^+) kg^{-1} and that mean value for that of electrostatically bound Al^+ was 0.07 cmol (p^+) kg^{-1}. The contribution of electrostatically bound hydrogen (EBH^+) to exchange acidity was varied from 3.33 to 45.47% with the mean value of 34.31%. However, contribution of electrostatically bound aluminium ($EBAl^{3+}$) to exchange acidity varied from 54.53 to 96.67% with a mean value of 65.69%. Thus, the contribution of EBH^+ towards exchange acidity was less than that of $EBAl^{3+}$.

Correlation study on nature of acidities and soil properties

Simple Pearson's correlation coefficient values of different types of acidity with soil properties are given in table 3. It was observed that pH_w had significant negative correlations with all the forms of acidity viz., TA (r = -0.991, P d" 0.01), HA (r= -0.993, P d" 0.01), EA (r= -0.914, P d" 0.01), $EBAl^{3+}$ (r= -0.795, P d" 0.01), EBH^+ (r= -0.903, P d" 0.01). Similarly pH_{ca} showed significant negative correlations with all the forms of acidity viz., TA (r = -0.985, P d" 0.01), HA (r= -0.993, P d" 0.01), EA (r= -0.901, P d" 0.01), $EBAl^{3+}$ (r= -0.793, P d" 0.01), EBH^+ (r= -0.878, P d" 0.01). Dolui *et al.* (2011) while studying soil acidity and lime requirement of two Inceptisols and an Entisol of Manipur, India also showed a significant negative correlation of pHw with EB-Al^{3+} acidity and exchange acidity. Badole *et al.* (2015) while studying the liming influences forms of acidity in soils belonging to different orders under subtropical India also indicated that pHw and pHCa both had a significant negative correlation with all types of acidity except EBH^+.

Organic C also had a significant positive correlation with all forms of acidity viz., TA (r = 0.763, P d" 0.01), HA (r= 0.773, P d" 0.01), EA (r= 0.692, P d" 0.01), $EBAl^{3+}$ (r= 0.597, P d" 0.01), EBH^+ (r= 0.689, P d" 0.01) indicating the role of soil humus as a source of soil acidity by dissociating H^+ at varying pH (Sarkar *et al.,* 1997). Soil organic matter possesses a number of functional groups containing H^+ that can contribute to different kinds of acidities depending

Table 1. Physico-chemical properties of the experimental soils

Locations	Sample No.	pHw (1:2.5)	pHca (1:2.5)	Organic C (%)	Clay (%)
Ranibandh	S1	5.3	4.5	0.17	22.50
	S2	5.4	4.6	0.32	23.40
	S3	5.7	4.8	0.25	21.50
	S4	5.5	4.7	0.27	22.50
Khatra	S5	5.2	4.4	0.38	22.20
	S6	5.7	4.8	0.21	30.30
	S7	4.9	4.1	0.41	25.30
	S8	5.4	4.6	0.17	19.20
Hirbandh	S9	5.4	4.6	0.28	22.40
	S10	5.2	4.4	0.22	24.80
	S11	5.7	4.8	0.21	25.30
	S12	5.0	4.2	0.25	23.60
Indpur	S13	5.2	4.4	0.39	22.40
	S14	5.5	4.7	0.45	27.50
	S15	4.9	4.1	0.35	26.30
	S16	5.8	4.9	0.27	28.20
Chhatna	S17	5.5	4.7	0.17	19.40
	S18	5.8	4.9	0.41	25.10
	S19	5.2	4.4	0.23	25.70
	S20	5.2	4.4	0.21	21.80
Saltora	S21	5.0	4.2	0.31	25.40
	S22	5.5	4.7	0.32	27.10
	S23	5.4	4.6	0.38	28.30
	S24	5.7	4.8	0.43	25.10
Range		4.9-5.8	4.1-4.9	0.17-0.45	19.20-30.30
Mean		5.38	4.55	0.29	24.39
SD		0.28	0.24	0.08	2.79

Table 2. Different forms of acidity [cmol (p^+) kg^{-1}] of the studied soils

Locations	Sample No.	TA	HA	EA	$EBAl^{3+}$	EBH^+	% $EBAl^{3+}$ of EA	% EBH^+ of EA	EA/TA	HA/TA	$EBAl^{3+}$/EA	EBH^+/EA
		[cmol (p^+) kg^{-1}]										
Ranibandh	S1	1.74	1.24	0.50	0.30	0.20	60.58	39.42	0.29	0.71	0.61	0.39
	S2	1.54	1.18	0.36	0.20	0.16	54.53	45.47	0.23	0.77	0.55	0.45
	S3	1.15	1.01	0.14	0.09	0.05	64.29	35.71	0.12	0.88	0.64	0.36
	S4	1.38	1.09	0.29	0.18	0.11	62.07	37.93	0.21	0.79	0.62	0.38
Khatra	S5	1.84	1.34	0.50	0.28	0.22	56.00	44.00	0.27	0.73	0.56	0.44
	S6	1.12	0.94	0.18	0.15	0.03	83.33	16.67	0.16	0.84	0.83	0.17
	S7	2.12	1.64	0.48	0.33	0.15	68.90	31.10	0.23	0.77	0.69	0.31
	S8	1.54	1.20	0.34	0.21	0.13	61.76	38.24	0.22	0.78	0.62	0.38
Hirbandh	S9	1.61	1.18	0.43	0.28	0.15	65.12	34.88	0.27	0.73	0.65	0.35
	S10	1.84	1.31	0.53	0.38	0.15	71.70	28.30	0.29	0.71	0.72	0.28
	S11	1.08	0.94	0.14	0.09	0.05	64.29	35.71	0.13	0.87	0.64	0.36
	S12	2.14	1.56	0.58	0.32	0.26	55.17	44.83	0.27	0.73	0.55	0.45
Indpur	S13	1.84	1.35	0.49	0.29	0.20	59.18	40.82	0.27	0.73	0.59	0.41
	S14	1.38	1.12	0.26	0.17	0.09	65.38	34.62	0.19	0.81	0.65	0.35
	S15	2.27	1.62	0.65	0.38	0.27	58.46	41.54	0.29	0.71	0.58	0.42
	S16	1.10	0.89	0.21	0.19	0.02	90.48	9.52	0.19	0.81	0.90	0.10
Chhatna	S17	1.38	1.09	0.29	0.17	0.12	58.62	41.38	0.21	0.79	0.59	0.41
	S18	1.13	0.83	0.30	0.29	0.01	96.67	3.33	0.27	0.73	0.97	0.03
	S19	1.78	1.34	0.44	0.25	0.19	56.82	43.18	0.25	0.75	0.57	0.43
	S20	1.84	1.37	0.47	0.29	0.18	61.70	38.30	0.26	0.74	0.62	0.38
Saltora	S21	2.09	1.58	0.51	0.33	0.18	64.71	35.29	0.24	0.76	0.65	0.35
	S22	1.38	1.09	0.29	0.19	0.10	65.52	34.48	0.21	0.79	0.66	0.34
	S23	1.54	1.18	0.36	0.24	0.12	66.67	33.33	0.23	0.77	0.67	0.33
	S24	1.11	0.94	0.17	0.11	0.06	64.71	35.29	0.15	0.85	0.65	0.35
Range		1.08-2.27	0.83-1.64	0.14-0.65	0.09-0.38	0.01-0.27	54.53-96.67	3.33-45.47	0.12-0.29	0.71-0.88	0.55-0.97	0.03-0.45
Mean		1.58	1.21	0.37	0.24	0.13	65.69	34.31	0.23	0.77	0.66	0.34
SD		0.37	0.23	0.15	0.09	0.07	10.55	10.55	0.05	0.05	0.11	0.11

TA=Total acidity, HA= Hydrolytic acidity, EA= Exchange acidity, $EBAl^{3+}$ and EBH^+= Electrostatically bound aluminium and hydrogen respectively

Table 3. Relationships (r) between different soil properties with different forms and their proportions of soil acidities

Variables	pHw	pHca	Organic C (%)	Clay (%)
Total acidity (TA)	-0.991**	-0.985**	0.763**	-0.168
Hydrolytic acidity (HA)	-0.993**	-0.993**	0.773**	-0.15
Exchange acidity (EA)	-0.914**	-0.901**	0.692**	-0.184
$EBAl^{3+}$	-0.795**	-0.793**	0.597**	-0.044
EBH^{+}	-0.903**	-0.878**	0.689**	-0.319
EA/TA	-0.676**	0.676**	0.472*	-0.201
HA/TA	-0.642**	0.642**	-0.472*	0.201
$EBAl^{3+}$/EA	0.042	-0.042	-0.39	0.504*
EBH^{+}/EA	-0.201	0.201	0.39	-0.504*

* and ** indicate correlation is significant at the 0.05 and 0.01 level (two tailed); $EBAl^{3+}$, EBH^{+} represent electrostatically bound aluminium and hydrogen respectively.

Table 4. Relationships (r) among forms of soil acidities

Variables	Total acidity	Hydrolytic acidity	Exchange acidity	$EBAl^{3+}$	EBH^{+}
Total acidity	1.000				
Hydrolytic acidity	0.983**	1.000			
Exchange acidity	0.955**	0.883**	1.000		
$EBAl^{3+}$	0.852**	0.761**	0.935**	1.000	
EBH^{+}	0.917**	0.879**	0.910**	0.704**	1.000

** indicate correlation is significant at the 0.01 level (two tailed); $EBAl^{3+}$, EBH^{+} represent electrostatically bound aluminium and hydrogen respectively.

upon their magnitude (Keeney and Corey 1963). A similar type of relationship was also observed by Pati and Mukhopadhyay (2011). Dolui *et al.* (2011) while studying soil acidity and lime requirement of two Inceptisols and an Entisol of Manipur, India also showed a significant positive correlation of organic C with pH-dependent acidity, TPA. Badole *et al.* (2015) in their study also indicated that organic C also bore a significant positive correlation with all types of acidity except EBH^+.

Correlation study also showed that different forms of acidity were significantly and positively correlated with each which indicates existence of a dynamic equilibrium amongst different forms of acidity (Table 4). This significant positive correlation amongst different forms of acidity also indicates that liming should be done to ameliorate not only the active acidity and/or exchangeable Al but also all other forms of acidities present in soils.

Correlation study also showed that the proportion of EA to TA and HA to TA would increase with decrease in pHw (r = -0.676 , P d" 0.01 and -0.642, P d" 0.01) and while increase with increase in pHca (r = 0.676 , P d" 0.01 and 0.642, P d" 0.01) (Table 4). Correlation study also showed that the proportion of EA to TA would increase with increase in organic C (r = 0.472, P d" 0.01) and while that of HA to TA increase with decrease in organic C (r = -0.472, P d" 0.01) (Table 4).

There was a wide variation in total acidity (TA), hydrolytic acidity (HA) and exchange acidity (EA) in the studied acidic Alfisols of Bankura district of red and lateritic belt of West Bengal. Contributions of HA and EA to TA and that of $EBAl^{3+}$ and EBH^+ to EA was also varied widely. Studied forms of soil acidity showed significant positive correlations with organic C and but negative correlations with pHw and pHca. Again, the different forms of soil acidity were significantly and positively correlated with each other.

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