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Characterisation of acidity under different land use patterns in Tarai soils of West Bengal

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Sixty soil samples from four different land use patterns in tarai agroclimatic region of West Bengal were studied to characterise their acidity in relation to land uses and physical and chemical properties. Soils of tea garden and orchard were strongly to moderately acidic while soils of cultivated land and forest were strongly acidic to neutral and slightly alkaline in reaction, respectively. The mean value of electrostatically bound H^+ constituted 17.2 - 20.5 per cent of exchange acidity while pH -dependent acidity comprised of 86.4 - 93.4 per cent of total potential acidity in these soils. The soils of tea garden exhibited maximum total potential acidity, pH-dependent acidity, hydrolytic acidity, extractable Al^{3+} and non-exchangeable Al^{3+} followed by orchard, forest and cultivated land while electro-statically bound H^+, Al^{3+}, total acidity and exchange acidity were maximum in the soils of orchard followed by tea garden , forest and cultivated land. Various forms of soil acidity were significantly related to pH, Org C, CEC, clay, exchangeable and extractable Al^{3+}. Among the soil properties CEC, exchangeable and extractable Al^{3+} caused most of the variations in different types of soil acidity.

Additional keywords **:** Forms of soil acidity, soil properties

Introduction

In tarai agroclimatic region, soil acidity poses a great problem for crop production. Rapid weathering and depletion of bases from upper horizons due to intense leaching under high rainfall favour development of soil acidity. Soil acidity is usually defined in terms of KCl extractable and pH dependent acidity (Coleman and Thomas 1967). The first type of acidity which is also known as exchange acidity or permanent charge acidity is ascribed to isomorphous substitution while the second type of acidity which is solely dependent on soil pH (pH-dependent acidity), is due to polymers of Fe and Al and soil organic matter. The production potential as well as lime requirement depend primarily on the proportion of these two types of acidity. In addition to uncontrollable climatic, geological and environmental factors, land use pattern also affect the acidity and thereby nutrient availability of the soils. A knowledge on different forms of acidity may provide a first hand information on acid soils for their better management. Thus, an attempt has been made here to characterise the different forms of soil acidity under different land uses and to evaluate the influence of soil properties on them as very little information is available for tarai soils of West Bengal on this aspect.

Materials and Methods

Sixty surface soil samples (0-15 cm) were collected taking 15 samples each from four land use under forest, tea garden, orchard and cultivated land in tarai region of West Bengal. The major forest species were Teak (*Tectona grandis*), Sal (*Shorea robusta*), Gamari (*Gmnelia arborea*) and Sissoo (*Dalbergia sissoo*), while the orchard crop was exclusively pine-apple (*Ananas comosus*). The major crops grown in cultivated land were rice (*Oryza sativa*), jute (*Corchorus sp.*), tobacco (*Nicotiana sp.*), potato (*Solanum tuberosum*), etc. Soils were collected from the area located in between 26°

12' to 26° 56' N latitude and 88° 7' to 89° 53' E longitude. The processed soil samples (< 2 mm size fractions) were analysed for different physical and chemical properties like particle- size distribution, pH, org. C (Black 1965), CEC, exchangeable bases following standard procedures. Effective CEC (ECEC) was calculated by the sum of exchangeable bases plus exchangeable Al^{3+}.

Total acidity and exchange acidity of the soils were determined by extracting with 1.0 M sodium acetate (pH 8.2) (Kappen 1934) and 1.0 M KCl (McLean 1965), respectively and subsequently titrating against standard NaOH. After determining exchange acidity, the electrostatically bound-Al^{3+} (EB-Al^{3+}) was determined from the same solution by titrating against HCl after adding NaF. The difference between total acidity (TA) and exchange acidity (EA) was considered as hydrolytic acidity (HA). The total potential acidity (TPA) was determined by extracting with $BaCl_2$-TEA (pH 8.2) by Peech's method (Black 1965) where pH-dependent acidity was calculated as the difference between TPA and EA. The extractable Al^{3+}(extractable acidity) was determined by extracting soil with 1.0 M NH_4OAc (pH 4.8) and subsequently treating with aluminon reagent (Hesse 1971). The electrostatically bound hydrogen (EB-H^+) was determined by subtracting EB-Al^{3+} from EA. Non-exchangeable Al^{3+} (hydroxy-Al monomers and polymers) was obtained by subtracting EA from extractable Al^{3+}.

Simple correlation and stepwise multiple regression between different forms of acidity and physical and chemical characteristics of the soils were computed following standard statistical methods.

Results and Discussion

Soil characteristics

Some relevant physical and chemical characteristics of soils are presented in table 1. Soils of tea garden and orchard were strongly to moderately acidic while soils of cultivated land and forest were strongly acidic to neutral and slightly alkaline in reaction, respectively. High pH values in few samples of forest land use which is restricted to south Khayerbari forest at Madarihat (Jalpaiguri district) might be due to deposition of dolomite brought down by the river Torsa from Bhutan hills. Average organic Carbon content of these soils was high which probably strongly influenced

Table 1. Some physical and chemical characteristics of the soils

Land use	Cultivated land		Forest		Orchard		Tea Garden	
Characters	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH (1:2.5)	4.8-7.1	5.7	4.6-7.9	5.3	3.8-5.9	4.7	3.7-5.5	4.8
Clay (%)	15.4-25.4	19.2	9.2-18.2	13.0	10.2-17.4	14.3	11.2-17.2	13.9
Silt (%)	20.0-32.3	26.2	23.4-49.1	32.8	17.4-42.5	27.5	18.0-33.1	27.3
Sand (%)	47.2-59.5	54.6	35.7-67.4	54.0	43.3-72.3	58.1	50.2-69.8	58.8
Org. C (%)	0.70-1.24	0.89	0.93-2.62	1.64	0.70-1.83	1.40	0.45-2.54	1.42
CEC[cmol(+)kg^{-1}]	4.67-13.56	10.44	9.33-26.68	18.36	9.75-24.14	18.16	9.75-28.80	18.22
Base saturation (%)	31.8-72.9	48.4	10.5-72.6	28.4	4.1-31.4	12.6	3.0-19.7	9.0
ExhangeableAl^{3+} [cmol(+) kg^{-1}]	0.17-1.14	0.47	0.17-2.39	1.21	0.23-4.77	2.53	0.91-3.18	1.85
ECEC[cmol(+) kg^{-1}]	3.68-10.07	5.45	3.83-14.62	6.09	3.28-5.67	4.47	2.27-4.51	3.36
Al-saturation of ECEC(%)	1.8-26.6	9.8	1.2-55.1	26.3	5.5-82.9	54.0	23.2-74.9	56.1

the cation exchange capacity. Soils of tea garden and orchard were loamy sand to loam while soils of cultivated land and forest were sandy loam to loam in texture. Soils of cultivated land recorded the highest average base saturation (48.4%) followed by forest (28.4%), orchard (12.6%) and the least in tea garden soils (9.0%) while reverse was the trend in Al saturation percent of ECEC. Average exchangeable Al^{3+} content was maximum in orchard soil followed by tea garden, forest and cultivated land which was similar with the sequence of variation of pH of the respective soils indicating the former's contribution to the later.

Nature of soil acidity

Range and mean values of different acidities under various land uses are presented in table 2. The soils under tea garden exhibited maximum TPA, PDA, HA, extractable Al^{3+} and non-exchangeable Al^{3+} followed by orchard, forest and cultivated land. With respect to other types of acidity like EB-H^+, EB-Al^{3+}, EA and TA, orchard soils exhibited higher average values followed by the soils under tea garden, forest and cultivated land. Lower values of acidity in cultivated land was probably because of less organic matter content as organic matter contributes to some forms of acidity through their functional groups like-COOH and phenolic-OH. Exchange acidity includes the EB-H^+ and EB–Al^{3+} held at the permanent charge sites of the exchange complex (Black 1965). The EB-H^+ constituted a minor component of EA of these soils. The average contribution of EB-H^+ to EA were 20.5, 19.2, 18.1 and 17.2% in soils of cultivated land, forest, orchard and tea garden, respectively. The result was in agreement with the findings of Kumar *et al.* (1995). However, PDA constituted the major component of TPA indicating the extent of variable charge present in these soils. The average contributions of PDA to TPA were 93.3,91.2,89.4 and 86.4% in cultivated land, tea garden, forest and orchard soils, respectively. Among the different land use patterns the highest contribution of PDA and TPA or the least contribution of EA to TPA in cultivated land soil was attributed to higher pH values and lower exchangeable and extractable Al content. Hydrolysis of exchangeable and extractable Al with the rise in pH might contribute to H^+ in the system. Thus, increase in pH with simultaneous decrease in exchangeable and extractable Al were directly related to

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

Land use	Cultivated land		Forest		Orchard		Tea Garden	
Soil acidities	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Electrostaticallybound-H^+(EB-H^+)	0.01-0.41	0.15	0.01-0.61	0.25	0.07-1.20	0.47	0.05-1.01	0.41
Electrostatically bound-Al^{3+}(EB-Al^{3+})	0.17-0.80	0.47	0.17-2.39	1.21	0.23-4.77	2.47	0.91-3.18	1.85
Exchange acidity (EA)	0.22-1.53	0.61	0.22-2.63	1.46	0.44-5.47	3.00	1.09-3.94	2.26
% EB-$H^+$of EA	4.1-30.8	20.5	2.4-48.4	19.2	8.0-48.0	18.1	3.1-33.8	17.2
Total Acidity (TA)	0.25-1.97	0.99	0.25-5.66	2.58	1.23-7.74	4.67	1.23-8.36	4.37
Hydrolytic acidity (HA)	0.01-0.79	0.38	0.03-3.03	1.15	0.79-3.06	1.68	0.01-4.98	2.14
Total potential acidity (TPA)	4.94-13.16	9.54	3.29-24.68	15.36	4.94-29.61	20.18	18.10-32.90	25.56
pH-dependent acidity (PDA)	4.50-12.83	8.93	5.71-22.82	13.90	4.50-25.78	17.18	16.79-29.51	23.29
% PDA Of TPA	85.4-98.1	93.4	60.1-97.8	89.4	76.3-96.0	86.4	86.7-95.9	91.2
Extractable Al^{3+}	0.34-6.04	3.00	0.34-8.11	4.59	2.93-8.11	5.90	5.52-8.11	6.42
Non-exchangeable Al^{3+}	0.12-4.94	2.39	0.12-6.25	3.13	0.14-6.42	2.89	1.58-6.03	4.16

the proportion of PDA to TPA as also indirectly evidenced by the relation between the proportion of EA to TPA and soil properties. Similar findings were also reported by Chand and Mandal (2000).

Forms of acidities and soil properties

Simple correlation coefficient values of different types of acidity with soil properties are given in table 3. pH had a significant negative relationships with all types of acidity viz. EA (r=-0.87), EB-H^+(r=-0.82), EB-Al^{3+}(r=-0.86), TA (r=-0.74), HA(r=-0.46), TPA(r=-0.67) and PDA(r=-0.62). pH alone could explain about 76% variation in EA and 45% variation in TPA. This should be taken into consideration during liming and nutrient management activities in such acid soils (Black 1973).

Organic C also had a significant positive correlation with all forms of acidiy indicating the role of soil humus as a source of soil acidity by dissociating H^+ at varying pH (Sarkar *et al.* 1997).The variation due to Organic C content was higher in HA(61%) and lower in EA(42%). This gives an indication of possible contribution of soil humus to HA, TPA, PDA and TA. Similar result was reported by Nayak *et al.*(1996).CEC and clay also had significant relationship with all forms acidity.

Different forms of Al viz.,exchangeable, extractable and non-exchangeble Al showed significant positive correlation with all types of soil acidity except between non-exchangeable Al and EA as well as its components. Exchangeable Al $^{3+}$ could explain 99% variation in EA suggesting its role in this type of acidity. Participation of non-exchangeable Al^{3+}in different forms of acidity were somehow lower indicating the active contribution of other form of Al^{3+} in developing soil acidity.

Table 3. Simple correlatiom coefficients (r) between different types of acidity and soil properties.

Soil Properties Soil acidity	pH	CEC	Clay	Org.C	Exch. Al	Extract.Al	Non Exch. Al
EB-H^+	-0.82**	0.71**	-0.45**	0.64**	0.89**	0.65**	0.11
EB-Al^{3+}	-0.86**	0.69**	-0.56**	0.63**	-	0.78**	0.24
Exchange acidity	-0.87**	0.70**	-056**	0.65**	0.99**	0.77**	0.22
Total acidity	-0.74**	0.84**	-0.58**	0.77**	0.92**	0.77**	0.28*
Hydrolytic acidity	-0.46**	0.86**	-0.51**	0.78**	0.65**	0.64**	0.32*
Total potential acidity	-0.67**	0.80**	-0.62**	0.72**	0.84**	0.78**	0.37**
PH-Dependent acidity	-0.62**	0.80**	-0.61**	0.71**	0.78**	0.76**	0.39**

*and ** denote 5 and 1 per cent level of significance respectively.

Table 4. Relationship between proportions of forms of soil acidity and soil properties.

Soil Properties Portion of acidity	pH	EC	Org. C	CEC	Exch. Al	Extract.Al	Clay
EB-H^+/EA	0.23	0.19	-0.29*	-0.14	-0.36**	-0.56**	0.40
EA/TA	-0.58**	0.28*	-0.01	-0.19	0.42**	0.31*	-0.22
EA/TPA	-0.86**	0.14	0.45**	0.35**	0.83**	0.66**	-0.46**
TPA-TA	-0.63**	0.06	0.68**	0.77**	0.79**	0.76**	-0.62**

* and ** indicate 5 and 1 per cent level of significance, respectively.

The proportion of EA to either TA or TPA would increase with decrease in pH while increase with increase in exchangeable and extractable Al^{3+} and clay content (table 4). Contribution of EB-H^+ to EA may decrease with increase in organic C, exchangeable and extractable Al^{3+}.The magnitude of difference between TPA and TA would be more in soils having lower pH and clay and higher organic C, CEC, exchangeable and extractable Al^{3+} (Chand and Mandal 2000).

During computation of stepwise multiple regression equations among different types of soil activities and soil properties, no restriction was imposed, i.e., the independent variables entered into the regression model competitively according to their relative contribution towards soil acidities. The variables included in the stepwise regression models developed with soil acidities were significant at 5% probability level.

Among the soil properties exchangeable and extractable Al and CEC could significantly improve the predictability of soil acidities. Though, organic C content had highly significant relationship with different acidities it could not enter into the regression models probably because of overshadowing by the other more potential independent variables like exchangeable and extractable Al and CEC. Exchangeable Al^{3+} alone could explain 99% variation in EA. Exchangeable Al^{3+} and CEC collectively could explain 91% and 76% variation in TA and TPA, respectively (Table 5) while both CEC and extractable Al^{3+} introduced in regression model could explain 76% variation in PDA.

Table 5. Step-wise regression equations for predicting different types of acidity (Y) by using soil properties.

Regression equations	R^2
Exchange Acidity	
$Y = 0.04 + 0.096^{*} + 0.03 + 1.19 X_1$	0.99
Total Acidity	
$Y = 0.45 \pm 0.78$[1] $+ 0.23 + 1.81 X_1$[2]	0.83
$Y = -1.30 \pm 0.56 + 0.22 + 1.27 X_1 + 0.05 + 0.16 X_2$[2]	0.91
Total Potential Acidity	
$Y = 8.16 \pm 4.15 + 1.21 + 6.40 X_1$	0.68
$Y = 0.71 \pm 3.54 + 1.41 + 4.12 X_1 + 0.29 + 0.67 X_2$	0.76
pH- dependent Acidity	
$Y = -2.0 \pm 4.0 + 0.24 + 1.08 X_2$	0.60
$Y = -4.79 \pm 3.11 + 0.21 + 0.75 X_2 + 0.56 + 1.67 X_3$[2]	0.76

[1] Standard error of estimate.
[2] X_1, X_2 and X_3 denote exchangeable Al, CEC and extractable Al, respectively.

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