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Variation of total acidity as influenced by land uses and soil depths in lateritic belt of West Bengal

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Abstract
Soil acidity induces iron, aluminium and manganese toxicities along with restricting phosphorus availability, reducing microbial population in soil and thereby reduces crop productivity. Among the different nature of soil acidity, total acidity is very important in determining nutrient supplying capacity of the soil. To study depth-wise and land use-wise variation of total acidity (TA) and its relationship with soil properties, fifty-four representative soil samples were collected from three depths (viz., 0-20 cm, 20-40 cm and 40-60 cm) from 6 various land uses viz., forest land, orchard land, pasture land, cultivated rice land, cultivated rice-potato land and fallow land of Birbhum district of lateritic zone of West Bengal. The soil samples were analyzed for TA and soil properties like pH, EC, organic C, bulk density, particle density, available N, P_2O_5 and K_2O using standard methodology. It was observed that there was significant depth-wise and land use-wise variation of TA. In all the land uses, TA was decreased with depth. In surface 0-20 cm soil depth, TA was highest and lowest in cultivated rice-potato and pasture land respectively. While in 40-60 cm soil depth the highest and lowest TA was documented in cultivated rice-potato and fallow land respectively. The mean TA irrespective of soil depths was highest and lowest in cultivated rice-potato and pasture land respectively. The mean TA irrespective of land uses was highest and lowest in surface 0-20 cm and 40-60 cm soil depth respectively. The interaction effect of land uses and soil depth showed that TA was highest in surface 0-20 cm soil depth of cultivated rice-potato land, and lowest in 40-60 cm soil depth of fallow land. The TA was significantly positively and negatively correlated with OC and BD of soil.

Keywords: Lateritic soil, total acidity, land uses, soil depth, soil properties

Introduction
Soil acidity is a big problem in crop productivity as it induces iron, aluminium and manganese toxicities in addition to retarding phosphorus availability, dropping microbial population in soil (Brady and Weil, 2008) [4]. Around 49 million hectares land i.e., roughly 34% of total cultivated land of India is acid soil (Maji *et al.* 2012) [12]. Approximately 2.0 million hectares out of total 5.57 million hectares of net cultivated areas of West Bengal is acid soil with pH less than 6.0 (Mandal *et al.*, 1979 [13]; Bhat *et al.*, 2017 [1]). Part of this acid soil area is located in the western part of West Bengal (district like Birbhum, Burdwan, Midnapore, Bankura, and Purulia) which are mostly red and lateritic in nature along with others. Around 0.086 million hectares of land of Birbhum district is under acid soil. The total acidity of soil solution includes the potential H^+ (hydrogen ions) which are capable of releasing along with already released H^+ present as H^+ in solution. Among the different nature of soil acidity, total acidity is very important in determining nutrient supplying capacity of the soil and managing acid soil (Kundu, 2017 [11]; Kundu, 2020 [10]). The weathering of rocks, continuous use nitrogenous fertilizers along with leaching of basic cations in high rainfall areas develop soil acidity. However, different types of land use also affect the acidity. The management of soil acidity requires detail information on total soil acidity across various land uses. With this background, the present study was conducted to assess depth-wise and land-use-wise variation in total acidity in Birbhum district which is part of Lateritic Belt of West Bengal.

Materials and Methods
Representative soil samples from three depths (viz., 0-20 cm, 20-40 cm and 40-60 cm) were collected from six dominant land uses (viz., viz., forest land, orchard land, pasture land, cultivated rice land, cultivated rice-potato land and fallow land) of Birbhum district of lateritic

zone of West Bengal in the year 2017. In fact, total 54 [6 (land use types) X 3 (representative fields) X 3 (depths) = 54] soil samples were collected which were processed by air-drying, mixing and sieving by 2 mm sieve for the analysis. Separate core samples from each soil depths were collected for determination of bulk density. Different soil properties like pH by glass electrode pH meter (1:2.5::soil:water; Jackson, 1973) [8], electrical conductivity (1:2::soil:water; Jackson, 1973) [8], oxidizable organic C (Walkley and Black, 1934) [16], sand, slit and clay content (hydrometer method), bulk density (BD) by core method (Black and Hartge, 1986) [3], particle density (PD) by pycnometer method (Black, 1965) [2], available nitrogen by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [15], available phosphorus by Bray's method (Bray and Kurtz, 1945) [5], available potassium by using neutral normal ammonium acetate extractant method (Hanway and Heidel, 1952) [7]. Total acidity was estimated using 1.0 M sodium acetate as extractant (pH 8.2) (Kappen 1934) [9] and then titration was done by sodium hydroxide (NaOH) and phenolphthalein indicator.

Data Analysis
The analysis of variance (ANOVA) of the effects of various land use types and soil depths on total acidity were tested by the procedure as described by Gomez and Gomez (1984) [6]. Simple Pearson's correlation analysis was done to estimate the relationship of total acidity with soil properties using SPSS software (version 20).

Results and Discussion
Effects of land use types and soil depths on total acidity
There was significant depth-wise variation in total acidity (TA) of soil in all the land uses studied (Table 1, Fig. 1 & Fig. 2). In all the land uses, the highest and lowest total acidity were recorded in 0-20 cm and 40-60 cm soil depth respectively.

While comparing the variation of TA of only 0-20 cm soil depth of all the land uses it was noted that the highest total acidity was recorded in cultivated rice-potato land [2.11 cmol (p^+) kg^{-1}] and lowest total acidity was observed in pasture land [1.35 cmol (p^+) kg^{-1}]. Its value for 20-40 cm soil depth was highest in cultivated rice-potato land [1.84 cmol (p^+) kg^{-1}] and lowest in pasture land [1.23 cmol (p^+) kg^{-1}]. Again, in 40-60 cm soil depth the highest total acidity was documented in cultivated rice-potato land [1.47 cmol (p^+) kg^{-1}] which was, however, statistically at par with forest land and lowest total acidity was observed in fallow land [1.09 cmol (p^+) kg^{-1}] (Table 1, Fig. 1 and Fig. 2).

Considering the main effects of land use types (irrespective of soil depths) it was detected that mean TA of cultivated rice-potato land was highest [1.81 cmol (p^+) kg^{-1}] and that of pasture land was lowest [1.26 cmol (p^+) kg^{-1}] which was, however, statistically similar with fallow land (Table 1, Fig. 1 and Fig. 2).. Thus, total acidity was decreased when land use was converted from forest to crop land. Exhaustion of basic cations in soil due to crop uptake or soil erosion and production of organic acid by microbial oxidation in soil may be the possible reason of having highest total acidity in cultivated rice-potato land. Mandal *et al.* (2006) [13], however, while studying the characterization of acidity under different land use patterns in Tarai soils of West Bengal observed that total acidity was maximum in the soils of orchard followed by tea garden, forest and cultivated land.

Considering the main effects of soil depths (irrespective of land uses) it was observed that the mean TA was highest in surface 0-20 cm soil depth [1.55 cmol (p^+) kg^{-1}] and lowest in 40-60 cm soil depth [1.22 cmol (p^+) kg^{-1}]. In general, it was observed that the total acidity (TA) was decreased with increase in soil depth (Table 1, Fig. 1 and Fig. 2). The main reason behind it may be the accumulation of basic cations (Ca and Mg ions) in the below surface horizon and at the same time removal of basic cations by plant uptake in the surface soil depths which increases soil acidity from top to down the soil depths.

While studying the interaction effect of land use types and soil depth [LSD (0.05) = 0.077] on TA, it was detected that its highest value [2.11 cmol (p^+) kg^{-1}] was noted at 0-20 cm depth of cultivated rice-potato land, and its lowest value [1.09 cmol (p^+) kg^{-1}] was attained at 40-60 cm depth of the fallow land (Table 2). With the exception of few treatment combinations of interaction effects of land use types and soil depth on total soil acidity, most of the treatment combinations were statistically at par ($P \leq 0.05$) with each other (Table 2).

Correlation of total acidity with soil properties
Simple Pearson's correlation studies between total acidity with soil properties showed that total acidity was significantly and negatively correlated with pH (r = -0.830, $P \leq 0.01$) and BD (r = -0.688, $P \leq 0.01$). However, TA was significantly and positively correlated with PD (r = 0.336, $P \leq 0.05$) and OC (r = 0.583, $P \leq 0.01$). Mandal *et al.* (2006) [14], Bhat *et al.* (2017) [1], Kundu (2017) [11] and Kundu (2020) [10] also reported almost same relationship of total acidity with OC and BD.

Conclusion
Total acidity (TA) was varied significantly along depth and land uses and its value was decreased with depth. In 0-20 cm soil depth, TA was highest and lowest in cultivated rice-potato and pasture land respectively. However, its value for 40-60 cm soil depth was highest and lowest TA in cultivated rice-potato and fallow land respectively. The mean TA irrespective of soil depths was highest and lowest in cultivated rice-potato and pasture land respectively. The mean TA irrespective of land uses was highest and lowest in surface 0-20 cm and 40-60 cm soil depth respectively. The interaction effect of land use types and soil depth showed that TA was highest in surface 0-20 cm soil depth of the cultivated rice-potato land and lowest in 40-60 cm soil depth of the fallow land. Again, TA was significantly positively and negatively correlated with OC and BD of soil respectively.

Table 1: Depth-wise and land use-wise variations in mean total acidity (TA) of soil

Depth of soil/ Land use	Total acidity [cmol (p^+) kg^{-1}]							
	Forest land	Orchard land	Pasture land	Cultivated land (rice)	Cultivated land (rice-potato)	Fallow land	LSD (0.05)	Mean TA [*LSD (0.05) = 0.032]]*
0-20 cm	1.71^{aB}	1.68^{aB}	1.35^{aD}	1.45^{aC}	2.11^{aA}	1.49^{aC}	0.09	1.55^{a}
20-40 cm	1.54^{bB}	1.44^{bC}	1.23^{bE}	1.31^{bD}	1.84^{bA}	1.32^{bD}	0.08	1.37^{b}
40-60 cm	1.39^{cAB}	1.31^{cB}	1.19^{cC}	1.25^{bBC}	1.47^{cA}	1.09^{cD}	0.08	1.22^{c}
LSD (0.05)	0.10	0.09	0.03	0.08	0.11	0.12		
Mean TA [LSD (0.05) = 0.084]	1.55^{B}	1.48^{B}	1.26^{D}	1.34^{C}	1.81^{A}	1.30^{CD}		
Mean values in each column followed by different small letter(s) and mean values in each row followed by different capital letter(s) superscripted refers to significant differences in TA among different depth and land uses respectively at *p<0.05*.								

Table 2: Interaction effects of land use types and soil depth on total acidity

Land use types	Total acidity [cmol (p^+) kg^{-1}] at various soil depth		
	0-20 cm	**20-40 cm**	**40-60 cm**
Forest land	1.71^{c}	1.54^{d}	1.39^{ef}
Orchard land	1.68^{c}	1.44^{e}	1.31^{f}
Pasture land	1.35^{f}	1.23^{g}	1.19^{g}
Cultivated land (Rice)	1.45^{e}	1.31^{f}	1.25^{g}
Cultivated land (Rice-Potato)	2.11^{a}	1.84^{b}	1.47^{de}
Fallow land	1.49^{de}	1.32^{fg}	1.09^{h}
LSD (0.05)	**0.077**		
Interaction effects means of total acidity of soil followed by the same small letter(s) are not significantly different from each other at *P*≤0.05			

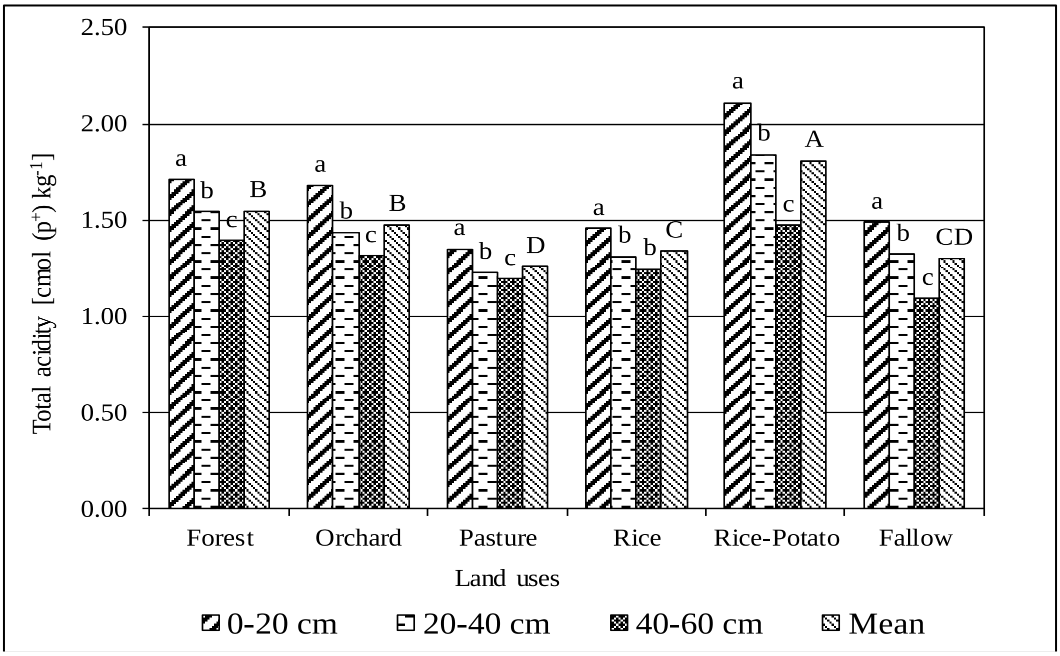

Fig 1: Depth-wise variation in total acidity (TA) of soil in each land use [different small letters written at the top of the three columns of each land use indicates significant variation in TA (*p<0.05*); different capital letters written at the top of the six columns of all the land uses indicates significant variation in TA (*p<0.05*)].

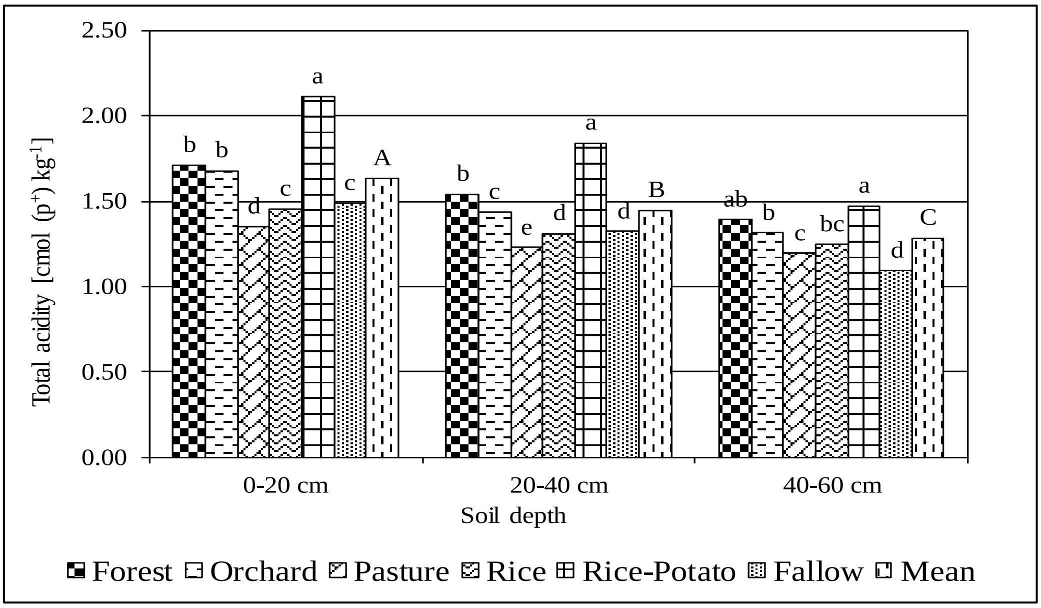

Fig 2: Land use-wise variation in total acidity (TA) of soil of three soil depths [different small letters written at the top of the six columns for each soil depth indicates significant variation in TA (*p<0.05*); and different capital letters written at the top of the three columns indicates significant variation in TA (*p<0.05*)].

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