Forms of soil acidity and the distribution of DTPA-extractable micronutrients in some soils of West Bengal (India)

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Abstract

The distribution of the DTPA- (Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+}) in different pedons under *Terai* situations of West Bengal (India) was found to be governed by the forms of soil acidity. The pH and the organic carbon in soils had the major contributions towards the variation in extractable cations. The exchangeable Al^{3+} and total acidity contributed to the variation of extractable Fe^{2+}, Mn^{2+} and Cu^{2+}, while all forms of acidity except non-exchangeable form accounted for the availability of Zn^{2+} in soil solution. The different forms of acidity of the soils were quite comparable, although, the contribution of exchangeable acidity to the total potential acidity was low. The availability of nutrients varied with the soil depth and with different forms of acidity under the *Terai* situations of West Bengal. Significant correlations of extractable acidity and total potential acidity with the extractable Cu^{2+} and Zn^{2+} were observed for the given soils. The distribution of the forms of acidity with depth of soils varied on account of the changing accumulation of exchangeable bases at different depths in soils.

Key Words

Micronutrients, pedons, acidity

Introduction

Micronutrients in soils are important for plant growth and nutrition. The distribution of cationic micronutrients especially Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+} in acid soils of India is sporadic. The different forms of acidity showed significant positive correlations with organic carbon and forms of Al^{3+} in soils but negative correlations with soil pH. Mondal *et al.* (2004) studied *Terai* soils of different land uses in India and found that exchange acidity (EA), total potential acidity (TPA), pH-dependent acidity (PDA) and total acidity (TA) had significant positive relationships with Al^{3+} and extractable-Al^{3+}. The non-exchangeable Al^{3+} and forms of soil acidity were positively and significantly correlated except for EA, indicating the dynamic equilibrium among different forms of aluminum and their role in soil acidity. The mean contents of iron and aluminium, extracted by various extracting reagents (Dolui and Maity, 2004), were in the order of dithionite>oxalate> pyrophosphate> KCl > ammonium acetate. The different forms of aluminium had significant contributions to the forms of soil acidity. Based on the above perspectives, the experiments were conducted with the following objectives; i) to determine the distribution of cationic micronutrients of some selected acid soils of *Terai* region of the Indian subcontinent and correlating the same with the important physicochemical properties of soils; ii) to characterize and compare different forms of acidity in soil layers and assess its influence on the availability of the extractable cationic micronutrients.

Methods

Eleven soil profiles representing three soil series (Binnaguri, Chunavati and Kharibari) of the order Entisol were exposed and soil samples were collected at different depths (0-90 cm.) in the districts of Darjeeling and Jalpaiguri under the *Terai* situation of West Bengal (India). The sampling areas were adjacent to tea gardens of different ages. The soil samples were analyzed for important physicochemical properties, following standard laboratory procedures. Micronutrient cations in soils were extracted with 0.005 (M) DTPA, containing 0.01 M $CaCl_2$, and 0.1 M TEA (Triethanol amine) buffered at pH 7.3 (Lindsay and Norvell, 1978). The extracts were analysed for Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+} by atomic absorption spectrophotometry. The exchangeable acidity of soils were measured following the method outlined by Sokolov (1939) and McLean (1965). The extractable acidity and total potential acidity were by the method of Baruah and Barthakur (1999). The non-exchangeable acidity was estimated indirectly as:

Non-exchangeable acidity = Extractable acidity – Exchange acidity

The pH-dependent acidity was estimated by the following equation

pH-dependent acidity = Total potential acidity – Exchangeable acidity.

Total soil acidity was measured by shaking the soil with 1N CH_3COOH (pH 8.2) for an hour (Kappen, 1934); the exchangeable-Al was determined following the principle as described by Baruah and Barthakur (1999). The statistical analysis was done with the standard software packages.

Results

There was variation of the exchangeable acidity (EA) of the soils at different depths (0-90 cm.) of the profiles under study. The contribution of EA to the total potential acidity (TPA) was low that corroborated the report of Dolui and Sarkar (2001). The mean value of exchangeable acidity in soils varied from 0.80-2.17 cmol(p^+) /kg. The form of non-exchangeable acidity varied from 0.17-0.80 cmol(p^+)/kg while that of exchangeable-Al^{3+} from 0.70-2.04 cmol(p^+)/kg. It was observed that the exchangeable aluminium had contribution towards the exchangeable acidity which was in agreement with the findings of Sharma *et al*. (1990), suggesting that the exchangeable acidity in soil was mainly due to monomeric Al^{+3} ions. Acidity occurring as variable charge (pH-dependent) as measured by the difference of total potential acidity (TPA) and exchangeable acidity (EA) varied from 28.32-59.29 cmol(p^+)/kg.It was observed that there was a decline in pH-dependent acidity in the sub - surface soils in most of the soils of the region. The other soils might have the participation of organic matter in the development of variable charge. The mean value of the total potential acidity of the soils varied from 29.43-61.32 cmol(p^+)/kg. It was apparent that the total potential acidity in most of the soils, decreased with the depth of soils (Figure 1). This might be due to the deposition of exchangeable bases with increasing soil depth. The higher values of the total potential acidity in some soils might be due to higher content of organic carbon which might have contributed to the total potential acidity through their functional groups like –COOH and phenolic –OH. The total acidity (TA) of the soils ranged from 2.85-4.66 cmol(p^+)/kg. The values of the total acidity were very low compared to those of TPA. This was related to the use of the extracting salts, i.e. $BaCl_2$ –TEA and CH_3COONa for this purpose. The extractable acidity varied from 0.97-2.71 cmol(p^+)/kg. This form of acidity possibly originated from the polyhydroxy molecule of Al^{3+} in soils.

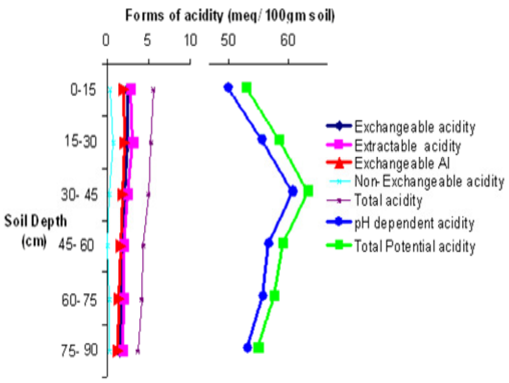
A gradual decrease of the Fe^{2+} content with soil depth (Figure 2) was observed. Considering the critical limit of 4.5 mg /kg soil (Anonymous, 1990), most of the soils were adequate in Fe^{2+} content in the surface soils.The DTPA-extractable Mn^{2+} content ranged from 0.40 to 6.14 mg /kg soil. A general trend of decrease of the Mn^{2+} content with the increase of the depth of the soils was observed. The DTPA-extractable Cu^{2+} content varied from 0.17 to 1.96 mg /kg, while that of extractable -Zn^{2+} varied from 0.28 to 0.91 mg /kg. A general trend of decrease of Zn^{2+} with depth was observed in the soils under study. Considering the critical limit of 0.60 mg /kg (Anonymous, 1990), the mean values of Zn^{2+} in some soils under study were low. A sharp decline in the extractable micronutrients (Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+}) in the sub-surface horizons indicated hardly any leaching to lower layers. It was observed that there was a general trend of lowering of the extractable cations with depth for the soil series under study. Initial sharp declines of the extractable iron up to a certain layers and subsequent gradual decrease to the lower zones for most of the soils were observed. The trend in distribution of extractable Cu^{2+} and Zn^{2+} in soil layers were similar, although, variations of the distribution of the extractable Mn^{2+} for some soils were observed.

A significant positive correlation (Table 1) was observed between the total acidity and extractable Fe^{2+} content (0.249*) of the soil. The exchangeable Al^{3+} and total acidity contributed 14.97% variation, although, inclusion of pH-dependent acidity could improve the variation to 18.43% on the availability of extractable-Fe^{2+}. Significant positive correlation of Mn^{+2} with exchangeable acidity (0.505**), extractable acidity (0.442**), and total acidity (0.560**) was observed (Table 1). The total acidity and pH-dependent acidity had the major contribution (5.56%) to extractable-Mn^{2+}. Significant positive correlations of extractable-Cu^{2+} with exchangeable acidity (0.371**), extractable acidity (0.324**), total acidity (0.340**) and total potential acidity (0.265*) were observed (Table 1). It was observed that the pH had a significant negative correlation (Table 1) with total acidity (-0.556**), exchangeable acidity (-0.607**), extractable acidity (-0.634**) and non-exchangeable acidity (-0.491**), suggesting that, these forms of acidity were responsible for lowering the pH of the soils. Exchangeable-Al contributed to 15.61% of the extractable-Cu^{2+} compared to the other factors (16.98%). Significant positive correlations of the extractable Zn^{2+} with exchangeable acidity (0.407**), extractable acidity (0.387**), total acidity (0.524**), pH-dependent acidity (0.337**) and total potential acidity (0.419**) were observed (Table 1). Total acidity had the major contribution (27.43%) to the variation of the extractable Zn^{2+}, although, both the exchangeable-Al and pH-dependent acidity could explained 32.21% of the variation in the DTPA-extractable Zn^{2+} of the soils.

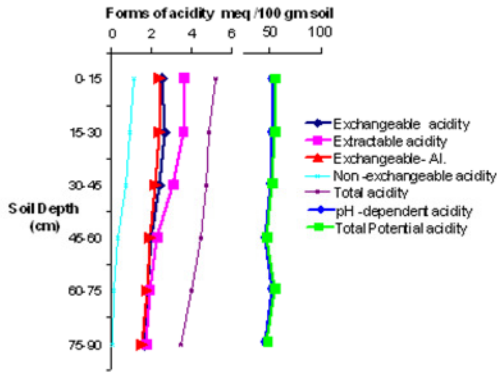
Table 1. Correlations between the forms of acidity with cationic micronutrients and soil pH.

Types of acidity	Micronutrients				
	Fe^{2+}	Mn^{2+}	Cu^{2+}	Zn^{2+}	pH
Exchangeable acidity	0.023	0.505**	0.371**	0.407**	-0.607**
Extractable acidity	0.016	0.442**	0.324**	0.387**	-0.634**
Non-exchangeable acidity	0.001	0.206	0.146	0.239	-0.491**
Total acidity	0.249*	0.560**	0.340**	0.524**	-0.556**
pH-dependent acidity	0.225	0.048	0.199	0.337**	0.033
Total potential acidity	0.175	0.065	0.265*	0.419**	0.006

Significant at 0.05% level, ** Significant at 0.01% level

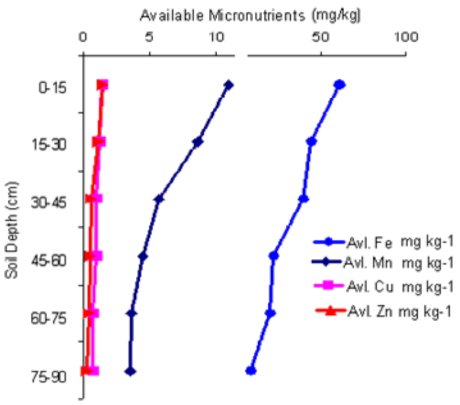


Binnaguri series

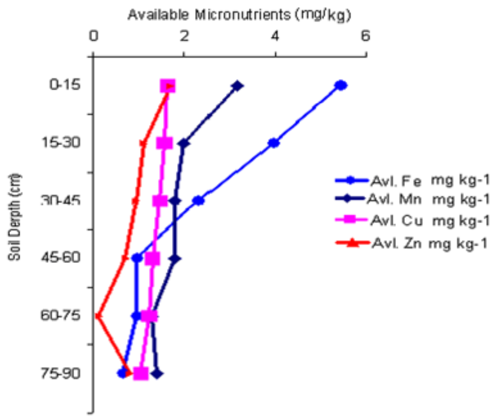


Chunavati series

Figure 1. Distribution of forms of acidity with depth in soils.



Binnaguri series



Chunavati series

Figure 2. Distribution of DTPA-extractable micronutrients with depth in soils

Conclusion

A general trend of decreasing extractable-micronutrients (Fe^{2+}, Mn^{2+}, Cu^{2+} and Zn^{2+}) with depth in soils under *Terai* situations was apparent. The different forms of acidity governed the distribution of the extractable –micronutrients in soils. The effects of exchangeable acidity on the total potential acidity was low in the soils under study, although, the exchangeable Al^{3+} and total acidity had influences on the distribution of the DTPA-extractable micronutrients in soils.

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