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THE BUFFERING CAPACITY OF ACRISOLS IN SOUTHEASTERN VIETNAM: PRELIMINARY AND FUTURE RESEARCH

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ABSTRACT

This paper summarized preliminary results of pH buffering capacity (pH_{BC}) of Acrisols under cassava production in Tay Ninh province, Southeastern Vietnam. Soils were coarse-textured, highly acidic (pH_{H2O}<5), low in SOC and clay content. Soil pH_{BC} were low and correlated well with exchangeable Al and Al-related components. Exchange acidity contributed significantly to pH_{BC}. Contribution of SOC to pH_{BC} was of little significance while that of clay minerals was unclear. Low pH_{BC} indicated a high risk for further acidification. Factors and processes involved in soil acidification and liming need to be addressed as a background for soil remediation.

Keywords: Acrisols, Southeastern Vietnam, lime buffer capacity, lime requirement.

1. INTRODUCTION

Acrisols in Southeastern Vietnam are located on slopes and suffer high rates of runoff and soil loss. They are mostly composed of 1:1 silicate-layer clay minerals of low exchange capacity, acidic (pH_{KCl} 3.5-5), and high exchangeable Al. These soils have been subjected to intensive cropping systems, which further exacerbates the problem of soil acidity. To remediate soil acidity, liming is supposed to be an appropriate measures. The background for liming is, however, still lacking. This research discussed soil pH buffering capacity and its relationships with other soil's physicochemical characteistics in Tay Ninh province (Southeastern Vietnam).

2. METHODS

2.1. Soil sampling

Sampling was conducted in Chau Thanh (12 cassava soils and 3 forest soils as reference, 20-cm interval) and Tan Bien districts (7 cassava soils, 10-cm interval) of Tay Ninh province to 60-cm depth (3 replicas). Composite samples of the same depth were used for analysis.

2.2. Sample treatment and analysis

Soils were air-dried and passed a 2-mm sieve. Soil pH_{BC} was determined by the titration method [1,2]. For Tan Bien soils, pH_{BC} was determined on original samples (pH_{BC1}) and those from which SOC were removed (pH_{BC2}), resulting in a ΔpH_{BC} ($\Delta pH_{BC}=pH_{BC1}-pH_{BC2}$). The physicochemical properties of the soils were determined using internationally-accepted methods. T-test, ANOVA, and Pearson correlation matrix were used to analyse the data.

3. RESULTS AND DISCUSSION

3.1. The condition of soil acidity

Soils were acidic (Tables 1, 2) with poor base nutrients. Exchangeable Al^{3+} accounted for 94.16% of exchange acidity. The high residual acidity indicated other important sources of acidity rather than those in soil solution and on the exchange complex.

A comparison with the nearby forest soils in Chau Thanh (Table 2) showed that cassava production is not necessarily the major culprit of increased soil acidity. This seems contrary to the general finding [3,4,5]. It can be inferred that impact of cassava production on soil acidity is dependent on the combination of both natural and anthropogenic factors.

Table 1. Variations of the indicators of soil acidity with depths (Tan Bien soils).

Depth cm	pH_{H2O} -	pH_{KCl} -	Ex.Al[1] cmol kg^{-1}	Ex.Acid[2] cmol kg^{-1}	Hy.Acid[3] cmol kg^{-1}	Re.Acid[4] cmol kg^{-1}
0-10	4.67^{e}	3.73^{d}	0.75^{a}	0.81^{a}	2.66^{a}	1.85^{a}
10-20	4.61^{de}	3.72^{cd}	0.98^{ab}	1.04^{ab}	2.97^{ab}	1.93^{a}
20-30	4.55^{cd}	3.68^{bc}	1.23^{b}	1.30^{b}	3.29^{b}	1.99^{ab}
30-40	4.49^{bc}	3.65^{ab}	1.53^{c}	1.61^{c}	4.06^{c}	2.45^{bc}
40-50	4.44^{ab}	3.64^{ab}	1.77^{cd}	1.86^{cd}	4.53^{cd}	2.67^{c}
50-60	4.40^{a}	3.61^{a}	2.02^{d}	2.11^{d}	4.87^{d}	2.76^{c}

[1]Ex.Al: Exchangeable Al^{3+}, [2]Ex.Acid: Exchange acidity, [3]Hy.Acid: Hydrolytic acidity, [4]Re.Acid: Residual acidity. Means with the same superscript(s) are not significantly different at $p<0.05$.

Table 2. Properties of cassava soils as compared with the reference soils (Chau Thanh district).

Soil properties	Cassava soils	Reference soils	Cassava soils (cm) 0-20	20-40	40-60	Reference soils (cm) 0-20	20-40	40-60
pH_{H2O}	4.40±0.11^{b}	4.18±0.14^{a}	4.52^{a}	4.40^{a}	4.25^{a}	4.33^{a}	4.19^{a}	4.02^{a}
pH_{KCl}	3.98±0.07^{a}	3.99±0.03^{a}	4.08^{b}	3.99^{ab}	3.86^{a}	4.00^{a}	3.99^{a}	3.97^{a}
pH_{CaCl2}	4.07±0.12^{b}	3.92±0.05^{a}	4.25^{b}	4.06^{ab}	3.87^{a}	3.96^{a}	3.92^{a}	3.87^{a}
Ex. Ac	1.70±0.21^{a}	1.75±0.25^{a}	1.40^{a}	1.75^{a}	1.98^{a}	1.61^{a}	1.72^{a}	1.90^{a}
Ex. Al	1.63±0.20^{a}	1.65±0.25^{a}	1.33^{a}	1.68^{a}	1.89^{a}	1.52^{a}	1.63^{a}	1.81^{a}
HA	4.52±0.37^{a}	4.66±0.50^{a}	3.91^{a}	4.84^{a}	4.85^{a}	5.01^{a}	4.32^{a}	4.66^{a}
BS	39.55±6.69^{b}	24.88±8.75^{a}	47.14^{a}	39.77^{a}	31.03^{a}	26.80^{a}	21.53^{a}	26.31^{a}
SOC	0.23±0.03^{a}	0.31±0.08^{b}	0.31^{b}	0.21^{a}	0.18^{a}	0.45^{b}	0.24^{a}	0.23^{a}
Sand	69.25±0.61^{a}	69.26±1.22^{a}	67.30^{a}	69.95^{b}	70.64^{b}	67.56^{a}	68.73^{a}	71.48^{b}
Silt	18.02±0.54^{a}	18.20±1.27^{a}	18.84^{a}	17.88^{a}	17.27^{a}	19.06^{b}	19.65^{b}	15.88^{a}
Clay	12.73±0.37^{a}	12.55±0.65^{a}	13.86^{b}	12.18^{a}	12.09^{a}	13.39^{a}	11.62^{a}	12.64^{a}

Ex. Ac: Exchange acidity, Ex. Al: Exchangeable Al, HA: hydrolytic acidity, BS: base saturation. Units of measurements: Exchange acidity, exchangeable Al, and hydrolytic acidity are expressed as cmolc/kg; base saturation, SOC, sand, silt, and clay are expressed as %.

3.2. The pH buffer curve and pH buffering capacity of Acrisols

The Acrisols were poorly buffered. The pH buffer curve was linear in the pH_{H2O} range from 3.97-5.24. Soil pH_{BC} (1.16±0.13 and 0.46±0.04 cmol kg^{-1} pH^{-1}, respectively in Chau Thanh and Tan Bien) was quite poor, lower as compared to that of many other soils in Australia [6], the North Platte (Nebraska, US) [7] or soils in New South Wales of Australia[1]. This was most probably ascribed to the low SOC (0.23±0.03% and 0.52±0.09%) and clay content (12.73±0.37% and 9.37±0.76%), respectively in Chau Thanh and Tan Bien districts.

3.3. Relationships between pH buffering capacity and soil properties

Soil pH_{BC} were positively correlated with exchange acidity, exchangeable Al^{3+}, Al saturation (Table 3) and hydrolytic acidity ($r=0.57^{***}$), in accordance with the inverse relationships between pH_{BC} and pH_{H2O}, pH_{KCl} (Table 3), and pH_{CaCl2} ($p < 0.001$). Exchangeable Al^{3+} was the main component of soil acidity (95.22±0.51%). When $Al^{3+}$are abundant on soil's exchange complex, the amount of base needed to neutralize it (i.e. flushing Al^{3+} out from the complex and precipitating it as $Al(OH)_3$ [8] also increases, leading to a slower rate of pH increase upon base additions. On the other hand, pH was relatively stable when it dropped to a certain value (as a result of logarithmic relationships between pH and H^+) while soils continue to be acidified under acid additions. This phenomenon must be noted when assessing acidification of soils having pH<4.

Soil pH_{BC} were inversely correlated with base nutrients but did not correlate with SOC and clay content. This was because of the low SOC contents (<2%). Besides, in the pH range of Acrisols,Fe and Al, not SOC or exchangeable bases, are the major contributors of pH_{BC}.

Table 3. Correlations between soil's buffering capacity and the indicators of acidity in cassava soils (Chau Thanh district). The correlation coefficient (r) and significance levels are presented.

Soil's buffering capacity	pH_{H2O}	pH_{KCl}	Exchange acidity	Exchangeable Al	Al saturation	Base saturation
pH_{BC}[1]	-0.68^{***}	-0.71^{***}	0.73^{***}	0.73^{***}	0.61^{***}	-0.60^{***}
pH_{BC}-BA[2]	-0.53^{**}	-0.52^{**}	0.52^{**}	0.51^{**}	0.49^{**}	-0.49^{**}
pH_{BC}-AA[3]	-0.35^{*}	-0.34^{*}	0.35^{*}	0.35^{*}	0.34^{*}	-0.34^{*}

[1]pH_{BC} (cmol/kg/pH), [2]pH_{BC}-BA: pH_{BC}-base addition (cmol OH^-/kg/pH); [3]pH_{BC}-AA: pH_{BC}-acid addition (cmol H^+/kg/pH). Significance level: * ($p<0.05$), ** ($p<0.01$), and *** ($p<0.001$).

There was no difference in pH_{BC} among the three measurement procedures. Soil pH_{BC}, pH_{BC}-base addition and pH_{BC}-acid addition showed similar patterns of correlations with the indicators of acidity (Table 3). The pH_{BC}-base additions were, however, more closely correlated with pH_{BC} (r=0.76***) than the pH_{BC}-acid addition (r=0.34*), suggesting that soils react more effectively with bases than with acids.

In Tan Bien, pH_{BC1} and pH_{BC2} did not differ but were significantly correlated ($r=0.64^{***}$). They both showed significant correlations with soil chemistry (Table 4). Exchangeable Al^{3+} and Al saturation were significantly correlated with pH_{BC1} and pH_{BC2}, suggesting that exchangeable Al^{3+} played an important role in pH_{BC}. This was because higher Al^{3+} and its hydrolysis products ($Al(OH)^{2+}$, $Al(OH)_2^+$) on the exchange complex would require more basetoneutralize. Soil pH_{BC2} showed closer relationships with the indicators of acidity as compared to pH_{BC1} (Table 4), suggesting that most of Al^{3+} were adsorbed on the surface or fixed in the lattice of silicate clay minerals, or on the surfaces of Fe-Al oxides/oxyhydroxides, rather than in combination with soil organic matter. Clay content was not correlated with pH_{BC1} or pH_{BC2}, most probably because of its low and kaolinite-dominated content [9], which is a low-activity clay mineral.

Table 4. Relationships between pH_{BC} and the indicators of soil acidity.

	pH_{H2O}	pH_{KCl}	Exchangeable Al^{3+}	Al saturation	Exchange acidity	Hydrolytic acidity	Residual acidity
pH_{BC1}	-0.42^{**}	-0.44^{**}	0.31^{*}	0.35^{*}	0.32^{*}	0.26^{ns}	0.10^{ns}
pH_{BC2}	-0.77^{***}	-0.75^{***}	0.57^{***}	0.57^{***}	0.57^{***}	0.60^{***}	0.38^{*}

The significance levels: ^{ns} (not significant), * ($p<0.05$), ** ($p<0.01$), and *** ($p<0.001$)

In Tan Bien, exchangeable Al^{3+} and Al saturation (46.19±4.27%) were significantly correlated with pH_{H2O}. Exchangeable Al^{3+} was completely precipitated in soils having $pH_{H2O}\geq5.07$, in accordance with previous research on Al solubility in acid soils. At this pH, Al saturation was reduced to 10.10% as calculated from Equation 2, similar to previous findings in tropical soils [10]. SOC were low and showed a weak positive relationship with pH_{BC1} and ΔpH_{BC} ($r=0.41^{**}$). Further, the relationships between pH_{BC} with pH_{H2O} and pH_{KCl} were changed after SOC removal. All have proved the contribution of SOC to pH_{BC}. This contribution was, however, of little significance because of the low SOC (0.52±0.09%).

3.4. Agronomic implications/Implications for liming

The pH_{H2O} of the soils (<4.53) was lower than the optimal pH for cassava (pH_{H2O} 5-5.5) [4]. Soil pH_{BC} was poor, indicating a high potential for further soil acidification. Al saturation was higher than the critical level (>40%) for a 10% reduction of cassava yield. These suggest that liming (to pH 5-5.5) be an appropriate remediation measures for cassava production in this area.

4. CONCLUSION

Acrisols under study were acidic and poorly buffered, mainly contributed by Al^{3+}. Soil pH_{BC} correlated significantly with pH, Al and Al-related components but not with SOC or clay content. Poor pH_{BC} indicated a potential for further soil acidification and that liming is a proper measures. Liming (to a target pH from 5-5.5) would be one of the options to acidity problem. Future research should focus on (1) the experimental conditions affecting soil-lime reactions and LR methods for routine soil test; (2) factors pertaining to pH_{BC} and lime requirement; and (3) lime buffer capacity and lime requirement of Acrisols.

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