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Soil Acidity Relationships of Soils From the Upper Amazon Basin and the Campo Cerrado and Their Implication On Plant Growth

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The highly weathered soils of the Tropics are very often quite acid and the predominant cation is exchangeable aluminum. (Pratt and Alvahydo, 1966). Crops yields on the highly weathered soils of the Campo Cerrado in Brazil have been greatly increased with relatively small additions of lime (de Freitas, McClung, and Lott, 1960; Mikkelsen, de Freitas, and McClung, 1963). Lime rates sufficient to neutralize the exchangeable Al apparently are adequate for optimum plant growth (Kamprath, 1970).

Relatively little work has been done with the soils of the Amazon Basin as related to their response to lime. The data of Sombroek (1966) for soils in the Amazon Basin of Brazil indicates that exchangeable Al accounted for 44% of the exchangeable cations in the A_1 horizon of well drained forest soil and 57% in the well drained savannah soils. The poorly drained soils, however generally had a very low aluminum saturation.

The objectives of this paper are (a) to examine the soil acidity relationships of soils from the Upper Amazon Basin and the Campo Cerrado of Brazil and (b) to discuss the implication of these relationships on plant growth and response to liming.

Experimental Procedure

For the study of the soil acidity relationships of the Humid Tropical Forest soils use was made of soil data reported by Sanchez and Buol (1971) and some additional unpublished data. They collected soils from the Amazon Basin at Yurimagas and Iquitos in Peru. The well drained soils were

Paleudults, the poorly drained ones are Paleudalfs or Tropaqualfs and the "giant podzols" are probably spodic quartzpsamments. These soils for the most part were uncultivated but in a few instances had been cleared. The exchangeable Al was extracted with 1N KCl and the exchangeable bases were extracted with 1N NH_4OAc. The soil pH was determined potentiometrically on a 1:2.5 soil-water mixture.

Soil samples also were collected from a lime study with a Red Latosol at the Federal Experiment Station located near Brasilia, Brazil. Samples were collected from the 0-20 cm depth. The exchangeable cations were extracted as previously described. The soil pH, however, was determined on a 1:1 soil-water mixture. The aluminum saturation is expressed as a percentage of the sum of the exchangeable cations.

Results and Discussion
Soils of the Upper Amazon Basin

Well drained soils. The results for the well drained soils are presented in Table 1. The A_1 horizons all were quite acid except for Y-11 which was in pasture. Burning of the area 8 years ago undoubtedly was the reason for the higher pH. The A_1 horizons of the soils with a pH of less than 5 had a moderate aluminum saturation, 31 to 52 percent, except for Y-11 which was 80 percent aluminum saturated. The A_2 and B_1 horizons however had a quite high aluminus saturation ranging from 71 to 92 percent.

In their natural state the surface soils had rather low pH values even though the Al saturations were not as high as one might expect. The low pH values of the surface soils are probably a result of rapid decomposition of the large amounts of fresh organic residues added annually and formation of acid groups in the organic matter. It appears that once the surface soils

are limed to pH 5 the Al saturation will be reduced to a very low level (Figure 1).

Response to lime would be expected with most crops when these soils are brought under cultivation. Fair growth of a relatively aluminum tolerant crop, such as, corn might be obtained on those soils which are less than 50 percent aluminum saturation (Kamprath, 1970). Where the pH is less than 4 there would probably be a beneficial affect from decreasing the H ion concentration by liming and removing the competitive effect of H ions on uptake of basic cations and the inhibitory effect on microbial reactions.

Depth of root penetration on these soils would be limited to the depth of lime incorporation because of the extremely high Al saturation of the A_2 and B horizons (Ragland and Coleman, 1959). Since the A_1 horizons are relatively shallow crops may suffer from moisture stress during short dry periods.

Poorly drained soils. The A_1 horizons of the poorly drained soils contained essentially no exchangeable Al (Table 2). Three of the soils contained very large amounts of basic cations, primarily Ca, in the A_1 horizon. The Al saturation of the B_2 horizons except for one soil was considerably less than that of the well drained soils. The Al saturation at a given pH for the sub soils of the poorly drained soils was much less than that of the well drained soils (Figure 2). The predominant clay mineral in the B_2 horizons of the poorly drained soils was montmorillonite. Pratt and Bair (1962) reported that soils containing predominantly montmorillonite contained very little exchangeable Al at pH 5 and above. Sanchez and Buol (1971) found that the poorly drained soils contained primarily montmorillonite. The low pH and

moderate Al saturation of the subsoils suggests that acid groups of organic matter may be influencing the H ion concentration of the soil solution.

Crop response to liming would not be expected to any large degree on the poorly drained soils. Except for species very sensitive to Al growth into the subsoils would not be hindered to nearly as great an extent as on the well drained soils.

Giant Podzols. The "Giant Podzols" of the Upper Amazon Basin have a very low Al saturation in both the A_1 and the A_2 horizons (Table 3). The low pH of the surface horizon is probably due to the acid groups of organic matter. The main supply of basic cations in these deep sandy soils is in the A_1 horizon. About the only response to lime would be that resulting from removal of any inhibiting effect of low pH on nutrient uptake and microbial activity.

The acreage of these soils is not large but their soil acidity relationships would be typical of the deep sandy soils.

Red Latosols

The relationship between pH and Al saturation for the Red Latosol is shown in Figure 3. At pH 5 and below the Al saturation was greater than 85 percent while above pH 5.6 the Al saturation was less than 10 percent. Between pH 5 and 5.6 there is a marked change in the Al saturation. The relatively small change in pH is probably due to the buffering effect of the hydroxy Al compounds. The shape of the pH- Al saturation curve for the Red Latosol is very similar to that for a Cecil soil from the North Carolina Piedmont. The similarity of the slope of the curves for the two soils suggest that the response of crops to liming should be very similar for the soils. Once the Al saturation is brought to less than 10 percent very little

response to liming should be obtained on the Red Latosol. The soil pH at 10 percent Al saturation would be in the range of 5.3 to 5.6.

The Al saturation of the 20-40 cm depth is the same as that of the Ap horizon (Table 4). The extremely high Al saturation of the soil will restrict root growth to the layer in which lime is incorporated.

Conclusions and Summary

The well drained soils of the Upper Amazon Basin have a moderate Al saturation of the effective cation exchange capacity. Crops sensitive to aluminum toxicity would probably respond to liming. It appears that once the pH of the surface soil is brought to pH 5 the Al saturation will be very low. The A_2 and B_1 horizons of the well drained soils have a very high Al saturation. Growth of roots into the subsoil will be very limited.

The poorly drained soils of the Upper Amazon Basin have a very low Al saturation in the A_1 horizon and are well supplied with calcium. Beneficial effects to liming would only occur on those soils where the pH is sufficiently low so that H ion concentration will adversely affect nutrient uptake and microbial activity. The A_2 and B_1 horizons generally only have a moderate Al saturation and growth of roots into the subsoil would only be restricted with those crops which are very sensitive to Al.

The giant podzols have a very low Al saturation. The supply of bases is concentrated in the A_1 horizon. Once this supply is depleted either by crop removal or leaching it will have to be replenished by liming or fertilizers.

The Red Latosol from Brazil is representative of the kind of soils that are extensive in the Campo Cerrado. The pH - Al saturation relationships of this soil are very similar to that of an Ultisol from the Piedmont region of

North Carolina. The subsoil of the Red Latosol is almost completely Al saturation. Lime will need to be incorporated to a sufficient depth so that plant roots will have access to soil moisture during short dry periods when the top few inches are depleted of available moisture.

Table 1. Soil acidity relationships of well drained soils in the upper Amazon Basin.

Soil	Horizon	Depth cm	pH	Exch Al	Sum exch. cations	% Al sat.	% OM
				meq/100g			
Y-1	A_1	0-7	4.0	0.85	2.73	31	2.5
	B_1	7-48	3.5	3.25	4.09	79	0.9
Y-2	A_1	0-20	4.0	3.65	6.70	54	4.0
	B_2	20-145	3.7	9.50	10.58	90	3.7
Y-3	A_1	0-30	3.4	3.00	8.54	35	2.8
	B_{21}	46-90	3.5	4.50	5.70	79	1.1
Y-9	A_1	0-12	4.5	2.60	7.64	34	2.1
	B_1	12-30	4.6	10.80	15.28	71	0.7
Y-10	A_1	0-5	3.6	1.90	3.64	52	4.0
	A_{21}	5-40	4.2	4.20	4.70	89	1.1
	B_1	60-90	4.2	6.05	6.55	92	1.0
Y-11	A_1	0-8	5.0	0.30	5.52	5	7.6
	A_{21}	8-40	4.7	4.40	5.78	76	1.3
	B_{21}	80-135	4.1	6.20	6.86	90	0.5
I-2	A_1	0-16	4.0	5.90	7.40	80	4.2
	B_1	16-35	4.5	6.70	7.38	91	1.8

Table 2. Soil acidity relationships of poorly drained soils in the upper Amazon Basin.

Soil	Horizon	Depth cm	pH	Exch. Al	Sum exch. cations	% Al sat.	% OM
				meq/100g			
Y-4	A_1	0-9	4.4	0.05	4.17	1	1.9
	A_2	9-20	4.4	0.10	5.84	2	1.4
	B_{21}	20-43	3.9	5.95	13.01	46	1.0
Y-5	A_1	0-15	7.0	0.05	39.17	0	1.0
	B_{21g}	15-33	4.1	16.50	37.10	44	0.8
Y-6	A_1	0-5	5.5	0.55	21.13	3	4.6
	B_{21g}	5-25	4.9	9.20	27.55	33	1.3
I-1	A_1	0-5	5.6	0.0	16.72	0	7.9
	A_{2g}	5-10	4.7	5.50	19.32	28	2.1
	B_{21g}	10-50	4.6	14.60	18.42	79	1.1

Table 3. Soil acidity relationships of Giant Podzols from the upper Amazon Basin.

Soil	Horizon	Depth	pH	Exch Al	Sum exch. cations	% Al sat	% OM
				meq/100g			
Y-8	A_1	0-19	4.6	0.25	2.89	9	2.1
	A_{21}	19-115	4.6	0.10	0.80	12	0.3
I-5	A_1	0-15	4.2	0.15	3.11	5	4.9
	A_2	15-50	5.1	0.10	0.90	11	0.5

Table 4. The soil acidity relationships of a Red Latosol from the Campo Cerrado of Brazil.

Depth cm	pH	Al	Sum exch. cations	% Al saturation
		meq/100g		
0-20	4.7	2.60	2.76	94
20-40	~~1.89~~ 4.8	1.89	2.04	94

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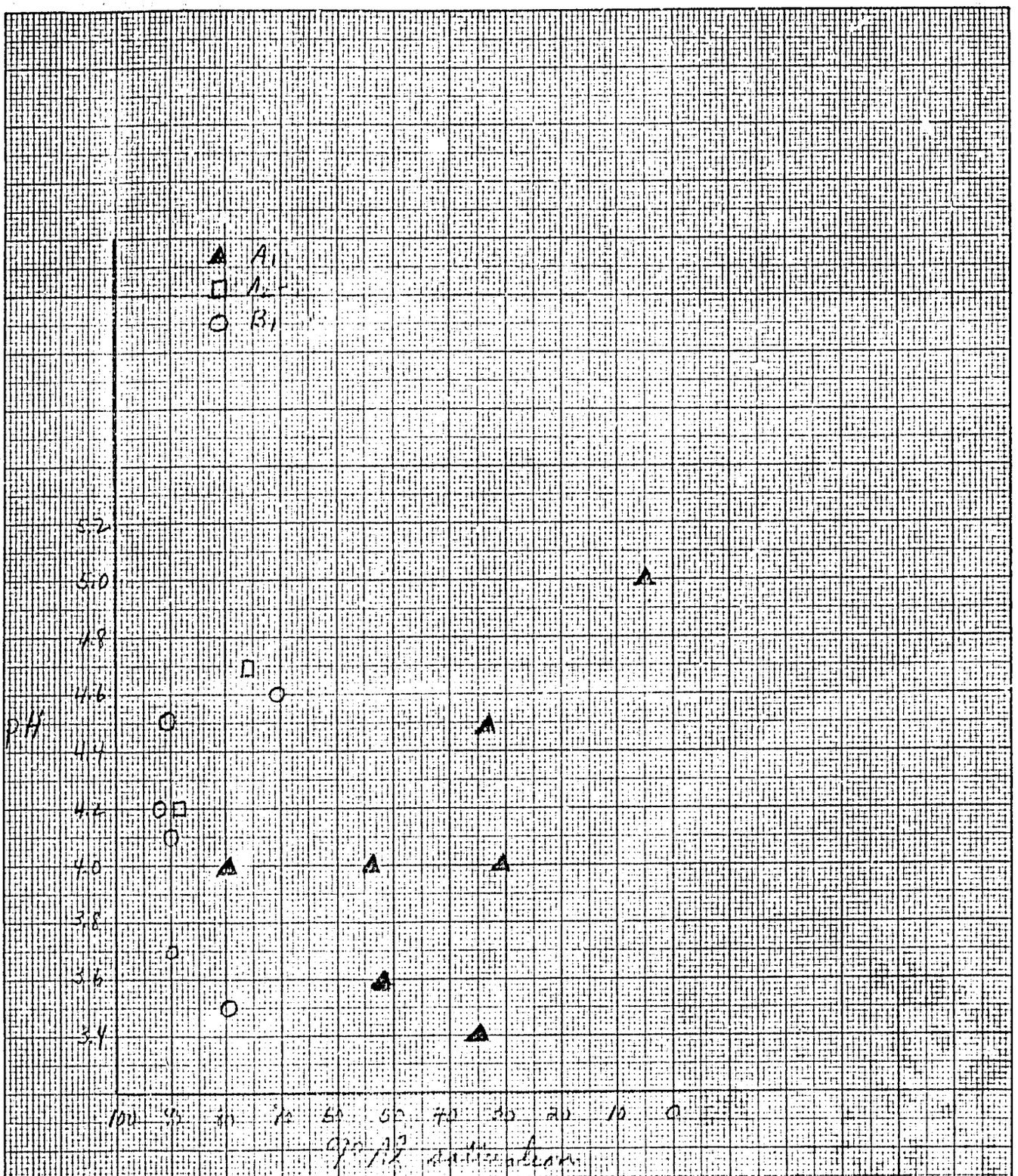

Figure 1 Relationship between % Al saturation and pH of well drained soils from the Upper Amazon Basin

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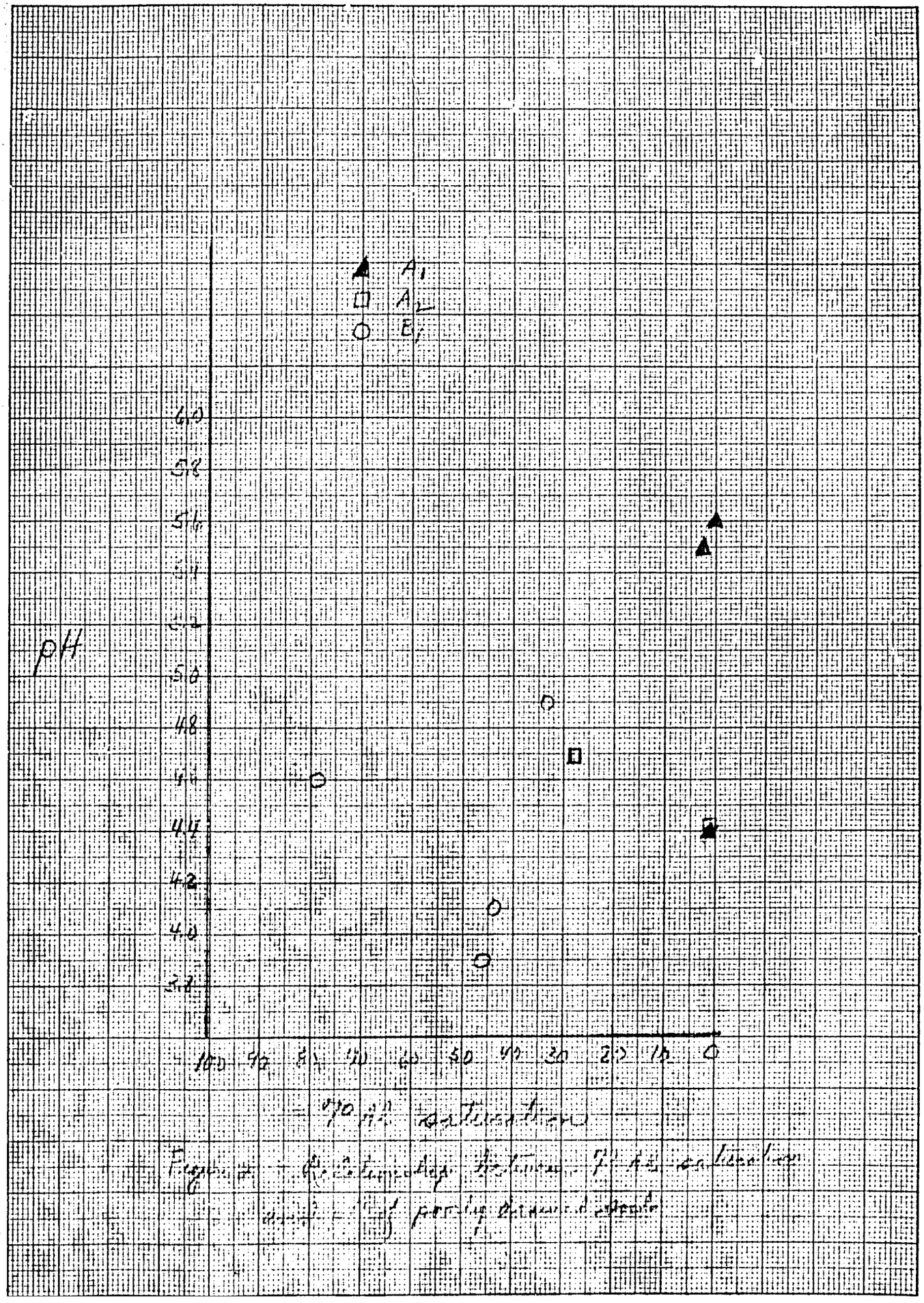

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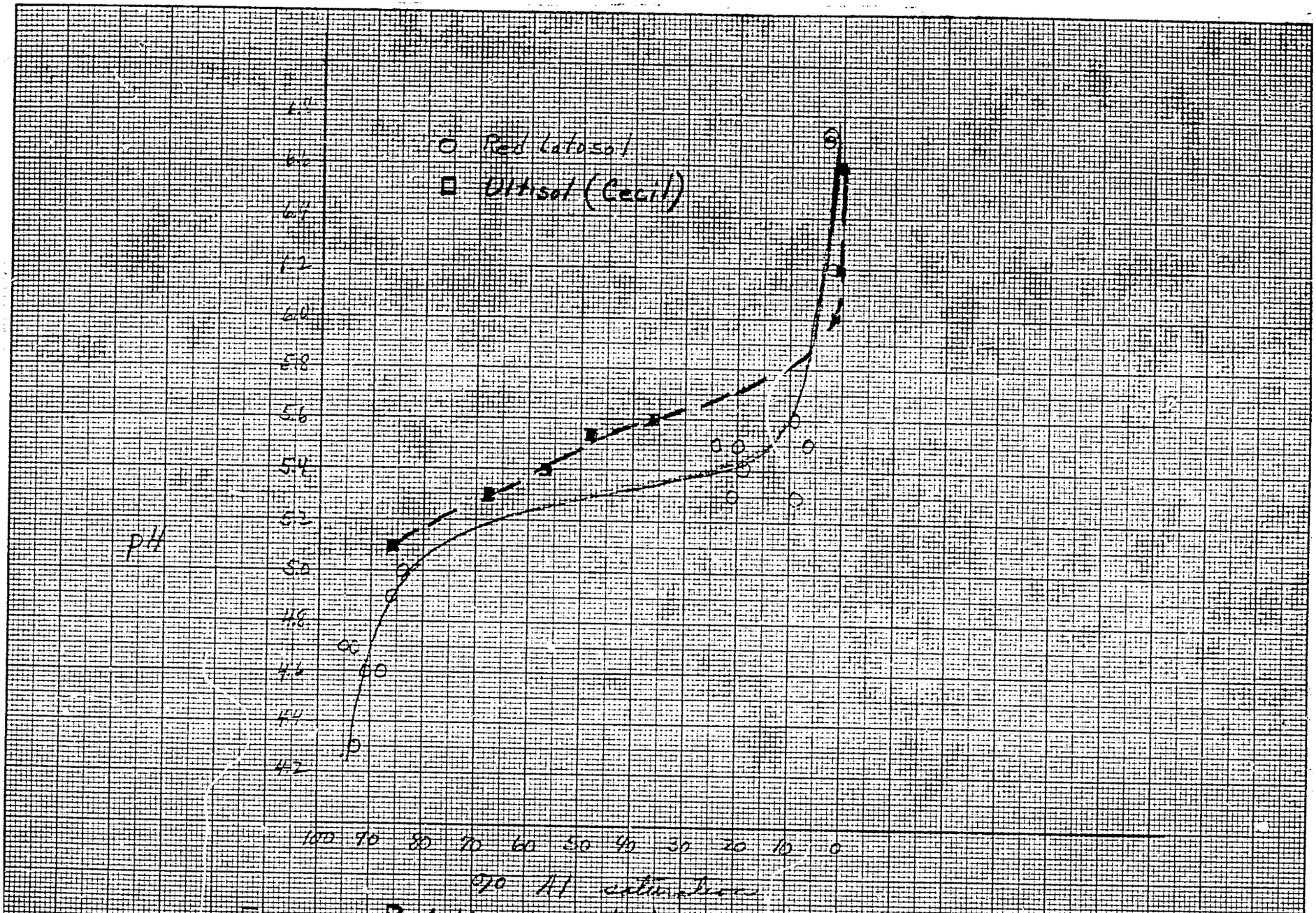

Figure 3 Relationship between Al saturation and pH for a Red Latosol from Brazil and an Ultisol from North Carolina

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