Research Note

THE EFFECT OF LIMING ON THE EXCHANGEABLE MAGNESIUM LEVELS OF TWO HIGHLY WEATHERED SOILS OF PUERTO RICO[1]

Although lime-induced magnesium deficiency has been recognized for some time, not until recent years has it received much attention from soil scientists.[2,3,4,5] Many propositions have been submitted to explain the mechanism involved. Two of the most popular explanations are specific adsorption of Mg^{++} into the Stern layer as the hydrolyzed species $MgOH^{+}$;[6] coprecipitation of Mg^{++} with Al^{+++} to form an amorphous Mg-Al gel.[7] Although a decline in exchangeable Mg^{++} after liming has been observed in Puerto Rico before,[8,9] this behavior has not been fully explained. There is nothing in the local literature that could alert agronomists, extensionists or farmers of this phenomenon. For this reason, a series of assays were performed on a Corozal clay soil (Aquic Tropudults) and a Cato clay soil (Tropeptic Haplorthox); two highly weathered soils frequently limed in Puerto Rico. The soils were limed to various pH levels by application of different rates of lime $[Ca(OH)_2]$ in amounts equivalent to either 1, 2, or 3 meq/Ca per meq of exchangeable Al^{+++}. Treated soils were kept at a 20% moisture content in plastic bags 1 week before being submitted to analyses. The exchangeable cations, (Ca^{++}, Mg^{++}, Al^{+++}) were extracted with 1N KCl. K^{+} was extracted with NaOAC. The cations were measured by atomic absorption.

Table 1 shows the results of the soil analyses of the various soils treated. Corozal, IA, IIB, and IIIA refer to three soils of the Corozal series obtained from different locations in Corozal. The letters A and B represent topsoil and subsoil samples, respectively. The Coto A soil was obtained in Isabela. The results indicate a decrease in the levels of exchangeable Mg^{++} in soils as a result of liming. This reduction fluctuated from 21 to 49% (table 1) among the soils studied. The 21% reduction was observed at a pH value of 4.65 for the Corozal IIIA soil. At that pH, 6.63 meq of Al/100 g of soil was still in the exchangeable form. If exchangeable Mg^{++} coprecipitates with ex-

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TABLE 1.—*Chemical analysis of the soils*[1]

	Meq Ca added			Ca	Mg	Al
Soil	Sample	meq Al	pH	Meq/100g of soil		
Coto A	1	0	4.99	2.72	0.64	.05
	2	1	5.71	4.30	0.53	ND[2]
	3	2	6.58	6.07	0.51	ND
	4	3	7.02	7.42	0.49	ND
Corozal IA	1	0	4.44	1.32	0.32	7
	2	1	NA[3]	6.68	0.33	2.5
	3	2	6.05	12.77	0.33	ND
	4	3	7.26	21.1	0.19	ND
Corozal IIB	1	0	4.76	6.78	1.30	4
	2	1	5.85	15.15	1.31	ND
	3	2	7.52	22.17	0.66	ND
Corozal IIIA	1	0	4.31	1.78	0.43	9.3
	2	1	4.65	6.20	0.34	6.63

[1] The Coto A and Corozal IA data represent the average of two samples per treatment. The Corozal IIB and IIIA were replicated three times.

[2] ND-Not detectable.

[3] Datum not available.

changeable Al^{+++} as a result of liming,[6,10,11] a further increase in pH could have decreased the levels of exchangeable Mg^{++} even more.

The Coto clay soil showed the lowest decline in exchangeable Mg^{++} as a result of liming. The levels of exchangeable Al^{+++} in this soil are not as high as in the Corozal clay soil; therefore, coprecipitation of Mg^{++} and Al^{+++} upon liming should occur to a lesser degree. In spite of this, this decrease could be enough to cause some yield depression or a nutrient imbalance in crops. This can be inferred from the ratios between exchangeable cations (table 2):

1. The proportion of exchangeable Mg^{++} as a part of the sum of exchangeable basic cations (table 2). This parameter decreased rapidly as a result of liming.
2. The ratio of exchangeable Ca^{++}/exchangeable Mg^{++}. A dramatic increase in this ratio was observed as a result of liming.

Some researchers have indicated that a Ca^{++}/Mg^{++} exchangeable ratio of 6.5 to 7.5 is appropriate for most crops.[10] In addition, McLean and Carbonell[10] recommended a 6 to 10% Mg^{++} saturation (high to low CED soils) as an optimum level to maximize crop yields. They also recommended that the Mg^{++} saturation level be increased 12 to 15% when grasses are to be grown as the main dietary constituent of ruminants.

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TABLE 2.—*Relations between exchangeable Ca*$^{++}$ and exchangeable Mg^{++}

Soil	Sample	% Reduction[1] exchangeable Mg^{++}	$\frac{Mg^{++}}{(Mg^{++} + Ca^{++} + K^{+})}$	% Reduction[1] $Mg^{+2}/Mg^{++} + Ca^{++} + K^{+}$)	Ca^{++}/Mg^{++} Ratio
Coto	1	—	0.18	----	4.25
	2	17.2	0.10	44.4	8.11
	3	20.3	0.08	55.6	11.90
	4	23.4	0.06	66.7	15.14
Corozal IA	1	----	0.13	----	4.12
	2	----	0.04	69.2	20.22
	3	—	0.02	84.6	38.69
	4	40.6	0.01	92.3	111.05
Corozal IIB	2	----	0.14	—	5.21
	2	----	0.08	42.9	11.56
	3	49.2	0.03	78.6	33.59
Corozal IIIA	1	----	0.14	----	4.14
	2	20.9	0.05	64.3	18.23

[1] % Decrease with respect to the control.

Therefore, it is apparent that critical levels of exchangeable Mg^{++} may be a result of liming in the two soils studied.

We have seen how lime applications can decrease the levels of exchangeable Mg^{++} to amounts that can limit forage yields and quality, which in turn can cause nutrient imbalance in animal diets. Although this effect is more noticeable at pH values near neutrality, *in some soils it has been observed at* pH values as low as 4.5. The following unanswered questions need further research:

1. What mechanisms cause this effect?
2. What are the kinetics or the thermodynamics behind this condition?
3. What is the role of exchangeable Al^{+++} in this phenomenon?
4. Why in some soils does this phenomenon become significant at lower pH values than in others?

Investigation addressed to these questions is in the planning stages.

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