Liming Effect on Pineapple Yield and Soil Properties in Volcanic Soils

By Francisco Mite, José Espinosa, and Lorena Medina

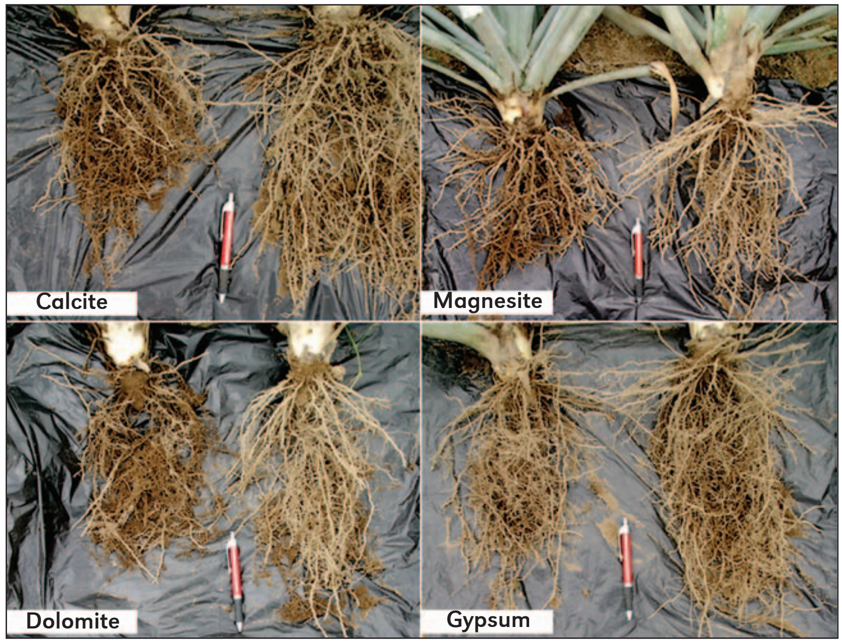
The coastal plain, volcanic soil region of Ecuador is well suited to pineapple cultivation. Crop area expansion continues within the central and northern coastal plain. This growth is based on the availability of new pineapple genetic material, particularly the high yielding MD2 hybrid, which has excellent flavor and good acceptance in the international market.

In Ecuador, the coastal plain region receives over 3,000 mm of rain each year. This high rainfall promotes high rates of leaching, which is related to the low CEC generated by acidity in variable charge soils. This condition, along with the high concentration of Al^{3+}, limits the yield potential of MD2 pineapple. In these conditions, the use of soil amendments can improve chemical, physical, and biological properties of the soil by precipitating Al^{3+} and increasing CEC. However, farmers and technicians commonly resist liming based on the preconceived notion that even severe soil acidity is not a problem in pineapple cultivation. It is commonly accepted that pineapple grows better in acid soils, but extreme soil acidity can cause problems even for this more tolerant crop.

A laboratory and field experiment was designed to test the effect of different soil amendments in volcanic soils cultivated with pineapple. The objectives of the study were: 1) to evaluate the effect of soil amendments on the chemical characteristics of volcanic variable charge soils, 2) to identify the best type and rate of soil amendment, and 3) to evaluate the effect of the amendments on pineapple root growth and yield.

A pot incubation experiment was carried out in this study's laboratory phase to test the effect of the addition of calcite ($CaCO_3$), magnesite ($MgCO_3$), dolomite ($CaCO_3 \cdot MgCO_3$), and gypsum ($CaSO_4 \cdot H_2O$) on soil pH, Al^{3+} precipitation, and CEC. Rates of 0, 1.5, 3.0, 4.5, 6.0, 7.5, 9.0, and 10.5 t/ha of each amendment were applied to an acid volcanic soil (**Table 1**). The treated soil was incubated for 30 days and then analyzed for pH, Al, and CEC.

For the second phase of the study, a field experiment was planted in February 2007 and harvested in May 2008. Climatic conditions of the experimental site are as follows: 24.4 °C average temperature, 3,530 mm annual precipitation, 88% relative humidity, 975 mm annual evaporation, and 779 hours annual solar radiation. The soil was a classic Andisol formed

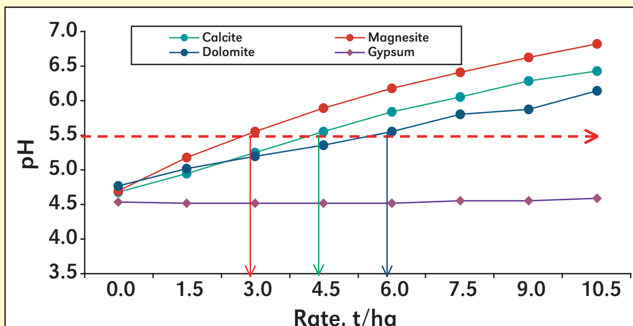


Effect of amendment application on root growth of MD2 pineapple cultivated in an acid volcanic soil.

Table 1. Chemical and physical characteristics of the site (Andisol, Ecuador).

Water (2:1) pH	OM	S	Modified Olsen ($NaHCO_3$ + EDTA) P	NH_4^+	K	Ca	Mg	Al+H
	%	------ mg/kg	-------		--------- $cmol_c$/kg	---------		
4.4	5.8	24(H)	16(H)	19(L)	0.3(M)	2.0(L)	0.3(L)	1.5(H)

H=high; M=medium; L=low; OM by Walkley-Black; S by $CaHPO_4 \cdot H_2O$; Al+H by 1N KCl.



Al^{3+} content, cmol/kg

	0.0	1.5	3.0	4.5	6.0	7.5	9.0	10.5
Calcite	0.9	0.3	0.1	0.1	0.0	0.1	0.0	0.0
Magnesite	0.9	0.5	0.2	0.2	0.2	0.3	0.3	0.3
Dolomite	0.9	0.3	0.0	0.2	0.1	0.0	0.1	0.3
Gypsum	0.9	0.6	0.6	0.6	0.7	0.6	0.5	0.5

Figure 1. Soil pH and Al content at each rate of different amendment in a volcanic soil from the coastal plain of Ecuador.

Abbreviations: CEC = cation exchange capacity; Al = aluminum; OM = organic matter; KCl = potassium chloride; $BaCl_2$ = barium chloride.

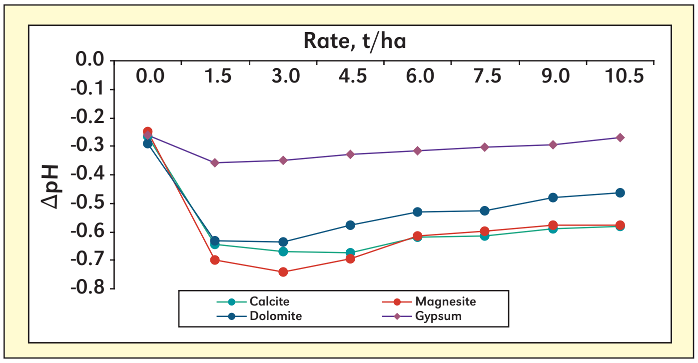
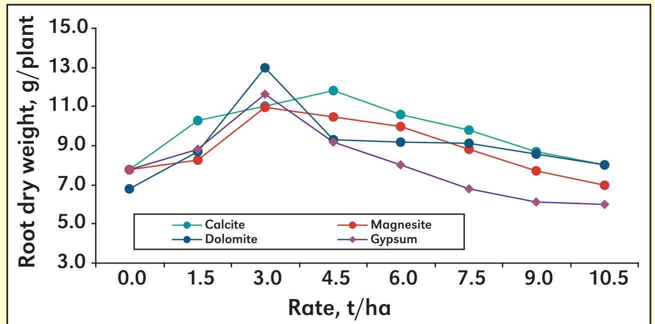


Figure 2. Effect of amendment application on Δ pH volcanic soil from the coastal plain of Ecuador.

from the depositions of volcanic ash from past activity within the northern highlands of Ecuador. The same treatments used in the incubation study were tested in this field experiment. Treatments were placed in the field as a randomized complete block design arranged in split plots with four replications. Main plots were the amendments and subplots were the amendment rates. Root weights at flowering and total yield at harvesting were evaluated.

Results of the incubation experiment show the effect of the different amendments on soil pH after 30 days of incubation **(Figure 1)**. As expected, calcite, magnesite, and dolomite had a marked effect on soil pH. To reach a pH value of 5.5, enough to precipitate Al^{3+} in this particular volcanic soil, 2.9, 4.4 and 5.9 t/ha of locally available magnesite, calcite, and dolomite, were needed, respectively. As expected, gypsum did not induce any change in soil pH.

One of the main chemical changes induced by amendment application is an increase in negative charge on the collective soil colloid surface. This change can be measured by the difference between pH determined in 1N KCl and pH measured in water (Δ pH = $pH_{KCl} - pH_{H2O}$). The sign and magnitude of the Δ pH correspond to the sign and magnitude of the colloid surface (Nanzyo et al., 1993), and the effect of amendment application on Δ pH is presented in **Figure 2**. The increase in surface charge was more evident with the carbonate-based amendments compared to gypsum, but in all cases an increase was observed only with the lower rate (1.5 t/ha), which was enough to precipitate Al^{3+}.



Al content at depth of 0 to 10 cm, cmol/kg

	0.0	1.5	3.0	4.5	6.0	7.5	9.0	10.5
Calcite	0.8	0.3	0.1	0.1	0.0	0.1	0.0	0.0
Magnesite	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Dolomite	0.8	0.3	0.0	0.1	0.1	0.1	0.0	0.0
Gypsum	0.8	0.7	0.5	0.6	0.7	0.6	0.7	0.3

Figure 3. Effect of amendment application on pineapple root growth and Al content in the soil.

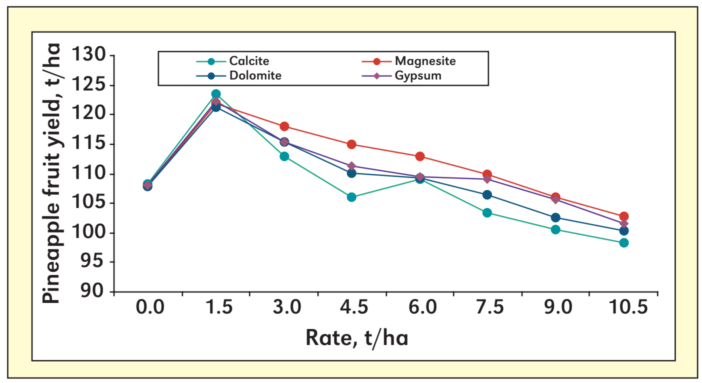


Figure 4. Effect of amendment application on MD2 pineapple fruit yield.

Another way of measuring the effect of soil amendments on surface charge is CEC determination. One of the most popular methods to determine CEC utilizes 1 M ammonium acetate (NH_4OAc) buffered at pH 7.0. There are other methods which also use buffered solutions at pH 7.0 or 8.2. These methods work well in soils dominated by permanent charge clays, but their use in soils dominated by variable charge clays is not satisfactory. Buffered solutions artificially create surface charge in the lab during CEC determination and do not represent the real soil CEC that plants "see" in the field (Uehara and Gillman, 1979). Methods which evaluate CEC using unbuffered (indifferent) solutions perform a better job in these types of soils.

One of these methods uses $BaCl_2$ as the saturating solution. **Table 2** presents CEC data obtained using NH_4OAc and $BaCl_2$ in the incubated volcanic soil utilized in this study. The CEC determination with the indifferent salt allowed for a better assessment of soil capacity to retain cations and reflects clearly the effects of the liming materials (calcite, magnesite, and dolomite) in charge generation on the colloid surface. Liming

Table 2. Comparison of CEC determination with $BaCl_2$ and NH_4OAc in an Andisol incubated after 30 days with four different soil amendments.

Rates, t/ha	$BaCl_2$ Calcite	$BaCl_2$ Magnesite	$BaCl_2$ Dolomite	$BaCl_2$ Gypsum	NH_4OAc Calcite	NH_4OAc Magnesite	NH_4OAc Dolomite	NH_4OAc Gypsum
	CEC, $cmol_c$/kg of soil							
0	7.03	6.43	7.61	5.83	24.02	23.72	23.42	21.84
1.5	7.66	7.43	7.45	6.29	23.72	23.92	24.02	22.03
3.0	8.36	9.41	7.56	6.17	22.83	24.42	24.22	22.13
4.5	9.21	10.15	9.43	6.47	25.81	23.72	24.91	22.03
6.0	9.75	11.75	9.71	6.76	23.62	24.71	24.61	22.33
7.5	11.64	13.31	10.85	6.62	23.52	25.51	25.81	22.43
9.0	12.44	13.74	11.23	6.29	23.72	24.81	24.61	23.22
10.5	13.61	14.63	12.06	6.90	24.12	25.31	25.41	22.23

High rates of amendments can induce the presence of Phytopthora sp in pineapple, as shown in this plot.

This study indicates that in tropical Andisols, soil amendments can be beneficial if caution is used to avoid over-application.

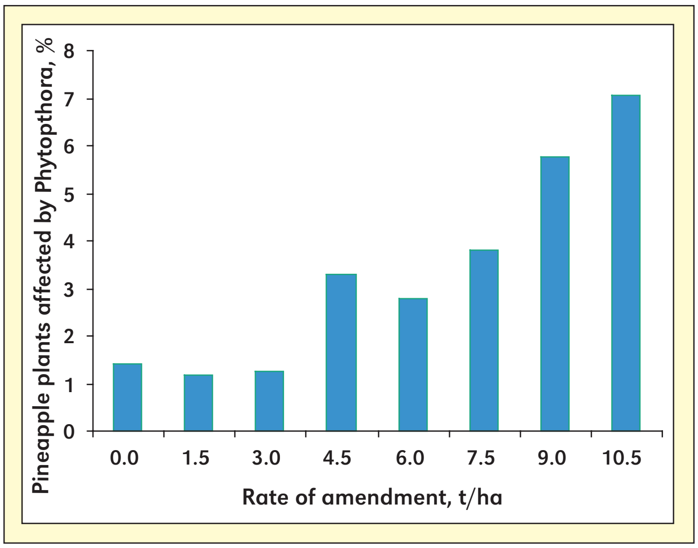


Figure 5. Effect of rates, across amendment materials, on the percentage of Phytopthora sp infection on MD2 pineapple.

of variable charge soils does not produce a radical change in soil pH. The OH^- ions, product of the lime reaction in the soil, are adsorbed by the active colloid surface generating negative charge. **Table 2** also shows that CEC determination with NH_4OAc overestimates the charge on the colloidal surface and for this reason it loses sensitivity in its ability to evaluate charge generation by lime application. One of the benefits of liming variable charge soils is the increase in CEC which allows greater cation retention, an important factor in soils subject to high leaching like the volcanic soils of the study.

Figure 3 presents the data of root growth measured at flowering and the concentration of Al^{3+} as affected by amendment application. A positive effect on root growth is observed with the 1.5 and 3.0 t/ha rates. The positive effect of amendment application is related to Al^{3+} precipitation by lime and the complexation of Al^{3+} by gypsum (van Raij, 2008). There is no response to amendment application once Al^{+3} has been eliminated as limiting factor as indicated by lack of response to the higher amendment rates. The reduction of root growth with the higher amendment rates suggests that other limiting conditions are affecting pineapple plants after soil reached pH values over 5.5.

The effect of amendment application on pineapple fruit yield is presented in **Figure 4**. A rate of 1.5 t/ha was sufficient to obtain the highest yields. Again, the effect of amendment application on soil Al^{3+} explains the response. Once Al^{3+} has been precipitated or complexed, there is no need for higher rates of application. Actually, fruit yield was reduced with higher amendment rates, due to the presence of *Phytopthora* sp, a known risk of over-applying lime (Fitchner et al., 2006) See **Figure 5** and photo of plots. This is perhaps the reason why pineapple producers resist lime application to improve soil pH.

The data of this study demonstrate that in tropical Andisols the application of soil amendments to eliminate Al^{3+} as a limiting factor is a proper and profitable practice if caution is used to avoid over-application. It is well known that Andisols have a high buffering capacity which varies with the type of ash and soil history (Nanzyo et al., 1993). For this reason, it's difficult to use general lime recommendation for all the sites based only on Al^{3+} content of the soil as is common practice in Ultisols and Oxisols. In the case of Andisols, this study suggests a simple incubation experiment as a good strategy to assess appropriate lime amendment rates required on a site-specific basis. BC

Dr. Mite is Senior Researcher and Head of Department, Soils Department, Pichilingue Tropical Experiment Station, Quevedo, Ecuador; e-mail: fmitev@gye.satnet.net. Dr. Espinosa is Director, IPNI Northern Latin America Program, Quito, Ecuador; e-mail: jespinosa@ipni.net. Ms. Medina is Research Assistant, Soils Department, Pichilingue Tropical Experiment Station, Quevedo, Ecuador.

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