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USE OF AN INDUSTRIAL BY-PRODUCT [(Ca(OH)$_2$] AS A LIMING SOURCE FOR SOILS UNDER PINEAPPLE PRODUCTION

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ABSTRACT

Calcium hydroxide [Ca(OH)$_2$], a by-product of acetylene production and calcium carbonate (CaCO$_3$) were evaluated as liming sources for Bayamón soil (Typic Haplorthox), the most important soil series used for pineapple production. The pineapple variety Smooth Cayenne was used as the test crop. Three soil samplings were performed at two depths, 0-20 and 20-40 cm. The first sampling was performed a month after the liming materials were applied. The other two samplings were performed at four and seven months. The industrial by-product was as effective as calcium carbonate in neutralizing soil acidity.

INTRODUCTION

Soil acidity is a major constraint for crop production in highly weathered soils of the tropics. In such soils high levels of exchangeable aluminum and manganese are quite common causing toxicity problems (13). Exchangeable Al^{3+} is the more determinant factor in soil acidity (5). Soil acidity may be enhanced by fertilizer applications (1, 3, 10, 11, 12, 15). Intensive use of ammonia or ammonium fertilizers acidify the soil by the release of H^+ ions once the conversion of NH_4^+ to NO_3^- takes place. Abruña et al. (1) observed a significant reduction in pH and exchangeable bases of an Alfisol and a Mollisol within a year after beginning N applications in the form of ammonium sulfate.

Liming acid soils to pH values between 5.5 and 6.5 is necessary to neutralize aluminum and manganese toxicity. Liming at pH values of 5.0-5.5 has resulted in maximum yields of grasses (2), sugarcane (3) and tobacco (4). Calcium carbonate ($CaCO_3$) is the liming material used by farmers in Puerto Rico. The government, through the Department of Agriculture has implemented a program to supply lime at low cost to the farmers. The first 10 tons of lime are free of charge if the farmer collects the material at the processing plant, and $7.00/ton if the material is delivered to the farm. Sometimes the lime is not of the best quality due to impurities present at the mining site. Also the finness, a very important factor in the quality of lime, can be quite variable between lots affecting its neutralizing power. The mining operations are costly and detrimental to the environment since we are exploiting a non renewable resource.

A possible alternative to correct soil acidity problems can be the use of an industrial by-product [$Ca(OH)_2$] generated from the production of acetylene. Liquid Air of Puerto Rico, a company located in the municipality of Cataño, Puerto Rico, has accumulated over 30,000 tons of this material which needs to be disposed in a safe and practical way. The study herein reported was conducted to evaluate the potential of this material as a liming source for acid agricultural soils dedicated to pineapple production.

MATERIALS AND METHODS

A field experiment was established in the Manatí area, northern part of the island, to evaluate the use of $Ca(OH)_2$ (industrial by-product) as a liming source for acid soils under pineapple production. The soil in the area is classified as an Oxisol (clayey, oxidic, isohyperthermic, Typic Haplorthox). The pineapple variety used in the study was Smooth Cayenne. Calcium carbonate ($CaCO_3$) the liming source commonly used by the farmers was also included in the study for comparative purposes. The following treatments were included in the study:

I	No liming
II	2.25 t/ha of $CaCO_3$
III	1.66 t/ha of $Ca(OH)_2$ (industrial by-product)
IV	4.50 t/ha of $CaCO_3$
V	3.32 t/ha of $Ca(OH)_2$ (industrial by-product)
VI	9.00 t/ha of $CaCO_3$
VII	6.66 t/ha of $Ca(OH)_2$ (industrial by-product)
VIII	4.50 t/ha of $CaCO_3$ + 3.32 t/ha of $Ca(OH)_2$ (industrial by-product)

The liming treatments were arranged in a complete randomized block design with four replications.

The experiment was planted six days after the application of the liming treatments. Each experimental plot (4.88 x 6.10 m) consisted of four double rows of pineapple 1.22 m apart and 6.10 m length. Three soil samplings were performed at two soil depths, 0-20 and 20-40 cm. The first sampling was performed a month after the application of the liming material. The other two sampling were performed at 4 and 7 months. The soil was analyzed for pH, exchangeable Al, exchangeable basic cations (Ca^{2+}, K^+, Mg^{2+}), exchangeable Mn^{2+} and available P, following recommended procedures (9). Data on yield, fruit quality were also collected.

RESULTS AND DISCUSION

Soil pH at a depth of 0-20 cm increased significantly with the application of 9.00 t ha^{-1} of $CaCO_3$ and 6.66 t ha^{-1} of $Ca(OH)_2$. The check treatment (no-lime) showed an average soil pH value of 4.22 (table 1). The application of 9.00 t ha^{-1} of $CaCO_3$ and 6.66 t ha^{-1} of $Ca(OH)_2$ increased soil pH to 4.85 and 5.16, respectively. Treatment VIII, a combination of 4.50 t of $CaCO_3$ and 3.32 t of $Ca(OH)_2$ resulted in the highest pH with a value of 5.37. The liming materials had little effect on soil pH at the 20-40 cm depth. The highest pH observed at 20-40 cm (4.40) corresponded to treatment VIII and it was significantly higher than treatments I and III. The little effect of the liming treatments on soil pH at the 20-40 cm depth indicates that the movement of the liming material to lower depths is limited.

Soil pH also decreased significantly with soil sampling at a depth of 0-20 cm (figure 1). Soil pH at 0-20 cm decreased from 5.19 on the first sampling to 4.39 on the third sampling. Usually, pineapple fields are limed every two years. The decrease in soil pH during the first year after lime application may be detrimental to pineapple performance. Soil erosion and intensive fertilization may be contributing to the fast decrease in soil pH. The farmer should implement management practices to reduce soil erosion. Soil erosion will not only result in significant losses of liming material but also exposes the subsoil which is significantly more acid.

Significant differences in exchangeable Al^{3+} were observed among liming treatments (table 1). At a depth of 0-20 cm, the application of 9.00 t ha^{-1} of $CaCO_3$ decreased exchangeable Al^{3+} by 70%, the 6.66 t ha^{-1} of $Ca(OH)_2$ treatment by 77%, and the mixed treatment (4.50 t ha^{-1} of $CaCO_3$ + 3.32 t ha^{-1} of $Ca(OH)_2$) by 84%. Exchangeable Al^{3+} also decreased significantly at a depth of 20-40 cm. The relationship between soil pH and exchangeable Al^{3+} for the 0-20 cm is presented on figure 2. As soil pH increased from 4.22 to 5.37, exchangeable Al^{3+} decreased from 153.18 to 24.13 mg kg^{-1}. Exchangeable Al^{3+} is held very tightly by soil colloids and its concentration in soil solution does not increase significantly until a saturation of 60 percent of the exchange sites occurred (6, 7). In the present study, the highest percent of aluminum saturation was 35.63. However, pineapple is fertilized intensively, and high fertilization rates could result in an increase of aluminum in the soil solution. The fertilizer increases the amount of salt in the system which favors the release of Al^{3+} and H^+ ions into the soil solution (8). Also, pineapple requires a strict balance of calcium and magnesium for optimum growth and quality. The uptake of these cations is depressed in the presence of aluminum due to competition to enter the root, and because aluminum reduces the permeability of the plasmalemma.

Exchangeable Mn decreased by 46 and 63% with the application of 9.00 t ha^{-1} of $CaCO_3$ and 6.66 t ha^{-1} of $Ca(OH)_2$ respectively. The application of 4.50 t ha^{-1} of $CaCO_3$ + 3.32 t ha^{-1} of $Ca(OH)_2$, decreased exchangeable Mn by 71% (table 1). Large variations in exchangeable Mn were observed among plots. The variation was associated to the topography of the field. The soil at the lower, flatter part of the experimental site contained considerable amounts of manganese nodules, whereas at the upper part of the field fewer nodules were observed. Exchangeable Mn did not vary significantly at a depth of 20-40 cm. The relationship between soil pH and exchangeable Mn for the 0-20 cm depth is presented in figure 3. The highest soil pH value observed was 5.37 and corresponded to the mixed treatment (4.50 t ha^{-1} $CaCO_3$ + 3.32 t ha^{-1} $Ca(OH)_2$). This treatment showed an exchangeable Mn content of 5.75 mg/kg.

Little variation in exchangeable basic cations at both depths was observed among liming treatments (table 2). No significant differences were observed in exchangeable K^+ and Mg^{2+}. However, exchangeable Ca^{2+} did increase significantly at a depth of 0-20 cm. An application of 6.66 t ha^{-1} of $Ca(OH)_2$ increased exchangeable Ca^{2+} from 1.10 to 4.23 $cmol_c$ kg^{-1}. The combination of 4.50 t of $CaCO_3$ and 3.32 t of $Ca(OH)_2$ also resulted in a significant increase of exchangeable Ca^{2+}.

The preliminary results indicate that both liming materials were equally effective in neutralizing soil acidity. The results indicate that some soils of the pineapple area (Manati-Barceloneta) may require more than 2 t/acre of lime every two years in order to achieve a desired pH of 5.50. In the present study twice that amount was not enough to reach that pH. The fast decrease in soil pH in a period of seven months after application indicates the need to improve management practices to minimize soil and lime losses. Also, some soils in this area may require not only larger but more frequent lime applications.

No significant differences were observed in pineapple production among liming treatments (Table 3). The highest yield was observed in the 3.32 t ha^{-1} of $Ca(OH)_2$ (industrial by-product) treatment with 92.5 t ha^{-1} and the lowest was observed in the no lime treatment, 70.2 t ha^{-1}. This treatment also showed the largest fruit weight, but the largest number of fruits/ha corresponded to the 9.00 t ha^{-1} of $CaCO_3$ treatment.

The evaluation of the industrial waste as liming material for acid soils planted to sugarcane is in progress. Although the future of the sugarcane industry is uncertain and not a promising one, acidity problems in these soils will prevail. The data obtained will be very useful for any other crop that might substitute sugarcane. Pasture and root crops have good potential in these areas.

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Table 1. Effect of liming treatments on soil pH and exchangeable / Al and Mn.

	Soil Depth (cm)					
	0-20			20-40		
	pH	Al	Mn	pH	AL	Mn
Treatment		mg kg^{-1}			mg kg^{-1}	
I	4.22	153.18	19.83	4.01	199.5	20.00
II	4.53	92.18	17.00	4.04	163.75	20.50
III	4.45	92.85	20.58	4.02	174.47	23.00
IV	4.48	88.58	18.67	4.03	183.53	24.92
V	4.72	70.37	11.92	4.03	182.48	16.50
VI	4.85	46.39	10.64	4.13	138.93	16.33
VII	5.16	35.37	7.25	4.36	141.64	19.50
VIII	5.37	24.13	5.75	4.40	124.93	12.00
LSD(0.05)	**0.37**	**40.97**	**11.85**	**0.37**	**40.97**	**11.85**

Table 2. Effect of liming treatments on soil exchangeable cations (cmol kg^{-1}).

	Soil Depth (cm)					
	0-20			20-40		
Treatment	Ca	K	Mg	Ca	K	Mg
I	1.10	0.35	0.32	0.54	0.25	0.17
II	2.04	0.42	0.36	0.80	0.30	0.20
III	1.88	0.38	0.32	0.74	0.22	0.17
IV	2.23	0.32	0.25	0.84	0.24	0.14
V	2.62	0.38	0.28	0.88	0.17	0.18
VI	2.35	0.33	0.26	1.09	0.23	0.21
VII	4.23	0.32	0.22	0.92	0.25	0.15
VIII	3.80	0.29	0.23	1.36	0.22	0.17
LSD(0.05)	**1.17**	**0.12**	**0.11**	**1.17**	**0.12**	**0.11**