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# Liquid micronized $CaCO_3$: an alternative to correct the pH of an acidic soil and improve pineapple development

# $CaCO_3$ micronizado líquido: una alternativa para corregir el pH de un suelo ácido y mejorar el desarrollo de piña

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## ABSTRACT

**Objective**: to determine the effect of liquid micronized $CaCO_3$ on soil pH and pineapple vegetative development in acidic soils at Isla, Veracruz.

**Design/Methodology/Approach**: randomized blocks with four replications and four treatments: Non-liming control (T1), 2.0 t ha$^{-1}$ of dolomite (T2), 10.0 (T3) and 20.0 (T4) L ha$^{-1}$ of liquid $CaCO_3$. The soil pH was measured, before liming and at 30, 60, 90 and 120 days after sowing, at depths of 0-5, 5-15 and 15-30 cm, and the biomass was determined at the 60, 90 and 120 dds. Analysis of variance and the 5% Fisher test were performed to separate means.

**Results**: up to 90 dds, with dolomite, optimal pH values were reached for pineapple, significantly higher than those of $CaCO_3$ in both doses. At 120 dds, with 20 L ha$^{-1}$ $CaCO_3$ the pH was higher than 5.0, similar to that of dolomite and higher than those of the low dose of $CaCO_3$ and the control. At the last date, with 20 L ha$^{-1}$ of $CaCO_3$ 1,346 g plant$^{-1}$ biomass were produced, an amount similar to dolomite and the low dose of $CaCO_3$ and significantly higher than that of the control.

**Findings/Conclusions**: up to 120 dds, with 20 L ha$^{-1}$ of liquid $CaCO_3$, the optimum pH for pineapple was reached in the three strata, the values were similar to those of dolomite and higher than those of the low dose of $CaCO_3$ and the control. $CaCO_3$ (20 L ha$^{-1}$) and dolomite (2 t ha$^{-1}$) produced 33.1 and 20.9% more biomass than the control.

**Keywords**: *Ananas comosus*, liming, edaphic acidity, plant nutrition.

## INTRODUCTION

Edaphic acidity negatively affects the availability of nutrients, which reduces crop yield and increases production costs by reducing the efficiency of chemical fertilizers (López *et al.*, 2018; Uriza *et al.*, 2018). Major problems appear when the pH is less than 5.5, since toxic levels of aluminum may occur (Zapata and Restrepo, 2010) or strong deficiencies of changeable bases (Zetina *et al.*, 2002; Caires *et al.*, 2008). In many agricultural regions, agricultural lime is applied to remove aluminium from the soil solution (Castellanos *et al.*, 2000).

In the municipalities of Isla, Juan Rodríguez Clara and José Azueta, Veracruz, Mexico, there are more than 100,000 ha that historically have been cultivated with pineapple (*Ananas comosus* (L.) Merr) and whose traditional management system has caused a marked

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decrease in soil fertility (Uriza *et al.*, 2018). Excessive tillage of the soil, the burning of crop residues and the excessive use of nitrogenous sources of acidic residual effect have caused greater acidification of the soil, with pH values of up to 2.7, which affects more than 80% of the cultivated area (Zetina *et al.*, 2005a; Rebolledo, 2011). In this region, dolomitic liming is used to increase the pH value of the soil and supply calcium and magnesium to the crop, as well as balance the ionic ratio Ca:Mg:K and reduce the toxic effects of exchangeable aluminium (Zetina *et al.*, 2002; 2005b). However, its use in large areas presents operational difficulties, because specialized machinery is required, and manual applications cause eye and skin irritation to field workers.

With the application of liquid lime, there have been positive impacts on various crops (Bambolin *et al.*, 2015; Camacho *et al.*, 2015; Garbanzo *et al.*, 2016). Therefore, this technology can be an alternative for regions with pineapple plants, because it is highly efficient, economical and easy to implement by producers who have equipment for its application. In addition, due to its high purity and $CaCO_3$ concentration, operating costs are lower by using lower doses of lime and obtaining greater efficiency in correcting the pH and improving the nutrition of the crop. Thus, the effect of a liquid amendment based on micronized $CaCO_3$ was determined on the pH of the soil where the rhizosphere develops and the initial vegetative development of pineapple MD-2 (*Ananas comosus*, var. *comosus*), in an acidic soil at Isla, Veracruz, Mexico.

## MATERIALS AND METHODS

The research was carried out from July 2018 to January 2019, at the "La Perla" farm, in Isla, Veracruz, Mexico (18° 14' 99.86" N and 95° 54' 73.94" W, at an altitude of 144 m). The climate is tropical sub-humid, with rains in summer (Awo), rainfall is 1147.3 mm and mean annual temperature of 25.9 °C (Díaz *et al.*, 2006). The soil is a Dystric Cambisol, with a sandy texture, with an extremely acidic pH, poor in exchangeable bases and organic matter (Zetina *et al.*, 2002).

The complete randomized blocks experimental design with four treatments and four repetitions was used. The treatments evaluated were: 1. Control without liming, 2. Liming with 2.0 t ha$^{-1}$ of dolomite, 3. Application of liquid micronized $CaCO_3$ in doses of 10 L ha$^{-1}$ and 4. Application of liquid micronized $CaCO_3$ at 20 L ha$^{-1}$. Each plot consisted of 22 rows (11 strips of 1.0 m wide and 5.0 m long, corresponding to 1560 m$^2$, considering corridors 2.0 m wide). As a useful plot, 18 central rows of 3 m long (144 plants per plot) were considered.

Soil preparation consisted of plowing, a heavy harrow step, a second trail, crossing the first one, a plough with plowshares up to 50 cm deep, mechanical bedding and the application of liming treatments and manual installation of padding with 150-micron thickness black plastic. The width of the beds was 1.0 m (1.25 m from center to center of each bed), with a height of 20 cm.

Pineapple planting was carried out manually on August 15, 2018, in 30 m wide patches, rows separated at 0.8 m (two per strip) and a separation between plants of 0.38 m, to obtain a density of 40,617 plants ha$^{-1}$. A medium-short peduncle vegetative material of the MD-2 pineapple hybrid was used, with an average weight of 300 g and a length of approximately 30 cm.

Fertilization and control of pests and diseases was carried out in accordance with the recommendations of the INIFAP for that region (Uriza *et al.*, 2018). For liming, the following sources were used: dolomite (12.6% MgO+36.64% CaO+10.8% $SiO_2$, with a particle size of 60 to 240 mesh) and liquid micronized $CaCO_3$ (66% $CaCO_3$, with a particle size of 0.7 microns). The liming treatments were carried out at the time of sowing, before the plastic padding, on the surface of the bed. In treatment 2, the dolomite was applied dispersed by hand; then the lime was incorporated with a rake. For treatments 3 and 4, the liquid lime was mixed with water in a tank with a capacity of 200 L, until a homogeneous mixture of micronized $CaCO_3$ was obtained, which was evenly sprinkled on the strip ("bed" of soil). For the above, an equivalent to 600 L of water ha$^{-1}$ was used.

Dolomite and $CaCO_3$ were used as sources of liming, due to the poor contents of magnesium (35 mg kg$^{-1}$) and calcium (124 mg kg$^{-1}$), determined in the soil sample collected before liming (Table 1). The dolomite dose was estimated with the method proposed by INIFAP (Zetina *et al.*, 2002), using the equation:

$$Y=10{,}484-2{,}095x$$

Where: $Y$=liming dose (t ha$^{-1}$) to obtain a pH value of 5.0 (expected value within the optimal range for pineapple cultivation) and $X$=initial pH of the soil in water. The dose of liquid micronized $CaCO_3$ was estimated with the same equation, considering that 10 L of $CaCO_3$=1 t of dolomite.

Before liming, a composite sample was obtained from 15 sub-samples of soil, collected at a depth of 0-30 cm, following a zigzag line in the longest part of the plot. The sample was analyzed in accordance with the Official Mexican Standard NOM-021-RECNAT-2000 (DOF, 2002) to determine soil fertility.

The response variables were: soil pH and total biomass. The pH was determined at sowing and at 30, 60, 90 and 120 days after sowing (dds). In each experimental plot, five plants with complete competition were selected; in each plant, on the indicated dates, a composite sample of soil was collected at depths of 0 to 5, 5 to 15 and 15 to 30 cm. Each sample consisted of 20 sub-samples, collected with a stainless steel auger in each of the cardinal points of each plant located in the rhizosphere of the crop (10 to 15 cm apart from the stem). For the measurement of pH in water, the 1: 2 soil / solution ratio, the As-02 technique described by the Official Mexican Standard NOM-021-RECNAT 2000 (DOF, 2002) was used. To determine the total biomass, in each experimental unit, by means of the crop-log technique, plant with complete competition and a representative size of the population of each plot was selected, of a representative size of the population of each plot (Sanford, 1962). The plants were pulled out of the ground with a straight shovel; then, the stem and leaves were separated, impurities were removed with running water and both organs were dried. Subsequently, with a digital electronic scale with a precision of 0.1 g, the leaves and stem of each plant were weighed, and then the total biomass in g plant$^{-1}$ was obtained. These measurements were made at 60, 90 and 120 dds. With the statistical program Minitab 15 version in Spanish, the analysis of variance of the quantified variables was carried out on each evaluation date and in the cases in which significance was detected, for the separation of means, the Fisher test was applied at 5% of error probability.

## RESULTS AND DISCUSSION

### Initial soil fertility analysis

The soil has a sandy-loam texture, with a strongly acidic pH (4.0), outside the optimal range of 4.5 to 5.5 for pineapple cultivation (Uriza *et al*., 2018). It is poor in organic matter and inorganic nitrogen, rich in phosphorus and poor in exchangeable bases (Table 1). The soil of the experimental site is typical of the soils cultivated with pineapple in the study region (Papaloapan basin), which respond favorably to liming and application of nitrogen and potassium fertilizers (Zetina *et al*., 2005a; Rebolledo, 2011).

### Soil pH

Statistical significance was detected in the four dates and three sampling depths, except at 90 dds, at the depth of 15 to 30 cm (data not shown). Table 2 shows the pH values observed at three depths, in the first four months of crop development, in response to three liming treatments and a control without lime.

### Days after liming

#### Sampling depth

At 30 dds, in the 0 to 5 and 5 to 15 cm strata, the most reactive source was dolomite, which significantly increased the soil pH, to statistically higher values than the rest of the treatments. In these two strata, both doses of $CaCO_3$ were statistically equal to the control without liming. At the depth of 15 to 30 cm, the same trend was observed, although with the application of dolomite, the pH was equal to that obtained with the low dose of liquid lime. In general, on this evaluation date, the pH reached with the application of dolomite was located within the optimal range for pineapple cultivation (4.5 to 5.5), close to the expected value of 5.0, estimated with the equation proposed by Zetina *et al*. (2002), to determine the lime requirement in this type of soil.

**Table 1**. Physical and chemical characteristics of the topsoil from the experimental site.

| Trait | | Content | Classified | Methodology |
|---|---|---|---|---|
| Textura | Sand | 59.20% | Sandy-loam | NOM 021 RECNAT 2000 AS-09 |
| | Clay | 12.80% | | |
| | Silt | 28.00% | | |
| pH (1:2, soil:water) | | 4.00 | FA | NOM 021 RECNAT 2000 AS-02 |
| Organic matter | | 1.41% | Poor | NOM 021 RECNAT 2000 AS-07 |
| Inorganic Nitrogen | | 7.0 mg/kg† | Poor | NOM 021 RECNAT 2000 AS-08 |
| Phosphorus | | 80.46 mg/kg | Rich | NOM 021 RECNAT 2000 AS-11 |
| Exchangeable Potassium | | 76 mg/kg | Poor | NOM 021 RECNAT 2000 A-12 |
| Exchangeable Calcium | | 124 mg/kg | Poor | NOM 021 RECNAT 2000 AS-12 |
| Exchangeable Magnessium | | 35 mg /kg | Poor | NOM 021 RECNAT 2000 AS-12 |

†Milligrams of $NO_3$+$NH_4$ per kilogram of soil. FA=Strongly acidic (Sp. equ. to SA).

**Table 2**. Edaphic pH values at three depths and four sampling dates, in response to liming with dolomite and liquid calcium carbonate, applied on a Dystric Cambisol from the experimental site.

| Treatment | Sampling depth (cm) | Days after liming | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 30 | 60 | 90 | 120 |
| Non-liming control | 0 a 5 | 4.0 | 3.8 b | 4.1 b | 3.6 b | 3.9 b |
| Dolomite 2.0 t $ha^{-1}$ | | 4.0 | 4.8 a | 5.0 a | 5.0 a | 5.4 a |
| Micronized $CaCO_3$ (10 L $ha^{-1}$) | | 4.0 | 3.8 b | 4.3 b | 3.7 b | 4.1 b |
| Micronized $CaCO_3$ (20 L $ha^{-1}$) | | 4.0 | 3.9 b | 3.9 b | 4.0 b | 5.8 a |
| Non-liming control | 5 a15 | 4.0 | 3.6 b | 4.0 b | 3.6 b | 4.0 b |
| Dolomite 2 t $ha^{-1}$ | | 4.0 | 4.7 a | 4.4 a | 4.4 a | 4.8 ab |
| Micronized $CaCO_3$ (10 L $ha^{-1}$) | | 4.0 | 3.7 b | 4.1 b | 3.9 b | 4.0 b |
| Micronized $CaCO_3$ (20 L $ha^{-1}$) | | 4.0 | 3.4 b | 4.0 b | 3.8 b | 5.5 a |
| Non-liming control | 15 a 30 | 4.0 | 3.5 b | 4.0 b | 3.7 | 3.8 b |
| Dolomite 2.0 t $ha^{-1}$ | | 4.0 | 4.3 a | 4.5 a | 3.9 | 4.4 ab |
| Micronized $CaCO_3$ (10 L $ha^{-1}$) | | 4.0 | 3.8 ab | 4.7 a | 3.8 | 4.0 b |
| Micronized $CaCO_3$ (20 L $ha^{-1}$) | | 4.0 | 3.6 b | 4.3 ab | 3.8 | 5.1 a |

Means with different letters in the same column are significantly different (Fisher, 0.05).

At 60 dds, in the two surface strata of the soil, the pH values recorded with dolomite were significantly higher than those of the other three treatments, which were statistically similar to each other. While, in the deeper stratum (15 at 30 cm), the pH values were similar between the liming treatments; but only with the application of dolomite and 10 L $ha^{-1}$ liquid $CaCO_3$ were statistically higher than the control without liming. With both treatments, optimal pH values (4.5 to 5.0) were reached for pineapple, although only with dolomite the expected value of 5.0 was reached, at a depth of 0 to 5 cm (Zetina *et al*., 2002).

At 90 dds, the same behavior was observed in the pH values reached with the application of dolomite in the strata from 0 to 5 and 5 to 15 cm. While in the deeper stratum, with the three liming treatments, pH values were statistically similar to that of the control. A trend towards reduction in all treatments was observed, which may be due to seasonal changes in pH, caused by a higher moisture content in the soil, volume and respiratory activity of microorganisms and roots (Zetina *et al*., 2002, Vásquez *et al*., 2013).

At 120 dds, when 20 L $ha^{-1}$ of liquid $CaCO_3$ was applied, the expected pH value was recorded in the three sampling strata. These pH values were statistically similar to those obtained with the application of dolomite and higher than those of the other two treatments.

In general, in this study, a higher reaction rate of dolomite was observed in the soil, than liquid $CaCO_3$ in both doses, which was more evident in the first three months, in the most superficial layer of the soil, followed by the depth from 5 to 15 cm. These results differ from those reported by Garbanzo *et al*. (2016) in the cultivation of corn (*Zea mays* L.), who pointed out that with liquid amendments the pH value of the soil increases very quickly, because it contains finer particles which neutralize the acidity in a few hours or days after being applied, compared to powdered materials, which have a coarser particle like dolomite. In addition, liquid lime can penetrate deeper into the soil, due to its greater mobility.

The largest increases in the soil pH value that were recorded in the surface layer were related to the depth at which the agricultural lime was incorporated (<10 cm), available humidity and the plastic padding. Agricultural lime requires moisture and $CO_2$ in abundance to dissolve, react and move to deeper layers of the soil (Scott and Fisher, 1989). Therefore, the little humidity from the rains (most intercepted by the plastic padding), favored a higher concentration in the 0 to 5 cm stratum, mainly during the first 30 days (Zetina and Romero, 1999). Later, when the moisture content increased considerably below the plastic, the dolomite and micronized $CaCO_3$ reached the deepest strata of the arable layer. At 120 dds, with liquid lime in doses of 20 L $ha^{-1}$, the pH of the soil was significantly improved throughout the profile and there was greater efficiency than with the application of dolomitic powder.

## Total biomass production

Table 3 shows that the total biomass production (fresh weight of leaves and stem per plant) varied significantly ($p \leq 0.05$), from 90 dds. With the application of liquid $CaCO_3$ in both doses, a higher biomass production was obtained, which was significantly higher than those obtained with dolomite and the control without liming, which registered statistically similar weights among themselves.

At 120 dds, the total biomass production was statistically similar in the three liming treatments, but only with the application of 20 L ha$^{-1}$ of liquid micronized $CaCO_3$ and 2 t ha$^{-1}$ of dolomite, quantities of biomass obtained were significantly higher than that obtained by the control without liming (Table 3). This is mainly due to the fact that with these two liming treatments, on that last evaluation date, the highest soil pH values were recorded in the three profile strata (Table 2), which favored greater availability of nutrients, and consequently better vegetative development of the pineapple plant, since most of these values are within the optimal range for that crop (Zetina *et al.*, 2002; Uriza *et al.*, 2018). Results obtained coincide with other reported in different species by Molina and Rojas (2005) and Camacho *et al*. (2015), as well as by Medina *et al*. (2009), who also found that liming with dolomite improved the vegetative development of pineapple.

**Table 3**. Biomass weight (g plant$^{-1}$) of MD-2 pineapple (*Ananas comusus* (L.) Merr) recorded at 60, 90 and 120 days after sowing, in three liming treatments and without application of agricultural lime.

| Treatment | Days after sowing and g plant$^{-1}$ | | |
|---|---|---|---|
| | 60 | 90 | 120 |
| Non-liming Control | 555.00 | 723.75 b | 1011.00 b |
| Dolomite 2.0 t ha$^{-1}$ | 583.75 | 720.75 b | 1223.00 a |
| Liquid micronized $CaCO_3$ 10 L ha$^{-1}$ | 580.00 | 833.75 a | 1168.75 ab |
| Liquid micronized $CaCO_3$ 20 L ha$^{-1}$ | 602.75 | 895.00 a | 1346.00 a |
| Mean | 580.38 | 793.31 | 1187.19 |
| Significance at analysis of variance | ns | * | * |
| Variation coefficient (%) | 4.15 | 7.64 | 10.36 |

Means with different letters in the same column are significantly different (Fisher, 0.05).

## CONCLUSIONS

The application of 20 L ha$^{-1}$ of liquid $CaCO_3$ increased the soil pH, in the three strata of the profile, up to 120 dds. These values were similar to those achieved with dolomite, and significantly higher than those of the low dose of liquid micronized $CaCO_3$ and the control without liming. With 20 L ha$^{-1}$ of liquid micronized $CaCO_3$ and 2 t ha$^{-1}$ of dolomite, amounts of total biomass higher than that of the non-liming control, were obtained.

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