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ORIGINAL ARTICLE

Liming of an Andisol of the Michoacan State Purepecha Plateau, Mexico

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ABSTRACT
Soils derived from volcanic ash are acidic cause problems because of the retention of phosphorus and molybdenum, their calcium and magnesium levels are low and those from aluminum high.The objective of this study consisted of determining the agricultural lime dose to reduce the soil acidity of a community of the Michoacán State, Mexico. It was worked in laboratory, greenhouse and field. It was carried out a soil sampling at the depth of 0.20 m to which was determined: pH, exchangeable aluminum, phosphorus retention capacity andcalcite dose to raise its pH to 7.0.Threecalcite dosesand one control was studied in greenhouse in a statistical design completely randomized with 4 replications. As indicator crop bean was used. As variables: days to flowering, dry matter of leaves, stems and petioles, and root length were considered. In the field, one control, two dolomite doses and one of calcite under a design of blocks at random with 4 replications each were studied in an orchard of avocado trees. As the response indicator variable was measured the growth of the avocado tree trunk perimeter. In greenhouse, 7500 kg ha^{-1}of calcite elevated the pH from 5.2 to 6.8 and had the highest yield in total dry matter production. This treatment was statistically the best at the level of significance of 5%.In field, the treatment of 6000 kg ha^{-1} of dolomite gave the greater growth of the avocado tree trunk perimeter and was the best at the level of significance of 5%.
***Key words**: Acid soil, Agricultural lime, Avocado tree, Bean crop, Neutralization.*

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INTRODUCTION

The acidity is a soil characteristic that influences various factors which affect plant growth; these include a) nutrient dynamics, b) microorganisms proliferation, c) organic solid waste humification; on the other hand, soil acidity is a function of: a) basic cations absorption by plants, b) leaching of base cations, c) humification of organic matter, d) acidic reaction fertilizers use, e)high content of exchangeable aluminum[1],f) aluminum toxic effects [2-4].Although a pH <7.0 characterizes an acid soil from the chemical point of view, considering their fertility level in relation to agricultural production, an acid soil is one that has a pH <5.5 for most of the year and is correlated with high aluminum content and deficiencies of phosphorus and molybdenum, calcium, magnesium, potassium and other factors that affect plant growth [5, 6].

In Mexico acid soils are the orders that correspond to Histosol, Gleysol, Acrisol, Nitosol, Planosol and Andisol and occupy 6.69% of the country located in the intertropical zone [7].

The soils of the Michoacan state Purepecha plateau, Mexico, were originated by weathering of volcanic ash, and have been classified as Andisols[8] which, throughout time came to acquire andic characteristics, high capacity of phosphate and molybdates retention.They have high content of allophane, imogolite, ferrihydrite and aluminum-humus complexes [9, 10] and low contents of calcium, magnesium and potassium [6]. In this region, in general, pH values vary from 4.9 to 6.3, but in the topsoil horizons, in part influenced by the organic matter content, the pH values vary between 5.3 and 6.2, so the horizons with greater amount of organic matter are the more acids [8].

The management of this order of soils should be integral, considering: a) acid-tolerant genotypes, b) chemical fertilizers efficient use, c) suitable crop rotation and d) application of different liming materials composed of carbonates, oxides, hydroxides and silicates of calcium or magnesium [5, 11-14].
The effect of liming may be benefic or damaging; among the first may be found: a) the increasing availability of phosphorus and molybdenum b) decreasing availability of manganese and aluminum, c) increases nitrification and nitrogen symbiotic fixation, d) slows plant bacterial disease, e) enriching the soil with calcium and magnesium; among the latter is the reduced availability of micronutrients such as iron, manganese, zinc, etc. [15].
The acidity control is an important factor for the productivity of those soils whose pH is below 7.0. The main cause of acid soils of high latitudes, with cold temperate temperatures, and coniferous vegetation, which have high permeability, is the high rainfall that allows leach, wash or eliminate carbonated alkali and alkaline-earth elements, which occurs at a speed higher than it of its formation, coming to predominate elements found in minerals slowly soluble in water such as aluminum, iron, manganese and hydrogen; that is elements acidity-generating. Aluminum is partly responsible for the soil acidity, and has toxic effects on nutrition and crop development [16], it is also the cause of the alitics properties in this order of soils that is in an acidic environment, and more acidity is generated [7, 17-18].Referring to anthropogenic origin of soil acidity, crop management and soil fertility are very important, because with the management of plant nutrition, usually ammonium fertilizers that generate an acidic reaction are applied, such as urea, di-ammonium phosphate, mono-ammonium phosphate, ammonium sulfate, that in the soil through microbiological action, nitrogen is oxidized and hydrogen ions are generated. When annual fertilization with ammonium fertilizers is repetitive, cumulative acidity arrives to cause problems with the crops nutrition affecting the plant vigor, the production and fruit quality.
The neutralizing action of liming materials is not due directly to the calcium and magnesium, but rather to the anions to which these cations are linked: $CO_3^{=}$, OH^-, and $SiO_3^{=}$; the cations replace to ion acids of its interchangeable positions and then they pass to the soil solution. When liming materials react with the soil water [19], the basic salts dissociate and generate cations and OH^- anions, these last, neutralize the acidity and lead to the precipitation of aluminum in the form of $Al(OH)_3$.The objective of this study wasto determine the dose of agricultural lime to reduce the acidity of soils of Santa Ana Zirosto, Michoacán, México.

MATERIALS AND METHODS

The present work was developed in three stages

Greenhouse stage

Soil sampling was performed in different representative areas of the Michoacán state Purepecha plateau, Mexico, allowing choose the location and the orchard where the field experiments were established. Once selected the orchard with the appropriate characteristics, it was proceeded to take samples, leaving an edge at the periphery of the field approximately 20 m; 40 subsamples were taken using the zigzag technic to the depth of 0.20 m which were mixed, dried in the shadow and sieved, its field capacity was determined, which was 39%, as well as lime needed to bring its pH to a level that is determined according to the needs required to have a response in terms of dry matter production curve.
For the selection of the lime treatments to use in the greenhouse research, the S.M.P., method was used [20].which resulted the dose of 00 (control); 3,750; 7,500 y 15,000 kg/ha of calcite, respectively. A statistic completely randomized design with 4 replications was used.To establish the experiment in greenhouse it was proceeded as follows: 4.0 kg of dry soil were weighed and sieved; the soil was placed in polyethylene bags which were weighed; and 0 (control), 7.5, 15.0 and 30.0 g of calcite were added to the bags properly labeled with treatments: 0.0 (control), 3,750, 7,500 and 15,000 kg/ha of calcite respectively. After mixing the soil and lime, to each bag 1,560 mL of distilled water were added to the soil to its field capacity. The bags were covered to protect them from the light and incubated during a period of 60 days to give a chance to the lime react with elements of interest and partly neutralize the H^+ in the soil solution where they were in interchangeable form. Once that soils were incubated with lime, they were fertilized with 80-100-100 treatment, using as sources of nutrients to the urea as nitrogen source, di-ammonium phosphate as source of nitrogen and phosphorus, and potassium chloride as a source of potassium; the treatment was applied in its entirety at the time of sowing of the crop indicator (bean Flor de Mayovariety); weekly was added a nutritive solution consisting of all the micronutrients necessary for good growth of the plants, with the purpose that they do not suffer by shortcomings and differences in dry matter yielded out exclusively due to the treatments applied and, consequently, to changes in acidity of the soil.

After applying the fertilizer treatments, it was proceeded to sow three seeds of beans at the depth of one centimeter as a response crop to applications of different treatments of calcite. After germination a plant was removed leaving the two more vigorous. In the course of the development of the plants, two irrigations were given weekly to field capacity, according to their needs, using distilled water to do so. There were some pests of interest such as leafhoppers and whitefly, which were adequately controlled with an infusion made with garlic, jalapeño pepper and tobacco.It was taken data: bloom, weight of dry matter (leaves, stems, stalks and roots) and length and dry weight of roots. At eight weeks the harvest was carried out, cutting the plants at ground level. The weight of dry matter of stems, leaves, stalks and roots was obtained.

Laboratory stage

In soils with the different treatments were determined: pH in suspension soil:water1:2; the interchangeable Al content by the aluminon method [21];available P content by the technique of Olsen[22];P fixing capacity by the technique of [23], calcium and magnesium content by flamometry. Once harvested bean plants developed with different treatments, foliar nutrient analysis for nitrogen with the Kjeldahl technique, phosphorus with nitro-perchloric mixture was performed using the method of ammonium molybdate [24], and in the same extract the contents of potassium, calcium and magnesium were determined by atomic absorption spectrometry.

Field Stage

It was selected an orchard of avocado trees located in the community of Santa Ana Zirosto, Michoacán, at an altitude of 2,000 meters above sea level, whereas the soil acidity level was measured through the pH in a suspension soil-water 1:2, which was of 5.2.For the establishment of the field experiments, calcite and dolomite were used in a randomized block design with three replications. A control and 3 levels of calcite were used: 0.0 (control), 1500, 3000 and 4500 kg/ha; three levels of dolomite: 0.0, 2000, 4000 and 6000 kg/ha.A constant fertilization to all plants of the experiment every two months was applied, including micronutrients. In an area of 10 m^2 of surface area of drip the treatments were applied. To each avocado tree the perimeter of the trunk at a height of 10 cm from the ground was measured.

RESULTS AND DISCUSSION

Greenhouse stage

The treatments influenced significantly on total dry matter production of the variables considered, although it was not considering the length of the roots of bean plants (Tables 1 and 2).

Table 1. Yield of dry matter (g) of the different parts of the bean plants

Treatment kg/ha	Leaves*	Stems	Roots	Total
Control	2.610^b	2.034^b	1.691^a	6.335^b
3750	2.701^{ab}	2.025^b	1.534^a	6.260^b
7500	3.963^{ab}	3.212^{ab}	1.390^a	8.565^a
15000	4.224^a	3.954^a	1.250^a	9.428^a

* Yields with the same letter are statistically the same

Table 2.Root length

Treatment (kg/ha)	Root length (cm)
Control	46.5^a
3750	44.75^a
7500	57.25^a
15000	56.25^a

*Lengths with the same letter are statistically the same

By applying lime, the levels of: calcium, phosphorus and molybdenum were raised, thus the plant had better conditions to absorb water and nutrients, consequently, the roots disposed them near the surface of the bag, so no significant differences demonstrated in its length.

The plants developed with treatments 7500 and 15000 kg/ha respectively, after germination pulled their cotyledons faster, had a more dark green color and its leaves were of a more consistent texture.

The plant fertilized with 15000 kg/ha treatment manifested chlorosis symptoms which began to manifest in the leaves with a metabolism of degradation, that is in the older parts of the bean plant, and was spreading towards the leaves immediately above, this was due to an effect of toxicity of lime and it is likely to be due to N deficiency; the same effect arose in the bean plants that were subjected to treatment of 7500 kg/ha, but in this case the symptoms appeared about four days later in relation to the former.

The plants developed with the treatment of 15000 kg/ha showed a significant prematurity compared with the control, starting its flowering eight days earlier; prematurity was also manifested itself in the bean plants with treatment of 7,500 kg/ha only to a lesser extent. This response observed in the precocity of bean plants with lime applications is similar to that observed when ethephon was applied on apple trees Northern Spy variety [25].

This is explained by arguing that the Ca gives greater stability to cell membranes,that in soil transform some nitrogen compounds in ammonia which is released into the atmosphere in gaseous form, and plants stressed by excessive levels of lime tend to produce faster seeds as a physiological response to such unfavorable condition.

The foliar analysis does not showed significant differences by effect of treatments on nutrient content; however, it can be seen that the higher the lime dose, the higher the calcium concentration. On the other hand, regarding the primary macronutrient generally the opposite trend was observed (Table 3).

Table 3 Foliar analysis of dry matter of beans with different lime treatments

Treatment (kg/ha)	N	P	K	Ca	Mg
Control	2.8 ± 0.13	1.50 ± 0.09	6.5 ± 0.99	3.2 ± 1.31	1.2 ± 0.09
3750	2.6 ± 0.18	1.67 ± 0.01	6.4 ± 0.98	3.6 ± 1.49	1.3 ± 0.11
7500	2.4 ± 0.11	1.56 ± 0.09	6.3 ± 0.97	3.7 ± 1.5	1.3 ± 0.11
15000	2.0 ± 0.09	1.20 ± 0.07	5.9 ± 0.91	3.9 ± 1.61	1.3 ± 0.11

Laboratory stage

With application of different doses of lime, soil pH increased from 5.2 to 7.2 (Table 4).

The aluminum level in soil with different lime dosage, ranged from 4,05 to 0.684 kg/ha, noting that with the application of different dosages of lime its content was significantly reduced (Table 4) which had repercussions on the response of the bean plants (Table 5).

From an agricultural point of view these aluminum levels are low, and associating them with the control pH (5.2) the problem is of little importance [26].

Similarly, highly significant differences to analyze data related to the content of labile P, and to make the separation of means according to $Tukey_{(\alpha = 0.05)}$, there was no difference between the control and the treatment of 3750 kg/ha, but there was to compare them with those which had 7500 and 15000 kg/ha respectively, but these two treatments had the same behavior.

Andisols are highly fixing P, partly because of its high levels of acidity, however, with doses of 7500 and 15,000 kg/ha retention reactions increased significantly (Table 6).

Table 4. Soil pH with different lime dose

Treatment (kg/ha)	pH (in water 1:2)
Control	5.2^{d}
3750	6.2^{c}
7500	6.8^{b}
15000	7.2^{a}

* Soil pH_S with the same letter are statistically the same

Table 5 Aluminum content in soil with different lime dose

Treatment	Soil Al Content	
(kg/ha)	me/100g	kg/ha
Control	0.0225	4.05
3750	0.0151	2.718
7500	0.0077	1.386
15000	0.0038	0.684

Table 6 Soil P content and applied P fixation

Treatment Kg/ha	Soil P Content (ppm)	P Fixation* (%)
Control	3.2[b]	93.0[b]
3750	3.6[b]	90.3[b]
7500	29.1[a]	98.0[a]
15000	29.7[a]	97.5[a]

* Quantities with the same letter are statistically the same

Field stage

The different treatments significantly influenced on the increase of trunk perimeter of the avocado trees, being treatment with 6 tha^{-1} of dolomite which had the greatest influence (Table 7).

Table 7. Increase of the avocado tree trunk perimeter with different lime treatment

Treatment Calcite– Dolomite (ton/ha)	Increase * (cm)
0.0 - 6	18.00[a]
0.0 - 4	12.43[b]
0.0 - 6	12.39[b]
0.0 - 6	11.72[b]
0.0 - 4	11.38[b]
0.0 - 6	11.47[b]
4.5 - 0	10.94[b]
4.5 - 0	10.42[b]
4.5 - 0	10.01[b]
Control	7.010[c]

* Quantities with the same letter are statistically the same

This treatment was formed by 6 ton/ha dolomite. As dolomite contains magnesium and calcium, the plants were better nourished. As a result, those plants had a statistically significant higher growth (Table 4). The response to the application of calcite was lower, partly due to containonly calcium. In addition, their level was below regarding that of the dolomite.

CONCLUSIONS

1. The avocado tree showed a better response to the application of dolomite at the dose of 6 ton/ha.
2. In general, dolomite had a better effect on the growth of the perimeter of the trunks of the avocado tree with respect to that of calcite.
3. There was a significant effect of liming on the growth of the perimeter of the trunks of the avocado tree respect to the control.
4. The liming of acid soils of the Michoacan state Purepecha plateau, Mexico, is beneficial to improve their nutritional conditions.

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