Research Article



# Effect of the liming on the soil chemical properties and the development of tomato crop in Sucre-Colombia


## Abstract

The acidity of the soil produces complex interactions on plant growth limiting factors that involve physical, chemical and biological properties of the soil, which can manifest in deficiencies of calcium, magnesium and phosphorus and toxicity of aluminum, iron, and manganese, which could limit plant growth. Based on the above and in order to contribute to better development of tomato crop in soils with a low nutritional offer and acid reaction of the Santa Clara region (Sucre), the following research has been proposed with five (5) commercial lime dose (0, 1, 2, 3 and 4 t $ha^{-1}$) and its effect on chemical properties, using tomato as an indicator plant. The effect on pH, P, Ca, Mg and K in the soil was evaluated, and in the plant, the yield components were evaluated (weight and dimensions of the fruit, yield). A completely randomized design with three repetitions was used, the information was processed with the statistical software SAS version 9.1. It was found that liming improves soil pH, availability of P, Ca, Mg and K, in the same way, the development and yield of tomato crop with doses of up to 3 t $ha^{-1}$of lime on the soil is improved.


**Keywords:** liming in sucre, exchangeable acidity, tomato yield, tomato production, exchangeable aluminum

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Eliecer Miguel Cabrales Herrera, Luis Fernando Acosta Pérez
Sustainable Agriculture Research Group, Universidad de Córdoba, Colombia

**Correspondence:** Eliecer Miguel Cabrales Herrera Universidad de Córdoba, Sustainable Agriculture Research Group, Universidad de Córdoba, Montería, Colombia, Email ecabralesh@correo.unicordoba.edu.co

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**Abbreviations:** CRD, completely randomized design; Ca, calcium, Mg, magnesium

## Introduction

The acidity of the soil with the low availability of nutrients, are one of the greatest limitations that can induce the low productivity of acid soils. Although acidification is a natural process, agriculture, pollution, and other human activities accelerate this process,[1] becoming one of the most common limitations in Colombian soils, where aluminum and iron can in conditions of excess, be toxic to crops, or its in effect retain phosphorus. The chemical interactions derived from acidity affect the fertility of the soil, by altering its ionic balance and inhibiting the absorption of important nutrients, such as calcium, magnesium, and phosphorus.[2–4]It is estimated that 40% of the world's cultivable soils are acidic and potentially have toxic effects of aluminum, iron, and manganese, which usually happens when the pH is below 5.5. Under these conditions, aluminum appears in the soil solution as $Al^{3+}$, which is a free ion that can form compounds with other ions present in the solution such as phosphates and sulfates. These $Al^{3+}$ions can also compete with other cations such as $Ca^{2+}$and $Mg^{2+}$for exchange sites in soil colloids, contributing to the washing of these interchangeable bases, so that the exchangeable aluminum potentially becomes a limiting factor in the fertility of the majority of acid soils.[5,6]The effects of acidity directly affect the fertility of the soils and are the determining factors in the evaluation of agricultural productivity, hence the importance of its valuation in establishing management strategies.[6,7] To reduce the acidity of the soil, fine limestone rock material (<0.25 microns) is used,[8] which in its reaction releases $OH^-$ groups that react with aluminum and hydrogen in the soil solution and neutralizes them, lowering their concentration and thereby increasing the pH of the soil. Likewise, the calcium provided in management plans (liming or fertilization) can displace these elements from the exchange sites, thereby releasing retained nutrients in the colloidal system the soils.[9]

The pH or reaction of the soil limits the implementation of many cultivars, not only because of the high concentration of $H^+$ (low pH), but they tend to be low in exchangeable bases, including calcium that contributes to the hardness of the cell wall, the magnesium that is part of the chlorophyll molecule, the potassium that is indispensable for turgor of fruits and the plant in general. In this order of ideas, crops that tolerate these conditions should be selected, which must be supplied in the fertilization plans, the missing nutrients for good development and yield.The soils of the El Roble municipality of the department of Sucre, are of acid reaction and low nutritional offer, the community in small areas sows vegetables including tomato for fresh and local consumption, in which multiple plant health problems appear as the apical rot of the fruit, leaf fungus and stem, possibly leading to low crop yields. In this sense, the tomato is a plant that demands high amounts of nutrients and the production of fruits of good caliber and high weight is related to the availability of nutrients in each of the stages of crop growth.[6] Some studies have shown that the application of calcium amendments to the soil, raise the pH and increase the yield of tomato fruits,[10,11] has been shown the positive effect of calcium available in the soil on the yield of the tomato crop, induces a positive effect on the appearance and weight of the fruit.[12]Based on the above and in order to contribute to the productivity of the agricultural area of Community of El Roble - Sucre, this research was proposed with the objective of evaluating the effect of the application of different doses of agricultural lime on the chemical properties of a soil acid and its effect on tomato crop yield under semi-controlled conditions.

## Materials and methods

The investigation was conducted in semi-controlled conditions in the El Roble - Sucre community, geographically located 9°6 'north latitude and 75º11' west longitude of the Greenwich Meridian, conformed by lomerío and undulations that go from 70 to 185 m.s.n.m. The climate is characteristic of tropical dry forest areas. The average annual temperature is 27.2°C, the precipitation fluctuates between 990 and 1,275mm annual average and the relative humidity is 80% on average. The physiographic, edaphic factors, winds, and degenerative anthropic actions of the natural environment, eliminate tree cover and degrade the soil, produce acidity conditions in the soil.The 20 cm deep soil of the Las Lauras estate of the Santa Clara district was used, municipality El Roble of the department of Sucre, the soil of frank sandy texture, considered as extremely acidic (Table 1), organic matter content low and nutritional offer low.

**Table 1** Physicochemical characteristics of the soil used in the trial

| pH | MO | P | Ca | Mg | Na | K | Al | %A | %L | %Ar |
|---|---|---|---|---|---|---|---|---|---|---|
| - | % | mg/kg | cmol+/kg | | | | | Loamy sand | | |
| 4,3 | 0,3 | 5,9 | 1,2 | 0,8 | 0,4 | 0,01 | 8,9 | 82,5 | 14,3 | 3,2 |

Doses of 0, 1, 2, 3 and 4 t ha$^{-1}$of commercial agricultural lime available in the area, whose composition is 37.05% CaO and 5.35% MgO, were applied to the soil, it was spread on the surface and incorporated in the first 5 cm of depth, then, water was added until it was completely moistened, left for 40 days in incubation with field moisture, during which time, 95% of the lime had reacted (Lime Residuality Index 5%).Seedbed was made in soil substrate: compost in a 2:1 ratio, it was solarized for 3 days in 10 cm layers, covered by plastic. When the seedlings had 3 true leaves (20 days), a transplant was made to nursery bags with a capacity of 20 kg, previously filled with soil from the Las Lauras farm. These bags were located at a distance of 0.8 m by 0.6 m.Fertilization was defined based on soil analysis and liming with the formula suggested by.[13] The fertilization was done with 120 kg ha$^{-1}$of nitrogen (Urea source, 46% of N), applied in a fractional form in three doses at 15, 30 and 45 days after transplantation. The phosphorus dose was 80 kg ha$^{-1}$(DAP source, 18-46-0), applied in two fractions the first in pre-planting and the second 30 days after transplantation. The dose of potassium was 80 kg ha$^{-1}$(source KCl, 60% $K_2O$) and its application was done in two fractions: one at the time of planting and the second 30 days after transplantation. For the supply of minor elements, a complete foliar fertilizer was used, with applications at 15, 30 and 45 days after sowing, sprinkling a solution with a concentration of 1 ml L$^{-1}$. Throughout the crop cycle, all the necessary work was carried out to maintain the crop. To observe the effect of the treatments (liming) on the soil, the pH was determined at the beginning and at the end of the experiment (soil: water ratio 1:1, Metrohm equipment), the content of P (Bray II) was also measured, Ca, Mg, K (Ammonium acetate, quantification by spectrophotometry) and Al+H (KCl, titration). The crop (tomato) was evaluated for yield, whose harvest of the fruits was done daily in those who had physiological maturity (reddish color). The following variables were evaluated: harvested fruits, fruit weight, fruit dimensions, and yield.The trial was established in a completely randomized design (CRD), with five treatments and three repetitions. The information was tabulated in Excel and processed with the statistical software SAS version 9.1, analysis of variance and regression was made at 5% probability.

## Results and discussion

### Soil parameters

**Acidity of the soil:**The analysis of variance showed significant statistical differences between the treatments for the pH variable (Table 2). In terms of pH, all treatments are statistically different, to the control. Regarding the graphic behavior of the data, it can be evidenced that there is a linear adjustment for its modeling, with high statistical significance ($p < 0.01$), indicating that the pH depends on 95.8% of the applied lime doses to the ground (Figure 1).

**Table 2** Mean squares and levels of significance of the chemical properties of liming soil

| S.V. | DF | pH | P | Ca | Mg | K | Al+H |
|---|---|---|---|---|---|---|---|
| Treatments | 4 | 0,74** | 1254,44** | 1,23** | 0,12* | 0,08** | 332,62** |
| Error | 10 | 3,0E-03 | 6,78 | 0,01 | 0,02 | 5,5E-04 | 0,05 |
| C.V. (%) | | 1,1 | 7,84 | 5,1 | 14,13 | 9,66 | 6,37 |
| $R^2$ | | 0,99 | 0,99 | 0,98 | 0,70 | 0,98 | 0,99 |

DF, degrees of freedom;P, phosphorus; Ca, calcium; Mg, magnesium; K,potassium;exchangeable acidity,

(Al + H); *, significant;**, highly significant; ns, not significant

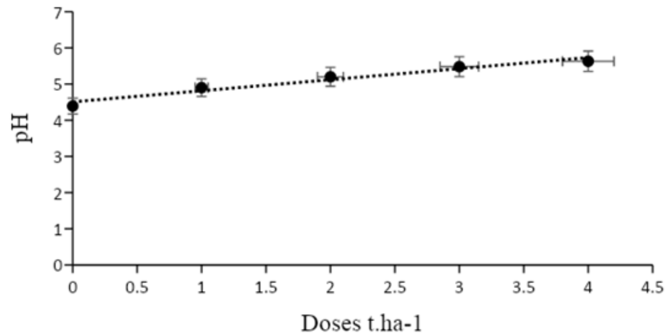


**Figure 1** Effect of the doses of the calcium amendment on the pH of an acid soil.

The highest response to liming was observed with the application of the dose of 4 t $ha^{-1}$ from an extremely acidic pH with a value of 4.3 to moderately acidic with a value of 5.63. This is possibly due to the fact that the added lime reacted with the moisture available during the incubation period, and by reacting it releases $OH^-$ groups that react with the aluminum and hydrogen in the soil solution: it neutralizes them and increases the pH, as it does affirms.[9] The pH of the soil showed an ascending behavior with the increase in the dose of the of liming material, similar to those reported,[2,3,6,14–17] who support the benefits obtained with the application of the liming material as a corrective for the acidity of the soil, and its effect on the chemical properties of the soil.

**Exchangeable acidity:** The dynamics of this variable conform to a linear order model (Figure 2) with high statistical significance (Table 2), explaining that the reduction in exchangeable acidity depends on 78.99% of the liming material. These results show that there are significant differences between treatments, the control treatment (0 t $ha^{-1}$) is statistically different from the other treatments, demonstrating that the doses of the amendment eliminate a high percentage of exchangeable acidity.

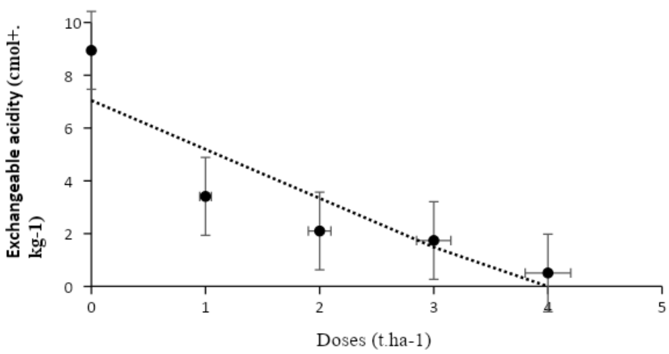


**Figure 2** Effect of the doses of the calcium amendment on exchangeable acidity.

Contrary to what happens with pH, the concentration of exchangeable acidity decreases as the dose of calcium amendment is increased. This behavior has been widely documented in soils,[2,14,15,18–20] who state that when chemical corrective agents (limes) are applied to the soil, the exchangeable acidity decreases.

**Phosphorus**: The phosphorus content varies significantly (Table 2), all treatments are different from the control (0 t $ha^{-1}$), there was a large increase in the phosphorus content in the soil, a trend that can be explained by a linear order model in 98.78% (Figure 3). The increase of the content of this element is possibly due to the contributions of the fertilizer (DAP) applied, the liberation of the element that is achieved by increasing the pH of the soil. This availability of the element was reflected in the good development of tomato cultivation. Similar results were obtained by other authors,[3,6,21] who achieved better availability of the element with increases in soil pH.

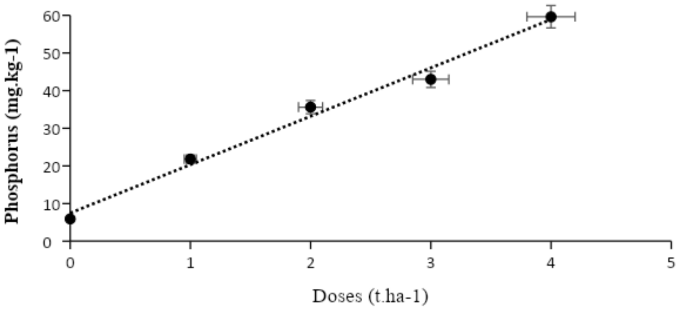


**Figure 3** Effect of treatments on the phosphorus content in the soil.

**Calcium, magnesium, and potassium**: With liming, calcium and magnesium presented a highly significant increase (Table 2), which is consistent with that reported by other researchers,[14,15]the same was presented for potassium but in smaller proportion. Similar results were obtained by Sikiric et al.,[22]with the application of lime in an inceptisol soil, thereby increasing the availability of Ca and Mg without significant changes in K levels. This can be explained because Mg (and Ca to a lesser extent) replaces K in the exchange complex[23] and by being free or available in the soil solution, it can be washed with greater ease and at the end of the trial not be in large quantities. For Ca, Mg and K the graphical behavior of the data, it can be evidenced that there is a linear adjustment for its modeling (Figure 4), with high statistical significance ($p < 0.01$).

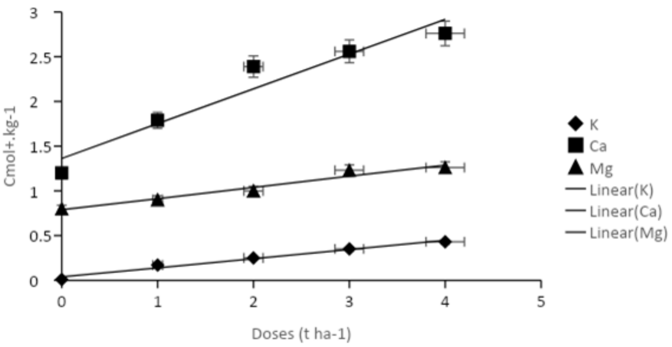


**Figure 4** Effect of liming on the content of potassium, calcium and magnesium in the soil.

Comparing what happened in the soil without liming (T0), in the liming soil at the end of the experiment an increase in the levels of P, Ca, Mg and K available for the plant in the soil solution was observed, similar results reported.[14] In this regard[6,24]reported that depending on the liming sources used, their reaction mechanisms enrich the interchangeable phase with $Ca^{++}$ and $Mg^{++}$ once they produce aluminum displacement interchangeable in the soil solution so that an improvement in the concentration of bases is induced. On the other hand, as the pH becomes less acidic, phosphorus increases its availability or solubility.

## Components of tomato crop yield

**Harvested fruits:** As for the harvested fruits, the analysis of variance showed highly significant differences between treatments (Table 3). The fit of the model is good at a level of significance of 1%, which suggests that 80.61% of the variability is explained by the model. Regarding the graphic behavior of the data, it can be evidenced that there is a quadratic adjustment for its modeling (Figure 5). In addition, an increase in the number of harvested fruits can be seen depending on the doses of lime up to the dose of 3 t $ha^{-1}$, from this point the variable is dominated by a negative opening parabola that shows a decreasing trend.The increase in harvested fruits up to the 3 t $ha^{-1}$dose is probably due to the calcium assimilated by the plant joined with pectins, producing calcium pectate, which gives resistance to the cell wall against the attack of pathogens of fruit and thus the fruit does not lose firmness,[12,25–28] so the probability of falling fruits is reduced.

**Table 3** Mean squares and levels of significance of the components of tomato crop yield

| S.V. | DF | NHF | FW | DF | FL | Yield |
|---|---|---|---|---|---|---|
| Treatments | 4 | 176,27 ** | 129,73** | 11,94** | 16,54* | 143,31 * |
| Error | 10 | 5,67 | 1,37 | 0,23 | 1,80 | 16,82 |
| C.V. (%) | | 4,87 | 2,37 | 1,3 | 3,21 | 9,5 |
| R² | | 0,93 | 0,97 | 0,95 | 0,79 | 0,77 |

DF, degrees of freedom; NHF, number of harvested fruits; FW, fruit weight; FL, fruit length; FD, fruit diameter *, significant; **, highly significant; ns, not significant

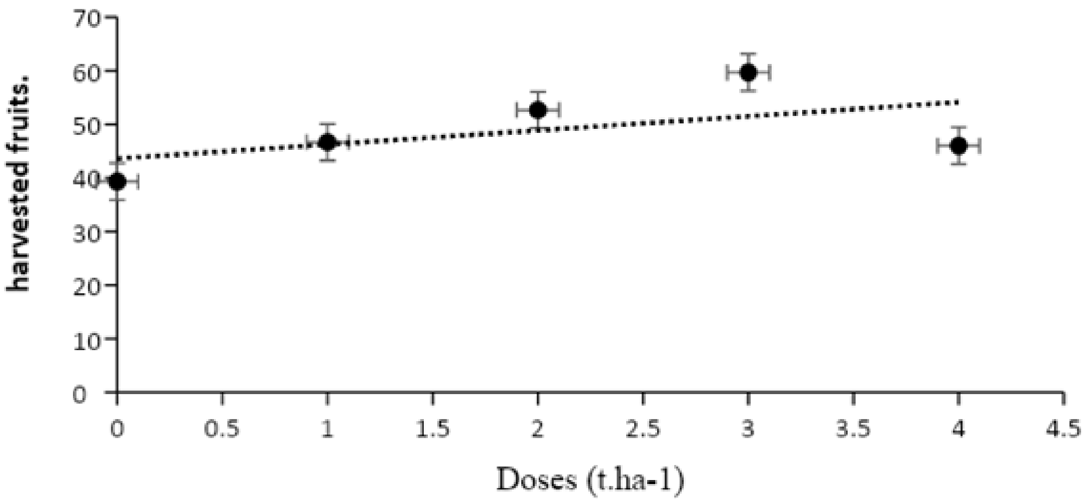


**Figure 5** Effect of lime doses on the number of harvested fruits.

**Fruit dimensions**: According to Table 2, the dimensions of the fruit show significant variation between treatments. The modeling of the data conforms to a quadratic order model with statistical significance. The largest dimensions of the fruit are obtained with the dose of 2 t $ha^{-1}$(Figure 6), possibly with this dose the balance or sufficient amount of calcium in the soil was achieved to satisfy the needs of the tomato plant, which in turn it could positively influence the plant to absorb it together with other nutrients, in addition the calcium applied to the soil probably influenced the epidermal extensibility and the development of the tissues of the fruit's pericarp, this division and elongation of the tissues of the pericarp of the fruit, are determining for the growth of the tomato.[29,30] In this regard, previous studies,[31–33]states that while epidermal cells divide throughout the development of the fruit, the division in the pericarp is limited to a short period of fruit development and it is located in the outer tissues around in the vascular bundles and in the hypodermis. Once the cell division ends, cell expansion begins to increase the size of the fruit. Likewise, it is possible that the increase in the diameter of the fruit is associated with the increase in the number and size of the cells as indicated by other researchers.[34,47]The results of this research are similar to those reported by earlier studies,[34–36,46]but differ from those reported by other researchers.[12,37–39]

**Fruit weight:** It can be evidenced that there is a highly significant variation between treatments (Table 3). As for the graphic behavior of the data, these fit a highly significant linear order model (Figure 7), this model indicates that there is a strong relationship between the two variables. This finding is possibly due to the fact that it is having an improved pH and more calcium available, it can be absorbed and incorporated into cell parts and influence the division of cells to induce fruit growth and weight. On the other hand, calcium that fails to enter the cytosol, remains in the cell wall, making them heavier.[30] When calcium is properly supplied, it provides greater fruit establishment, greater growth and lower incidence of physiological disorders, together with an increasing number and weight of tomato fruits.[35]These results are below 129 g reported by Muhammad et al.,[40]and 96.4 g reported by Martínez et al.,[41]but are consistent with those reported by other authors,[34,35] who achieved increases in the weight of tomato fruit with calcium additions to the soil. However, Arruda et al.,[42]report contrary results, decrease in fruit weight.

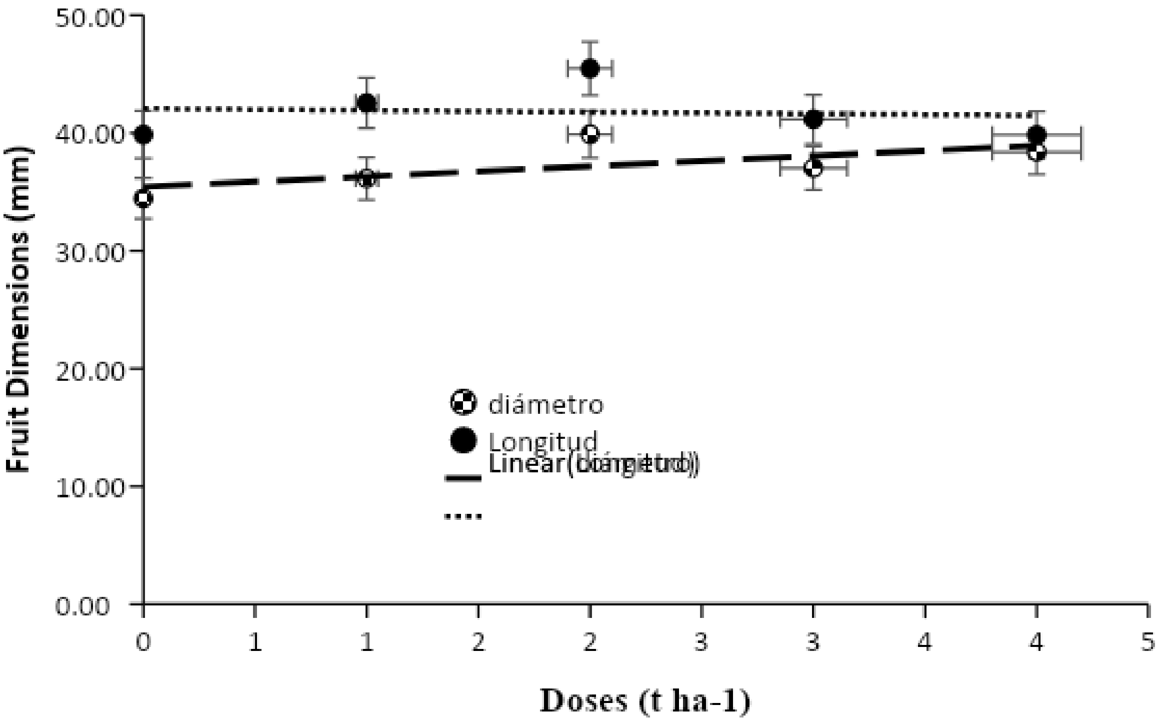


**Figure 6** Effect of lime doses on tomato fruit dimensions in semi-controlled conditions.

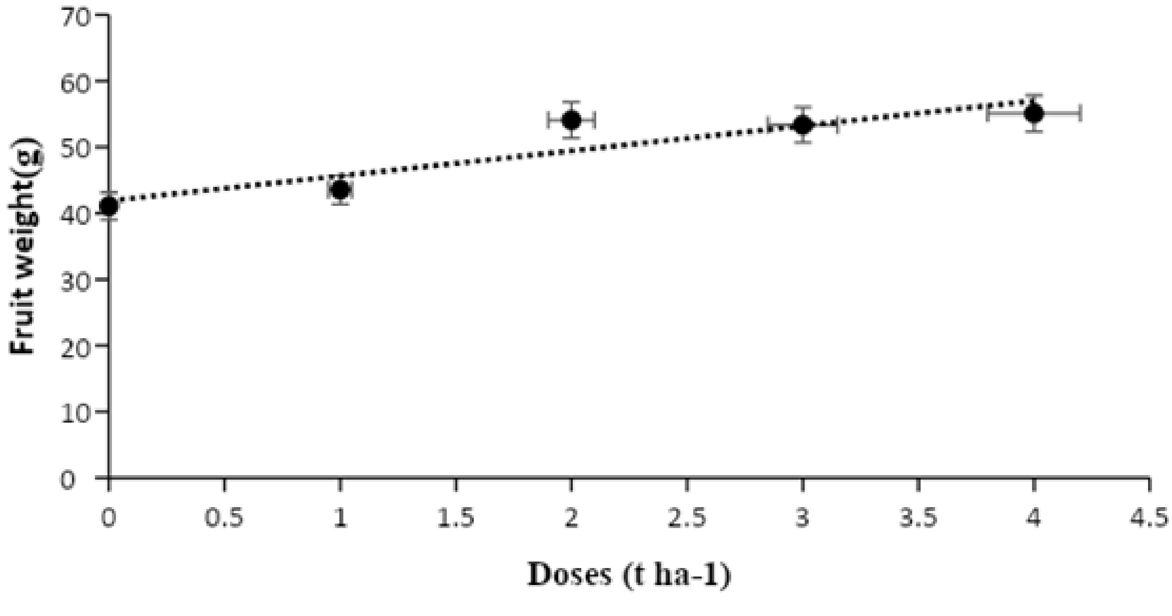


**Figure 7** Effect of lime doses on tomato fruit weight.

**Tomato yield**: It is evident that the behavior of the data conforms to a quadratic order model (Figure 8) with statistical significance. The analysis of variance showed that there are significant differences between the treatments (Table 3), the control treatment (0 t $ha^{-1}$) is statistically similar to the treatments of 1, 2 and 4 t $ha^{-1}$but different from the treatment of 3 t $ha^{-1}$. It is evident that the treatments with lime showed higher values than the control, which suggests a strong tendency of the positive effect of calcium in this parameter evaluated.

The graph shows an increase in crop yield up to 3 t $ha^{-1}$, from then on it tends to decrease, possibly because with larger doses the lime, the available calcium can negatively affect the chemically balanced soil, thereby decreasing the possibility of absorption of other nutrients. In this sense, Thompson[43] states that calcium is essential for the division and cellular elongation of formed set fruits, favoring a larger size, however, it is required to take other nutrients proportionally.This increase in crop yield is possibly due to the fact that the availability of calcium in the soil improved the reaction of the soil and improved the chemical balance of the soil. When this occurs, the plants nourish much better and, therefore, will be more tolerant to the attack of pathogens. These results suggest that, with the liming practice and the fertilization plan based on the soil analysis, a good crop response is obtained in terms of production. These results are consistent with those reported by other researchers,[10,35] but different from other authors.[6,12,39,42,44,45–47]

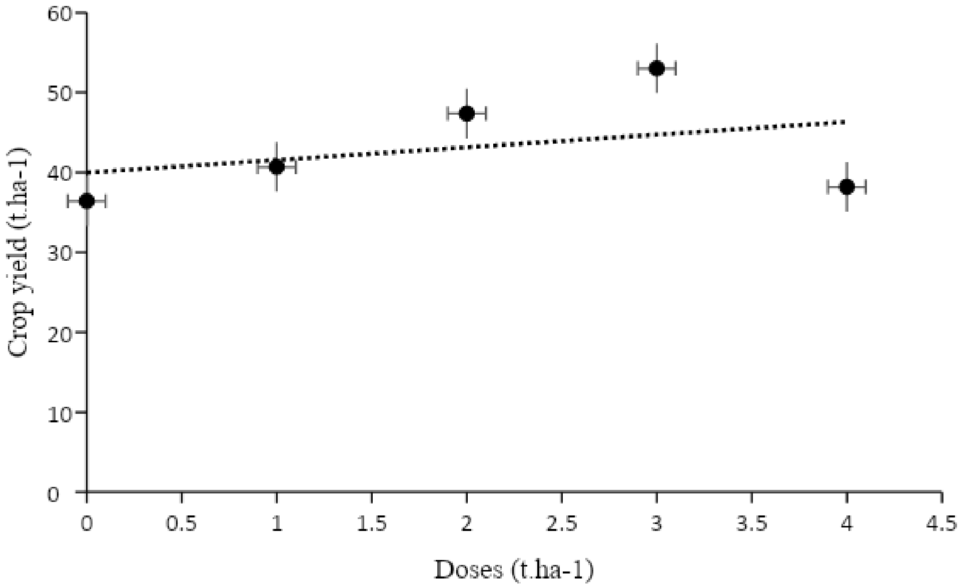


**Figure 8** Effect of lime doses on tomato crop yield.

## Conclusion

With the application of lime in acid soil of Sucre, better chemical conditions are achieved, the pH of the same is increased, which favors the nutritional availability, especially phosphorus and supply of interchangeable bases, which were used by the tomato crop.Liming and supply of nutrients in acidic soils with sandy characteristics and low nutritional offer can improve the production and characteristics (weight and dimensions) of tomato fruit, which is reflected in better yields of this crop.

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## Conflicts of interest

This manuscript was prepared and reviewed with the participation of the authors, who declare that there is no conflict of interest that jeopardizes the validity of the results presented.

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