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DOI: 10.1080/00103620802137613

Effect of Liming on the Mineral Nutrition an of Growing Guava Trees in a Typic Haplud

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Abstract: High soil acidity influences the availability of mineral n increases that of toxic aluminium (Al), which has a jeopardizing ef growth. The objective of this research was to evaluate the effects of s the development of guava (*Psidium guajava* L.) plants, on s characteristics, and on fruit yield. The experiment was carried Bebedouro Citrus Experimental Station, state of São Paulo, Brazi Hapludox soil, from August 1999 to March 2003. The treatments limestone dose: D_0 = zero; D_1 = half dose; D_2 = total dose; D_3 = dose, and D_4 = 2 times the dose to raise the V value to 70% corresponded to zero, 1.85, 3.71, 5.56, and 7.41 t ha^{-1} applied to t layer (0–30 cm deep) before planting. The results showed that limi improvement in the evaluated soil chemical characteristics up to a d in soil samples both in the line and between lines. The highest fru obtained when the base saturation reached a value of 55% in the between the lines. Foliar levels of calcium (Ca) and magnesium (Mg 2.5 g kg^{-1}, respectively. The highest limestone dose maintained saturation (at the layer of 0–20 cm) in the line close to 55% duri months after the incorporation of limestone.

Keywords: Fruit-bearing trees, limestone, mineral nutrition, *Psidiu* acidity

Received 10 September 2001, Acceped 20 January 2008
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INTRODUCTION

Brazilian soils usually show high levels of acidity and high aluminum (Al) saturation in addition to low levels of nutrients and are considered to be low fertility soils. Under these circumstances, the productivity of a perennial species, such as guava, would be dependent upon soil liming, because the plant grows for a long period of time, exploiting practically the same volume of soil.

A review of the literature showed that information concerning the practice of liming when the species is under cultivation is scarce, especially when the guava orchard is in an initial growth phase. On the other hand, it is generally agreed that the best moment for correcting soil acidity is at planting time, for this will give the future adult plants a good start. In addition to that, the genetic improvement of fruit crops has resulted in high-yielding genotypes, which demand higher levels of mineral nutrients and, at the same time, are less tolerant to Al toxicity. Examined from this perspective, soil acidity is recognized as one of the most important factors contributing to low agricultural productivity (Raij 1991). Experiments conducted either with annual crops (Raij and Quaggio 1984) or with perennial (citrus) crops (Vitti 1991) showed that fewer investments in agriculture are as profitable as those destined to soil acidity correction. Nachtigal et al. (1994), on the other hand, report that guava plants of a genotype naturally developed in low fertility and acid soils of mountain ranges nevertheless exhibited positive responses to soils of good fertility levels.

It is also important to consider that the several genetic improvement programs underway obtained high-yielding genotypes, which are more demanding of soil fertility and pH correction. Although there is little information on the acidity correction for the guava crop in the state of São Paulo, a work by Santos and Quaggio (1996) recommended raising the base saturation value to 70%.

Thus this work had the objective of studying the effects of soil liming on the growth and yield of a guava orchard.

MATERIALS AND METHODS

The experiment was carried out in the Citrus Experimental Station in Bebedouro, state of São Paulo, Brazil, at latitude of 20° 53′ S and longitude of 48° 28′ W with an average altitude of 601 m above sea level. According to Köeppen's classification, the local climate is of the Cwa subtropical type, with a short, moderate, and dry winter and a warm and rainy summer. The soil is a Typic Hapludox (Soil Taxonomy), and its chemical characteristics are presented in Table 1.

Table 1. Chemical analyses of the Typic Hapludox before the installation of the experiment

Layer (cm)	pH ($CaCl_2$)	O.M. ($g.dm^{-3}$)	P resin ($mg.dm^{-3}$)	K ($mmol_c.dm^{-3}$)	Ca ($mmol_c.dm^{-3}$)	Mg ($mmol_c.dm^{-3}$)	(H+Al) ($mmol_c.dm^{-3}$)	SB ($mmol_c.dm^{-3}$)	T ($mmol_c.dm^{-3}$)	Al ($mmol_c.dm^{-3}$)	V (%)
0–20	4.7	18	6	1.3	9	4	40	14.3	54.3	8	26
20–40	4.4	16	3	0.8	6	4	41	10.8	51.8	11	21
40–60	4.4	16	4	0.6	7	4	45	11.6	56.6	12	20
60–80	4.0	9	1	0.3	7	3	58	10.3	68.3	11	15

A randomized complete block design with five treatments and four replications was employed. The experimental plots were composed of five plants, of which the three central ones were used for the measurements. The treatments consisted of doses of lime, which were calculated considering the desired V (base saturation) value of 70%. The doses turned in at the upper 0- to 30-cm soil layer were D_0 = zero; D_1 = half the dose; D_2 = the total dose; D_3 = 1.5 times the dose; D_4 = 2 times the dose necessary to increase V to 70%. These doses correspond to 0, 1.85, 3.71, 5.56, and 7.41 t ha^{-1}. The limestone had 456 g of calcium oxide (CaO) and 102 g of magnesium oxide (MgO) per kilogram, a reactivity value of 94%, neutralizing power of 107%, and a relative power of total neutralization of 100%.

Four months after liming, in December 1999, the guava orchard was installed. Guava cuttings of the cultivar 'Paluma' were planted within a spacing of 7 × 4.2 m. Limestone was manually spread over the entire area of the orchard, half of it before incorporation with a moldboard plows and the other half incorporated with a plowing harrow (at top 30-cm layer).

The application of fertilizers before the installation of the orchard, as well as the ones made during the ensuing years, obeyed procedures indicated by Natale et al. (1996).

Six months after the rootstocks were successfully rooted, a micro-sprinkling irrigation system was activated to provide each plant with 26 L of water per hour.

Soil samples from the lines and in-between lines were taken at the depths of 0–20, 20–30, 30–40, and 40–60 cm until 40 months after liming. The analytical determinations were made according to methods described by Raij et al. (2001).

In accordance with methodology described by Bataglia et al. (1983), the nutritional status of the plants was determined by the chemical analyses of the sixth leaf starting from the branch's tip (Natale et al. 2006). In each tree, four of these leaves were randomly taken when the plants were 21 and 34 months of age.

The biological variables measured to give an indication of the plants, degree of development were as follows: stem diameter at 10 cm above soil surface, height, and the radius and volume of the plant crown. The production of three plants from each plot was obtained during two seasons (2001/2002 and 2002/2003), covering the months from March through August 2002 and January through July 2003.

Based upon the results, the analysis of variance of the several parameters was made and, when necessary, a regression analysis was also calculated to establish the relations between the treatments and the data for soil chemical attributes, plant biological characteristics, and fruit yield (SAS Institute 1985).

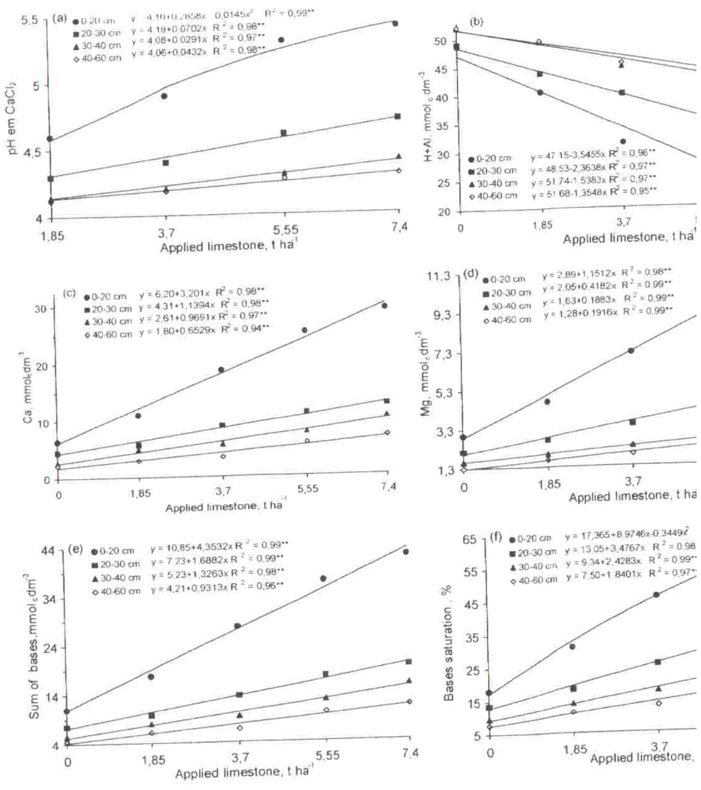

Figure 1. Effects of the application of limestone on the pH in Ca((b), Ca (c), Mg (d), sum of base (e), and base saturation (f) of soil in-between the lines from different depths. The dots are means of five sampling moments at the layers 0–20, 20–30, 30–40, and 4 respectively, and four replications. ** Significant $P < 0.01$.

RESULTS AND DISCUSSION

Effects of the Treatments on Soil Characteristics

Soil liming, as expected, reduced the potential acidity and values and the concentrations of calcium(Ca) and magnesiu consequently the values of the sum and that of base satur: samples taken in the lines of trees and between the lines (Fi respectively). The combined analysis of the results showed interaction between time of soil sampling and doses of lii depths, both for samples taken in the lines and those betv The absence of interactions is an indication that the variat

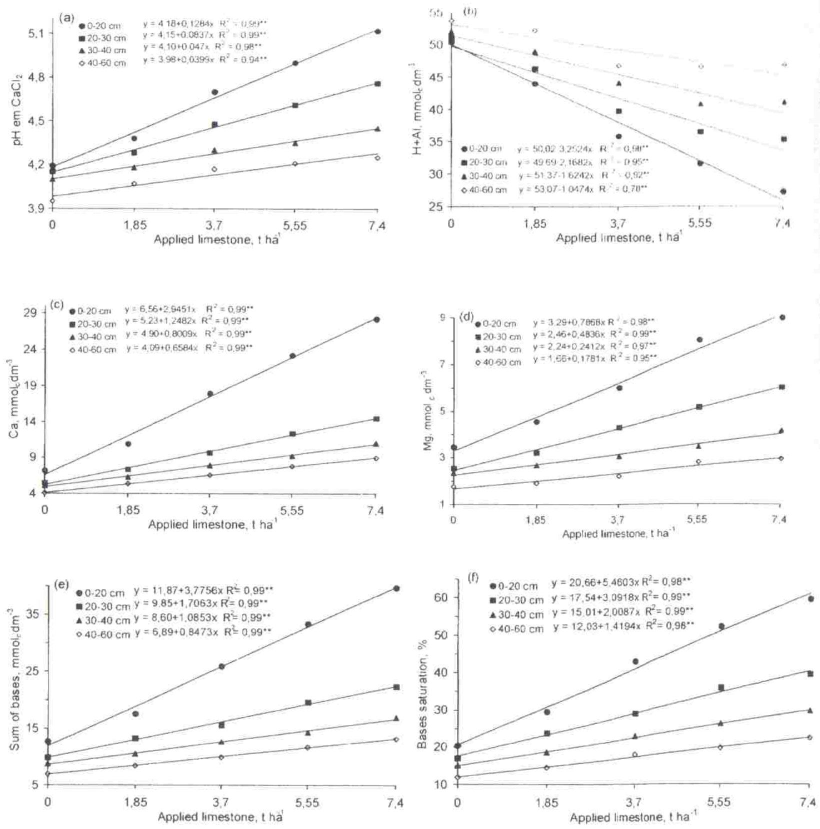

Figure 2. Effects of the application of limestone on the pH in $CaCl_2$ (a), H + Al (b), Ca (c), Mg (d), sum of base (e), and base saturation (f) of soil samples taken from the line from different depths. The dots are means of eight, six, and five sampling moments at the layers of 0–20, 20–30, 30–40, and 40–60 cm deep, respectively, and four replications. ** Significant $P < 0.01$.

chemical properties resulting from the applied dose of limestone was proportionally similar at the different sampling times.

Liming led to an improvement of the chemical reaction of the layers below the incorporation zone (30 to 60 cm of depth), especially when the doses of limestone were 1.5 to 2.0 times that necessary to raise V to 70%, and this is in agreement with Quaggio et al. (1993). It is opportune to point out that explanations in the literature can be found clarifying the effects of liming on soil acidity and on the increment of bases according to which these facts are due either to physical or to chemical factors. Physical factors are described as resulting from channels made in the soil by the macro fauna and by the rotting of roots. Through those channels,

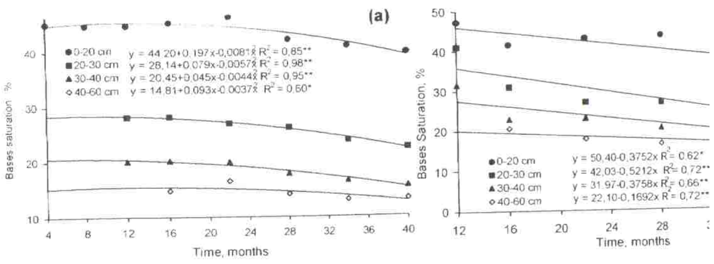

Figure 3. Effects of the time elapsed after soil liming on the base sa the soil as measured in samples taken in-between lines (a) and in different depths (b). The dots are the average of five doses of limesto replicates. ** Significant $P < 0.01$ and * significant $P < 0.05$.

the limestone particles would be carried down, dissolv percolating water to lower depths in the soil. The chemical ex for the effects of liming hold that highly soluble and low- weight pairs of Ca/Mg and organic acids (RO- and RCOO-) r formed, with these pairs being easily carried down to layers

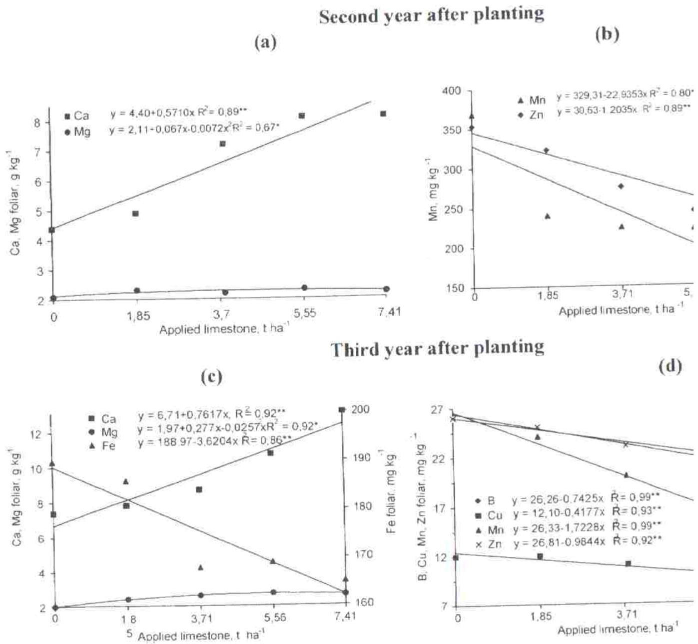

Figure 4. Effects of soil liming on the foliar levels of Ca and Mg and Zn (b) in the second year after planting, and of Ca, Mg, and I Cu, Mn, and Zn (d) in the third year after planting. (Data are the r replicates.)

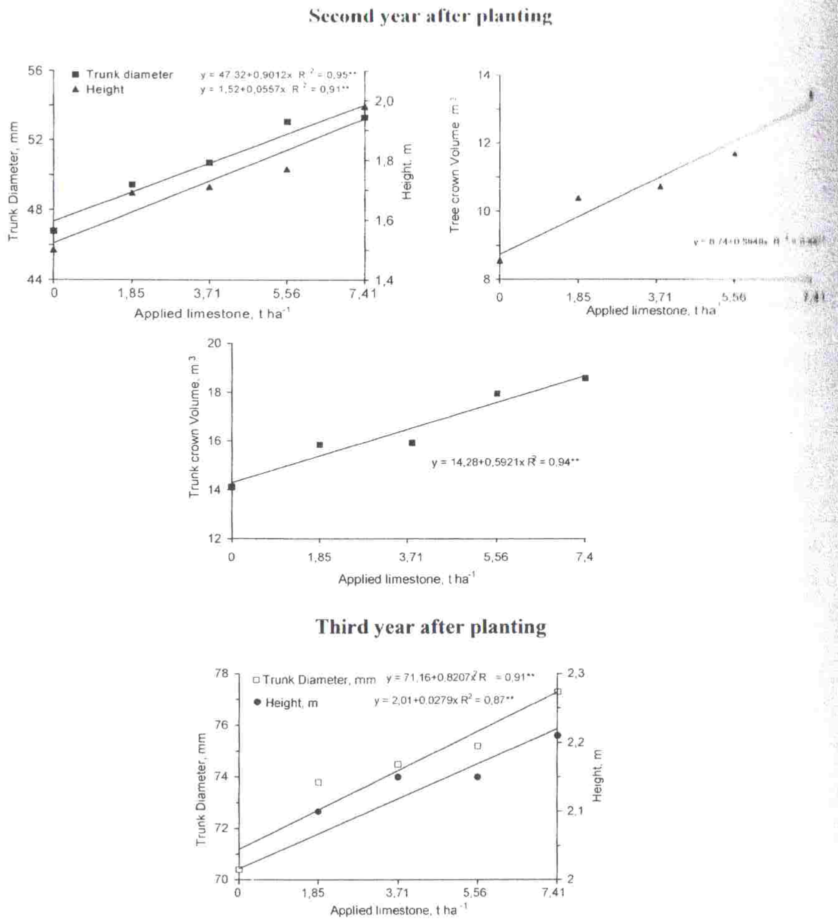

Figure 5. Effects of soil liming on the diameter of the trunk, and the height and volume of the tree crown in the second and the third year after planting.

incorporation zone (Harter and Naidu 1995). The moving of the limestone through the soil profile and the consequent correction of the acidity below the plowable layer may have important practical implications because the guava tree has an expanded and deep root system (Bassoi et al. 2001), and this has an influence on plant establishment and later its yielding capacity.

When the highest dose of limestone was employed, the pH and the base saturation at the layer between 0 and 20 cm of depth showed higher values when the sampling was made between lines (5.4 and 64%, respectively) than in the lines (5.2 and 62%, respectively). This is supposed to be due to the losses of nitrate as derived from the

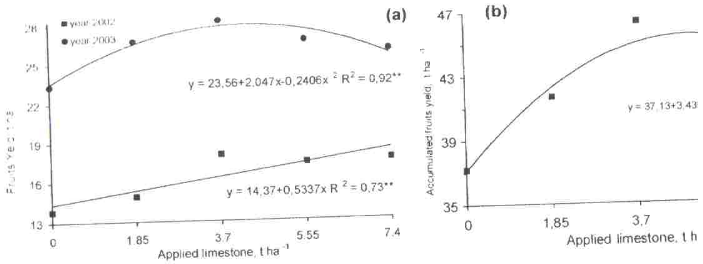

Figure 6. Effects of soil liming on the yield of fruits in the after (2002) and the third year (2003) after planting (a) and the accum (years of 2002 and 2003) (b).

nitrogenous fertilization (urea split into four applications January), when leached with an accompanying cation. Those are likely to become larger with time because the nitrogenou are supplied in larger doses for the adult plant.

It is also important to observe that the limestone dose raise the V value to 70% in practice determined an increase to value of eight samplings made between the lines) as can Figure 1f. Although the method employed to determine the limestone to be applied has a sound theoretical basis, a serie found in the literature shows significant differences b calculated V and the V value actually found (Quaggio, I Van Raij 1982; Caires and Rosolem 1993; Oliveira, Parra 1997). According to Tescaro (1998), this difficulty in raisin values is likely linked to the high potential of pH-dependen the displacement of the equilibrium of the reaction of limestc to the formation of new products, such as hydroxides of lo

Lime showed positive effects starting from 4 m incorporation in the samples taken between the lines (I which initial base saturation was low (V = 26% at the 0- to

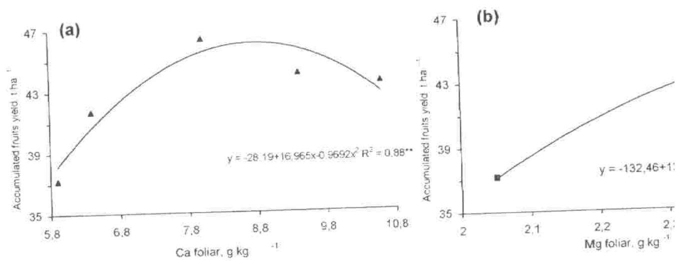

Figure 7. Relation between the foliar levels of Ca (a) and M accumulated yield of fruits from the first and second harves seasons of 2002 and 2003).

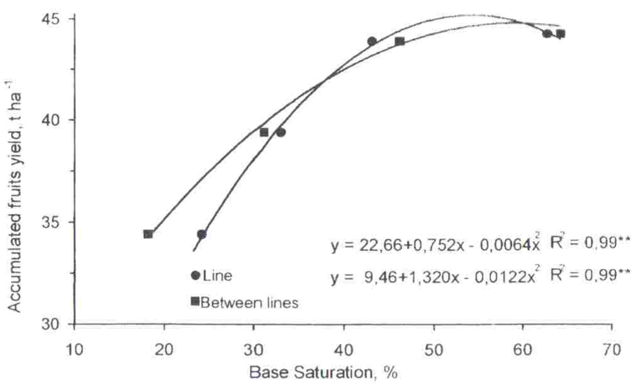

Figure 8. Relation between the base saturation (in the line and in-between lines) and the accumulated yield of fruits from the first and second harvests (agricultural seasons of 2002 and 2003).

as seen in Table 1. From that sampling until 16 months later, the soil reaction showed a certain stability. After that, the residual effect began to decrease both for samples between the line (Figure 3a) and in the line (Figure 3b) at all depths.

As shown by the regression analysis, maximum effect of limestone (maximum point) took place 12 months after incorporation at 0–20 cm deep for samples taken between the lines (Figure 3a). It is necessary, however, to emphasize that the variation in base saturation values is small and kept practically constant; as a consequence, the residual effect should last longer. The duration of the effect depends also on the fertilization of the crop itself and local experiments. According to data published by Embrapa (1981), the maximum limestone reaction occurs

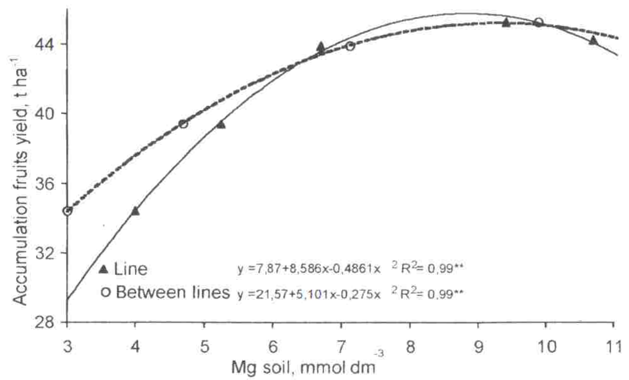

Figure 9. Relation between the concentration of Mg in soil samples taken from the line and in-between lines and the accumulated yield of fruits.

approximately 4 months after liming, although a few other v out a period between 18 and 33 months, after incorporatic reaction to reach its peak (Quaggio, Dechen, and Van Oliveira, Parra, and Costa 1997). Natale and Coutinho (1994) a period of 18 months after incorporation to be necess reactivity of limestone fractions to reach their peak value. P period of 3 months established by Brazilian legislation for reactivity to be reached was based on overestimated reactivi

Base saturation values determined monthly dropped lii the samples were taken from the lines and quadratically wh was made between the lines.

This drop in base saturation values was greater at the layers (0.5 to 0.7%) than that at the 40- to 60-cm one, whic This is ascribed to the high acidifying effect of the nitrogen applied on the surface layer, to the addition of organic mat to irrigation. It is also necessary to consider the bases that w as Ca (y = 20.53–0.12x, R^2 = 0.83**) and Mg (y = 8.11–(0.66*), which in a yearly basis reach a mean value of 2 n These losses are frequently reported in the literature (Raij et this experiment, an annual drop of 6–8% of the base satu superficial layer was detected.

Effects of the Treatments on the Plant

The chemical analyses showed a significant effect of soil l foliar levels of Ca, Mg, manganese (Mn), and zinc (Zn). found to increase linearly, whereas Mg increased (Figure 4a). Manganese and Zn decreased linearly (Figu second year after planting. During the third year, a linear in and a quadratic in Mg (Figure 4c) were found as a conseque The micronutrients iron (Fe), boron (B), manganese (Mn) and zinc (Zn) displayed linear reductions (Figure 4d). As Malavolta, Vitti, and Oliveira (1997), this reduction consequence of the effects of liming on the soil chemi which in turn influence availability.

Adequate levels of N, phosphorus (P), potassium (K for the guava plant are considered to be 30, 3, 30, 13, respectively, whereas for Cu, Fe, Mn, and Zn these values a 162, 202–398, and 28–32 mg kg^{-1}, respectively (Malavo Oliveira 1997). In a work with the cultivar Paluma, Nata indicate, for the adult tree, foliar levels of 20–23, 1.4–1.8 3.4–4.0, and 2.5–3.5 g kg^{-1} of N, P, K, Ca, Mg, a respectively. For the micronutrients B, Cu, Fe, Mn, and foliar levels would be 20–25, 20–40, 60–90, 40–80, and 25–35 mg kg^{-1}, respectively.

Taking into account the average leaf level of the nutrients, it is seen that Nn, Ps, and Mg in both the samplings are slightly below the values given by Natale et al. (2002) as the adequate ones. In the second year, both the lowest dose and the check treatments show a calcium level lower than that suggested as adequate by Natale et al. (2002). It is necessary not to forget that those standards were established based on a study with adult plants.

Liming treatments did not significantly affect the growth of the plants during their first year after planting. Trunk diameters showed values of 27.1, 27.7, 27.8, 27.1, and 29.3 mm, respectively, for the limestone doses of zero, 1.85, 3.71, 5.56, and 7.41 t ha^{-1}. Liming, nonetheless, caused a linear increment in trunk diameter, in plant height, and in plant crown volume in both years (Figure 5). In a similar experiment, in which common guava plants were grown in a nutrient solution, Salvador et al. (2000) reported the Al phytotoxic effects to be shown more strongly at the aerial part than at the root system.

Fruit yield both at first and second harvests was found to increase significantly as a consequence of liming. The observed effects were linear and quadratic, respectively (Figure 6a). When the yield of both harvests are considered, a quadratic effect can be seen (Figure 6b). This is explained by the positive effects due to liming, the development of the plant top, and next, its yielding capacity, evidenced by the high relation between these characteristics and the foliar levels of Ca (Figure 7a) and Mg (Figure 7b). The role played by the limestone, as a source of Ca and Mg as nutrient, should be considered besides that of correcting acidity.

The data show that fruit yield was highest when base saturation was 55% for soil samples taken in the line and 62% when the sampling was carried out between the lines (Figure 8). These values are less than those that suggested by Santos and Quaggio (1996) as being adequate for guava cultivation in the state of São Paulo, that is, 70%, although the authors do not mention whether this value is indicated for young or adult guava plants.

A quadratic relation between the accumulated fruit production and the Mg concentration is observed in the soil when samples were taken either in the line or between the lines. The highest yields were reached when Mg concentrations in the soil were 9.0 and 9.5 mmol$_c$ dm^{-3} for samples taken in the line and between the lines (Figure 9), respectively. These values are in agreement with those given by Santos and Quaggio (1996), that is, 9.0 mmol$_c$ dm^{-3} for guava orchards.

Although the application of limestone to the soil led to increases of up to 25% in fruit production in comparison to the control treatment, it can be noticed that when base saturation was raised even more, it caused

a reduction in yield. This is supposed to be caused by the [...] acidity, which leads to the insolubilization of some micronu[...] reduction in solubility of those micronutrients in the soil wa[...] the plant where the levels of Fe, B, Mn, Cu, and Zn were lo[...] expected, according to analyses made on the third year afte[...]

CONCLUSIONS

Soil liming caused an improvement in the evaluated s[...] attributes (pH, Ca, Mg, SB, V, and H + Al) up to 60 cm of de[...] soil samples taken in the planted lines and between the l[...] caused an increase in the levels of Ca and Mg in the leaves.

Highest yields of fruit were associated with base satura[...] and 62% for soil samples taken in and between the lines, resp[...] to foliar levels of Ca and Mg of 8.8 and 2.5 g kg^{-1}, respecti[...]

The highest dose of limestone (7.41 t ha^{-1}) was capabl[...] the base saturation value at 55% in the lines and 62% betw[...] for 40 months after limestone incorporation, whereas that [...] maintained those V values only for 30 months.

ACKNOWLEDGMENTS

The authors are thankful to FAPESP (Foundation for th[...] Research of the State of São Paulo, Brazil) for the doctora[...] granted to the first author as well as for the financial [...] conducting this work.

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