6. Guava

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6.1. Introduction

Globally, India, Pakistan and Brazil are the principle producers of commercial guava cultivars. India has the greatest number of trees, but in dispersed and poorly productive plantations, the fruit is used for the production of white guava juice. Pakistan is the principal exporter of the fresh fruit. In Brazil, guava is consumed more as a fresh fruit, especially the red pulp variety (Plate 6.1), and the fresh fruit is exported principally to France, Canada, Germany and Portugal (Guedes and Vilela, 1999, cited by Almeida, 1999).

Guava is one of the most widely accepted tropical fruits worldwide and in Brazil. It is enjoyed both as fresh fruit and processed as sweets, jelly, jam and juice. The fruit is rich in sugars, vitamin C and mineral salts. The increase in consumption both as a table fruit and natural juices is a worldwide trend, accompanying a growing popular preoccupation over health and aesthetics.

In Brazil, the guava is grown in all states, being grown commercially on approximately 17 million ha (IBGE, 2002 cited by Goiabrás, 2004). Total annual production of approximately 350,000 mt is small compared to the potential productivity of the plants (Natale, 1993). Although the guava has long been considered a rugged plant in its tolerance of acidity and adaptation to small soil nutrient reserves, the rational application of fertilizers promotes substantial increases in fruit production (Natale, 1993). Further, genetic selection and vegetative multiplication of guava has given rise to plants with a large yield potential, like the cultivars Rica and Paluma (Pereira *et al.,* 1982), but these cultivars have large nutrient demands and thus export more nutrients from the

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soil. Thus, better knowledge of nutrient and fertilizer requirements is fundamental to guarantee greater yields.

6.2. Climate, soil and morphology

The guava originates from Tropical America, possibly between Peru and Mexico, where it can still be found in the wild form. The plants capacity for dispersion and rapid adaptation to different environments made possible the presence of this *Mirtaceae* in many tropical and subtropical areas of the world, and it is even considered a weed species in some regions (Menzel, 1985). Avilan (1988) studied the plants development cycle in a tropical region (Venezuela) and identified four phases: (a) growth, between ten months and two years of age; (b) full production, from three to five years; (c) production, from five to eight years; and (d) senility, starting at nine years of age. In each of these stages of development fruit production was about 30, 35, 50 and 22 kg/plant/yr, respectively. Thus Avilan (1988) considered the guava to be a short-cycle fruit tree starting production between 10 and 12 months after planting, and with maximum productivity when three or four years old. However, with the vegetative propagation of herbaceous cuttings, the plants can become fully productive earlier. In spite of being a plant native to tropical regions, the guava develops and produces well in regions from sea level up to 1700 m altitude, and for this reason is found in many regions worldwide, including Brazil.

The ideal temperature for growth and production is between 25 and 30ºC. Temperature not only limits, but also determines the season of fruit production. A long photoperiod is necessary for optimal fruit production. The plants can be severely damaged by frost and strong winds.

The ideal range for rainfall is 1,000 to 1,600 mm/yr, well distributed throughout the year, and should not be less than 600 mm/yr. In regions with prolonged dry seasons, irrigation is necessary.

Air relative humidity should be between 50 and 80%, because this can influence both the physiology of the plant and fruit production.

Although guava adapts well to growing on most soil types, soils with high clay content, low drainage capacity and excessive salts should be avoided. Ideally, orchards should be planted on flat or slightly sloping land to facilitate mechanical operations.

6.3. Soil and cultivation

Prior to planting, initial soil preparation should aim to destroy compacted layers in the subsurface soil and correct acidity by incorporation of lime when necessary. Prado and Natale (2004) tested different methods for incorporating lime during soil preparation. Shallow ploughing incorporated lime only in the superficial layer of the soil. First disking the soil then ploughing it shallowly proved satisfactory but was less satisfactory than deep ploughing. The superior performance of deep ploughing was not only the depth of incorporation but also the greater degree of mixing of the lime with the soil throughout the entire 0 to 30 cm soil layer. With discing, only half of the lime reached the deeper soil, with the rest being incorporated superficially with the shallow ploughing. The advantage of deep ploughing, other than optimizing the incorporation of lime, is less demand for time and total energy. However, this method demands the use of a powerful tractor. The deep incorporation of lime is important where perennial crops are to be grown because soil acidity at depth can compromise the productivity of an orchard for a long time (Raij *et al.,* 1996). Also surface applications only very slowly improve soil acidity at depth. Corrêa (2004) showed that it took 12 and 24 months after the surface application of calcined lime and common lime, respectively, for acidity to be neutralized in the 0-20 cm soil layer. Ploughing to incorporate lime is not recommended in existing orchards because of possible damage to the root system, which causes an increase in the occurrence of phyto-sanitary problems in the plants.

In orchards established on acidic soils with high levels of aluminium (Al), liming precipitates the toxic Al in the surface soil. This allows greater development of the root system and, therefore, greater plant growth owing to the more efficient use of water and nutrients.

When establishing guava orchards, a soil base saturation close to 60% is adequate (Prado, 2003). However, the concentration of magnesium (Mg) in the soil should not be less than 9 $mmol_c/dm^3$. For plants up to three years old, leaf calcium (Ca) and Mg of around 9.0 and 2.5 g/kg, respectively, are considered adequate (Prado, 2003a).

When producing guava seedlings, soil acidity can be corrected with alternative materials like eucalyptus biomass ashes and steel mill slag. These residues may also be a source of nutrients, increasing production and preserving the environment by recycling such materials. Prado *et al.* (2003b) tested the application of five amounts of biomass ash to two soils with base saturation of 50 and 80% on which guava seedlings were produced. Starting with a soil of base saturation of 50%, the amounts of ash tested aimed to produce a range of soils with base saturation up to a maximum of 70%, there was also a nil treatment as control. After 135 days, the growth of the seedlings was evaluated; they responded positively to the application of ash independent of the soil's reaction. The largest response was associated with applications of 1.0 to 1.2 and 1.2 to 1.6 g ash/container in soil with base saturation 50% and 80%, respectively.

To establish an orchard, the seedlings should be planted in a line of pits 0.40 m deep by 0.30 m wide. The soil below the crown of the seedling should be kept free of weeds by periodical manual weeding, or application of herbicides. In between the rows and in the areas between the plants, weeds can be controlled mechanically with a mower.

Guava responds positively to irrigation. To satisfy the plant's demand for water 1,000 to 1,800 mm/yr are required (Maranca, 1981). Pereira *et al.* (2000) observed that a deficiency of 73 to 119 mm water for 5 consecutive months, was sufficient to reduce the fruit production of different cultivars by as much as 51% of the fresh weight. Bassoi *et al.* (2001a) estimated the K*c* in a guava orchard growing cv. Paluma at 6 x 5 m, on Red-Yellow Argisol (120 g/kg of clay), in the north-east region (Petrolina, PE). The plants were irrigated by jets that wetted 42% of the soil surface. During the first year of growth the average water consumption was 36.7 L/plant, and this increased to 46.3 and 45.6 L/plant in the second and third years, respectively. The value of K*c* in the first year was less than that in the second and third years. For the same physiological phases, the K*c* values in the first, second and third years were, respectively, for (i) vegetative growth: 0.50; 0.55 and 0.65; (ii) florescence: 0.60; 0.65 and 0.75; (iii) fruit growth: 0.60; 0.65 and 0.75; and (iv) maturation and harvest: 0.60; 0.80 and 0.70. The K_c values referred to previously were estimated by the class A evaporation pan. The efficiency of the application is estimated by the percentage of total water supplied by irrigation that is considered useful to the plants (Bernardo, 1995).

Application efficiency is a result of a greater uniformity in distribution of water in the whole horizontal and vertical soil volume occupied by the root system, such that superficial losses by evaporation, and losses by leaching are minimized.

Fertilization of guava depends on whether irrigation is used. If the plants are irrigated, nutrients can be supplied with the irrigation water (fertigation). In a non-irrigated system, fertilizers have to be applied to the soil. In special situations, foliar application of nutrients is possible, and this is often recommended for supplying micro-nutrients.

6.4. Mineral nutrition

6.4.1. Export of nutrients

Table 6.1 shows the nutrients exported by the fruits (pulp and core with the seeds) (Natale, 1993). For cv. Rica, the amounts of macro-nutrients in decreasing order are: K>N>P>S>Mg = Ca: and those of micro-nutrients are: Mn>Fe>Zn>Cu>B. For cv. Paluma the order for both the macro- and micro-nutrients is slightly different to that for cv. Rica. For the macro-nutrients the order is: K>N>P>S = Mg>Ca, and for micro-nutrients: Zn>Mn = Fe>Cu>B. There is greatest variation in percent nitrogen (N) and potassium (K), the principal macro-nutrients in the fruits. Cv. Rica had 15.7 g/kg K and 9.8 g/kg N in dry matter, and cv. Paluma had lower values, 12.4 g/kg K and 8.6 g/kg N in the fruit dry matter.

Table 6.1. The uptake of macro- and micro-nutrients by the guava cultivars Rica and Paluma, in experiments in the municipalities of Jaboticabal and Sao Carlos, Sao Paulo state.

Nutrient	cv. Rica			cv. Paluma		
	Dry matter	Fresh matter		Dry matter	Fresh matter	
Macro-nutrient	g/kg	g/mt	kg/ha	g/kg	g/mt	kg/ha
N	9.80	1,353	66.8	8.6	1,146	84.3
P	1.20	166	8.3	0.9	121	8.9
K	1.57	2,167	107.1	12.4	1,662	122.8
Ca	0.80	110	5.4	0.7	94	6.9
Mg	0.80	110	5.4	0.9	114	8.4
S	1.10	152	7.5	0.9	114	8.4
Micro-nutrient	mg/kg	g/mt	g/ha	mg/kg	g/mt	g/ha
B	6	0.83	41	5	0.67	50
Cu	8	1.11	54	11	1.48	109
Fe	15	2.07	98	14	1.88	139
Mn	28	3.87	188	14	1.88	139
Zn	13	1.73	84	15	1.95	144

Adapted from: Natale, 1993 ; Natale *et al.*, 2002. The calculation is based on the dry matter of the fruits being, on average, 13.8 and 13.4% of the fresh matter for the cv. Rica and Paluma respectively. Average fruit production was 49.4 and 73.6 mt/ha for cv. Rica and Paluma, respectively, in the third year of production.

Knowledge of the chemical mineral composition of the fruits provides information to optimise the fertilization program to maximise efficient production and maintain soil fertility. The quantities of nutrients exported are for the whole fruit. About 95% of the total production of an orchard is useable leaving a 5% residue of fresh material (27% moisture). Fernandes *et al.* (2002) studied the application of such a residue on soil fertility. The chemical analysis of the residue (in g/kg) was: N, 17.2; P, 2.1; K, 2.9; Ca, 1.1 and Mg, 0.9. The application of such a seed residue at up to 120 mt/ha of fresh material, increased soil organic matter (SOM) ($y = 11.23 + 0, 1680x$, $R^2 = 0.98^{**}$) and exchangeable K ($y = 1.15 + 0.0217x$, $R^2 = 0.99^{**}$) in the soil, with benefits on the sum of the base cations and CTC. Extrapolating the data for one application of 60 mt/ha of this fresh seed residue (44 mt dry weight) can make about 127 kg K and 64 kg P available to the crop in the first year after application. Also there was an increase in available N from the mineralization of the extra SOM.

The removal of nutrients from guava orchards occurs because of the harvested fruit, as was stated earlier, and also by pruning the trees. In adult guava orchards, drastic pruning is common, which may greatly reduce the aboveground biomass to 40 to 60%. The material removed consists of about 24.5 kg of green material per plant (7.8 kg of leaves; 2 kg of boughs and 14.7 kg of branches, twigs and small fruits) (Natale, 1997). Assuming that this material contains 85% moisture and that there are 285 plants/ha, pruning the plants could remove, in kg/ha, about: N, 7.4; P, 0.6; K, 5.9; Ca, 6.5; Mg, 1.8; S, 1.4 and g/ha, B, 22; Cu, 122; Fe, 207; Mn, 282 and Zn, 21.

6.4.2. Functions and importance of nutrients

From a studying of growing six-month-old guava plants in a Hoagland and Arnon nutrient solution with one nutrient omitted from each solution, Accorsi *et al.* (1960) described the symptom of the deficiencies of N, P, K, Ca, Mg and S in guava, as follows:

Nitrogen (N): Accorsi *et al.* (1960) showed that guava leaves deficient in N had the normal shape but the lamina was uniformly pale yellow. The veins were lightly yellowed and without spots. The lower surface of the leaves was a less intense green than the upper surface.

In experiments in guava orchards growing on in a Red-Yellow Argisol, Natale *et al.* (1994) studied the effects of N fertilizers, using one-year-old plants of the cv. Rica, during three consecutive years. The plants responded to N applied at 52, 75 and 120 kg/ha in the first, second and third years, respectively. Over the three years, 90% of the maximum production was associated with 23 to 25 g N/kg in leaves sampled in the period of full florescence.

Natale *et al.* (1996b) extended their field investigation for a further three years, using one-year-old plants of the cv. Paluma, planted in a Red-Yellow Latosol in the region of São Carlos, SP. The N treatments in the first year were 0, 9, 17, 34, 51, 68 and 85 kg N/ha and in the second and third years these amounts were doubled and then tripled, respectively. Leaf samples were taken in the florescence stage, and the fruits were counted and weighed at harvest. Yields were increased only in the third year when yields increased linearly with N applied, and 90% of the maximum yield was given by 178 kg N/ha and 22.2 g N/kg in the leaf. There was a significant effect of N on fruit quality. Excessive amounts of N tended to decrease the size of the fruit, inversely to the number of fruits produced by the plant, and seriously compromised the commercial value for the fresh fruit market (Fig. 6.1).

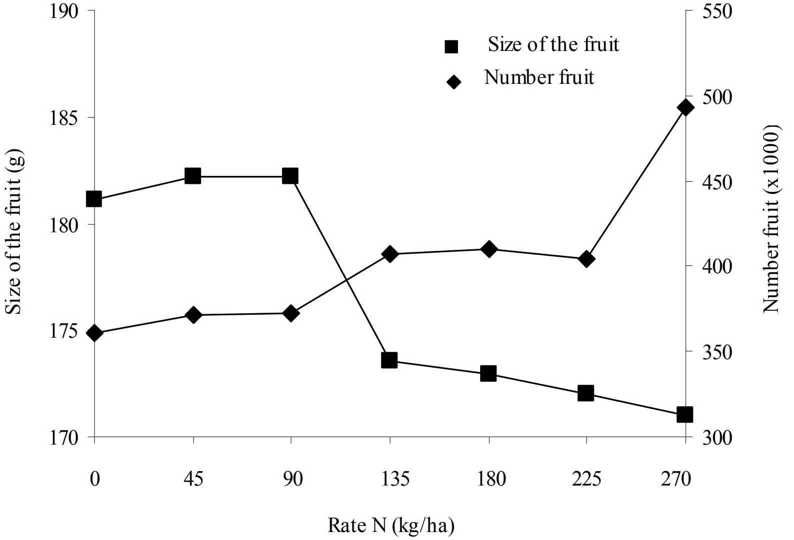

Fig. 6.1. Effects of N fertilizers on the production and quality of guava fruits (*Adapted from*: Natale *et al.*, 1995).

Phosphorus (P): The nutrient solution experiment (Accorsi *et al.,* 1960) showed that when P was deficient, the upper surface of the leaf is a scarlet color, which progresses from the base to the apex and edges until only the vicinity of the main vein remains green. When the deficiency is more severe, the whole upper surface turns purple. When the leaves are viewed against a light background, the secondary veins are transparent and the extremities of the veins become light purple. When seen against light, the under surface of the leaf has a dark background because of the scarlet coloring of the upper surface. The shape of the leaf is normal.

Studies on the response of guava to P fertilizers are rare. Corrêa *et al.* (2003) tested the response of guava seedlings to both amounts and methods of applying P fertilizer. Seedlings were transplanted into plastic bags (18 x 28 cm) divided in such a way that the root system could be divided equally between the two halves of the bag. Each half of the bag contained 2.8 dm^3 of Argisol subsoil containing 1 mg/dm^3 P-resin. Phosphorus, as triple superphosphate, was tested at 70, 140 and 280 mg P/dm^3 soil. Methods of applying P were tested as follows: either it was applied only to one half of the bag or it was divided equally between both halves; in addition the P was mixed throughout the entire soil volume or it was mixed only into the top 1/3 of the soil in the half-bag. The guava seedlings responded positively to P and about 100 mg P/dm^3 of soil was sufficient for good growth, in excess of this amount growth was decreased. Applying the P only in the topsoil or throughout all the soil did not effect the supply of P to the seedlings. However, applying P uniformly throughout the soil resulted in a larger root system and less aboveground growth compared to applying P only in the surface soil.

Natale *et al.* (2000) tested the effects of increasing amounts of both lime and P fertilizer on the growth of seedlings in a factorial 4 x 4 test, and measured effects on the soil, the production of dry matter and seedling development. In the soil, lime increased the amount of exchangeable Ca and Mg, base saturation of the CEC and soil pH. In plant dry matter, both percent Mg and P were increased while Mn and Zn were decreased. In general, 1.2 g lime and 200 mg P/dm^3 soil were sufficient to give optimum dry matter weights. In a field experiment lasting three years, Natale *et al.* (2001) studied the effects of P fertilizers on one-year-old plants of the guava cv. Paluma, grown on a Red-Yellow Latosol near Sao Carlos, SP. Seven amounts of P_2O_5, 0, 9, 17, 34, 51, 68 and 85 kg/ha were tested in the first year and these amounts were doubled in the second and the third years. Although soil P was increased there was no effect on the P concentration in the leaf or on the production of fruit. Natale (1999) observed similar results with the cv. Rica.

In view of the small response to soil applied P by adult plants, Natale *et al.* (1999) studied the application of P to the leaf, together with phytosanitary treatments. This was done by spraying a liquid solution of monoammonium phosphate (MAP) at 2% with a specific activity of ^{32}P equal to 0.15 µCi mL^{-1} on every third pair of guava seedlings. The maximum amount of P absorbed corresponding to 12% of the total applied at 20 days after the application. Approximately 20% of P absorbed by the leaves was redistributed in the plant, especially to the newer growth. Natale *et al.* (2002b) also tested a foliar application of P in a field experiment for three consecutive years on adult cv. Paluma guavas. The amounts were 0, 0.5, 1.0 and 2% P_2O_5 as MAP and these were compared with 200 g P_2O_5/plant applied to the soil. Although the concentration of P in the soil and the plant were increased, yields were not affected.

Potassium (K): According to Accorsi *et al.* (1960), guavas grown under K deficiency in solution culture exhibit numerous brown, small and grouped spots of different shapes on the leaves. These spots are distributed throughout the leaf lamina, starting from the edges and moving towards the main vein, but are concentrated in the upper middle lamina resulting in a mottled appearance. There are smaller spots on the main vein and on many of the secondary veins. As the deficiency progresses, the spots fuse, especially around the leaf edge, forming larger and darker spots that lead to necrosis of the lamina tissue. Small areas of the lamina remain green. The under side of the leaf has a yellowish-brown color corresponding to the position of the spots on the upper side. The leaves appear a reddish color.

In field experiments, 0, 9, 17, 34, 51, 68 and 85 kg K_2O/ha, was tested in the first year and double and triple these amounts in the second and third years, respectively, on cv. Paluma. Yield was increased by applying K in the third year and 90% of the maximum production was associated with 16.2 g K/kg in the leaves and 0.75 $mmol_c/dm^3$ of exchangeable K in the soil. These values were obtained with an application of 82 kg K_2O/ha (Natale *et al.,* 1996c).

In similar experiments with cv. Rica, 90% of the maximum production in the third year was associated with 18.9 g K/kg in the leaves and an application of 150 kg K_2O/ha (Natale *et al.,* 1996b).

Calcium (Ca): The effect of Ca on the function of the middle lamella may influence the texture, firmness and maturation of the fruits by reducing the rate of degradation of vitamin C, the production of ethylene and CO_2 and the incidence of post-harvest disease. An increase in Ca in the fruit promotes firmness and reduces water loss, producing better quality fruit and a longer post-harvest storage period (Fig. 6.2).

Magnesium (Mg): When grown in Mg deficient conditions, guava leaves have two rows of yellow spots, parallel to the main vein, one on each side, on the upper side. Each spot is situated between two secondary veins. The rows start at the base of the leaf and end a short distance from the apex. Other than these spots, there are numerous other brown spots of different sizes, shapes and contours, which at times fuse together. On the under side of the leaf there are the same symptoms but the spots are less visible. The main vein is light green (Accorsi *et al.,* 1960). Prado (2003) observed a positive response in the initial phase of production to an application of Mg, like calcareous dolomite. There is a significant relationship between the leaf compositions of Mg (g/kg) and the production of guava fruit (mt/ha), as follows:

$$\text{Production} = -132.4 + 136.9\ Mg_{leaf} - 26.4\ Mg_{leaf}^2;\ R^2 = 0.80^{**}.$$

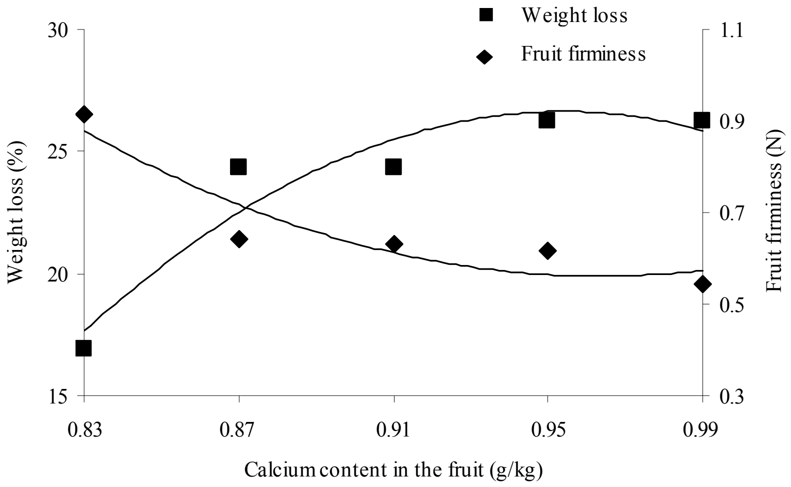

Fig. 6.2. Relationship between calcium concentration in the fruit pulp and the loss of weight and firmness of guava, after eight days in storage at room temperature (Prado *et al.*, unpublished data).

Sulphur (S): According to Accorsi *et al.* (1960), S deficiency of in guava is characterized by the occurrence of necrotic spots that vary in shape, size, number and contour, localized principally in the middle underside of the leaf. These spots are more clearly seen when the leaf is examined against the light. The color is purplish along almost the full extension of the main vein (except on the extremities, in this phase of the symptoms) and the secondary veins (except in the basal and apical region of the leaf). The interveinal areas have a uniform citrine-green color. The under surface of the leaf, other than being a little lighter than the upper side, has chlorotic spots, although these are no easy to see. Only the secondary veins have a lighter purple on the upper surface. The main vein has normal coloring.

Micro-nutrients: There is a lack of information on the response of guava to micro-nutrients. However, some studies have evaluated their effect on guava seedlings. Natale *et al.* (2002c) tested applying zinc (Zn) on the growth and nutrient composition of guava seedlings grown in pots containing 2.8 dm^3 of a Red-Yellow Argisol. The amounts of Zn, as zinc sulphate, tested were: 0, 2, 4, 6 and 8 mg of Zn/dm^3 soil, and the experiment was in a mesh net nursery. After 135 days the height, leaf area and aboveground and root dry matter of the plants were measured together with the concentrations of the macro-nutrients and Zn. There was a positive response to Zn up to 2 mg of Zn/dm^3. Amounts equal to or larger than 4 mg/dm^3 decreased seedling yield and macro-nutrient content significantly. Micro-nutrients are important especially in tropical soils. Steel mill slag, which is a residue of cast iron and stainless steel production, is a suitable source of micro-nutrients. Prado *et al.* (2002) tested slag as a source of micro-nutrients for guava seedlings. The amounts used aimed to increase the base saturation of the soil by 0.5, 1, 1.5, 2 and 2.5 times, with the largest amount increasing the base saturation to 70%. The amounts of slag applied were 1.68, 3.36, 5.04, 6.72 and 8.40 g per 2.8 dm^{-3} soil, as well as a control with no application. The soil, a Red-Yellow Argisol, and slag were incubated for 90 days before the guava seedlings (cv. Paluma) were planted and then grown for 110 days in a mesh net nursery. The slag made the soil less acid and increased the availability of Zn, Cu, Mn and B in the soil. There were exponential effects on the concentrations of Zn, Cu and Mn in the soil with the larger amounts of slag at 5.8; 6.3 and 7.5 g/pot, respectively, while, for B, the effect was linear. A soil base saturation between 51 and 55% increased the availability of Zn, Cu and Mn, but for B the value was 65%. In the same way as occurred in the soil, the application of slag had exponential effects on the concentrations of Zn, Cu and Mn in the aboveground and root dry matter, but the effect for B was linear. It was concluded that the slag both helped correct acidity and was also a source of micro-nutrients for guava seedlings.

6.4.3. Leaf analysis

Leaf analysis is an important diagnostic tool, which together with soil analysis makes it possible to devise a fertilizer management programme of an orchard. Leaves should be sampled during flowering because any deficiencies can be corrected at that time. Samples should be taken from groups of trees with similar cultivar characteristics, age and productivity where the soil is homogeneous and orchard management the same. The leaves sampled are the third pair from the extremity of the branch. In Sao Paulo state, sampling is done during full flowering, usually in September and October. However, the time may vary according to several factors, specifically the start of the rainy season or the period of pruning. The sample should consist of four leaves per plant from at least 25 trees per sample area (Natale, 1993; Natale *et al.,* 1996a; Natale *et al.,* 2002a).

Nutrient concentrations considered adequate for the cvs. Rica and Paluma, the latter is the one most planted in Brazil, are shown in Table 6.2. These values differ slightly from those recommended by Quaggio *et al.* (1996); their adequate ranges, in g/kg were: N, 13 to 16; P, 1.4 to 1.6; K, 13 to 16; Ca, 9 to 15; Mg, 2.4 to 4.0) but these do not discriminate between varieties.

Table 6.2. Composition of macro- and micro-nutrients in leaves collected during the period of full flowering and considered adequate for guava from the third year of age.

Nutrient	cv. Rica	cv. Paluma
Macro-nutrient	---------------------------- g/kg	--------------------------
N	22-26	20-23
P	1.5-1.9	1.4-1.8
K	17-20	14-17
Ca	11-15	7-11
Mg	2.5-3.5	3.4-4.0
S	3.0-3.5	2.5-3.5
Micro-nutrient	--------------------------- mg/kg	-------------------------
B	20-25	20-25
Cu	10-40	20-40
Fe	50-150	60-90
Mn	180-250	40-80
Zn	25-35	25-35

Source: Natale *et al.*, 1996; Natale *et al.*, 2002.

The concentration and accumulation of nutrients in the tree varies, among other factors, with the phenological stage of the plant. Thus, for each phenophase there is an adequate level of macro- and micro-nutrients and studies on the rate of nutrient absorption must aim to correlate the nutrients in the sampled organ with the phenological stage. Through these studies it is possible to predict the time (or times) of greater plant nutrient demand. Unfortunately, in spite of this importance, there are no studies of rate of nutrient absorption by guava plants grown in the field where the plant has an extensive root system. This makes studies done in pots of little relevance.

6.5. Fertilization

6.5.1. Fertilization before planting the orchard

The amount of P fertilizers to apply depends on the P status of the soil. Because P is not very mobile in soil it should be added to the planting pit together with 20 to 30 L of organic compost consisting of cured corral manure (or a third part chicken manure) according to the recommendations in Table 6.3 (Natale *et al.*, 1996a). It is also recommended to apply micro-nutrients, especially B (1 g/pit) and Zn (2 g/pit) to the planting pit. The organic compost, P fertilizer and micro-nutrients should be mixed with the soil before filling the pit about 30 days before planting of the seedlings.

Table 6.3. Phosphorus application required at planting a guava orchard, according to the phosphorus composition of the soil.

P-resin (mg/dm^3)	Amount of P_2O_5 (g/pit)
<6	180
6-12	140
13-30	100
>30	60

Source: Natale *et al.*, 1996a.

6.5.2. Fertilization for initial growth

From planting the seedlings until they are three years old the recommended fertilization is based on soil analysis, on the cultivar and its age (Table 6.4).

Table 6.4. Fertilizer recommendations for the growth of guava plants according to age, cultivar and soil analysis.

Age	N	P-resin (mg/dm^3)				K-exchangeable (mmol$_c$/dm^3)			
		<6	6-12	13-30	>30	<0.8	0.8-1.5	1.6-3.0	>3.0
yr	g/plant	------------ P_2O_5 (g/plant) ---------				----------- K_2O (g/plant) ------------			
cv. Rica									
0-1	120	0	0	0	0	120	90	60	30
1-2	240	120	80	40	0	240	180	120	60
2-3	480	240	160	80	0	480	360	180	90
cv. Paluma									
0-1	100	0	0	0	0	100	80	50	30
1-2	200	100	50	30	0	200	150	100	50
2-3	400	200	100	60	0	400	300	150	80

Source: Natale *et al.*, 1996a.

The quantities of fertilizer to be applied, using commercially available sources, should be according to local need (see Tables 6.4, 6.5 and 6.6). These recommendations were determined for on non-irrigated guava production systems but they can be also used for fertigated orchards up to two years old. Bassoi *et al.* (2001b), studying the distribution of the guava root system during the initial stages of growth in an Argisol (clay content was 120 g/kg), found that more than 70% of the root system was related to the age of the plant, increasing up to 34 months. At the same time, the effective distance of the roots was increasing, at 6, 12, 24 and 34 months it extended up to 20, 40, 60, and 100 cm, respectively. The authors also found that the effective rooting depth was 80 cm

18 months after planting. This information may be useful for managing the location of emitter and tensiometer installations where irrigation is used, as well as for placing fertilizer throughout the growth of the crop. However, it should be noted that this pattern of root distribution may vary with the variety and the soil and climatic conditions where the orchard is planted.

Table 6.5. Micro-nutrient solution for boron and zinc for foliar application.

Nutrient source	Concentration	Quantity per 100 L of water	Time of application 1st	2nd
	%	g		
Boric acid	0.06	60	September	November
Zinc sulphate	0.5	500		

Adapted from: Natale *et al.*, 1996.

Table 6.6. Fertilizer recommendations for fruit production by cultivar and expected productivity and according to soil and leaf analysis data.

Production	N(1)	P-resin (mg/dm^3)				K-exchangeable (mmol$_c$/dm^3)(2)			
		<6	6-12	13-30	>30	<0.8	0.8-1.5	1.6-3.0	>3.0
mt/ha	kg/ha	------------- P_2O_5 (kg/ha) -----------				------------- K_2O (kg/ha) ------------			
cv. Rica									
<40	210	60	45	15	0	210	140	70	35
40-60	230	60	45	15	0	270	200	100	60
60-80	290	70	60	30	0	330	240	145	85
>80	340	90	70	45	0	390	290	190	115
cv. Paluma									
<60	230	45	30	15	0	230	145	85	45
60-80	290	45	30	15	0	315	230	115	70
80-100	340	60	45	30	0	370	270	170	100
>100	400	70	60	45	0	430	330	230	115

(1)When the leaf composition of N is above 26 g/kg (cv. Rica) or 23 g/kg (cv. Paluma), reduce the N applied by withholding the final application.

(2)When leaf K is above 19 g/kg (cv. Rica) or 17 g/kg (cv. Paluma), reduce the K applied by withholding the last final application.

Source: Natale *et al.*, 1996a.

In orchards more than two years old with fertigation, fertilizers can be applied more frequently according to the needs of the plants. Silva *et al.* (2000) studied the dynamics of K with fertigation and observed that there was a larger concentration of K ions in the soil solution with increased frequency of irrigation (every three days) when the recommended amount of K or less was applied. However, when the amount of K applied was larger than that recommended, applying irrigation every three days resulted in a lower concentration of K in the soil solution. They concluded, therefore, that with fertigation the rational management of both irrigation and fertilization is as important as the quantities of fertilizer applied. If frequent fertigation results in an increase in the amount of fertilizer applied, there is an increased risk of loss of nutrients by leaching. In regions like south-eastern Brazil, which is characterized by a concentration of rains in one short period of the year, this loss of nutrients may be even more pronounced.

Other than N, P and K fertilizers, micro-nutrients should also be considered, especially B and Zn, because of their general deficiency in tropical soils and removal in the harvested fruits. Micro-nutrients can be applied when required as foliar sprays often in two applications (Table 6.5). It may be possible to apply them together with insecticides and fungicides. Leaf analysis is an adequate monitor of the nutritional and micronutrient needs of the plant.

It is important to suspend irrigation at least 30 days before pruning during fruit development to cause the plant to undergo water stress.

6.5.3. Fertilization for production

Differences between conventional fertilization and fertigation should be considered, especially in the period of fruit production. In this phase, the trees have increased physiological activity and, consequently, greater nutritional needs. Studies to determine the nutritional needs of the plant and fertilizer recommendations were mainly in the absence of irrigation. With the use of fertigation, there are changes in the plant-soil system that requires adjustments to fertilizer recommendations.

Factors that may lead to an increase in fertilizer recommendations are directly related to the plant and the Brazilian climate, especially in Sao Paulo state. Regarding the plant, irrigation must increase the yield potential, which increases the demand for nutrients. With irrigation, especially when the water is applied to a limited volume of soil, the plant root system is confined to the wetted soil, inhibiting root expansion. Consequently, it is necessary to increase the concentration of nutrients in the wetted soil. The second factor is climate. In the Sao Paulo region, there is increased rainfall for a short period with the risk of greater nutrient losses by leaching, especially of nutrients that are readily mobile within the soil solution. Zanini (1991) followed the concentration of K in the soil when it was applied by drip fertigation. In the wetted area, where soil samples were taken 24 hours after fertigation and again after six successive irrigations only with water, the concentration of K had decreased by between 58 and 66% in the 0 to 40 cm depth of soil.

With irrigation that applies water to a limited volume of soil the distribution of roots may be affected, indicating that fertigation is the most appropriate method for nutrient application. This allows the roots, especially the fine and very fine ones that take up nutrients, to exploit the whole soil volume to which nutrients are applied. When nutrients are applied to the soil surface only part of the root system has access to nutrients, necessitating larger inputs to ensure adequate quantities are available (Coelho *et al.,* 2001). When water and nutrients are applied together, the nutritional demands of the plant can be met in any phase of the production cycle.

There are no long-term data specifically for guava that allow definite recommendations for fertigation. Until experiments provide conclusive results, fertilizer recommendations for fertigation should consider the features of the plant-soil system for the region of production. However, research results of the nutrient requirements of the plant under drought conditions can be adjusted taking into consideration phyto-technical information for the crop, and even data for other fertigated fruit trees, to make a first approximation for recommendations for the guava grown with fertigation.

Fertilizing for fruit production should start in the fourth year after planting the orchard, when the plants enter the full production phase. At this time, fertilizer applications should take into account the nutritional needs of the crop, as much for maintenance as to compensate for the offtake of nutrients in the fruits and ensure adequate fruit quality. The amount of fertilizer to be applied should be based on annual soil and leaf analysis data and related to the age of the plants, management of the orchard and expected productivity. The aim is to obtain maximum productivity with minimum cost. To achieve this other inputs, like pruning and irrigation, must be appropriate to ensure three harvests every two years.

Table 6.6 gives amounts of N, P_2O_5 and K_2O to be used in the orchard, based on soil and leaf analysis and expected production, according to the experimental results of Natale (1993) and Natale *et al.* (1994, 1995, 1996a,b,c). Differences in the fertilizer recommendations for the two varieties are related to their production potential. Of the two cultivars, Rica and Paluma, the latter is the one most planted in Brazil.

The first application of fertilizers by fertigation in the production phase should start one month before pruning, aiming to produce the appropriate amount of vegetation and meet the nutrient demand for future fruit production. Although the period from pruning to harvest is about 6 months depending on soil and climatic conditions, fertilizers should be applied every 30 days for 7 months.

6.6. References

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