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Economy

Agricultural and economic characterization of guava production in Brazil

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Abstract-This study was designed to analyze the relationship between guava crop production variables in the Matão region of central São Paulo, Brazil, and to better understand the economic importance of this crop to its growers. Data were obtained through a questionnaire applied during interviews with guava growers and after the data collection, statistical analyzes were made using Chi-Square hypothesis tests. Analysis results indicate a distinct association between the variables variety and plant age, between variety and number of plants per hectare, and between number of plants per hectare and yield, while no association was found between yield and variety. The Paluma guava variety spaced seven meters by five meters apart and pruned throughout the entire year was found to be the most common crop arrangement. The mean yield of the plots studied was 110 Kg plant^{-1}. The use of irrigation added 22.8 Kg of guava production per plant, annually.
Index terms: chi-square test, P*sidium guajava*, variety, yield, economic importance.

Caracterização agronômica e econômica da produção de goiaba no Brasil

Resumo-Este estudo foi desenvolvido para analisar a relação entre as variáveis de produção de goiaba na região de Matão, São Paulo, Brasil, e para entender melhor a importância econômica dessa cultura para os produtores. Os dados foram obtidos através de um questionário aplicado durante as entrevistas com os produtores de goiaba e, após a coleta dos dados, foram realizadas análises estatísticas utilizando testes de hipótese Qui-Quadrado. Os resultados da análise indicam uma associação entre as variáveis variedade e idade da planta, entre variedade e número de plantas por hectare e entre número de plantas por hectare e produtividade, enquanto que não foi encontrada associação entre produtividade e variedade. A variedade de goiaba Paluma, com espaçamento de sete por cinco metros e podada durante todo o ano foram consideradas as características mais representativas entre os produtores. O rendimento médio das parcelas estudadas foi de 110 Kg planta^{-1} e o uso da irrigação agregou anualmente 22,8 kg de produção de goiaba por planta.
Termos para indexação: teste Qui-Quadrado, *Psidium guajava*, variedade, produtividade, importância econômica.

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Introduction

Guava (*Psidium guajava L.)* belongs to the family *Myrtaceae*, which includes more than 70 genera and approximately 2,800 species (Pereira, 1995; Somogyi et al., 1996). Although guava (P. guajava) is the most economically important species in Brazil, several other Psidium species produce fruits and wood or are ornamental, presenting potential for commercial exploitation (Bezerra et al., 2006; Sousa et al, 2017).

The economic importance can be evaluated from many perspectives: from its uses, from the volume and value of the raw material, and from the outlays for guava research and agricultural outreach services. The increased guava production in Brazil is related not only to the growing consumption of fruit in its fresh form, but also products originating from its industrialization (Quintal et al. 2017). Many food industry products contain guava, such as juice, nectar, pulp, jam, jelly, slices in syrup, fruit bar, dehydrated products, additive to other fruit juices and its consumption as fresh fruit, guava has attained real economic importance in all the world's tropical and subtropical regions (Kadam et al., 2012; Leite et al. 2006).

Guava fruit is rich in antioxidant activity, maybe due to its high vitamin C content (the concentration is ten times higher than in orange) (Itoo et al., 1980; Leite et al., 2006), as well as sugar, vitamins A and B, pectic substances, proteins and mineral salts, mainly iron, calcium and phosphorus.

The country's guava crop is cultivated over an area of 20 thousand hectares that annually yield around 460 thousand tons of fruit. In the region our study addresses, the Matão region, guava production is approximately 70 thousand tons per year (IBGE, 2019). In 2017, 13,268 tons of guavas were sold through the São Paulo Warehouses and General Warehouses Company (CEAGESP), making it the organization's 45th most traded fruit (CEAGESP, 2017). São Paulo's Matão region was selected for this study because it is it one of the main guava producing regions in Brazil due to favorable climate, soil conditions, and the large local guava processing industry.

The analysis and characterization of guava production and producers presented in this paper is intended to increase understanding of selected agronomic and economic realities that affect both guava production and guava producers in the Matão region.

Material and methods

Data for the study were obtained through a questionnaire applied during interviews with guava growers between January and November of 201. The growers cultivated guava on 550 separate plots of land in the Matão region (48º 21' 57" W, 21º 36' 12" S, 585 m asl). This research was conducted in 23 cities that have guava producers in the region of Matão. It should be noted that some areas visited had only one plot containing guava plants and other areas had 15 plots containing guava. Plots were segments of a farm differentiated by assorted criteria, such as spacing, guava variety and plant age. The questionnaire was formed by the questions on the Table 1.

Data for approximately 550 plots were collected. Only data classified by plot rather than by farm were considered for analysis. Also, the present study was realized with a regional sample of primary data.

After data collection, statistical analyzes were made using chi-square hypothesis tests, according to HOFFMANN (1980); with the null hypothesis being that two variables are independent of each other and the alternative hypothesis being that the variables are associated. To perform this test it is necessary to consider the vector of observed counts with multinomial distribution (Oij = [O11, O12, ..., Oij], and the expected frequencies (Eij), which are obtained using formula (1):

$$Eij = n\,\frac{ni}{n} \times \frac{nj}{n} = \frac{ninj}{n}, \qquad i = 1, \ldots, r; \qquad j = 1, \ldots, c$$

where n corresponds to the sample size and ni and nj correspond to the two variables analyzed in each test. With these data we calculate chi-square statistic test using the formula described in equation 2.

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(Oij - Eij)^2}{Eij}$$

If the calculated frequency (X^2) is greater than the tabulated one with its predetermined degree of freedom and significance level $p < 0.01$, there will be evidence to reject the null hypothesis that the two variables' values are independent of each other.

In order to perform this test, some parameters were established regarding the ranges of plant age, yield and number of plants per hectare to be considered (Table 2). During the interviews, guava farmers indicated that the guava plant produces optimally until it is approximately ten years old and that maximum production was reached after five years. With this, the low, medium and high ranges of the plant age variable were defined. Data from the interviews were also used to ascertain the ranges for guava yield and the number of plants per hectare. Four chi-square tests were performed: 1. Number of plants per hectare and yield; 2. Varieties and yield; 3. Variety and age; and 4. Variety and number of plants per hectare.

Table 1. Questions asked for interview with guava producers

	Questions
1	Farmers name _____
2	Telephone number
3	Total farm area (ha)
4	Total farm area under guava cultivation (ha)
5	Guava variety under cultivation in each plot
6	Number of guava plants
7	Plant ages
8	Spacing
9	Yield
10	Pruning season
11	Use of irrigation
12	Economic importance of the crop to the property owner (% of farm income)
13	Owned or leased land
14	Other crops cultivated on the farm
15	Whether the guava is sold into the consumer market or only to industry
16	The farmer was considering planting a different crop instead of guava

Source: research data.

Table 2. Ranges considered for the chi-square test.

Ranges	Yield (Kg ha^{-1})	Numbers of plants per hectare	Ages (years)
Low	< 125	< 278	< 5
Medium	125 - 250	278 - 556	5 – 15
High	> 250	> 556	>15

Source: research data.

Results and discussion

The results and discussions are divided into two parts. The first part characterizes the guava plots and the second contains the statistical analysis using chi-square tests for variable relationships.

Guava Production In Brazil

In Brazil, *Psidium guajava* L. has a wide geographical distribution and is most widely planted in the Southeast (São Paulo) and Northeast (Pernambuco), but can be found in significant areas in the South. It is considered one of the favorite fruits for industrialization to produce guava sweet, jam and juice. Brazilian guava is growing in domestic and foreign markets (EMBRAPA, 2015).

In Brazil, the southeast region concentrates 44.3% of national production, and only the state of São Paulo represents 34.92% of the volume produced in Brazil in 2016, with 146943 tons. In addition, the state of São Paulo is responsible for generating a production value of 129,855 million reais, representing 25% of Brazil's production value. Also, this state the second highest average yield (kilograms per hectare) of Brazil, with a value of 30505 Kg t^{-1}, according to Table 3.

The 23 cities studied in this survey, have a production volume of 93470 tons, representing 63.6% of São Paulo's production volume. The harvested area was estimated at 2819 hectares, covering 58.2% of the guava production area of the state of São Paulo. The production value of these cities represents 32% of the state (Table 4).

Characterization of the guava farms

This study considered five guava varieties (see Table 5): Paluma, Pedro Sato, Século 21, Tailandesa and Cascão. The Paluma variety was the most observed and was cultivated in 79.23% of the plots, followed by Pedro Sato variety with 11.76% of the plots and Século 21, Tailandesa and Cascão varieties with 7.78%. Figure 1 contains information number of plants, average annual yield per plant, and average age according to variety.

Paluma was found to be the preferred variety among Matão guava farmers because it has a relatively high yield and the characteristics most desired by industry, such as pulp coloring and fruit strength. In the food industry, knowledge of the physical properties of food is fundamental for the operations. They influence the treatment received during the processing and good indicators of other properties as well as the qualities of food (Kadam et al., 2012; Ramos and Ibarz, 1998).

Table 3. Harvested area, production, average yield and production value of guava in 2016.

Regions	Harvested area [1]	Production[2]	Average yield[3]	Production value [4]
Brasil	17486	420809	24065	515830
North	497	6286	12648	9435
Northeast	8743	196445	22469	242691
Pernambuco	4053	130238	32134	161207
Southeast	6672	186280	27920	197701
São Paulo	4817	146943	30505	129855
Sul	1093	20790	19021	48953
Centro-Oeste	481	11008	22886	17051

[1] Harvested area in hectares. [2] Production in tons. [3] Average yeild in kilograms per hectare.
[4] Production value in in thousand reais.
Source: IBGE, 2019.

Table 4. Harvested area, production, average yield and production value of guava in 2016 in the 23 cities studied in this survey.

	Harvested area [1]	Production[2]	Average yield[3]	Production value [4]
São Paulo	4817	146943	30505	129855
Ariranha	33	831	25182	831
Bebedouro	26	454	17462	197
Borborema	23	713	31000	285
Cândido Rodrigues	30	750	25000	274
Dobrada	8	160	20000	59
Elisiário	4	144	36000	144
Fernando Prestes	5	150	30000	55
Guaíra	32	1856	58000	705
Irapuã	25	875	35000	263
Itápolis	484	16940	35000	6183
Júlio Mesquita	24	960	40000	384
Marapoama	18	441	24500	441
Matão	110	4400	40000	6600
Monte Alto	400	9200	23000	3386
Motuca	8	200	25000	300
Novo Horizonte	2	46	23000	14
Pirangi	280	8680	31000	3624
Santa Adélia	7	280	40000	280
Taiaçu	240	8400	35000	3591
Taiúva	22	822	37364	355
Taquaritinga	612	24480	40000	9045
Urupês	126	4498	35698	1574
Vista Alegre do Alto	300	8190	27300	3002

[1] Harvested area in hectares. [2] Production in tons. [3] Average yeild in kilograms per hectare. [4] Production value in in thousand reais.
Source: IBGE, 2019.

Table 5. Guava varieties and their main characteristics.

Varieties	**Main characteristics**
Paluma	Currently, this cultivar is the most widespread in Brazil. Its plants are very vigorous, have good lateral growth and are highly productive [1]
Pedro Sato	The plants are vigorous, showing good growth, both vertically and side, and are reasonably productive [1]
Seculo 21	This cultivar is the result of crossing Supreme 2 with Paluma. It is a little plant vigorous but very productive [1]
Tailandesa e Cascão	Varieties used to make homemade jams, but not widespread in industry [2]

Source: [1] Kavati, 2004. [2] EMBRAPA, 2019.

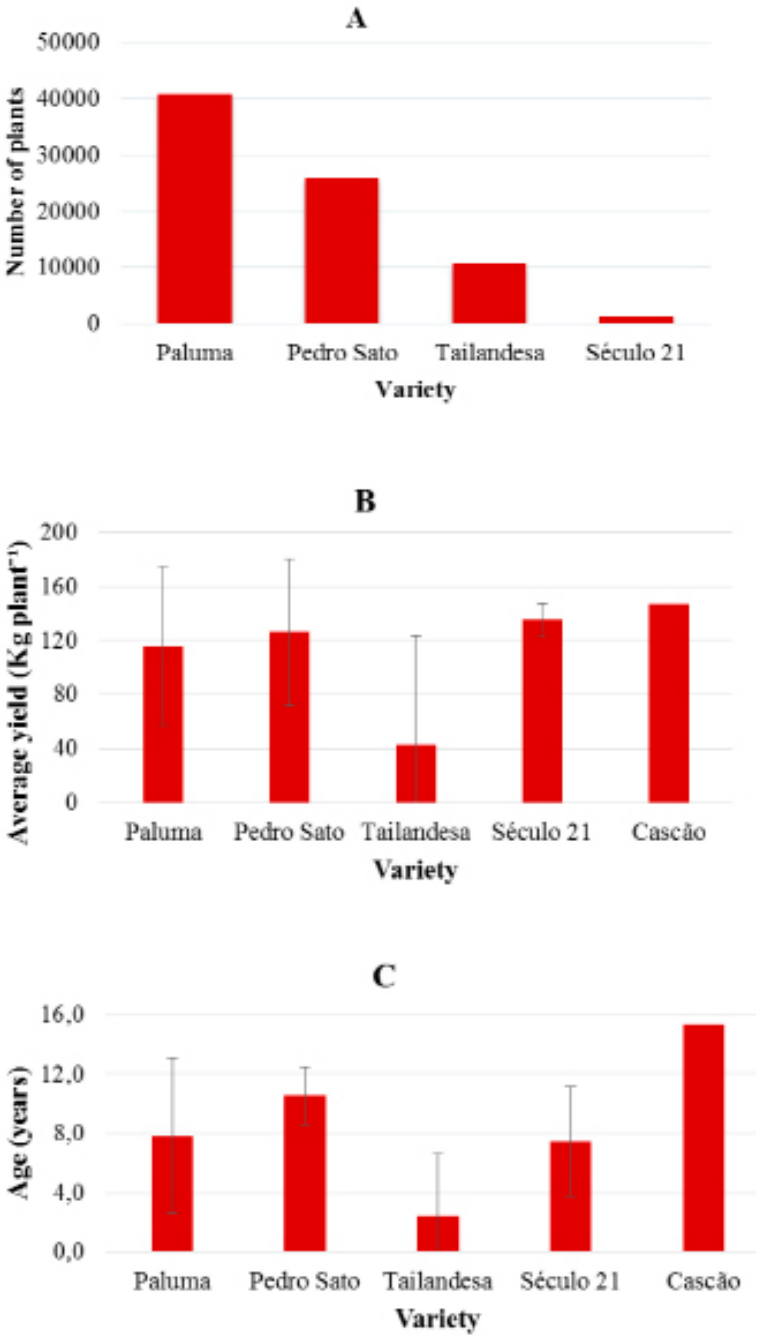

Figure 1. Characteristics of the varieties studied. Number of plants (A), average annual yield (B) and average age (C) according to variety. Each histogram is the mean value + s.d. Source: research data.

Each segment, final consumer or industry, has different fruit preferences, such as fruit shape, pulp consistency and color, size, shell color and specific physicochemical characteristics. An awareness that Paluma is the variety most planted by the interviewed guava farmers should help align the focus of those tasked with increasing these farmers' production and income by improving the variety's quality and yield.

A total of 550 plots were analysed, the smallest was 0.072 hectares and contained 30 guava plants spaced 6m x 4m, while the largest was 44.8 ha and contained 8,000 guava plants spaced 7m x 8m apart. The mean average size of the plot analyzed was 3.83 ha. Using this information one can calculate the inputs needed for later application in the guava production profitability calculation.

In addition, the age range of the guava plants in the analyzed plots was from less that one year to thirty years. In addition, farmers said that after 20 years of production, the yield from a guava plant begins to decrease, and the old plants then need to be replaced by a new planting. The most numerous guava plants, 86,000, were two years old (Figure 2).

These data are very important for the guava markets as it gives an indication of the yield in future years. As shown in Figure 2, most plants are less than six years old; and as maximum production is expected when the plant is five years old, guava supply should be expected to exponentially increase within a few years. Stakeholders in the guava market are quite stimulated to increase demand to absorb this additional supply.

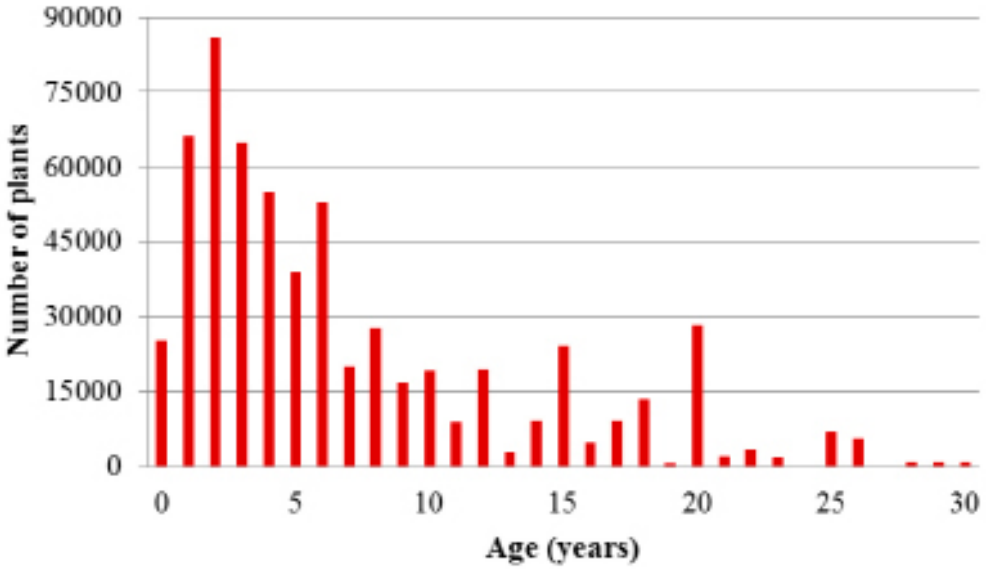

Figure 2. Number of plants per age. Source: research data.

Guava seedlings were found to be planted using 42 different spacings between plants. The most used spacing was 7m x 5m, represented by more than 177,000 plants in 222 of the analyzed plots. The least used spacing was 4.5m x 6m, represented by 385 guava plants in two plots. The smallest observed spacing was 4m x 3m ($12m^2$ $plant^{-1}$), represented by 42,000 plants in three plots. The largest spacing was 8m x 12m ($96m^2$ $plant^{-1}$), represented by 5500 plants in only one field.

The farmers adjust plant spacing to minimize loss due to disease and infestation. Denser spacing leads to a higher risk of fungi growth, for example. On the other hand, more open spacing results in low plant density per hectare and possibly less fruit. Experience has taught guava growers in the Matão region that the 7m x 5m spacing is the most appropriate to maximize yield and minimize crop damage.

Annual yields from the plants analyzed ranged between 0 and 375 Kg $plant^{-1}$, with the non-producing plants usually being the youngest: from zero to three years of age. The average annual yield was approximately 110 kg $plant^{-1}$, with more than 320 thousand plants below average and approximately 295 thousand plants equal to or above average. Thirty-eight different yields were observed, and the yield of zero from young plants was the most observed (Figure 3). This data implies that guava growers are expecting increased demand for the fruit and planting to meet this future demand.

In addition, there are two types of pruning were employed in the region: total pruning, which occurs at a specific time in the year, and partial/continuous pruning. One time total pruning facilitates scheduling but retards production over the short term as it diverts plant energy to regrowth rather than fruit production. If the guava grower schedules total pruning for production (a type of guava

pruning), the grower then knows that the guava crop can be harvested: 5 months after total pruning. Partial/continuous pruning is a series of sequential pruning of parts of the plant throughout the year and ensures fruit production throughout that year but increases management duties and responsibilities. This pruning method was practiced in 35% of the analyzed plots. Figure 4 lists the number of guava plants pruned at different times of the year and plants that undergo continuous (whole year) pruning.

Pruning is an important factor not only in guava production but also in the fruit's commercialization efforts in that it contributes to adjust the logistics flow of fruit to market or industry. If the pruning occurs over the whole year, the logistics considerations involved to ameliorate late or unforeseen at harvest. Losses of a very perishable product are quite complex.

Pruning method has emerged as an alternative method for regulating the crop in guava (Lal et al., 1996; Tiwari et al., 1992). This method gives the opportunity to increase the number of trees per unit area and subsequently the higher yield (Kumar and Rattanpal, 2010).

Among the farmers interviewed, there were those who preferred pruning at specific times of the year, such as from April to August or from July to September. This forces guava production to occur over specific periods, not while being pruned, and also damages the plant more than selective pruning over the entire year. However, logistics flow management should be much simplified, theoretically, if periodic rather than continuous pruning is employed. Also, due to the wide distribution and early infection of quiescent diseases in guava, starting at flowering, preventive management should consider disease monitoring and removal of crop residues (Fischer et al., 2017; Prusky and Lichter, 2007).

With respect of the use of irrigation, the number of guava farmers who use irrigation is similar to those who do not, with a difference of only 17,247 plants and one plot. The data indicates that irrigation increases guava production by 22.8 kg per plant, annually. Not only does irrigation increase production, it lessens the risk of diminished yield arising from climatic events or a drought weakened plant.

Studies with irrigation in guava reported that irrigation requirement met through drip irrigation along with polythene mulch gave the highest yield of guava (37.70 t/ha) with 164% greater yield as compared to ring basin irrigation (Singh et al., 2006).

If producers decide to irrigate their orchards, they need to evaluate irrigation systems to determine which will lead to the greatest economic gain from each plot. The evaluation needs to consider not only whether increased production and profits will exceed installation, maintenance and water costs, but also the stress related costs and benefits—the stress of buying and maintaining the system against the stress of drought damaging the crop.

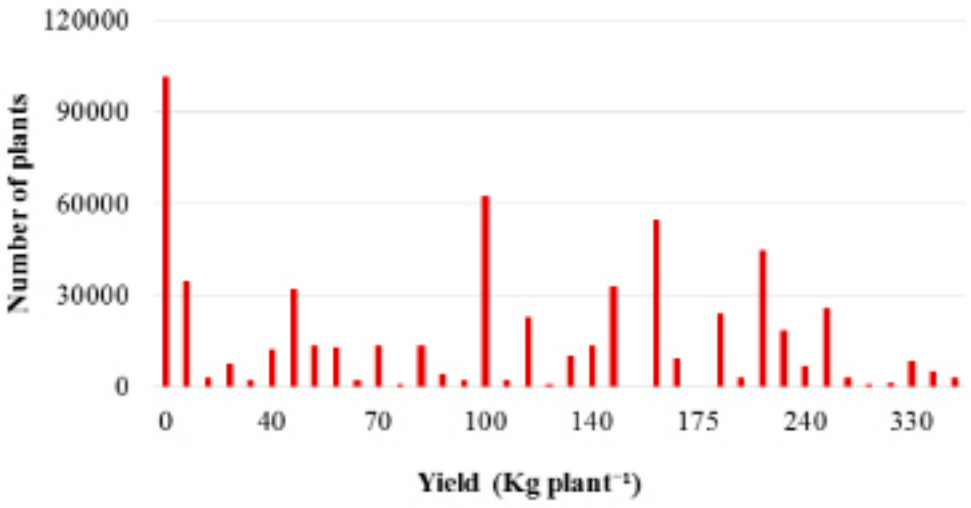

Figure 3. Number of plants per yield. Source: research data.

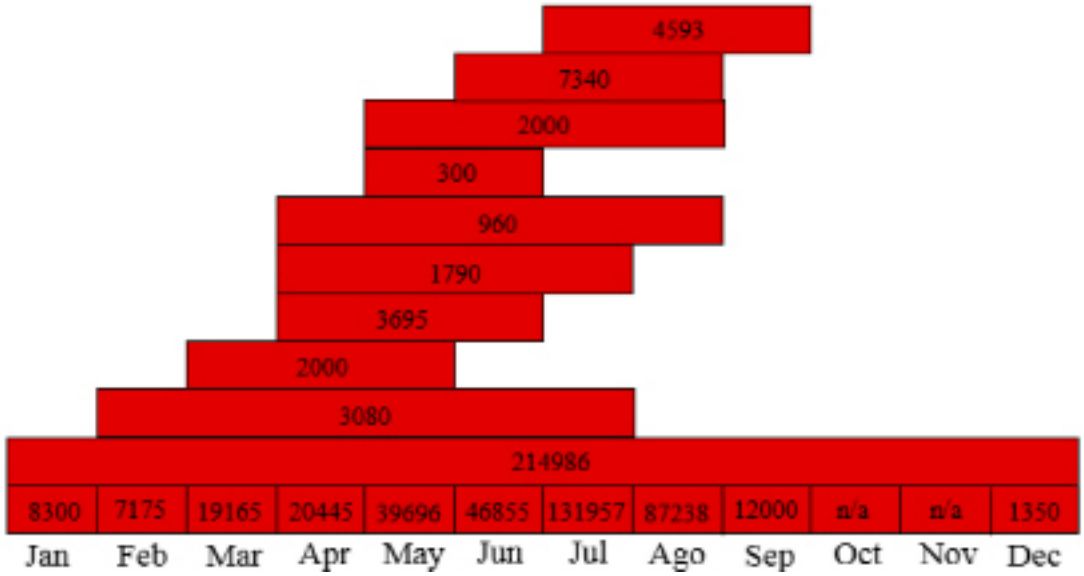

Figure 4. Number of guava plants pruned during each pruning period. Source: research data.

Economic characterization of guava production

This variable was designed to understand the guava crop's relative economic importance to the growers. Most of the interviewed farmers have guava as their only income producing crop, making the crop of 100% economic importance to these farmers. In addition, approximately 70% of the region's guava production comes from farms where guava is responsible for more than 50% of the farmer's income. Among the analyzed plots, there were some on which guava had 0% economic importance to the farmer at the time of the interview because the plants in that plot were immature— from zero to three years old (Figure 5).

This analysis is important because if there is any problem with guava, such as nematodes, sunburn, or some unwanted climatic factor, the farmer can predict how much of total income will be lost, which underscores the importance of income diversification. As a farmer, the individual should examine the use of land for the production of livestock or other crops that, preferably, do not have problems with nematodes. For this, a more in-depth study of the farm to define the best alternative land use options according to prevailing conditions.

Some of the growers interviewed have diversified their production. In addition to guava production, more than half of the interviewed growers engage in assorted profitable livestock activities, such as milk production, or have planted other crops. Among these crops, mango, lemon and sugarcane stand out, as they were observed in 232 of the plots analyzed. In addition, other crops such as carambola, grass, zucchini, avocado, onion and orange were in another 80 plots. Three hundred and fifty-eight of the analyzed plots (75.5% of total) generated income through the production of guava and only one other agricultural activity.

These results suggest that crop diversification is at a minimum on the analyzed farms, although the land is certainly capable of producing other income generating crops. Farming activity diversification is of benefit in the non-agribusiness setting (smaller farms), as the greater the number of activities the farmer/owner develops, the greater the chances of increasing income while decreasing risk.

In addition, six hundred thousand guava plants were cultivated on grower owned land in the plots under analysis, which was 20 times more than the number cultivated on leased land. This disparity is likely the result of the long period between guava planting and production, with the crop showing no product or profit for three years after planting.

Also, during the interviews, the farmers were asked whether they intended to replace their guava plants with another crop for economic or environmental reasons. Only 10.8% of the analyzed plot owners responded that they intend to exchange guava for other activities, such as growing citrus fruit or corn, which would result in the loss of more than 46,000 guava plants.

Furthermore, the shelf-life of guavas varies from two to six days, depending on the stage of fruit maturation at harvest time (Nogueira Júnior et al., 2016). The high perishability of the fruit makes their commercialization in distant markets difficult (Azzolini et al., 2005). In the Matao region, the industry is close to the farmers, so the fruit are delivered quickly.

The guava farmers analyzed have access to essentially two types of market: the retail market, which consists mainly of supermarkets, and the industrial market, which processes guava. Industry consumes approximately 66% of the production from the guava plants addressed in this study and half or more of the production from 94% of them. Owners of 2,300 plants in four plots stated

that intend to start selling at least a percentage of their production to the retail market, but in the Matão region, industry will continue to be the more important market.

Relationship between guava production variables

The first test was to determine if number of plants per hectare and yield were associated or independent, with the test results rejecting the null hypothesis of independence. Results from statistical analysis gave evidence that variation in spacing was associated with variation in yield.

The planting recommendations spacings changes as new crop cultivation technologies appear; consequently, studies on the range of yields and quantity of plants per hectare are continuously required. Studies in other fruit crops have reported that closer plantings resulted in early productivity leading to early returns on capital invested (Iyer and Kurien, 2006; Ravishankar et al., 2008). Close-planted trees fill their allotted space earlier and the intense root competition increased the depth (Miles and Guarnaccia, 1999). With an awareness of the effect the number of plants per hectare has on yield, the grower can optimize the quantity of plants in an area to theoretically increase yield. With the perennial guava plant, proper spacing when planting the seedling provides the foundation for optimum yield over a well managed plant's 20 years of productive life.

Another variable that affects spacing is that with the frequent nematodes infestations, farmers tend to adhere to a more densely spaced area to theoretically have more fruit per area until the appearance of this pest. *Meloidogyne enterolobii,* known as the galls nematode, often causes yield reduction and plant death (Castagnone-Sereno, 2012). This pest attracts a soil fungus when it infects the guava trees, *Fusarium solani*, that accelerates the process of plant depletion and death (Gomes et al., 2011). Once the guava plant becomes infested it is eradicated, because there are no nematode eradication procedures available for use. Spacing in considered important both optimize yield and as a factor that can be used to prevent disease and deleterious infestations.

The test two was carried out to determine whether guava variety is associated with yield in the Matão region. The test considered data from the Paluma, Pedro Sato and Século 21 varieties, since data for other varieties was considered insufficient for a proper chi-square test. Statistical analysis of chi-square test results indicated that the null hypothesis of independence could not be rejected: planting one or another of the selected guava varieties in the Matão region was not shown to be associated with yield.

Guava varieties differ in several aspects, such as crown shape (erect or spreading); production season (early, mid season and late); number, size and shape of the fruit; and staining of the pulp; but according to the data collected, there is no evidence that yield values are not associated with guava variety.

It should be emphasized that this result is based on sample of more than 220 farmers and these farmers did not employ the same system to manage their plant cultures. More studies would be helpful to determine if the lack of association between variety and yield may have been influenced by the different cultivation techniques used by the interviewed growers.

The test three was conducted to determine if the variety and age variables are associated or independent. The results from statistical analysis led to rejection of the null hypothesis of independence.

We could find no inherent reason for there to be an association between variety and age: why one variety was predominately less than five years old and another variety predominately more than five years old in the analyzed plots. The association between age and variety might well be a reflection another factor, possibly, grower perception of future market conditions. Should the grower think that three years in the future consumer/industry will favor a particular variety of guava; and knowing that guava trees need two to three years to begin producing a salable product, the grower would favor immediately planting the particular variety suited for the predicted market. This situation would mean that particular varieties would be planted to meet estimated future demand and lead to a correlation between plant variety and age. More research is needed to determine why plant variety and age show association.

The test four was to determine if the variables variety and number of plants per hectare are independent of each other. There was enough data to include the Tailandesa variety with the Paluma, Pedro Sato, Century 21 varieties in this test. After analyzing these data, the null hypothesis of independence was rejected: the number of plants per hectare (or spacing) was shown to be associated with the variety planted.

The Paluma variety was the most planted, and the 7m x 5m was the most popular spacing. These two data points indicate that spacing and variety are associated, so that if the farmer plants Paluma, there is reason to believe that their spacing will be 7m x 5m.

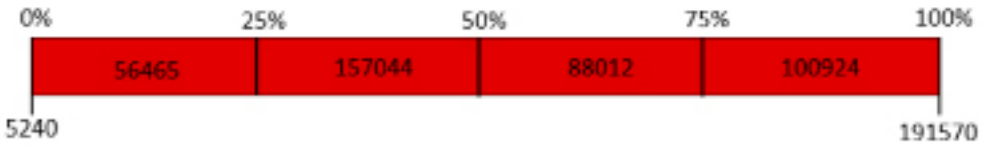

Figure 5. Number of plants per economic importance (%).Source: research data.

Conclusions

In conclusion, our study suggests that these farms are characterized by a preference for the Paluma guava variety, spaced 7m x 5m apart, and pruned over the entire year, which generates an average annual yield of 110 kg plant^{-1}. With this information, it is possible to calculate the yield of 31.4 ton ha^{-1} in the studied areas, with approximately 1 ton ha^{-1} more than the average yield of the state of São Paulo. Additionally, guava plants were cultivated mostly on grower owned land, at least 50% of the income from the studied commercial growers comes from their guava production and industry consumes approximately 66% of the production from the guava plants addressed in this study. Also, in the coming years, the guava production in the Matão region, should increase dramatically because more than 170 thousand guava seedlings were planted over the two years preceding this study.

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