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Postharvest and sensory quality of pineapples grown under micronutrients doses and two types of mulching

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Mineral nutrition has a major influence on growth and, consequently, on the production and quality of fruits. However, little is known about the effect of fertilization with micronutrients on pineapple, especially under tropical conditions. So, the goal of the present study was to evaluate the effects of soil and leaf fertilization with micronutrients on the postharvest and sensory quality of pineapple cv. Vitória produced under two different soil covers. The physical (weight and length) and chemical (total sugars and ratio soluble solid/titratable acidity-SS/TA) characteristics of the fruits were determined. A sensory analysis was performed to evaluate the acceptability of the external appearance of the whole fruit and slices (color, flavor and overall acceptability). The purchase intent and intensity of acid taste were also assessed. Application of micronutrients increased sugar content and SS/TA ratio, especially when applied on leaves, and caused higher weight and length of the fruits. Therefore, these positive effects of micronutrients can be contributed to the good market acceptability of pineapple cv. Vitória, evidenced by sensory analysis. Fruits of Vitória pineapple mulched with black plastic showed higher total sugars concentrations, which may have contributed to a sweeter taste and, consequently, better consumer acceptance.

Key words: *Ananas comosus,* fertilization, soil cover, fruit quality, sensory analysis.

INTRODUCTION

Fresh-cut pineapple is greatly appreciated worldwide because of its sensory qualities such as tastes, flavor and juiciness (Calderón et al., 2008). Pineapple growing is highly profitable and assumes great importance by generating employment and income, as it is widely exploited throughout the tropical regions and requires intensive hand-farming by a rural labor force. Many of the crops worldwide are affected by *Fusarium* wilt, a disease that attacks the pineapple crop and causes losses of plants, fruits and seedlings estimated at more than 40% of total production. Therefore, the use of such resistant cultivars as Vitória seems to be one of the ways to control this disease.

Consumer requirements and demands for good-quality

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fruits that are free of diseases are increasing every year. The quality attributes of pineapple include size, shape, skin color, the pulp characteristics and sensory properties, which are responsible for the fruit's market acceptance (Saradhuldhat and Paull, 2007). Sensory evaluation can serve as a quality assurance tool for final products on the market, detecting peculiarities that cannot be perceived using other instruments (Liu et al., 2011).

Mineral nutrition has a major influence on growth and, consequently, on the production and quality of fruits (Malézieux and Bartholomew, 2003; Soares et al., 2005; Agbangba et al., 2011). However, little is known about the effect of fertilization with micronutrients on tropical crops. Some studies report the importance of boron and zinc in the pineapple crop (Maeda et al., 2011; Siebeneichler et al., 2008). Currently, there seems to be some awareness among farmers about the use of micronutrients in the growth of pineapple; but, they are usually used empirically (Siebeneichler et al., 2008).

Mulching is taken into account by producers before planting. The objective in covering the soil is to minimize the effects of erosion, conserve the soil moisture by reducing evapotranspiration, control the use of irrigation water and reduce weed growth. Several materials can be used for this purpose: *bagana* of carnauba (*Copernicia prunifera*), portions of grassy and leguminous plants, and polyethylene plastics.

Given the importance of mineral fertilization to the harvest of excellent quality fruits, the goal of the present study was to evaluate the effect of applying micronutrients via soil and leaves on postharvest and sensory qualities of Vitória pineapples produced under two mulching conditions: *bagana* and black polyethylene.

MATERIALS AND METHODS

Experimental conditions

The experiment was conducted from December 2008 to October 2010 in a 0.348 ha irrigated perimeter area located in Marco county. This county is in the northern part of the state of Ceará, Brazil. According to the Köppen classification, the area is under the influence of an Aw' (tropical rain) climate, at a latitude of 3°07'13''S and a longitude of 40°05'13''W. The soil of the experimental area is classified as "Typic Quartzipsamment", with a sandy texture and a density of 1.590 kg m^{-3}. The chemical characteristics of the soil, in layers from 0 to 20 cm, are pH, 5.8; EC, 0.15 dS m^{-1}; and 0.77, 0.30, 0.08, 0.02 and 0.75 $cmol_c$ kg^{-1} of Ca, Mg, K, Na and Al, respectively.

Within 90 days after micropropagation, pineapple (*Ananas comosus* L. Merril) cv. Vitória seedlings were transferred from trays to black polyethylene plastic bags containing sand as substrate, with 800 gm^{-3} of simple superphosphate. They were acclimated for six months and, during this period, irrigated twice a week with water with an electrical conductivity of 0.44 dS m^{-1}. Transplantation was performed in April 2009; the plants were arranged in double rows, spaced 0.90 × 0.40 × 0.30 m, with an area of 38.4 m wide and 88.0 m long, totaling 14,080 plants in 0.348 ha. Each plot consisted of four subplots, with four double rows with 11 plants per row, and the two central lines indicated the usable area of the subplot.

In the experimental area, two mulching experiments were conducted: one with *bagana* (the straw resulting from the extraction of the carnauba wax sheet) of carnauba (*C. prunifera*) and other with black polyethylene plastic. In both, the plants were exposed to different doses of micronutrients applied with two different types of fertilization: soil fertilization and leaf fertilization (15 applications every 28 days).

The experimental design was a randomized block split plot with four levels of soil fertilization and four levels of leaf fertilization, with five repetitions. For the soil fertilization, the commercial micronutrient formulation FTE-12 (9.0; 1.8; 0.8; 3.0 and 3.0% of Zn, B, Cu, Fe and Mn, respectively), was used. It was applied in the pits of each plot before planting at doses of 0, 60, 120 and 180 kg ha^{-1}. The four levels of leaf fertilization were: LF0 (no fertilizer), LF 1 (15 leaf fertilization applications, using 1158.8, 844.7, 391.5, 322.7 and 216,0 gha^{-1} of Fe, Mn, Zn, Cu, and B, respectively), LF2 (15 leaf fertilization applications, using twice the quantities used in LF1), and LF3 (15 leaf fertilization applications, using three times the amount used in LF1). The leaf fertilization was performed monthly, and the concentrations were defined using a modified Murashige and Skoog (1962) nutrient solution as a base. The total volume of the solution in each application was 463 L ha^{-1}.

Macronutrients were applied to all plants via fertirrigation beginning two months after transplanting, following similar recommendations used by producers. The applied amount of each compound was 20 kg ha^{-1} $Ca(NO_3)_2$, 24 kg ha^{-1} $MgSO_4$, 80 kg ha^{-1} $NH_4H_2PO_4$, 98 kg ha^{-1} H_3PO_4, 688 kg ha^{-1} urea and 797 kg ha^{-1} K_2SO_4 . The irrigation management was based on soil moisture sensors installed at soil depths of 15 and 25 cm, the first representing the soil depth from 5 to 15 cm, while the second band of 15 to 25 cm aimed to determine the water storage in the soil, thereby indicating how much irrigation was necessary.

The first month after transplantation, preventive control of pineapple tree rot eye was performed with the fungicide Aliette. On the sixth month, the plants suffered white mealy bug attack, which was controlled with methyl parathion 600 CE, and on the 12th month, weed control was performed using Metrimex 500. Floral induction was performed 13 months after transplanting by spraying with ethephon at a concentration of 1,500 mgL^{-1} when sampling revealed that the green mass of the largest treatment plants weighed approximately 2 kg.

Quality evaluation

Harvest took place in October 2010. The pineapple fruits were physiologically mature, presenting yellow fruitlets along the entire length, and they were classified as in the yellow maturity stage, according to the standards of pineapple classification. Based on the color of the fruitlet, pineapple may be ranked as green or greenish, painted, colored or yellow. The pineapples from the usable area of each subplot were weighed and measured. One fruit of each repetition (subplot), with an average representative weight, was taken for physicochemical evaluations. For the sensory analysis, 30 pineapples were taken from the group in each of the mulching treatments (*bagana* and black plastic) that received the greatest amount of nutrients in the soil and leaf fertilization applications. Fruits of the Pérola pineapple cultivar were also used in the sensory analysis, as Pérola is the most widely consumed and appreciated variety in Brazil. The Pérola fruits came from a producer in the Baixo Acaraú irrigated perimeter who cultivates pineapple using black plastic to cover the soil and the same mineral nutrition package used by other producers in the perimeter. After their weights and lengths were measured, the pineapples were identified, packed in plastic boxes (cap. 20 kg), and cold transported (15°C) to laboratory, where they remained in a cold chamber at the same temperature for 24 h before undergoing physicochemical and sensory assessments.

For the physicochemical property evaluation, the fruits were peeled and cut longitudinally without the central axle, using sharp knives. The slices were processed in a domestic centrifuge machine with a 650 watts engine and a microhole sieve. The resulting liquid was used for the immediate measurement of total sugars, titratable acidity (TA) and soluble solids. The total sugars were determined using the anthrone method (Yemn and Willis, 1954).

Sensory analysis

For the sensory analysis, consumers were recruited among students (undergraduate and graduate) and workers. The group was composed of 60 individuals of both sexes, aged between 18 and 55 years old. Hedonic tests were performed at the Laboratory of Sensory Analysis of Food. Two acceptance tests were simultaneously conducted regarding the external appearance of the whole pineapple and the fruit's palatability (color, flavor and overall acceptance). The acceptance test for the external appearance of the whole fruit was set up on a bench. Two fruits were placed in white trays coded with random three-digit numbers. The acceptance of the overall appearance was evaluated using a hedonic scale with nine categories varying from disliked extremely to liked extremely. The evaluation form also included a purchase intent test that used a five-point scale. Both the hedonic scale and the purchase intent scale are described in Meilgaard et al. (1999). To perform statistical analyses, each category of the hedonic scale was assigned a numerical value from one to nine (1 = disliked extremely; 5 = neither liked nor disliked; 9 = liked extremely).

Palatability tests were held in air-conditioned booths (24°C) under fluorescent daylight-type white light. The pineapples were peeled and cut into slices approximately 1 cm thick. Each slice was cut into four pieces with the central axis removed. The samples were presented to panelists in white disposable plastic containers coded with three-digit numbers, along with evaluation forms. Overall acceptance and color and flavor attributes were evaluated using the hedonic scale described above. On the same ballot, the intensity of the sample's acidity was assessed with a just-right scale according to the method described by Meilgaard et al. (1999). In this test, each subject compared the sample with his/her mental criterion of what is an ideal acidity for fresh pineapple. To eliminate the after taste influence, a piece of bread and mineral water were offered between samples. The order of sample presentation was balanced among the panelists according to a design proposed by MacFie et al. (1989) to minimize first-order and carryover effects.

Statistical analysis

The data were submitted to analysis of variance (ANOVA) and Tukey tests ($p < 0.05$) for the comparison of means. Regression analysis was performed for data in which significant effects occurred. The analyses were performed using the statistical software SAS® (2002). The results from the purchase intent and just-right tests were presented as frequency distribution histograms.

RESULTS AND DISCUSSION

Quality evaluation

Both fertilization procedures (soil and leaf) influenced the pineapples' weight and length ($p < 0.01$) in both experimental conditions (*bagana* and black plastic). Leaf fertilization also influenced the total sugars ($p < 0.05$) and SS/TA ratios ($p < 0.01$) under the black plastic mulching condition and the SS/TA ratio ($p < 0.05$) under the *bagana* mulching condition. The interaction between these effects was significant for the weight and length of the fruits ($p < 0.01$) grown in *bagana* and for the weight of the fruits ($p < 0.01$) grown in black plastic.

As shown in Figure 1, there was an increase of fruit weight in relation to the application of FTE-12, even in the absence of leaf fertilization, in both experiments. There were positive responses in weight with the leaf applications, even in the absence of FTE-12. However, the increments provided by the micronutrient application, especially in the form of FTE-12, were higher when it was applied at the highest level of leaf fertilization, indicating an interaction between factors ($p < 0.01$). At the highest level of leaf fertilization in the *bagana* condition, each kg ha^{-1} of FTE-12 was associated with a 0.0026 kg weight increase in the fruits, while for the lower level of leaf fertilization, this increase was 0.0021 kg (Figure 1). The heaviest fruits in this study weighed 1.26 and 1.31 kg and came from plants subjected to higher doses of FTE-12 and leaf fertilization and mulched with *bagana* and black plastic, respectively. These results are lower than those observed by Ventura et al. (2009), who found an average weight of 1.5 kg for the Vitória pineapple. On the other hand, Silva et al. (2012) found a maximum weight of 1.0 kg for Vitória pineapples grown in doses of 409.2 kg ha^{-1} N. Siebeneichler et al. (2008), working with Pérola pineapples subjected to different boron treatments, found no changes in the weights of the fruits and observed values ranging from 1.653 to 1.696 kg. As shown in Figure 2A, pineapple fruits grown under *bagana* had an increased length with the application of FTE-12 even in the absence of leaf fertilization, and positive responses were observed in this variable with increasing levels of leaf fertilization, even in the absence of FTE-12. The increases provided by the application of micronutrients, especially in the form of FTE-12, were higher with higher levels of leaf fertilization, with values ranging from 10.23 to 12.84 cm for doses of 0 and 180 kg ha^{-1} FTE -12, respectively.

The two forms of fertilizer with micronutrients contributed to increases in the length of pineapples for the experiment with black plastic, but the effect was not interactive (Figure 2B and C). Considering the FTE-12 doses applied during the experiment with black plastic (Figure 2B), the fruit length varied from 8.54 to 11.18 cm for plants that received 0 and 180 kg ha^{-1} FTE 12, respectively. The increases provided by leaf fertilization ranged from 8.65 cm at the lowest dose of fertilization to 11.07 cm at the highest level (Figure 2C).

The lengths of Vitória pineapple fruits mulched with *bagana* and treated with the highest level of leaf fertilization (Figure 2A) are consistent with findings for this cultivar by other authors (Ventura et al., 2009; Silva et al., 2012). In the experiment with black plastic, only the

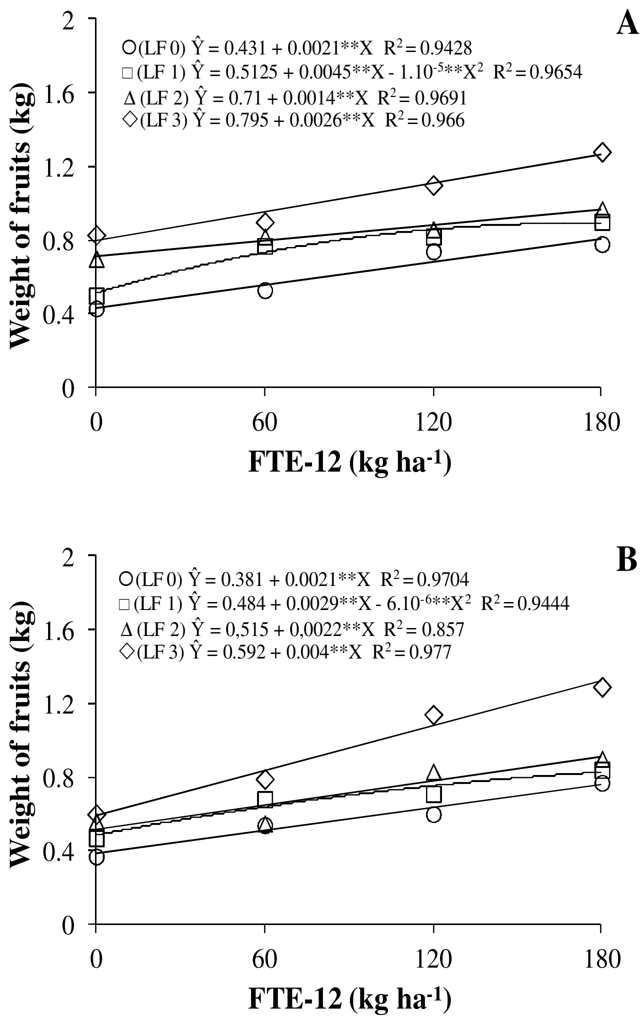

Figure 1. The average weight of Vitória pineapple fruits grown in the Baixo Acaraú irrigated perimeter with different doses of FTE-12 and levels of leaf fertilization (LF), under two types of ground cover: *bagana* (A) and black plastic (B). $^{**}p < 0.01$ and $^{*}p < 0.05$.

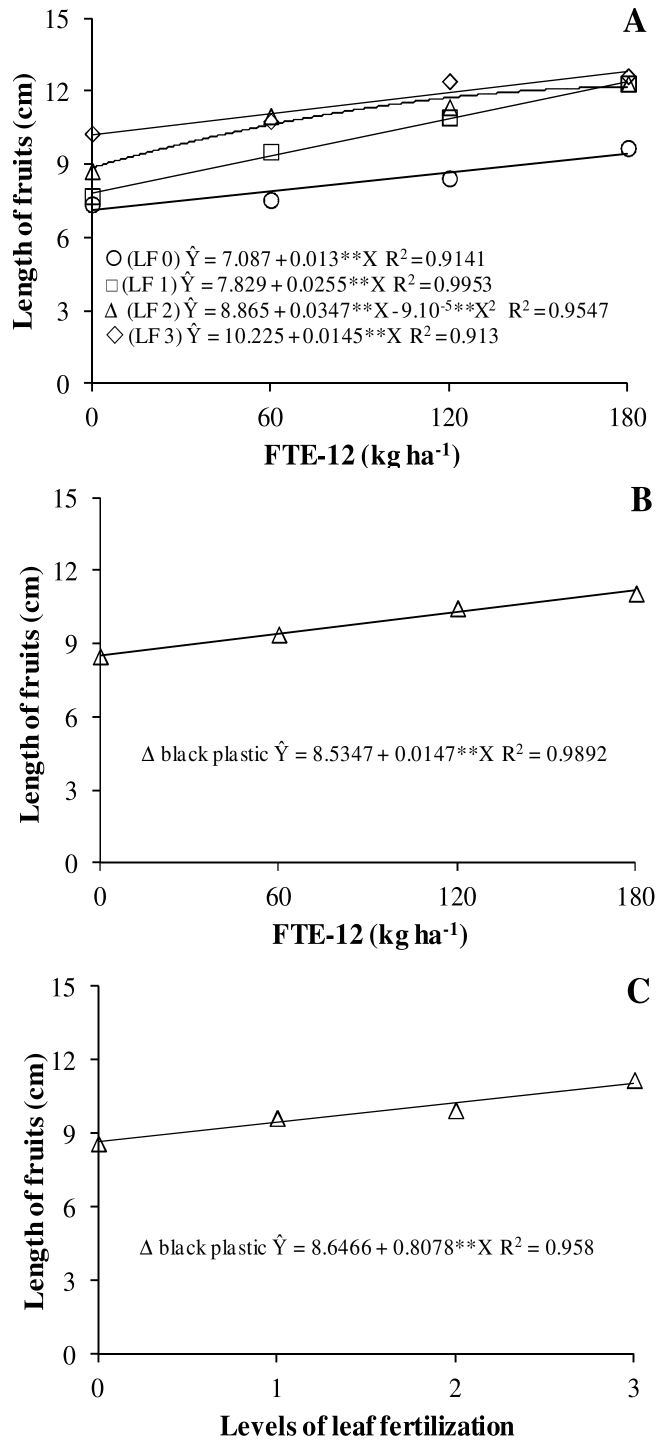

Figure 2. Length of Vitória pineapple fruits without crown grown in the Baixo Acaraú irrigated perimeter for different doses of FTE-12 and levels of leaf fertilization (LF), under two types of ground cover: *bagana* (A) and black plastic (B and C). $^{**}p < 0.01$ and $^{*}p < 0.05$.

fruits of plants cultivated under the doses of 120 and 180 kg ha^{-1} of FTE-12 and at leaf fertilization level 3 (Figure 2B and C) were within the range of lengths found for this cultivar of pineapple. The Vitória pineapple has a cylindrical shape and is shorter than other cultivars. For example, the average length of Smooth Cayenne pineapples subjected to different boron and zinc sources was 19.8 cm (Maeda et al., 2011), and Silva et al. (2012) observed an average length of 14.6 cm for Vitória pineapples fertilized with different ratios of N.

The soluble sugar levels in Vitória pineapple were not influenced by the FTE-12 levels in the experiments with *bagana* and black plastic (Figure 3A). Taking into account the levels of leaf fertilization in the *bagana* condition, no differences were found and the results are expressed as average (Figure 3B). However, in pineapples grown under black plastic, there was a linearly increasing correlation between soluble sugar levels and leaf fertilization levels, with values ranging from 12.07 g (100 ml^{-1}) at leaf fertilization level 0 to 14.57 g (100 ml^{-1}) at leaf fertilization level 3 (an increase of 20.71%). In general, the total carbohydrate levels were higher in black plastic

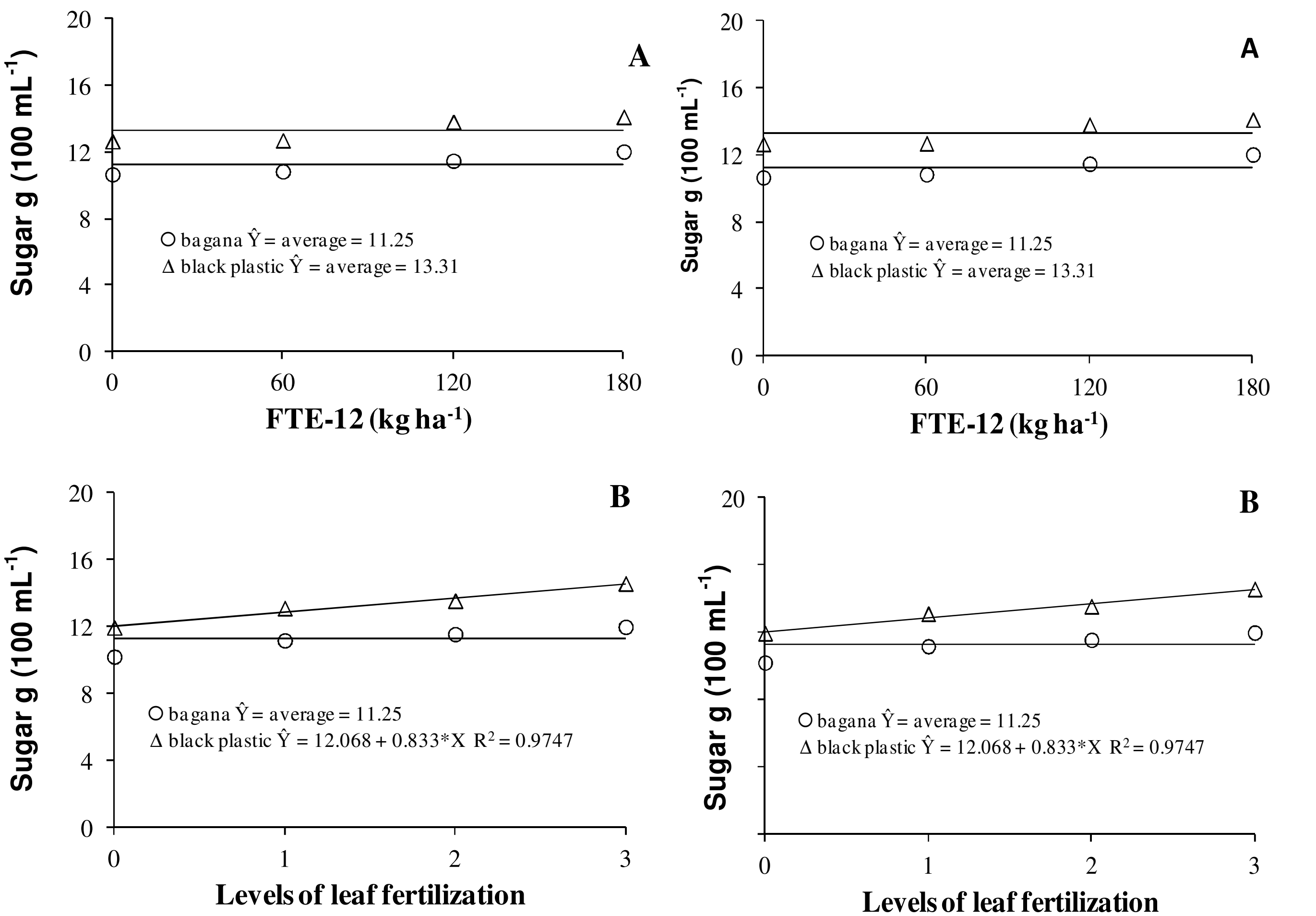

Figure 3. Sugar content in the pulp of Vitória pineapple grown in the Baixo Acaraú irrigated perimeter and treated with different doses of FTE-12 (A) and levels of leaf fertilization (B) and two types of ground cover. $^{**}p < 0.01$ and $^{*}p < 0.05$.

experiment; total carbohydrates averaged 18.31% higher among fruits grown with black plastic mulch than mulched with *bagana* (Figure 3).

The sugars in pineapple represent an important fraction of its edible part. The sugar values obtained in this study were within the acceptable range of total sugars in freshly picked pineapple and were suitable for consumption. These values were similar to those found by Wardy et al. (2009) in other three pineapples varieties and by Brat et al. (2004) in ripe fruits of a pineapple hybrid (FLHORAN 41 Cv.). The FTE-12 dose used did not influence the SS/TA ratio of Vitória pineapple; however, the leaf fertilization amount provided linear increases ranging from 17.50 to 21.29 for plants mulched with *bagana* and from 17.51 to 21.05 for plants mulched with black plastic (Figure 4). The SS/TA ratio found by Ventura et al. (2009) for Vitória pineapple was 19.7, an amount within the range observed in this study. Maeda et al. (2011) found SS/TA values ranging from 15.35 to 18.01 in Smooth Cayenne pineapple. This relationship is one of the most widely used indexes in flavor evaluation; it is more representative than measuring soluble sugars and acids separately because it reflects the balance between them.

Sensory analysis

Table 1 shows the mean hedonic values consumers assigned to express their sensory acceptance of pineapple cultivars grown in the Baixo Acaraú irrigated perimeter. All attributes were well accepted, and their assigned hedonic values ranged from 6 (liked slightly) to 8 (liked very much). There was no variation among the samples for acceptance of the external appearance ($p > 0.05$), indicating that the consumers would accept any sample, despite differences in shape, size or other physical characteristics. The same was observed for the internal color of the fruit, as evaluated in the pineapple slices.

Table 1 shows that Vitória pineapple fruits grown under black plastic (BP) mulch presented the highest flavor

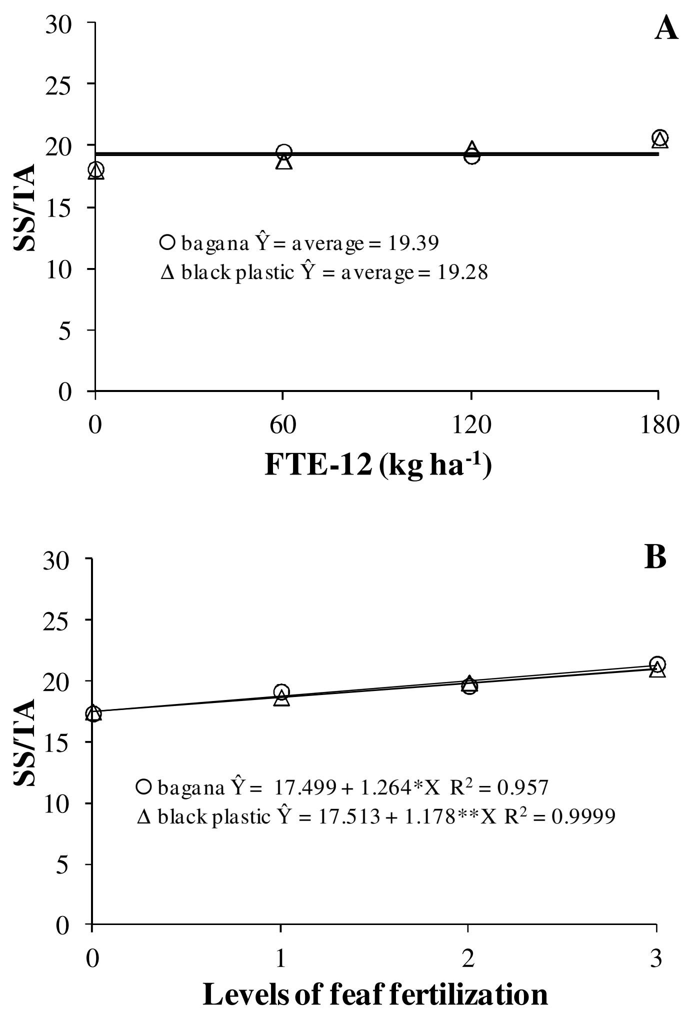

Figure 4. Titratable acidity (TA) in the pulp of Vitória pineapples grown in the Baixo Acaraú irrigated perimeter with different doses of FTE-12 (A) and levels of leaf fertilization (B) under two types of ground cover. **$p < 0.01$ and *$p < 0.05$.

acceptability, which was reflected by an overall acceptance not different from that of Pérola. This was very important because Pérola and Smooth Cayenne pineapples are considered leaders in global market acceptance. The average hedonic value, however, did not always faithfully represent the opinions of the judges as a group. Univariate analyses of data implicitly assume that all subjects exhibit the same behavior and that a single value is representative of all subjects. However, individuals' opinions may vary or cluster into similar groups, and if the individuals show opposite opinions about the products, the mean values will be similar for all products. Although similar mean values would suggest that there was no difference in acceptability among products, that would clearly not be true in such cases. In this case, the frequency distribution of the responses along the hedonic scale should be considered.

The purchase intent test conducted in this study (Figure 5), we observed that approximately 31.7% of the panelists would definitely buy the Pérola pineapple, while 21.7 and 28.3% would buy the Vitória pineapple cultivated in soil covered with *bagana* and black plastic, respectively. The small difference between these percentages shows a good performance of the Vitória pineapple, meaning that consumers liked its smaller size and cylindrical shape. According to Kader (2002), 83% of the decision to purchase or reject a product is determined by the product's appearance or physical condition. Regarding external appearance, color could be the most important criteria for consumer acceptance or rejection of pineapples. This may explain why the small size of the Vitória fruits did not impair its appearance acceptability. In most cases, though fruit size is a crucial criterion at the time of purchase.

Figure 6 shows the frequencies of the hedonic values assigned to the external appearance of the pineapple, the color of slices, flavor and overall acceptance. Although no differences were detected between means for appearance (Table 1), some differences in frequency distributions were observed (Figure 6A). Vitória (B) had a distribution that was more concentrated in the higher acceptance region than the other varieties, with a mode of 8. Vitória (BP) and Pérola each had a mode of 7; however, Vitória (BP) performed better, earning a higher percentage of liked extremely responses. It was clear that consumers liked the small size of the Vitória pineapples, despite being accustomed to the elongated shape of the Pérola variety.

Frequency distributions for the color of the slices (Figure 6B) were very similar among the three pineapple samples, confirming results of Table 1. However, Vitória pineapple grown under *bagana* performed slightly lower than the others, with more than 10% of respondents indicating indifference (5 = did not like or dislike) and approximately 16% indicating rejection responses on the hedonic scale (1 to 4).

Histograms for flavor acceptance (Figure 6C) and overall acceptance confirmed the mean results (Table 1), with Vitória (B) being less accepted than the other two samples. The responses observed for this sample showed a distribution clustered around Category 7 on the hedonic scale (liked slightly) and a 25% frequency in the rejection and indifference region (Categories 1 to 5). There were some differences between the frequency distributions of the Pérola and Vitória (BP) samples, which did not differ in their flavor acceptance means (Table 1). Although Pérola showed a slightly higher percentage of responses in the maximum categories of the scale (8 and 9), Vitória presented a lower rejection rate (that is, responses in Categories 1 to 4). Furthermore, a summation of the frequencies in the last three categories (7 to 9) showed that Vitória (BP) scored slightly higher than Pérola (88 and 79%, respectively).

Table 1. Mean hedonic values consumers assigned for the sensory acceptance of Peróla pineapple, Vitória pineapple grown under *bagana* (Vitória B) and Vitória grown under black plastic (Vitória BP) in the Baixo Acaraú irrigated perimeter – CE.

Samples	Sensory attributes			
	External appearance	Color slices	Flavor	Overall acceptance
Pérola	6.8[a]	7.4[a]	7.4[a]	7.4[a]
Vitória (B)	7.0[a]	6.8[a]	6.5[b]	6.6[b]
Vitória (BP)	6.6[a]	7.2[a]	7.6[a]	7.6[a]
CV (%)	22.98	21.58	22.26	20.92

Means with same letters in the same column are not significantly different, according to Tukey's test set at 5% probability. CV: coefficient of variation percentage. Hedonic values: 1 = disliked extremely, 2 = disliked very much, 3 = disliked, 4 = disliked slightly, 5 = neither liked nor disliked, 6 = liked slightly, 7 = liked, 8 = liked very much, 9 = liked extremely.

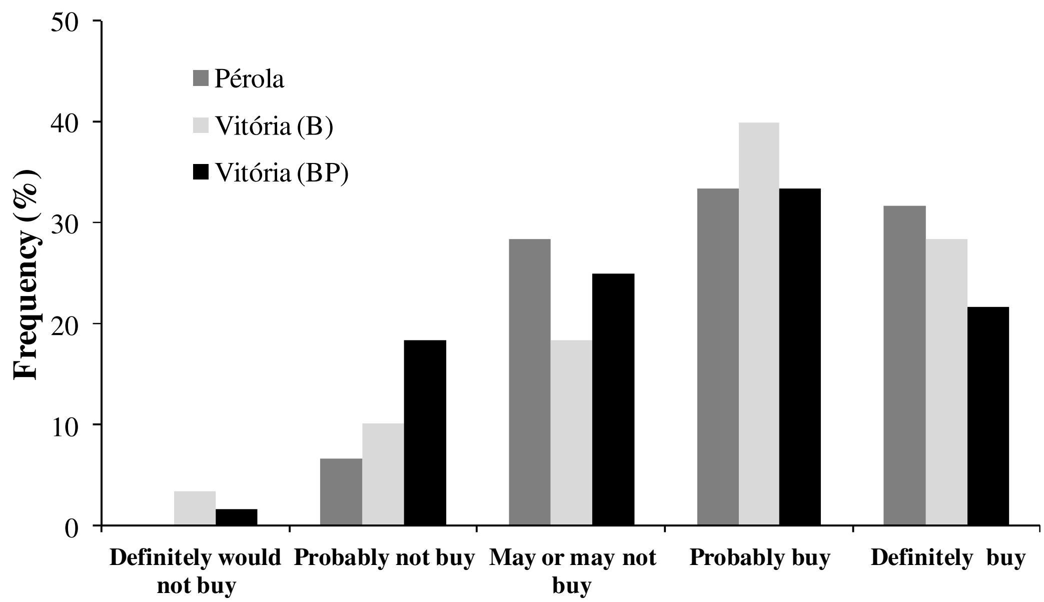

Figure 5. Consumer purchase intent based on the external appearance of "Peróla" pineapples, Vitória pineapples grown in soil covered with *bagana* (Vitória B) and Vitória pineapples covered with black plastic (Vitória BP) grown in the Baixo Acaraú irrigated perimeter - CE, 2010.

The same phenomenon was observed for overall acceptance, for which Pérola reached 76% in Categories 7 to 9 and Vitória (BP) reached 85%. The internal quality of fruit and the physicochemical constituents of the pulp (which are responsible for its characteristic flavor and aroma) are important to the fruit's overall acceptance. This was verified in this study, as Vitória (BP) pineapples showed the best chemical composition related to total sugars (Figure 3), which may have contributed to a sweeter taste and, consequently, better consumer acceptance. Regarding the intensity of acidity (Figure 7), Vitória (BP) and Pérola had a high frequency of responses in the ideal category (73 and 63%, respectively), while Vitória (B) showed a higher percentage of responses in the category stronger than ideal (40%).

Conclusion

the results of this study showed that application of the micronutrients influences some characteristic of pineapple fruit quality, especially when applied on leaves, and increases the fruit growth. Therefore, these positive effects of micronutrients can be contributed to the good market acceptability of pineapple cv. Vitória. Fruits of Vitória pineapple mulched with black plastic showed higher total sugars concentrations (Figure 3), which may have contributed to a sweeter taste and, consequently, better consumer acceptance.

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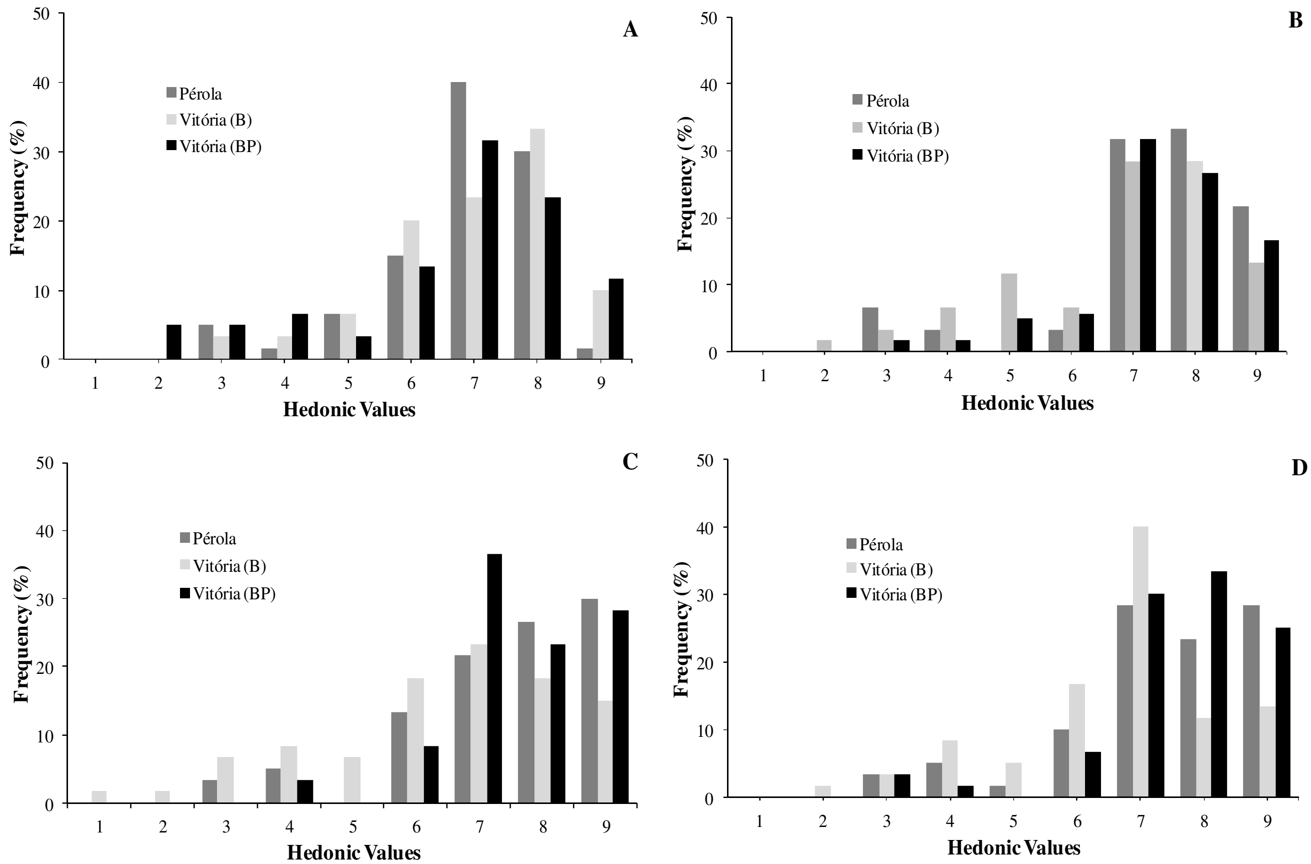

Figure 6. Frequency of the hedonic scale values assigned for (A) external appearance, (B) color of slices, (C) flavor and (D) overall acceptance in samples of Pérola and Vitória pineapples. Vitória (B) = *bagana*; Vitória (BP) = black plastic. Hedonic values: 1 = disliked extremely, 2 = disliked very much, 3 = disliked, 4 = disliked slightly, 5 = neither liked nor disliked, 6 = liked slightly, 7 = liked, 8 = liked very much, 9 = liked extremely.

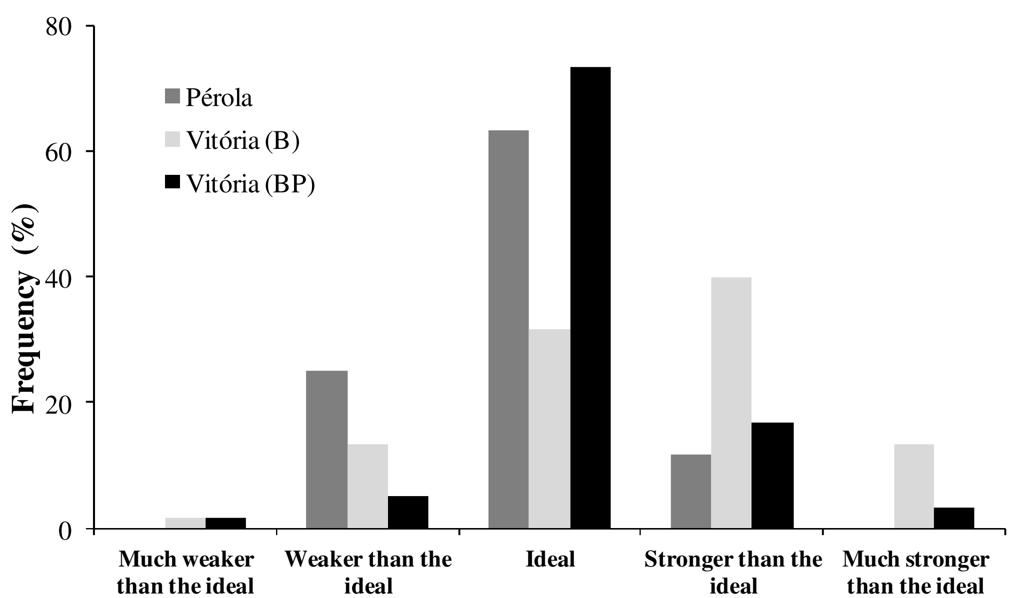

Figure 7. Consumers' assessment of the intensity of acid taste, indicated with the just-right scale, in Peróla pineapples, Vitória pineapples grown in soil covered with *bagana* (Vitória B) or black plastic (Vitória BP) in the Baixo Acaraú irrigated perimeter - CE, 2010.

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ABBREVIATIONS

SS, soluble solid; **TA,** titratable acidity; **SS/TA,** ratio soluble solid/titratable acidity; **FTE,** fritted trace elements; **LF,** leaf fertilization; **B,** Bagana; **BP,** black plastic.

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