African Journal of Agricultural Research Vol. 7(33), pp. 4620-4626, 28 August, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.2334
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Sensory and physico-chemical quality of banana fruits "Grand Naine" grown with biofertilizer

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Accepted 12 July, 2012

Bio fertilizer was applied to "Grand Naine" plantain, and its effect on the physicochemical and sensory characteristics of the plantain was studied. Two treatments were established: I) Bio fertilization (BIOF); and II) Conventional fertilization (CONV) practiced by farmers. When BIOF was exclusively applied as a fertilization strategy, similar values (p > 0.05) were obtained, like the ones in CONV, in all physical characteristics assessed in the fruits. In the fruits' chemical composition, difference in sugar and vitamin C (p < 0.05) contents was found; the contents in fruits coming from BIOF were higher. The difference in sugar content, also detected and verified by trained judges, scored BIOF fruits with a 2.62 value versus 1.36 for CONV ones in relation to sweetness descriptor. These results demonstrate that biofertilization can replace synthetic fertilizers action on plant nutrition, and consequently can lead to the obtaining of fruits with similar quality, higher sugar and ascorbic acid contents.

Key words: Sweetness, *Musa*, sensory evaluation, Bokashi, ascorbic acid.

INTRODUCTION

Banana is among the most important worldwide consumed fruit product (*Musa* spp.). It was reported that its world's production exceeded 91 million tonnes (FAO, 2012), and it was the second most produced fruit. Its wide consumption is due to its sensory characteristics, leading to its demand mainly by developed countries who account for nearly 70% of world's consumption (FAO, 2012); and due to its caloric contribution of vitamins and minerals, mainly potassium (Temple et al., 2005).

Mexico occupied the 9th place of production of this fruit-bearing with 2.1 million tonnes for the same year (FAO, 2012). The main varieties cultivated in the South region of México (Soconusco, Chiapas) are those that are widely marketed to be consumed as dessert; they are of the group AAA and subgroup Cavendish, with more important clones like Grand Naine, Willams and Valeri (SAGARPA, 2009). In the last decade, the area cultivated in this region of the country has diminished to 30%. The main factors responsible for this descent include high costs of chemical inputs (Sarhan et al., 2011), employment of skill labour for fertilization and control of plagues and illnesses (black leaf streak, Panamá disease, blood disease, rhizome rot), caused by the decrease in petroleum reserve world wide (Leng, 2008).

Other undesirable effect of the employment of synthetic agro-inputs in the systems of agricultural production is salinization (Esmaili et al., 2008), loss of symbiont biota (Fox et al., 2007), complexation of available minerals for the plants (Sleutel et al., 2006), eutrophication of water bodies (Xue and Landis, 2010) and overall chemical contamination of the products (fruits, vegetables, roots, legumes, etc.). As a result, there is an increased tendency to include alternatives less dependent on synthetic inputs. One of such is the employment of bio-fertilizers (amendment and inoculants), which improve soil characteristics (Hirzel et al., 2010; Haynes and Naidu, 1998), provide necessary nutrients for development and production of plants (Hegazi et al., 2007) and improve the physico-chemical characteristics of quality fruits, as seen

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in tomato. They also increase soluble and insoluble solids content (Gutiérrez-Miceli et al., 2007) and vitamin C (Thybo et al., 2005) which have effects on sensorial characteristics. This also occurred in the same way in *Cucumer* cultivars, where Sarhan et al. (2011) applied bio fertilizers (bacteria) and organic material (manure of sheep), and produced fruits of similar quality to those obtained conventionally.

Another benefit of the use of bio- fertilizers is from the production perspective. Since it is possible to equal the yields obtained with synthetic fertilization, just as Song et al. (2010) report in organic cultivation of *Cucumis melo*, likewise Echeverry (2002) found bunches of similar weight to those obtained with conventional fertilization in the organic cultivation of *Musa* cultivar "Cachaco". In other studies, where organic material was combined with synthetic fertilizer, it is even possible to increase yields. This way, Abd el Moniem et al. (2008) increased the average weight of grapes (3.1 g) in a combination of solid residuals stabilized with synthetic fertilizers *versus* single synthetic fertilization, with average weight of 2.7 g.

The results of biofertilizers used, even when used as a complement to synthetic fertilization for a banana production cycle, show that they are able to promote beneficial interactions and supply the necessary nutriments in order to obtain fruits of similar quality to those obtained by conventional fertilization. So, it is believed that the sensory and physicochemical characteristics of the fruits obtained by the customary use of biofertilizers (for more than one harvest) should not devalue their quality and acceptance. Based on this, the objective of the present study was to evaluate the effect of bio- fertilization of banana plant clone "Grand Naine" on the physicochemical and sensory characteristics of fruits during two harvest cycles.

MATERIALS AND METHODS

Study site

The study was carried out in the banana cooperative “Sector de Producción Mazatán R.S.M.” in Chiapas, Mexico. Its geographical location is 14° 49' 20.41" N latitude, 92° 28' 7.62" W longitude and 12 m altitude.

Treatments

The study was conducted in two experimental fields of one hectare each without replications for two productive cycles (years 2008-2009). The field had been cultivated with bananas (*Musa* AAA Cavendish cv. “Grand Naine”) in a conventional way (using fertilizers and chemical pesticides) for more than 20 years. Both fields had similar conditions at the beginning of the experiment which include organic material (2.4 g 100 g^{-1} dry soil), total nitrogen (0.16 g 100 g^{-1} dry soil), phosphorus as P_2O_5 (0.002 g 100 g^{-1} dry soil), potassium as K_2O (0.15 g 100 g^{-1} dry soil), total calcium (0.16 g 100 g^{-1} dry soil), total magnesium (0.16 g 100 g^{-1} dry soil), pH 6.2 and electrolytic conductivity (1.1 dS m^{-1}). The treatments established were: a) bio fertilization (BIOF), using only Bokashi compost and fermented liquid fertilizer enriched with *Streptomyces* sp. EPCH0497 and growth-promoting bacteria (*Rhizobium* 11B) without any synthetic fertilizer and b) conventional fertilization (CONV), applying a fertilizer formula 167-62.5-125 g $plant^{-1}$ N-P_2O_5-K_2O around each banana plant. The planting system used was double row with a density of 1200 plants ha^{-1}. Planting distances were 1 m between rows, and 2 m between plants in each row; they were arranged in an equilateral triangle and 4 m in the grooves. Banana sucker clone "Grand Naine" produced by micropropagation was used.

Bio fertilizer elaboration and application

Compost

The compost used in this work was prepared using the procedure of Adriano et al. (2012) with co-products generated in the same field (pseudostems, banana rachis, leaves and some defective fruit), mixed in a 1:1 ratio with palm fibre (*Elaeis guineensis*). 100 kg ash, 20 L molasses, and 80 kg of fresh manure and 1 kg of baker's yeast were added to 800 kg of this mixture placed in a tank. To maintain an aerobic system, it was turned twice a day, and then turned once a week, until it was stabilized. Once the compost was stabilized and it did not show harmful microbiota activity (16 weeks), it was applied at a rate of 4 kg per plant every 16 weeks around the pseudo-stem. The characteristics of the compost with a water content of 60 g 100 g^{-1} were on a dry weight basis as follows: organic carbon, 22.2 g 100 g^{-1}; total nitrogen, 2 g 100 g^{-1}; phosphorus as P_2O_5 1.1 g 100 g^{-1} and potassium as K_2O 1.34 g 100 g^{-1} (Adriano et al., 2012).

Liquid bioferment production

This was prepared following Adriano et al. (2012), by mixing 50 kg fresh manure, 4 L molasses, 4 kg ash, 2 L natural yogurt, 2 kg baker’s yeast and the necessary 200 L water. The used containers were hermetically sealed to achieve anaerobiosis during 21 days. The fermented liquid fertilizer was diluted until it had an electrolytic conductivity of 2.5-3.0 dS m^{-1} and then added. It was applied with suspensions (1.5% v/v) containing 10^{11} UFC ml^{-1} of both *Rhizobium* 11B and fungi controller *Streptomyces* sp EPCH0497 diazotrophic bacteria; both microorganisms were obtained from the strain bank of Centro de Biociencias-UnACh. The liquid bioferment average composition (w v^{-1}) was as follows: total nitrogen: 1.5%, P_2O_5: 0.98% and K_2O: 1.04% (Adriano et al., 2012). Applications were made every 14 days, both in leaf area (until leaves were completely wet) with a manual pump sprayer, and soil (2 L $plant^{-1}$) around the pseudostem.

Sampling and evaluated variables

To evaluate morphometric variables and fruit mass using systematic sampling, 10 plants were employed in each plot; and in every 120 plants, the followings were monitored: a) size (fruit diameter measured as thickness at the middle section of the fruit), b) fingers' length by the outer curvature, from the fruit apex to the pedicel base. For both measurements, four fingers from the central part of the second hand, two from the top row and two from the bottom, were taken. It was also quantified as: c) number of fingers per hand (considering the second hand as a reference), d) total number of hands per bunch and e) bunch weight (IPGRI-CIRAD/INIBAP, 2006).

The bunches were cut when 90% of the fruits became mature green. They reached 3.8 cm in diameter (harvest index denotes physiologic maturity). Later on, they were moved to the laboratory

Table 1. Physics parameters in fruits and bunches of banana “Grand Naine”.*

Parameter	1st harvest		2nd harvest	
	Bio-fertilization	Conventional fertilization	Bio-fertilization	Conventional fertilization
Fingers·per hand	16.50 ± 2.99[a]	18.20 ± 3.91[a]	16.20 ± 1.39[a]	15.20 ± 4.44[a]
Hand·per bunch	5.30 ± 1.05[a]	5.10 ± 0.73[a]	5.50 ± 0.52[a]	6.70 ± 1.76[a]
Fruit length (cm)	15.37 ±1.48[a]	14.92 ± 1.72[a]	12.00 ± 1.50[a]	11.85 ± 1.01[a]
Fruit diameter (cm)	3.03±0.34[a]	2.96 ± 0.40[a]	2.90 ± 0.49[a]	3.03 ± 0.29[a]
Bunch weight (kg)	17.82±5.08[a]	16.59 ± 3.25[a]	13.43 ± 6.10[a]	11.28 ± 4.99[a]

*The values shown are the mean and standard deviation of 10 data. [a]Values with the same letter in the same row denote statistical equality per harvest (p > 0.05).

where they were recovered with perforated plastic bags and maintained in a room isolated temperature of 30°C and relative humidity of 80% until they reached commercial maturity (yellow color in total peel area), as suggested by Muchui et al. (2010).

A bromatological analysis was carried out only in fruits of second harvest, using the following methods: moisture determination (method 925.09), fat (method 920.39), ash (method 923.03), crude fibre (method 962.09) protein (method 954.01); also titratable acidity was measured (AOAC, 2005), reducing sugars by the DNS method (Miller, 1959) and ascorbic acid by 2,6-dichloro-phenolindophenol method (Loeffler and Pointing, 1942).

Firmness and colour of fruit

There were made three punctures along the fruit with a penetrometer TR® (Italy) in order to determine firmness. 8 mm cylindrical punch was used. The results were expressed in Newton (N) and three readings taken from the ripe fruits, using a Minolta CR-410®colorimeter were used to measure peel colour. CIE, L, a* and b*, system were used and the colour tone was calculated [°Hue = arctg (b*/a*)] according to CIE (1986).

Training and sensory evaluation

A sensory evaluation of banana fruits from both treatments was carried out by a group of trained judges. The judges who took part in the evaluation were 10 undergraduate students (5 women and 5 men) aged between 20 and 24 years old. They were selected from a group of 18 participants under the following criteria: affinity for banana consumption and / or derivatives, possess the ability to identify basic tastes, to be able to perceive smell and aroma, non smoking persons, to be interested in the study and ability to express their judgements (Plemmons and Resurrección, 1998). The judges took part in 8 sessions; they were held every week for about 2 h each. Training was based on descriptive and discriminative sensory tests; they were established in order to define fruit properties, measure their objectively and to determine the magnitude and intensity of their attribute, so that differences between samples could be established (Larmond, 1982; Lawless and Heymann, 2010).

During the first two training sessions, judges were given banana samples commercially purchased; from them there were generated descriptors that have a great impact in commercial quality: sweetness, lumpiness, smell and aroma intensity. Over the next four sessions, judges familiarized themselves with the descriptors until they were fully trained, statistically speaking. In the first evaluation, a 2 cm piece of peeled banana from each treatment was submitted to each judge, in duplicate, selected at random from sampled fruits with commercial ripeness, in coded containers with three digits (O´Mahony, 1986). Evaluation was carried out in a room at 25°C, with sufficient ventilation and under natural lighting. The judges assessed sweetness and lumpiness attributes and made judgements using unstructured scales of 10 cm with minimum and maximum values of 0 and 5 (1 value every 2 cm), respectively. The distance was measured in cm, marked by the judges (Lawless and Heymann, 2010).

For smell and aroma attributes, judges were trained with solutions with different isoamyl alcohol concentrations. For the evaluation, under the same conditions as in the first one, fruits from each treatment (coded with three digits) in closed glass were given to the judges. Once they were uncovered and smelled during 5 s by the judges, they were asked to score the smell in similar scales to those used in the first evaluation. After chewing 8 times each sample, judges recorded their score for aroma. For all tests, each panellist evaluated two fruits from each treatment.

Statistical analysis

The results obtained from morphometry and bromatological composition of fruits were presented with measures of central tendency and dispersion; mean difference was evaluated by *t* test using Info Stat© statistical package, version 2008 (Montgomery, 1997). To validate testers' training, an analysis of variance and correlation tests between the tested attributes and the responses were carried out. The results from the sensory evaluation were subjected to a one-way analysis of variance and appropriate comparison of means was done by Duncan test, using the same statistical package (O´Mahony, 1986).

RESULTS

Morphometric variables

Table 1 shows the measurements made in banana fruits clone “Grand Naine” obtained from two harvests. Within each harvest there was no significant difference (p > 0.05) for the five morphological measurements. It is noteworthy that, contrary to what was expected, for the second harvest there were obtained lower values in the number of fingers per hand, fruit length and total weight of the bunch in relation to the first harvest. Although there

Table 2. Chemical composition of banana fruits “Grand Naine” (g 100 g^{-1} fresh weight).

Component	Biofertilization	Conventional fertilization
Moisture	77.77[a]	78.86[a]
Protein	1.06[a]	1.05[a]
Fat	1.44[a]	1.03[a]
Crude fiber	0.40[a]	0.45[a]
Ash	2.93[a]	2.89[a]
Nitrogen free extract	16.40	15.72
Sugar reducing	12.88[a]	12.19[b]
Titratable acidity (malic acid)	0.30[a]	0.30[a]
Vitamin C (mg·100 g^{-1})	0.069[a]	0.047[b]

[a-b]Values with different letters in the same row denote significant difference (p < 0.05).

Table 3. Firmness and peel color of banana fruit “Grand Naine”.

Treatment	Attribute	
	Firmness (N)	Color (°Hue)
BIOF	3.59[a]	88.43[a]
CONV	3.56[a]	89.48[a]

BIOF = biofertilization, CONV = conventional fertilization. [a]Values with the same letter in same column denote statistical equality (p > 0.05).

second one); however, the high variability in the same weight for this treatment was not reflected in the average value.

Bromatological composition

The fruits analysed for their chemical composition reveal a difference in reducing sugars and vitamin C contents (p < 0.05), resulting in more ascorbic acid content of 68%, in the treatment that was bio fertilized. It was not significant (p > 0.05) for any other bromatological determinations (Table 2). Even though the numerical difference in sugar content was minimal (0.69 g 100 g^{-1} fresh weight), it was significant; as shown in Figure 2, and it was well appreciated by the trained judges in sweetness test.

Sensory, colour and firmness evaluation

Trained judges found no significant differences in relation to smell, aroma and lumpiness (p> 0.05), but confirmed the difference found in reducing sugar content shown in Table 2. So for this descriptor, it was given a score of 2.62 for BIOF versus 1.36 for CONV. These values were significantly different (p < 0.05) as shown in Figure 1.

In relation to instrumental measurements for colour and firmness, both variables were statistically equal (p > 0.05) and numerically very similar for both treatments as shown in Table 3.

DISCUSSION

Morphometric variables

It has been reported that the use of biofertilizers brings benefits to soil and therefore to the plant; so they can improve fruit's physical characteristics. In this context, Echeverry (2002) points out some benefits of using biofertilizers. Their impact is reflected in the fruit; for example cattle manure was used in “Cachaco” banana crop and there were obtained similar results in relation to the weight of bunches on both: bio fertilized plants (14.30 kg) and for the fertilized plants with chemical inputs (14.31 kg). These results are similar to the ones reported in the present study.

In a similar way, Abd el Moniem et al. (2008) reported an increase in the number of hands, fingers, and fruit weight when applying organic fertilizers (banana waste, poultry manure and seaweed extracts) to banana plants, “Williams” variety. This is consistent with Ramadan (2007), who used chicken manure (75%) combined with mineral fertilization (25%) and obtained a meaningful increase in tomato production. The author attributes this beneficial effect to poultry manure because it complemented the deficiency of conventional fertilization. Others such as Sarhan et al. (2011) demonstrated a similar effect in *Cucurbita pepo* L. vegetable, using organic fertilizers (manure of sheep) and beneficial bacteria (*Azotobacter*). They improved the production of fruit and the quality of two cultivars of this plant.

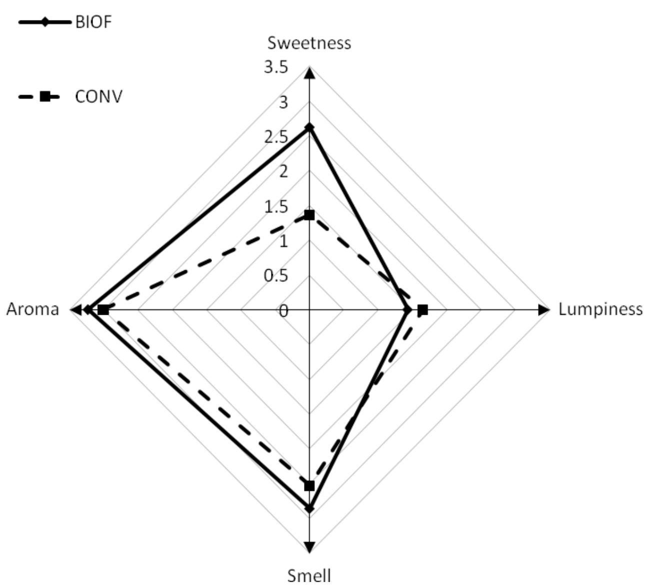

Figure 1. Sensory attributes in banana fruits. BIOF = biofertilized, CONV = conventional fertilizer.

Attia et al. (2009) reported that when Maghrabi banana plants were inoculated with phosphate solubilising bacteria as biofertilizers (*Pseudomonas fluorescent* and *Bacillus megaterium*) and combined with phosphorus (25%), there were improvements in relation to the morphometric characteristics of the fruit, increasing fruit diameter (3.7 cm). These studies show that by reducing the application of synthetic phosphorus and by combining it with bio-fertilization, it plays a great role by replacing the nutritional requirements of the plant and that which the first one does not provide. However, those study designs differ from the present, because in this one, no synthetic fertilizer was applied in BIOF plot. This provides more benefits when obtaining similar physical results between the tested strategies.

It has been proven that the addition of organic material (compost) increases the contents in N, K, P, Ca and Mg in the soil in the 140 days of beginning the application under the same conditions employed in this study (Adriano et al., 2012).

The microorganisms added to BIOF treatment (diazotrophic bacteria and *Streptomyces* sp EPCH0497 11B) may have established a symbiotic interaction with their native counterparts from compost (solubilising bacteria), and in that way they favoured the availability of nutrients for the plant so that they could be better assimilated by it. As seen earlier, the application of organic fertilizer and microorganisms provides benefits to the plant, like promoting a better availability of nutrients. This explication is supported by Hanč et al. (2008), who found out that organic fertilizer application increases phosphorus and potassium in soil and makes it more available.

It is important to note that the production region where the study took place has an agricultural management history of at least 70 years (cotton, soja, banana), during which chemically synthesized fertilizers were applied. So, it might be thought that these could have led to the impoverishment of the present micro biota that provides benefits to the crops (Fox et al., 2007), and also act as pest and disease predators. This resulted in negative effects for the plantations, such as sigatoka damage (black leaf streak) that overruns the banana region during the course of the investigation. This damage may have had a partial effect on the low yield of both physical and chemical parameters, mainly for the second harvest (Table 1).

Therefore, soil recovery may be slow, so bio fertilizer effect in the plants may be gradual. Bearing in mind the obtained results, it may be assumed that if the plantation is being bio fertilized, the results in terms of physical variables could be more favourable than those obtained in this study, as reported by Attia et al. (2009) who asserted that the plantation may stabilize after the fourth or fifth harvest.

Bromatological composition

The proximal composition of the fruits under the two tested treatments is similar in general terms to other banana fruits grown and evaluated at commercial maturity, like moisture values reported by Adeyemi and Oladiji (2009) with 77.19% and Onibon et al. (2007) with 70.60%. The fruits obtained in this study have higher values than those reported by the above mentioned authors, for ash content (0.80 and 0.28% respectively), which may be an indicative of the important mineral contribution of banana "Grand Naine".

The non-application of chemical fertilizers in BIOF treatment was replaced with compost addition. This promoted a greater interaction of the micro biota with the plant and in that way the nutrients were more available for it. It has been proved that in compost, there are multiple interactions between the micro-organisms mainly bacteria, as well as actinomycetes, fungi, protozoa that help for fragmentation and decomposition of organic matter, so that they are more available for the plant as reported by Polat et al. (2009). Although the role of added micro-organisms was not explored, it has been documented that mycorrhizal fungi colonize the roots of most plants, establishing a required symbiosis and receive carbon compounds as energy of the host plants. During this association there are transferred nutrients, generally phosphorus and zinc, as reported by Frąc et al. (2009). There are reports about the positive effects of fungi colonization in wheat crops. They improve nitrogen, phosphorus, potassium, calcium, copper and zinc absorption. Besides, in the inoculated treatments there were observed more spikes·m^{-2}, grain weight and yield.

These responses were similar to the fertilized treatment

(Ryan and Angus, 2003).

In relation to rhizobacteria, there have been postulated mechanisms that involve them in growth promoting activities, such as mobilization and efficient intake of nutrients, improvement of stress tolerance, solubilisation of insoluble phosphates, inducement of resistance to systemic diseases, production of phytohormones, vitamins and siderophores (Baset and Shamsuddin, 2010). Many of these activities are important in bio-molecule accumulation in the fruits from the plants where it is applied, similar to what was reported in this study. The highest content in BIOF (Table 2) was vitamin C. This fact supports the hypothesis of accumulation in response to the biological treatment and the values were in the reported range (2.1 to 18 mg 100 g^{-1}) for other dessert banana varieties (Wall, 2006).

Sensory, colour and firmness evaluation

The consumer's first selection criterion is the external appearance of the fruit and it is strongly influenced by the colour, which under a normal ripening process is mainly given by chlorophyll degradation and the appropriate carotenoid synthesis major lutein, α-carotene, and β-carotene (Wall, 2006). In it, there was no difference between treatments ($p > 0.05$). Both showed the characteristic yellow colour of ripening, reported by Pelayo et al. (2003), about 91° Hue for completely yellow bananas. The firmness shown in Table 3 for Cavendish bananas, Grand Naine belongs to it. It matches with the one found by Duan et al. (2008) who reported a value inferior to 2 N (measured with a 4 mm punch) for completely yellow banana and the reported one by Pelayo et al. (2003) (3N) in bananas stored for 12 days. A puncture instrument was used for it, with the same diameter as the one used in this study.

In relation to banana acceptance, the judges did not perceive a significant difference in banana aroma and smell ($p > 0.05$), demonstrating that bio fertilization process in plants does not have an apparent effect on the production of fruit volatiles that spread their *sui generis* smell and aroma.

Panellists' assessment in relation to sweetness descriptor can be supported with the findings from bromatological composition (Table 2) as the sugar contents found in bio fertilized fruits were higher than the ones found in the conventionally fertilized fruits. Therefore, the obtained results allowed a more accurate interpretation: the judges' opinion has the same value as the instrument one. From banana soluble glucides components, fructose holds the highest sweetening power and it may be present in BIOF fruits in a great proportion as it has been demonstrated for *Musa paradisiaca* (Englyst and Cummnins, 1986; Duan et al., 2008). This fact contributed to the score assigned by the judges for this descriptor; it was nearly the double than the one assigned to fruits from CONV treatment (Figure 1).

The results show that bio fertilization did not have any negative influence on the sensory quality of banana fruit clone Grand Naine; on the contrary, it improved the sweet taste and increased the ascorbic acid content. For lumpiness descriptor, whose importance is not questionable because it determines consumer's acceptance, in this study there was no statistical difference between treatments (Table 3). This can be correlated with the results obtained in the fruit chemical composition, since lumpiness, understood as the texture perceived by the tongue, gums and cheeks, is given by components such as fats, sugars, proteins etc. (Lawless and Heymann, 2010) and when these show equality in relation to chemical composition, they contribute to the fruit texture.

Related to the texture perceived by the judges, it is associated the resistance to penetration showed by the fruits; since it was the same in both treatments ($p > 0.05$), it did not influence the sensory test. The fruits showed the firmness that characterises bananas when they are going to be commercialized, similar to what Chang and Saenz (2005) reported.

Conclusion

The application of compost and biofertilizer, enriched with beneficial microorganisms on banana "Grand Naine" plants without any synthetic fertilizer, provides fruits with physical and yield characteristics similar to conventionally fertilized plants. However, this treatment provides sweeter fruits due to higher contents of reducing and total sugars and vitamin C.

ACKNOWLEDGEMENTS

Thanks are given to CONACYT- Chiapas State Mixed Fund for the financial support for the project CHIS-2006-C06-43 894 and to the participants as panellists in the sensory evaluation.

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