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REGULAR ARTICLE

Fruit production and quality of guava as a function of biofertilizer and nitrogen fertigation in Brazilian semiarid

E. A. Santana[1], Í. H. L. Cavalcante[1,2]*, D. de S. Brito[1], R. N. do Carmo[1], K. dos S. M. de Sousa[1]

[1]Federal University of São Francisco Valley, Agronomy Engineering, Petrolina (PE), Brazil, [2]Researcher fellow of the National Council for Scientific and Technological Development (CNPq), Brazil

ABSTRACT

Adequate agronomic management is crucial to reach high guava yields that demand a well-defined fertilizer management, including organic fertilizer such as biofertilizers, which have emerged as an important component of the integrated nutrient supply system aiming environmentally better nutrient supply using fertigation systems in Brazil. This way, an experiment was carried out to evaluate the fruit production and quality of guava as a function of biofertilizers and N fertilizing in brazilian semiarid. The experimental design was in randomized blocks with treatments distributed in a factorial arrangement (5 x 2) referring to biofertilizer concentrations [0, 2.5, 5.0, 7.5 and 10%] and mineral fertilizing with N (fertilization with 50% and 100% of recommended N), with four replications of five plants each. Fruit quality and production of guava depend on bovine biofertilizer and N fertigation. Biofertilizer promotes significant enhancements on fruit firmness, vitamin C and pH, beyond titratable acidity reduction of guava. It is possible to recommend fertigation with biofertilizer at 5.66%, independently of N fertilizing with 50% or 100% of recommended N. Bovine biofertilizer is an important key to the production of guava under semiarid climate.

Keywords: Alternative fertilizer; Post-harvest; *Psidium guajava*

INTRODUCTION

São Francisco Valley is the main Brazilian region of growing irrigated fruits, especially mango, grape, guava, coconut and acerola (IBGE, 2016). Among the fruit crops grown in São Francisco Valley, guava detaches with production of nearly 106.3056 t, corresponding to 32% of all guava produced in Brazil (IBGE, 2016).

Fertigation is a commonly used for growing guavas in São Francisco Valley, due to it's a proven tool efficiency for uniform and balanced nutrient distribution since it provides water and nutrient availability in the higher root activity area of plant canopy, especially if a localized irrigation is used (Chavez and Torres, 2012).

One of the nutrients applied through fertigation is nitrogen (N) which is the second nutrient more required by guava tree and it is essential for plant growth and development, as an essential constituent of amino acids, enzymes, nucleic acids, and chlorophyll (Marschner, 2012). A negative feature of N fertigation is possible groundwater contamination and N loss to the atmosphere, since plants are not able to absorb all N of the fertilizer.

One possibility to mitigate N fertilizer excess is partial or total replacement by organic fertilizers such as bovine biofertilizer, which is an organic matter source able (or not) to supply N plant demand, it can also be supplied through fertigation, it is decomposed faster than solid fertilizers, has low-cost distribution and fast organic matter decomposition (Gross et al., 2008).

Biofertilizer has positive effect soil physical and chemical characteristics (Pires et al., 2008) and consequently on plant growth and development, and, fruit production and quality (Gross et al., 2008). Especially for fruit quality it is registered in the scientific literature the biofertilizer effect on improving or maintaining fruit quality of yellow passion fruit (Dias et al., 2011; Cavalcante et al., 2012), papaya

***Corresponding author:**
Í. H. L. Cavalcante, Researcher fellow of the National Council for Scientific and Technological Development (CNPq), Brazil.
E- mail: italo.cavalcante@univasf.edu.br

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(Mesquita et al., 2007), custard apple (Leonel et al., 2015) and banana (Santos et al., 2014; Senthilkumar et al., 2014). For guava Chavez and Torres (2012) compared organic and conventional production systems partially replaced by biofertilizer applied through fertigation and reported that biofertilizer was better than other treatments. Additionally, Batista et al. (2015) concluded that organic inputs use for growing guavas beyond synthetic inputs provides high fruit yield and fruit quality compatible to market demands for soluble solids, pH, titratable acidity, pulp firmness and soluble solids/titratable acidity ratio.

Hence, the present study aimed to evaluate the fruit production and quality of guava as a function of biofertilizers and N fertilizing in Brazilian semiarid.

MATERIAL AND METHODS

Plant materials and growth conditions

Guava (*Psidium guajava*) plants cv. Paluma propagated by cuttings were used in this study.

The study was carried out from July 2014 to August 2015 (two consecutive trials) on the experimental farm of Federal University of São Francisco Valley, Petrolina County, Brazil. The climate of this region is classified as Bswh (Köeppen), which corresponds to a semiarid region.

During the execution of the experiment, the climatic data were collected by a meteorological station installed inside the experimental site (Fig. 1), while physical and chemical characteristics of the soil before the experiment are in Table 1. The soil is a Yellow Argisol (Ultisol - American classification Soil Taxonomy).

One year old guava plants, spaced 4m between rows and 4m between plants, were daily micro-sprinkle irrigated with one emitter per plant for a flow of 42 L/h based on daily evapotranspiration registers recorded by a meteorological station inside the experimental station and corrected according to the guava culture coefficient (Kc) defined by Natale (2009).

Table 1: Chemical and physical characteristics of the soil (0-20 and 20-40 soil depth) in the experimental site before the execution of the experiment

Soil characteristic	Value	
	0-20 cm	20-40 cm
Organic matter (%)	0.56	0.53
pH (in water)	6.2	5.4
Ca^{2+} ($cmol_c/dm^3$)[b]	2.1	2.0
Mg^{2+} ($cmol_c/dm^3$)[b]	1.4	1.2
Al^{3+} ($cmol_c/dm^3$)[b]	0.0	0.0
K^+ ($cmol_c/dm^3$)	0.74	0.63
Na^+ ($cmol_c/dm^3$)	0.11	0.19
P (mg/dm3)[a]	207.0	58.0
Clay (g/kg)	95	11
Silt (g/kg)	32	60
Sand (g/kg)	870	774

[a]P, K: Mehlich 1; [b]Ca, Mg and Al: KCl 1 M extractor

The biofertilizer used in the experiment was obtained by anaerobic fermentation and consisted of [water + fresh bovine manure] at a ratio of [1:1] (in volume), under anaerobic fermentation during 30 days, as proposed by Santos (1991). The bovine manure used was once collected during the morning as soon as produced by dairy confined Holstein cows, property of the Animal Department of Federal University of São Francisco Valley, in Petrolina County, Brazil.

Biofertilizers were biweekly distributed in a soil area of 0.283 m^2 (30 cm of radius around plant stem) under water: biofertilizer ratios according to each treatment, but fixing the amount of 2.4 L m^2 of plant canopy quoted by Cavalcante et al. (2008). The biofertilizer used in the experiments presented the 0.72 g $\cdot dm^{-3}$ of N, 0.04 g $\cdot dm^{-3}$ of P, 0.50 g $\cdot dm^{-3}$ of K, 0.20 g $\cdot dm^{-3}$ of Ca, 0.12 g $\cdot dm^{-3}$ of Mg and 0.39 g $\cdot dm^{-3}$ of S.

All management practices for pruning, control of weeds, pests and diseases were performed following the instructions of Natale (2009). The nutrient management was carried through a fertigation system (Viqua® venturi injector of 1" at 10 bar operating pressure), according to soil analysis (Table 1) biweekly, starting after production pruning until 20 days before harvest, using a formulated fertilizer composed by 12% of N, 5% of P, 11% of K, 13.1% of Ca and 0.2% of B. Treatments fertilized with 100% of N also received urea (45% of N). Zinc (Coda Zinc®, 10.4% of Zn), magnesium (Coda Mg®, 6.6% de Mg) and iron (Codamin Br®, 2.0% of Fe) were leaf applied.

Treatments and experimental design

The experimental design was randomized blocks with treatments distributed in a factorial arrangement (5 x 2) referring to biofertilizer concentrations [0, 2.5, 5.0, 7.5 and 10% of the fertigated volume] and mineral fertilizing with N [fertilization with 50% and 100% of N recommended by Natale (2009)], with four replications of five plants each, to evaluate three.

Data gathered and statistical analyses

During the fruit harvest time, i.e., July 2014 to August 2015, 10 fruits per parcel were manually harvested still firms at intermediate green color (yellow-green color) placed in plastic boxes and taken to the Laboratory for post-harvest fruit quality analyses. This harvest parameter

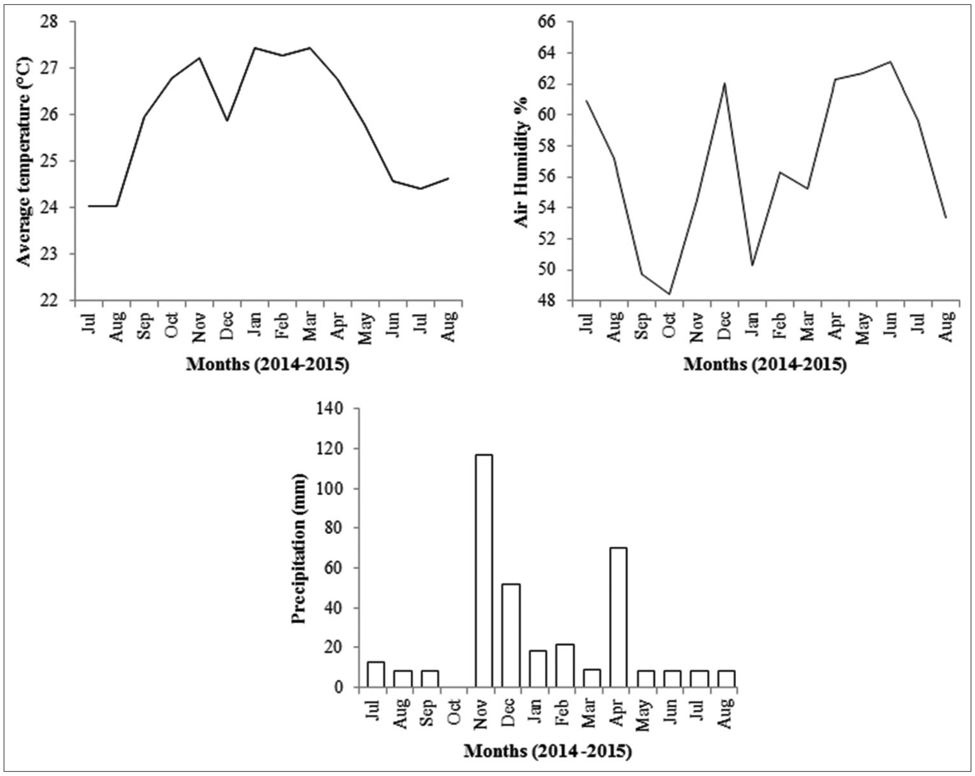

Fig 1. Average air temperature, air humidity and precipitation during the execution of the experiment.

for fruit selection was recommended by Natale (2009) for commercial farms.

The fruit analyses of the guava fruits followed the instructions of Zenebon et al. (2008) and included the usual parameters: I) the fruit mass was measured using a Sartorious® (Göttingen, Germany) brand precision balance (0.01 g precision) and expressed in g; ii) length and width were obtained with a digital paquimeter (0.01 mm–300 mm, Starret®) and expressed in cm; iii) for the titratable acidity (TA), 20 g of macerated fruit pulp was taken from yellow passion fruits and brought to a final volume of 100 mL by adding distilled water. A 20 mL sample was taken from the mixture, and three to four drops of phthalein were used as an indicator. This suspension was titrated with 0.1 N sodium hydroxide (NaOH). The results were expressed as a percentage; iv) the soluble solids (SS), expressed as °Brix, were measured using an Abbe® refractometer (Bausch and Lomb, Rochester, NY, USA); v) The vitamin C content was defined with 5 g of fruit pulp taken from acerola and brought to a final volume of 100 mL by adding distilled water plus 1 mL of 1% amid solution. A 20 mL sample was taken from the mixture and titrated with 1N iodine. The results were expressed in mg/100 g of fresh fruit; vi) the pulp pH was measured using a Marconi® pH meter; vii) fruit firmness (N) was measured using a fruit hardness tester (Instrutherm®, Brazil); viii) after chemical analyses, the relation between the soluble solids and the titratable acidity (SS/TA ratio) was calculated; and ix) the fruit production was measured as kg per plant.

Statistical analyses

Statistical analyses included analysis of variance (ANOVA), mean separation of N fertilizing using Tukey's test, simple regression to separation of biofertilizers doses, using combined data of two consecutive trials. All the calculations were performed using the SAS Statistical Program, and terms were considered significant at $P \leq 0.01$.

RESULTS AND DISCUSSION

Physical fruit characteristics

Among the guava fruit physical characteristics, the interaction between biofertilizer and nitrogen fertilization were significant only for fruit width (Table 2).

As can be seen in Table 2, plants fertigated with 50% of recommended N presented significantly higher fruit length and width than those plants which received 100% of recommended N. All average values quoted in Table 2 are higher than 72.9 mm (width) and 58.0 mm (length) reported by Medeiros et al. (2004) who evaluated the physical and chemical characteristics of guava fruits cv. 'Paluma' as a function of N doses; and also higher than 62.9 mm (width) and 52.7 mm (length) recorded by Lima et al. (2002) in study about different guava cultivars in São Francisco Valley.

Table 2: Fruit characteristics (length, width, firmness and mass) of guava as a function of biofertilizer concentrations and N fertilizing (fertilization with 50% and 100% of recommended N following plant demand)

	Length (mm)	Width (mm)	Firmness (N)	Mass (g)
Biofertilizer (B) 'F' value	4.30*	8.48**	8.36**	0.90ns
N Fertilizing (N) 'F' value	11.28**	56.06**	0.01ns	0.01ns
50%	87.25a	78.27a	54.34a	176.12a
100%	81.44b	70.43b	54.43a	177.72a
General median	84.35	74.35	54.39	176.92
SMD	3.63	2.20	11.69	26.72
Interaction (B x F) 'F' value	2.50ns	6.52**	0.77ns	0.54ns
Coefficient of variation (%)	5.62	3.85	12.30	19.67

**Significant at $P<0.01$ probability error; *significant at $P<0.05$ probability error; ns: Non-significant, data followed by different letters in columns are significantly different according to tukey test ($P<0.01$); SMD: Significant minimum difference

Fruit width and length were affected by biofertilizer doses (Fig. 2A and 2B), i.e., the average values of both variables decreased with biofertilizer dose increasing. The largest fruit size (width and length) recorded to lower biofertilizers doses can be attributed to the N supply associated with biofertilizer action that contains humic substances able to interact with N availability (Cunha et al., 2015) and even in small amounts provide the N adequate supply for guava. It is important to point that fruit width showed in Fig. 2B refers to plants fertigated with 100% of recommended N, because those fruits produced by guava plants fertilized with 50% of recommended N presented no adjustment to any regression model.

The fruit firmness values ranged from 43.90 N (0.0% of biofertilizer) to 63.68 N (2.5% of biofertilizer) (Fig. 2C), a result similar to that reported by Mesquita et al. (2007) who evaluated the effect of two bovine biofertilizers (simple and enriched) on papaya cv. 'Baixinho de Santa Amália'. This way Paiva et al. (2009) detach that the molecular processes responsible for major fruit changes during ripening is related to fruit firmness, which is one of the key attributes that guarantee fruit quality for *in natura* consumption, and fruit firmness is related with K nutrition, since, according to Lima et al. (2008), K supports the maintenance of cell turgor and it contributes to tissue resistance, but the NK combination affects fruit firmness along the maturation stages. Additionally, the biofertilizer used in the present experiment had high K levels (Table 2), which probably favored the fruit firmness increasing with a maximum value at 2.5% of biofertilizer (Fig. 2C). Whether compared to the scientific literature, the average values of Fig. 2C are much higher than those obtained by Lima et al. (2008) in study about guava 'Paluma' in São Francisco Valley, but lower than the average reported by Pérez-Barraza et al. (2015) in Mexico for the same guava cultivar.

Chemical fruit characteristics

The biofertilizer x N fertilizing interaction was significant for all chemical variables evaluated, while the N fertilizing simple effect was verified for soluble solids (SS), soluble solids/titratable acidity ratio (SS/AT) and vitamin C (Vit.C), with higher values recorded to those plants fertilized with 100% of N (Table 3).

Plants of all treatments produced fruits compatible with the current legislation requirements (MAPA, 2000) i.e., minimum 7.0 SS, and higher than 7.41 ± 0.14 range recorded by Batista et al. (2015) for guava cv. Paluma grown in São Francisco Valley (Table 3). Nitrogen plays an important role for leaf sugar biosynthesis, which can be translocated to fruits and increase fruit SS concentration (Souza et al., 2010) that should have occurred in the present study, since the highest SS average was recorded at the higher N (Table 3). Biofertilizer doses significantly affected guava SS, but there was no adjustment to any regression model.

Titratable acidity of fruits from plants fertigated with 100% of N decreased with biofertilizer doses increasing (Fig. 3A). Increasing biofertilizer doses also increased the supply of nutrients related to organic acids metabolism, especially potassium, because the biofertilizer used in the experiment present high K content (Table 2) and, according to (Busato et al., 2011) larger K amounts stimulates TA reduction due to acids degradation, especially malic acid by fruits transpiration. Independently of biofertilizer dose, all TA values recorded in the resent study are higher than those reported by Lima et al. (2008), lower than Oliveira et al. (2014) results, both of them in study about guava, but all of them are higher than minimum value required by Brazilian government, which is 0.4% (MAPA, 2000). Accordingly Chitarra and Chitarra (2005) detach that less acid fruits are more recommended to consumption as fresh fruit, while more acid fruits are required for food industry.

The SS/TA ratio as a function of biofertilizer doses presented no adjustment to any regression model. On the other hand, there was simple effect of N fertigation with superiority for plants fertigated with 100% of N (Table 3), which can be explained by the N action that favored the SS increase through the sugar translocation from leaves to

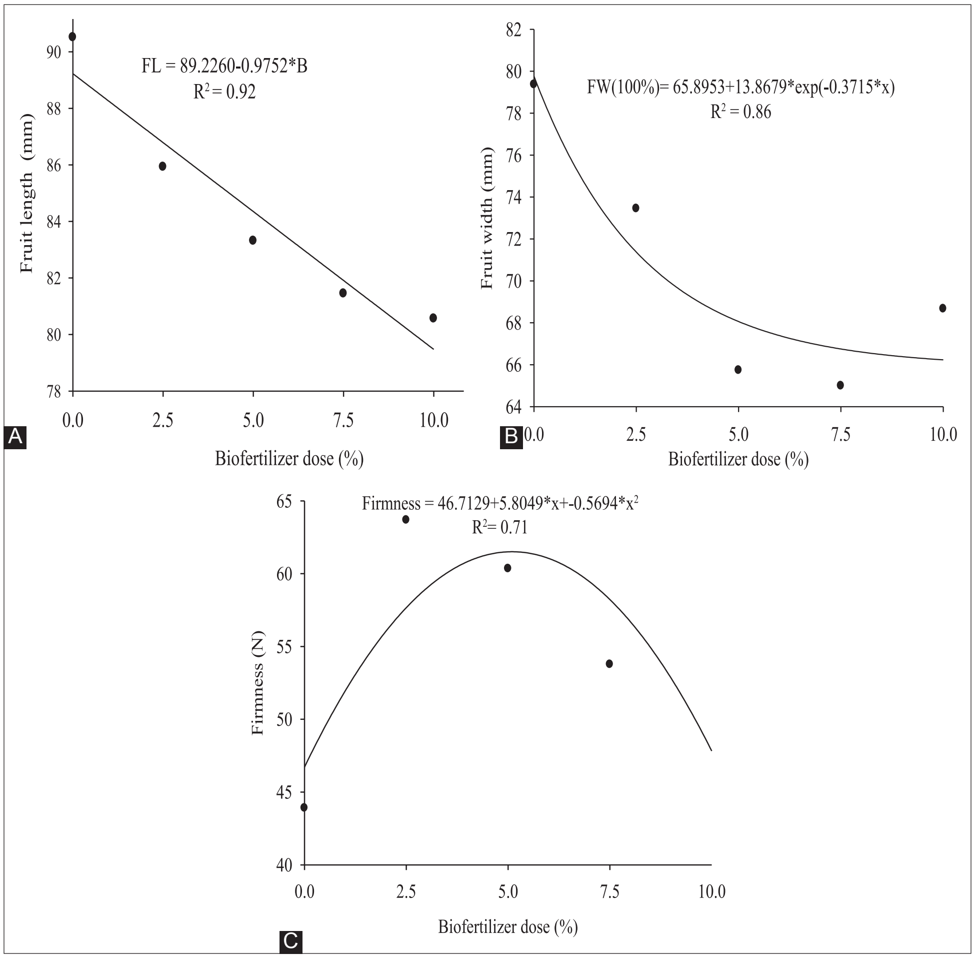

Fig 2. Fruit characteristics [length (A), width (B) and firmness (C)] of guava as a function of biofertilizer concentrations.

Table 3: Chemical fruit characteristics [soluble solids (SS), titratable acidity (TA), SS/TA ratio, vitamin C (Vit.C) and pH] and fruit production of guava as a function of biofertilizer concentrations and N fertilizing (fertilization with 50% and 100% of recommended N following plant demand)

	SS (ºBrix)	TA (%)	SS/TA	Vit.C (mg/100g)	pH	Fruit production (kg perplant)
Biofertilizer (B) 'F' value	60.17**	3.31*	41.11**	7.31**	12.92**	1.12*
N Fertilizing (N) 'F' value	26.49**	0.30ns	13.51**	128.52**	1.59ns	20.84*
50%	8.7b	0.49a	17.79b	70.08b	4.33a	40.04a
100%	9.7a	0.49a	18.59a	79.88a	4.35a	35.93b
General median	9.2	0.49	18.19	74.98	4.34	37.98
SMD	0.18	0.01	0.45	1.82	0.03	9.21
Interaction (B x F) 'F' value	16.68**	3.25*	17.06**	13.62**	16.93**	1.06ns
Coefficient of variation (%)	2.68	3.20	3.29	3.16	0.90	37.36

**Significant at P<0.01 probability error; *significant at P<0.05 probability error; ns: Non-significant, data followed by different letters in columns are significantly different according to tukey test (P<0.01); SMD: Significant minimum difference

fruits (Souza et al., 2010). In this sense Batista et al. (2015) evaluated guava fruit quality and found SS/AT of 18.87, therefore compatible with 18.59 contained in Table 3. According to Chitarra and Chitarra (2005), SS/TA ratio is one of the chemical variables commonly used to determine the fruit palatability and maturation, since it is a flavor indication. The average values of SS/AT of the present study are compatible to the current legislation requirements (MAPA, 2000), which requires least 17.5.

Vit.C guava concentration enhanced with biofertilizer doses increasing (Fig. 3B) that is in agreement with Dias et al. (2011) and Freire et al. (2010) who suggested that organic acids and sugars present in organic sources available for plants, such as biofertilizer can increase fruit vitamin C concentration. In general, all treatments produced fruits with Vit.C concentrations compatible to legislation requirements, i.e., 40 g/100g. Guava plants fertigated with 100% of N with Vit.C concentration

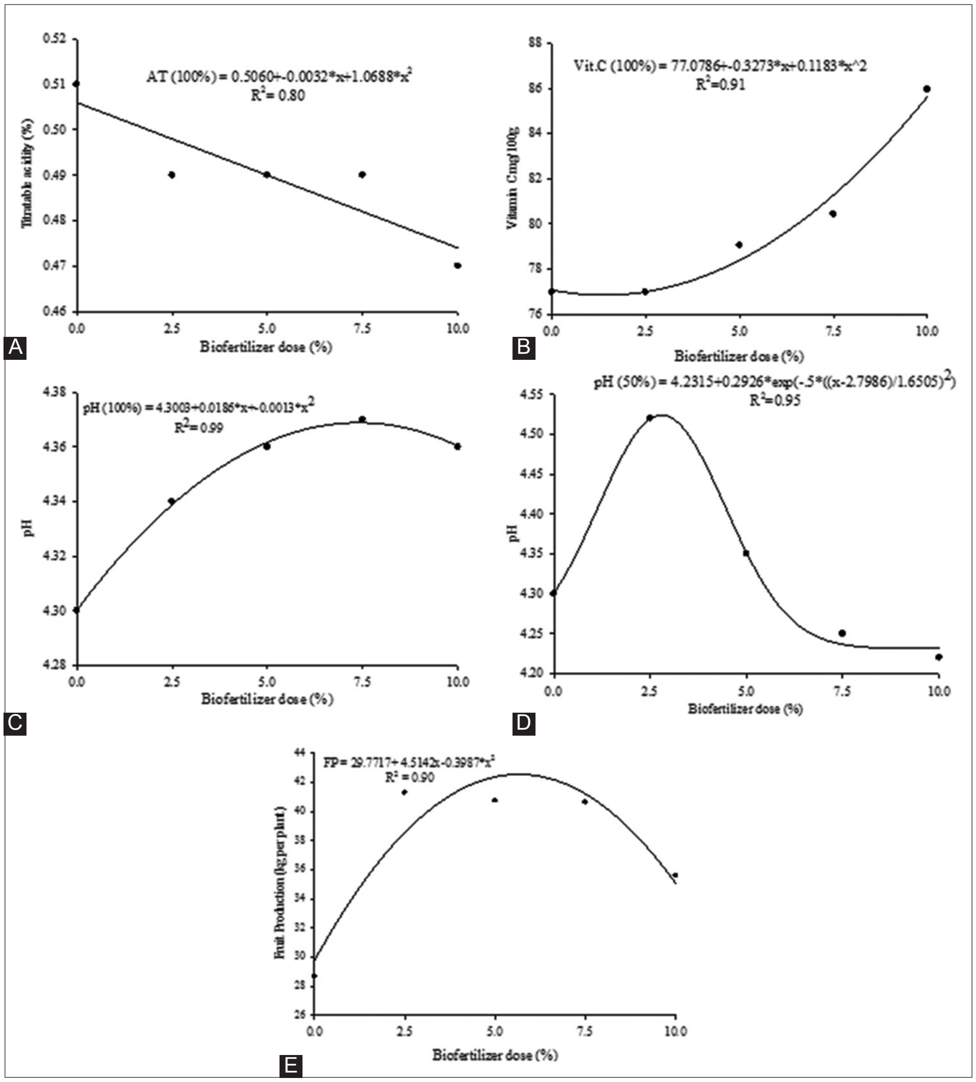

Fig 3. Chemical fruit characteristics [titratable acidity (A), vitamin C (B) and pH (C and D)] and fruit production (E) of guava as a function of biofertilizer doses. In the equations 50% and 100% means plants fertilized with 50% and 100% of recommended N.

higher than 73.2 g/100g registered by Malta et al. (2013), but lower than 89.78 g/100g average reported by Lima et al. (2002) for guava trees grown in São Francisco Valley. Indeed, Rufino et al. (2009) ague that vitamin C fruit concentration can vary depending on several factors such as light intensity, air temperature, air humidity and rainfall, of the region where plants are grown. In this sense, during the last 60 days before harvest of the first trial (December 2015 and January 2016) it was registered 70mm rainfall which may have effects on this vitamin C fruit concentration.

Fruit pH depended on biofertilizer doses (Table 3). Fruit pH increased until reach a peak at 7.5% (plants fertigated with 50% of N) and 2.5% (plants fertigated with 100% of N) followed by a consecutive decay, as can be seen in Fig. 3C and 3D, respectively. According to Busato et al. (2011), high fruit pH values are related to K absorption during fruit maturation, because ion K^+ accumulation result in cation exchange with H^+, thus increasing fruit pH. This can be happened in the present study because the biofertilizer used is K concentrated (0.50 g dm^{-3} K), according to Marrocos et al. (2012) reference. pH is a chemical variable that measures fruit acidity, therefore it can indicate the treatment necessary to preserve processed fruits (Chitarra and Chitarra, 2005). All treatments surpassed the maximum value required by Brazilian legislation (4.2) (MAPA, 2000). Evangelista and Vieites (2006) also found higher values than the maximum set by MAPA (2000), while Batista et al. (2015) found a pH range of 3.92 ± 0.07, thus within the standard defined by MAPA (2000).

Fruit production

Guava fruit production (kg per plant) for two production cycles was significantly affected by both N fertigation and biofertilizer doses (Table 3). Plants fertigated with 50% of N produced 4kg more than those fertigated with 100% of N, which corresponds to an estimated fruit yield of 25 tons per hectare (Table 3), a value higher than the most recent national data publication, which is 22,699 t/ha (IBGE, 2016). On the other hand non biofertilized plants produced almost 21% less fruits if compared to Brazilian statistics.

Biofertilizer doses had significant effect on guava fruit production (Table 3) with a large quantitative range from 28.69kg per plant or 17.96 t/ha (no biofertilizing) to the calculated peak of 42.54kg per plant (26.59 t/ha) recorded at 5.66% of biofertilizer. This average quantitative difference of 13.85kg per plant (8.66 t/ha, or 48.27%) should be evaluated by commercial farmers to define the economic viability of bovine biofertilizer through fertigation system.

Ramos et al. (2010) in study about guava cv. Paluma at five years old recorded in maximum 55.82kg per plant, while Amorim et al. (2015) in study with seven years old guava plants recorded 175kg per plan, this higher than 40kg per plant registered in the present study. Accordingly, plant age has a direct impact on guava fruit production and the plants of the present study were 2 years old at the first fruit harvest. Accordingly, Lima et al. (2008) evaluated N doses on 1.5 years old guava plants and registered 25kg per plant.

CONCLUSION

The results of this study indicate that: i) fruit quality of guava depends on bovine biofertilizer and N fertigation; ii) biofertilizer enhanced the fruit firmness, vitamin C and pH, beyond titratable acidity reduction of guava; iii) it is possible to recommend fertigation with biofertilizer at 5.66%, independently of N fertilizing with 50% or 100% of recommended N; and iv) bovine biofertilizer is an important key to the production of guava under semiarid climate.

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Author's Contributions

This experiment is an interdisciplinary one developed under field conditions with fruit analysis in laboratory. This manuscript is part of the M.Sc. Thesis (Plant Production) of Elisson Alves Santana advised by Prof. Dr. Ítalo Herbert Lucena Cavalcante and Profa. Dra. Karla dos Santos Melo de Souza. Thus, all authors accompanied all practices of the research, but more specifically Diogenes de Souza Brito and Raí Nascimento do Carmo acted on field data gathering, fruit analysis in laboratory and data preparations for statistical analysis.

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