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Manejo da aplicação do paclobutrazol na produção e qualidade de mangas ‘Tommy Atkins’

Efficient management of the application of paclobutrazol for the production and quality of 'Tommy Atkins' mango

Gestión de la aplicación de paclobutrazol en la producción y calidad de mangos 'Tommy Atkins'

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Kalline Mendes Ferreira
ORCID: https://orcid.org/0000-0002-9453-5334
Universidade do Estado da Bahia, Brasil
E-mail: kmf.agronomia@gmail.com
Welson Lima Simões
ORCID: https://orcid.org/0000-0003-1474-9410
Empresa Brasileira de Pesquisa Agropecuária Semiarido, Brasil
E-mail: welson.simoes@embrapa.br
Maria Aparecida do Carmo Mouco
ORCID: https://orcid.org/0000-0003-0697-9638
Empresa Brasileira de Pesquisa Agropecuária Semiarido, Brasil
E-mail: maria.mouco@embrapa.br
Juliana Leite da Silva
ORCID: https://orcid.org/0000-0002-7521-4017
Universidade do Estado da Bahia, Brasil
E-mail: juliana1697@outlook.com
Jucicléia Soares da Silva
ORCID: https://orcid.org/0000-0003-3409-0326
Empresa Brasileira de Pesquisa Agropecuária Semiarido, Brasil
E-mail: jucicleiass@gmail.com
Alessandro Carlos Mesquita
ORCID: https://orcid.org/0000-0002-9754-1676
Universidade do Estado da Bahia, Brasil
E-mail: alessandro.mesq@yahoo.com.br

Resumo

A aplicação do paclobutrazol (PBZ) via sistema de irrigação, para induzir o florescimento da mangueira, possibilita uma aplicação de forma segura além de sua melhor disponibilização, reduzindo-se os custos de produção enquanto se protege o operário e o ambiente. O objetivo desse trabalho foi determinar a dose mais eficiente do PBZ a ser aplicada via sistema de irrigação para manejo da produção e qualidade de frutos na mangueira cultivar Tommy Atkins na região do Submédio Vale do São Francisco. O delineamento experimental utilizado foi em blocos casualizados, com cinco doses de PBZ aplicadas via sistema de irrigação (0,5; 1,0; 1,5; 2,0; 2,5 g i.a.m^{-1} linear de copa) e um tratamento adicional (controle), com a aplicação de uma dose na forma convencional (2,0 g.i.a.m^{-1} linear de copa aplicada manualmente a lanço), com quatro repetições. As variáveis analisadas foram: número e comprimento da panícula, número de frutos por planta, peso médio de fruto, produção por planta e as características qualitativas dos frutos. A aplicação do PBZ via sistema de irrigação demonstrou-se mais eficiente que a aplicação convencional, na qual a dose 1,4 g i.a.m^{-1} linear de copa proporcionou um maior número de frutos e produção por planta. O maior teor de sólidos solúveis totais nos frutos foi obtido na dose 1,3 g.i.a.m^{-1} linear de copa e a acidez diminui à medida que se aumentou a dose de PBZ aplicada. Em relação à análise econômica, os resultados mostram que a aplicação de pbz pelo sistema de irrigação aumenta a receita em R$ 5.328,00 por hectare em comparação à aplicação convencional.

Palavras-chave: *Mangifera indica* L; PBZ; Pós-colheita; Frutas.

Abstract

The application of paclobutrazol (PBZ) by irrigation system to induce the flowering of mango may be an economically and environmentally more efficient practice. The objective of this work is to determine the most efficient dose of PBZ to be applied by irrigation system to manage the production and quality of fruits of the mango cultivar ‘Tommy Atkins’ in the middle region of the São Francisco Valley. The experimental design was randomized blocks with five paclobutrazol doses applied by irrigation system (0.5, 1.0, 1.5, 2.0 and 2.5 g a.i.$^{-1}$, linear canopy) and an additional treatment (control) with the application of a dose using the conventional form (2.0 g a.i.$^{-1}$ linear canopy applied manually by haul), and four replications. The variables analyzed were number of panicles, panicle length, number of fruits per plant, average fruit weight, production per plant, economic viability, and qualitative characteristics of fruits. The application of paclobutrazol by irrigation system is more efficient than the conventional application, in which the dose 1.4 g a.i.$^{-1}$ linear canopy provided a greater

number of fruits and a greater production per plant. The highest content of total soluble solids in fruits was obtained at the dose 1.3 g a.i.$^{-1}$ linear canopy, and acidity decreased as the applied dose of PBZ increased. Regarding the economic analysis, the results show that the application of PBZ by irrigation system increases the revenue by R$ 5,328.00 per hectare in comparison with the conventional application.

Keywords: *Mangifera indica* L; PBZ; Post-harvest; Fruits.

Resumen

La aplicación de paclobutrazol (PBZ) a través del sistema de riego, para inducir la floración de la manguera, permite una aplicación segura además de su mejor disponibilidad, reduciendo los costos de producción y protegiendo al trabajador y el medio ambiente. El objetivo de este trabajo fue determinar la dosis más eficiente de PBZ que se aplicará a través del sistema de riego para administrar la producción y la calidad de las frutas en el cultivar de mango Tommy Atkins en la región Sub-Media del Valle de São Francisco. El diseño experimental utilizado fue en bloques al azar, con cinco dosis de PBZ aplicadas a través del sistema de riego (0.5; 1.0; 1.5; 2.0; 2.5 g corona lineal iam^{-1}) y un tratamiento adicional (control), con la aplicación de una dosis en la forma convencional (2.0 giam^{-1} lineal de copa aplicada manualmente al arrastre), con cuatro repeticiones. Las variables analizadas fueron: número y longitud de la panícula, número de frutos por planta, peso promedio del fruto, producción por planta y las características cualitativas de los frutos. La aplicación de PBZ a través del sistema de riego demostró ser más eficiente que la aplicación convencional, en la que la dosis lineal de 1,4 g i.a.m^{-1} de la corona proporcionó un mayor número de frutos y producción por planta. El mayor contenido de sólidos solubles totales en las frutas se obtuvo a una dosis de 1.3 g.i.a.m^{-1} de corona lineal y la acidez disminuyó a medida que aumentó la dosis aplicada de PBZ. Con respecto al análisis económico, los resultados muestran que la aplicación de PBZ por el sistema de riego aumenta los ingresos en R$ 5.328,00 por hectárea en comparación con la aplicación convencional.

Palabras clave: *Mangifera indica* L; PBZ; Post cosecha; Fruta.

1. Introduction

Mango (*Mangifera indica L.*) is one of the most prized tropical fruits worldwide due to its pleasant taste and aroma and its attractive coloring and high nutritional value (Silva et al., 2012). The cultivation of mango is one of the main activities of the Brazilian fruit

agribusiness and has experienced a constant growth in recent years (Reetz *et al*., 2015). Brazil ranks seventh as a world producer and fourth as exporter of mango (FAO, 2020). It is grown in all Brazilian regions, and 75% of the production is in the Northeast region. In this region, cultivation occurs preferentially in irrigated areas of the semiarid, which provide excellent conditions for the cultivation of this fruit, enabling high productivity and fruit quality (Almeida *et al*., 2015).

The second most planted cultivar in the Northeast region is 'Tommy Atkins' mainly due to its tolerance to anthracnose, the high productivity, and the high acceptance by domestic and foreign markets. Despite being a widely explored crop, it still faces problems related to regular flowering, which affects the supply of this fruit. Therefore, further research is needed to identify products and methods that control this phenomenon (Oliveira *et al*., 2014).

For an efficient management of mango production and in order to meet the different available markets during periods suitable for commercialization, it is necessary to use plant growth regulators, which makes it possible to modify the processes that stimulate flowering (Silva *et al*., 2017). Among regulators, paclobutrazol (PBZ) is the most used for mango crops. It acts by inhibiting the biosynthesis of gibberellins (Taiz and Zeiger, 2017), resulting in the reduction of vegetative growth and the promotion of mango flowering (Mouco *et al*., 2011).

Responses to the application of PBZ in mango may vary depending on cultivar and size, in addition to climatic conditions, especially temperature. The dose and form of application also influence the response of plants to PBZ (Mouco *et al*., 2010; Souza *et al*., 2016; Souza *et al*., 2018a). According to Chatzivagiannis *et al*. (2014), the knowledge of the dose to be applied to each mango cultivar is important for the establishment of marketing strategies for times of better market prices.

PBZ has been applied in a conventional way in the cultivation of mango by diluting the commercial product in water. The dilution is released into the soil next to the plant base or in the projection of the canopy. In order to increase economic viability, the application by irrigation system has been tested by some producers. However, few studies aim to certify this technique for cultivars planted in the middle region of the São Francisco Valley (Souza *et al*., 2016; Simões *et al*., 2017; Souza *et al*., 2018a).

Studies on the impacts of PBZ on fruit quality parameters are still contradictory. Reddy and Kurian (2014) did not report a significant effect of PBZ on the quality of 'Alphonso' mango. However, Burondkar *et al*. (2013), working with the same mango cultivar, reported that PBZ increased fruit quality. Souza *et al*. (2018a) also found a significant effect of PBZ on the fruit quality of 'Palmer' mango.

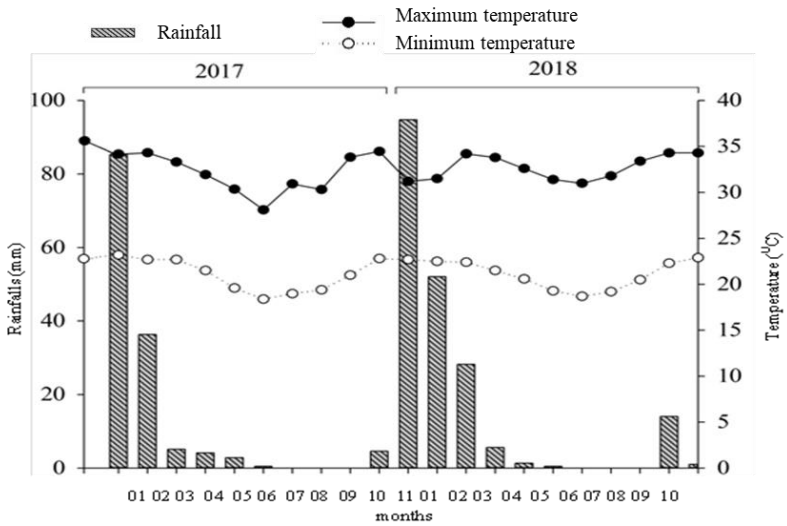
In this context, the objective of this work is to determine the most efficient dose of PBZ to be applied by irrigation system to manage the production and quality of fruits of the mango cultivar 'Tommy Atkins' in the middle region of the São Francisco Valley.

2. Material and Methods

The research aims to bring new knowledge to society as recommended by Pereira et al. (2018), this being a case study, ethnographic work conducted in the field. Some characteristics described in the methodology were analyzed in the laboratory, being the nature of the qualitative / quantitative work.

The experiment was conducted during two crop cycles in the field. The first cycle was from February to November 2017 and the second cycle was from February to November 2018. The site was an orchard of the mango cultivar 'Tommy Atkins' at the Fazenda Special Fruit in the municipality of Petrolina, PE, located at 9°8'8.9" S, 40°18'33.6" W, and 373 m of altitude. According to the Köppen classification, the region has a BSwh' climate, classified as semiarid. Rainfalls concentrate in November to April, with an average annual rainfall of around 500 mm, irregularly distributed. The relative humidity and the average annual temperature are 66% and 26.5ºC, respectively. The climatic data during the period of study are shown in Figure 1. Data were obtained from a meteorological station installed close to the experimental area.

Figure 1. Temperatures and rainfalls recorded during the two cultivation cycles of 'Tommy Atkins' mango in Petrolina, PE



Source: Research data, 2017/2018. Elaborated by the authors (2020).

As we can observe, since it is a semi-arid region, there is a low precipitation in the characteristic rainy months and a very low or zero precipitation in the others, with minimum temperatures above 18,4ºC. This highlights the need for irrigation in crops and the improvement of techniques to maximize efficiency in the use of water.

The orchard of mango trees of the cultivar 'Tommy Atkins,' with eight years of age, consisted of a spacing of 3 m x 10 m. The irrigation of the area was carried out by micro sprinklers installed next to the plant base. The time was determined based on crop evapotranspiration (ETc), which was obtained from the reference evapotranspiration (ETo) provided by a meteorological station installed close to the experimental area, using the Penman-Monteith model. A commercial mango orchard was managed with pruning, weeding, fertilizing and phytosanitary treatments, as described by Mouco (2015). The source of PBZ used to aid floral induction was Cultar, a commercial product with 25% active ingredient (a.i.).

The experimental design was randomized blocks with five PBZ doses applied by irrigation system (0.5, 1.0, 1.5, 2.0 and 2.5 g a.i.$^{-1}$, linear canopy) and an additional treatment (control) with the application of a dose in the conventional form (2.0 g a.i.$^{-1}$ linear canopy applied manually by haul), and four replications. The plots consisted of four plants; the two central plants were considered useful.

The plants were pruned and, after the emission of two vegetative flows, PBZ was applied in the forms and doses described above. PBZ was applied in the first cycle on 02/24/17 and in the second cycle on 02/26/18. After the application of PBZ, the irrigation system remained on to meet the evapotranspiration demands of the day's crop and to assist in the distribution of the product in the soil profile into which the root system was distributed. After 65 and 70 days after the application of PBZ, the leaf spraying of calcium nitrate and the reduction of the water blade started in order to induce the sprouting of branches that were already mature.

The following evaluations were performed: number and length of panicles (using a graduated ruler) during the flowering phase. For the evaluation of production per plant, the fruits of two useful plants per replication were collected, counted and weighed. The fruits were harvested at the E2 maturation stage, adopted as the standard for export.

Regarding quality assessment, four fruits were harvested and taken to the Embrapa Semiarid Post-harvest Physiology laboratory, where they were analyzed. The firmness of the pulp (N) was determined using a manual penetrometer (McCormick, FT 327) with a tapered

tip plunger (8 mm in diameter); the measurements were taken after peel removal at two opposite points in the equatorial region of the fruits.

The pulp was crushed in a domestic juice processor after peeling to determine the content of soluble solids (SS) using a digital refractometer (Milwaukee MA871) and readings within the range of 0 and 85°Brix; titratable acidity was determined by titrating 1 g of juice diluted in 50 mL of distilled water with 0.1 N NaOH; and pH was determined in the aqueous extract using a Kasvi pH digital LCD bench meter.

The economic analysis was performed in the conventional system and in the non-conventional system, verifying how many kilos per plant were produced. The result obtained was multiplied by 555, which is the number of plants in one hectare considering the planted spacing in the middle region São Francisco (3 x 6 m). The total production was multiplied by R$ 1.00, which is the average value of approximately one kilogram of 'Tommy Atkins' mango based on a historical series of producer prices obtained from CEPEA (2019), thus obtaining the total revenue per hectare. In relation to costs, the difference between the conventional and the non-conventional system was performed by subtracting from the total amounts the payment of a tractor and the employees that manually applied the PBZ.

It was established that, in the conventional way, it took an hour and twenty minutes of a tractor running with four employees throwing the product on plants per hectare. The cost of the tractor was R$ 120 per hour. The cost of a labor day's work was R$ 50.00. The values were transformed into minutes and then multiplied by 80 to obtain the results for one hour and twenty minutes. The system with the highest economic viability was the one that obtained the greatest positive difference between revenue and cost.

Data were submitted to analysis of variance. The average values of the dose 2.0 g a.i.$^{-1}$ linear canopy applied by irrigation system and conventional application (evaluation qualitative) were submitted to Tukey test (5%). The doses applied by irrigation system were submitted to regression (evaluation quantitative) when significant (5%). The analyses were performed using the SISVAR® 5.6 software.

3. Results and Discussion

Based on the analysis of variance of the factors, there was no significant interaction between doses of PBZ applied by irrigation system and crop cycles for all variables evaluated. Among cultivation cycles, the variables number of panicles, production per plant, average

fruit weight, firmness and titratable acidity presented higher averages during the 1st cycle of cultivation (Table 1).

Table 1. Production and post-harvest of the mango cultivar 'Tommy Atkins' in two crop cycles regardless of doses applied by irrigation system. Petrolina/PE, 2018.

	Number of panicles	Production (kg/plant)	Average fruit weight (g)	Firmness (N)	Titratable acidity (%)
1st cycle	148.25 a	58.83 a	0.45 a	5.04 a	1.50 a
2nd cycle	119.57 b	51.03 b	0.41 b	4.73 b	0.77 b
CV%	15.80	13.56	13.46	8.34	13.63

Means followed by the same letter in each column do not differ by Tukey test at 5% probability.
Source: Elaborated by the authors (2020).

The highest averages of number of panicles, production per plant and average fruit weight during the 1st cycle (Table 1) may be related to the biannual characteristic of mango. Years of high and low production alternate. In addition, the differences observed for these characteristics from one cycle to another may be associated with a difference in temperature during flowering (July), in which, as can be seen in Figure 1, the 2nd cycle was hotter, which may have impaired flowering and consequently mango production.

According to Narvariya and Singh (2018), this alternative behavior of mango may be due to improper orchard management practices, environmental factors, varietal character or hormonal imbalance, alone or in combination. Souza *et al*. (2018b), evaluating the productive performance of three mango cultivars during three agricultural cycles in the subtropical conditions of the state of São Paulo, also found such biannual behavior for mango and justified this fact in function of changes in climatic conditions in each cycle.

The difference in firmness and titratable acidity of fruits from one cycle to the next may be related to climatic and cultivation conditions in each cycle, in addition to the degree of ripeness of fruits at the time of analysis, since these factors exert a direct effect on the physiological and metabolic processes of plants and fruits.

The harvest of fruits of the 2nd cycle coincided with periods of higher temperatures, which may have accelerated ripening. Fruits presented less firmness and acidity, which are characteristics highly desired by consumers for the consumption of fresh fruits.

Souza *et al*. (2018a), evaluating the post-harvest of fruits of 'Palmer' mango during different cultivation cycles, also found a lower firmness (3.03 N) during the 2nd cycle, a value very close to that found in the present study.

Considering the forms of application of PBZ (dose 2 g i.a.$^{-1}$ linear canopy), it can be seen from Table 2 that the variables number of panicles, number of fruits per plant, production per plant and average weight of fruit had a significant effect.

Table 2. Number of panicles, number of fruits per plant, production and average weight of fruits of the mango cultivar 'Tommy Atkins' in function of forms of application of PBZ (dose 2 g i.a.$^{-1}$ linear canopy). Petrolina/PE, 2018.

	Number of panicles	Number of fruits per plant	Average fruit weight (g)	Production (kg/plant)
Conventional	122.63 b	113.19 b	0.39 b	49.58 b
Non-conventional	134.71 a	141.21 a	0.43 a	59.18 a
CV%	26.24	15.74	13.09	11.57

Means followed by the same letter in each column do not differ by Tukey test at 5% probability.
Source: Elaborated by the authors (2020).

Table 2 shows some phytotechnical characteristics that were analyzed, comparing the traditional way of applying PBZ with the proposed method (non-conventional), seeking to optimize the application of the growth regulator and, consequently, improvement in production. These evaluations were carried out in the field during the flowering and fruiting process of the plant, culminating in its production.

In general, the highest averages were obtained by non-conventional application, in which the number of panicles, the number of fruits per plant, the average fruit weight and the production per plant increased by 9%, 20%, 9% and 16%, respectively, compared to the conventional method. Therefore, the greater number of panicles resulted in a greater number of fruits per plant and, consequently, increased the production and yield of plants.

Souza *et al*. (2018a), evaluating the effects of PBZ applied in different ways on the production and quality of fruits of the mango cultivar 'Palmer,' also observed that the number of panicles, the number of fruits per plant and the productivity of the orchard presented higher averages by applying PBZ by irrigation system in comparison with the conventional method. According to these authors, this may have happened because the application by irrigation system allows a greater contact between PBZ and the mango root system since the distribution of the root system of the crop is within the range of soil watering, which can promote a more efficient assimilation of the product.

Regarding cultivation cycles, regardless of the application method (dose 2 g i.a.$^{-1}$ linear canopy), the highest values of number of panicles, production, number of fruits per plant,

average weight of fruits, firmness and titratable acidity were obtained in the first cultivation cycle (Table 3).

Table 3. Production and post-harvest of the mango cultivar 'Tommy Atkins' in two crop cycles regardless of application method (dose 2 g i.a.$^{-1}$ linear canopy). Petrolina/PE, 2018.

	Number of panicles	Production (kg/plant)	Number of fruits per plant	Average fruit weight (g)	Firmness (N)	Titratable acidity (%)
1st cycle	149.63 a	60.61 a	142.56 a	0.45 a	5.15 a	1.51 a
2nd cycle	107.71 b	48.16 b	111.83 b	0.37 b	3.98 b	0.78 b
CV%	26.24	11.57	15.74	13.09	11.57	14.53

Means followed by the same letter in each column do not differ by Tukey test at 5% probability. Source: Elaborated by the authors (2020).

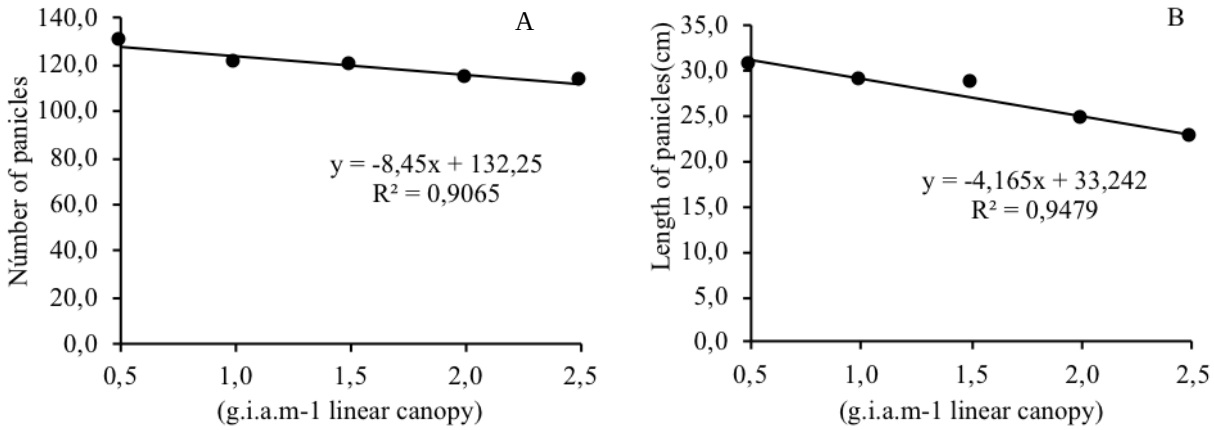
Table 3 shows flowering data and quantitative and qualitative fruit production, evaluated in the field and in the laboratory, considering the seasonality factor (climate), since two plant production cycles are considered.

These results further demonstrate the biannual behavior of mango, during which there is alternation of production from one cycle to another. In addition, the lower production averages observed in the 2nd cultivation cycle are probably due to the high temperatures that occurred in July, when plants were in full bloom (Figure 1), which ended up making flowering and plant production more difficult. According to Rodrigues *et al*. (2013), higher temperatures provide a greater plant vegetative development, while milder temperatures promote the development of reproductive buds with excellent mango growth between 24°C and 30°C because very low temperatures and very high temperatures affect growth, development and production, in addition to fruit quality. Souza *et al.* (2018a), working with the cultivar 'Palmer,' and Mouco and Albuquerque (2005), working with the cultivar 'Tommy Atkins,' also found the highest number of fruits and productivity during the 1st harvest.

Regarding post-harvest characteristics, the lowest averages found in the 2nd cycle can also be related to higher temperatures that occurred near the harvest period, as the climatic data in Figure 1 show. Silva *et al*. (2012), evaluating the cultivars 'Palmer,' 'Parwin,' 'Haden' and 'Tommy Atkins,' reported values of firmness ranging from 67.91 to 103.19N, well above those found in the present study. However, the authors found values of titratable acidity varying from 0.84 to 0.90% of citric acid, results close to those verified in this study.

When evaluating the influence of PBZ doses applied by irrigation system on biometric variables, the number and the length of panicles showed a decreasing linear behavior (Figure 2A and 2B).

Figure 2. Number (A) and length (B) of panicles of the mango cultivar 'Tommy Atkins' in function of paclobutrazol doses applied by irrigation system in the sub-middle region of the São Francisco Valley. Petrolina/PE.



Source: Elaborated by the authors (2020).

It is important to highlight that the characteristics evaluated in this figure showed an inverse response when the dose of the regulator applied.

The highest number (131) and length (31 cm) of panicles were found at the dose 0.5 g i.a.$^{-1}$ linear canopy. The dose of 2.5 g i.a.$^{-1}$ linear canopy provided a lower number of panicles per plant (113) and decreased panicle length by 8 cm.

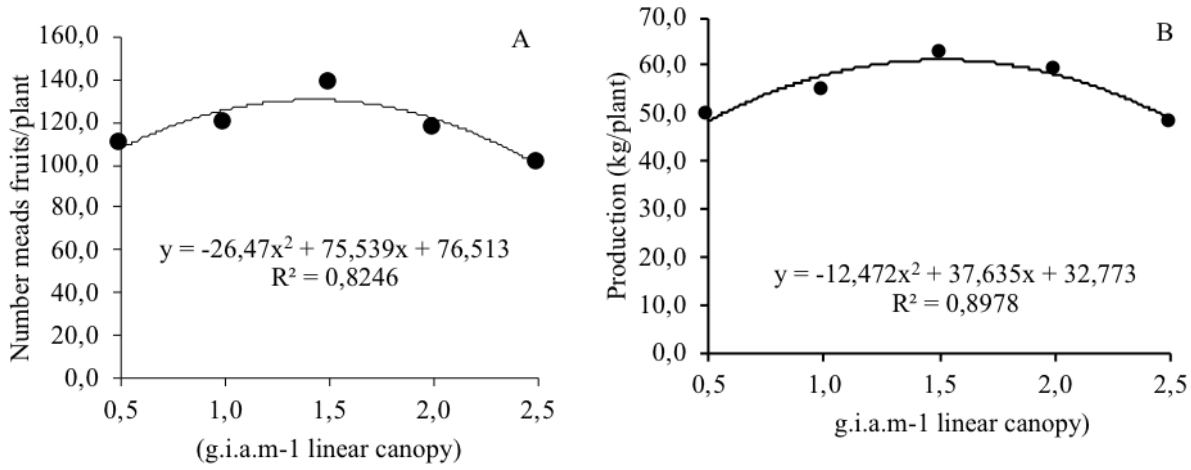
Oliveira *et al*. (2017), studying the flowering of 'Ubá' mango trees in Viçosa in function of PBZ doses, observed that the increase in the PBZ dose provided a higher percentage of flowering, whose values were higher in the presence of 1.62 g of PBZ linear canopy meter. The same behavior was observed by Coelho *et al*. (2014) analyzed the effects of different doses of PBZ on the flowering of 'Tommy Atkins' mango in the Vale do Paraguassu region and found that the application of PBZ promoted an increase in the percentage of flowering at all doses when compared to the control. Thus, the reduction in the number of panicles observed in the present study, due to the increase in PBZ dosages, may be related to the fact that each cultivar responds differently to the application of PBZ, and cultivars that have an intense vegetative capacity require higher doses of the product to control sprouting (Albuquerque *et al*, 2002). In addition, according to the same authors, sensitivity to PBZ will also depend on climate, age and the vigor of the plant.

The reduction in panicle length due to the increase in PBZ doses (Figure 2B) may have occurred because PBZ acts by inhibiting the conversion of ent-kaurene into ent-kaurenoic acid by the gibberellic acid pathway, thus decreasing the levels of gibberellins and resulting in

a reduction in the rate of cell stretching and division (Luna *et al*., 2014). The use of PBZ in mango promotes the regulation of plant vegetative growth, stimulating flowering and fruiting (Ramiréz and Davenport, 2010). According to Husen *et al*. (2012), the application of high concentrations of PBZ leads to the compaction of the canopy and panicles.

Evaluating the average number of fruits and the production per plant in function of doses of PBZ applied by irrigation system (Figures 3A and 3B), these variables fitted the quadratic model and there was an increase with the addition of the PBZ doses up to the maximum dose of 1.4 g i.a.$^{-1}$ linear canopy, which was equivalent to 130 fruits per plant and a production of 61.16 kg/plant.

Figure 3. Number of fruits (A) and production per plant (B) of the mango cultivar 'Tommy Atkins' in function of paclobutrazol doses applied by irrigation system in the sub-middle region of the São Francisco Valley. Petrolina/PE.



Source: Elaborated by the authors (2020).

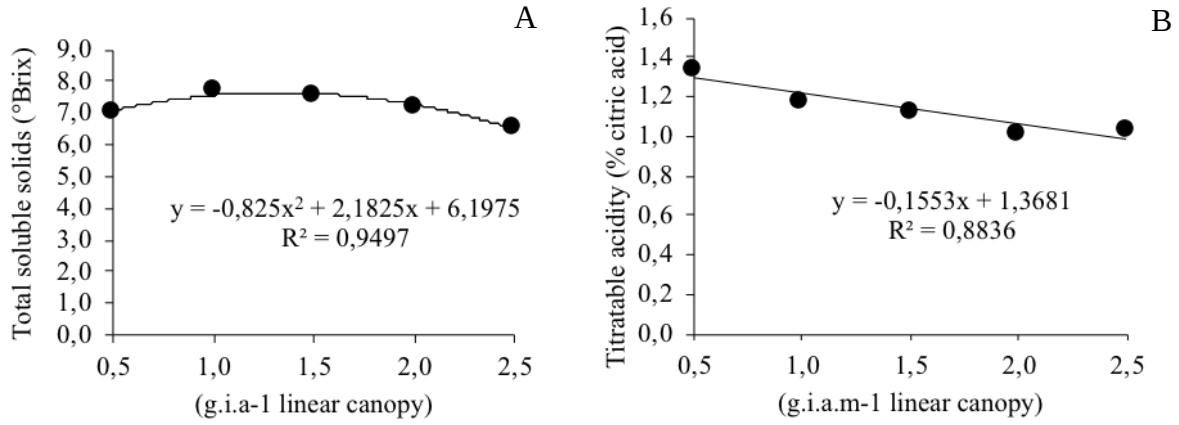
Similar results were reported by Souza *et al*. (2018a), who sought to adjust the dose of PBZ to be applied by irrigation system in order to manage production of 'Palmer' mango cultivar; the authors observed that the number of fruits per plant increased up to the dose of 1.3 g i.a.$^{-1}$ of canopy, with a production of 132 fruits per plant. Chatzivagiannis *et al*. (2014), analyzing the influence of different concentrations of PBZ applied conventionally in different mango cultivars, found a significant increase in number of fruits up to the dose 0.8 g i.a.$^{-1}$ linear canopy, and after that limit there was also a decrease in production.

Regarding production per plant, Coelho *et al*. (2014), evaluating the effects of different doses of PBZ on flowering and fruiting of 'Tommy Atkins' mango applied in a conventional way, also found that the increase in production per plant followed a second degree polynomial

function, in that the highest production (57 kg/plant) was obtained with the application of the dose 1.1 g i.a.$^{-1}$, corroborating the results obtained in the present study.

Regarding the post-harvest characteristics, there were significant differences between the doses applied by irrigation system only for the variables total soluble solids and titratable acidity. The content of total soluble solids showed a quadratic behavior, in which the increase in doses promoted an increase in total soluble solids content up to a maximum dose of 1.3 g a.i.$^{-1}$ linear canopy, which corresponded to 7.64 ºBrix (Figure 4A).

Figure 4. Total soluble solids (A) and titratable acidity(B) of fruits of mango cultivar 'Tommy Atkins' in function of paclobutrazol doses applied by irrigation system in the sub-middle region of the São Francisco Valley. Petrolina/PE.



Source: Elaborated by the authors (2020).

This parameter meets the standard required for the crop for fruits destined to distant markets, which can be harvested with a total soluble solids content of 7-8 ºBrix (Mouco, 2015). Oliveira *et al*. (2017) and Souza *et al*. (2018a) found no significant differences in the evaluation of total soluble solids contents in 'Ubá' and 'Palmer' mangoes submitted to different doses of PBZ. However, Oliveira *et al.* (2015), working with 'Palmer' mango, observed that the increase in the dose of PBZ reduced the soluble solids content from 16 ºBrix to 13 ºBrix; the lowest values were verified in fruits whose plants received the dose of PBZ of 0.9 g per linear canopy meter. Sarker and Rahim (2018), on the other hand, reported an average value of total soluble solids of 28 ºBrix in mango cultivar 'BARI Manga-3' (Amrapali), when they applied 7,500 ppm of PBZ. These results were higher than those found in the present study, which may be associated with the genotype and the fruit harvest point.

Regarding titratable acidity, there was a significant decrease with the increase in PBZ doses (Figure 4B). The highest titratable acidity (1.34%) was observed in the application of the lowest dose of PBZ (0.5 g i.a.$^{-1}$ linear canopy), while the lowest (1.03%) was verified with the application of the highest dose (2.5 g i.a.$^{-1}$ linear canopy).

Souza *et al*. (2018a) found that titratable acidity gradually decreased from the 1.0 g dose i.a.$^{-1}$ linear canopy applied by irrigation system. According to these authors, this behavior is probably related to fruit ripening, in which, according to Chitarra and Chitarra (2005), the ripening process reduces acidity and increases the amount of sugars (fructose). Reis *et al*. (2011), evaluating the effects of PBZ doses on the post-harvest of the 'Haden' mango cultivar, observed an average soluble solids content of 5.85° Brix and 0.14% of titratable acidity, values lower than those found in this study, which may be due to the fact that it is another cultivar and there is difference in the point of ripeness of the fruits during harvest. Oliveira *et al*. (2014), found that there was a significant increase in titratable acidity in 'Tommy Atkins' mango fruits up to the maximum applied dose (2.0 g i.a.), with an average value of 0.74%, thus confronting the result obtained in this study.

According to Sarker and Rahim (2018), the improvement in fruit quality in response to PBZ may be related to the assimilation of the plant's partition due to the greater suppression of vegetative growth. The assimilates become unidirectional for fruit development and as a result trees treated with PBZ have better fruit quality attributes.

Table 4 shows the economic analysis results by comparing the conventional and non-conventional PBZ application.

Table 4. Economic analysis of the estimated profitability difference between conventional and non-conventional application (by irrigation system) of PBZ for a hectare with a 3 x 6 m spacing.

	Production (kg/plant)	Total revenue (R$)	Cost to apply PBZ (R$)	Profitability (R$)	Difference between profitability (R$)
Conventional	49.58	27,528.00	205.00	27,323.00	5,328.00
Non-conventional	59.18	32,856.00	0.00	32,856.00	

Source: Research data, 2019. Elaborated by the authors (2020).

It is important to demonstrate that the use of the growth regulator aim to provide improve cultivation efficiency and consequently increase in productivity. Thus, in Table 4, we seek to describe the economic parameters that may justify to rural producers to implement such suggested techniques.

It appears that the total revenue from the non-conventional method (R$ 32,856.00) is higher than the conventional method (R$ 27,528.00), which is mainly associated with production per plant.

Regarding costs related to the form of application by irrigation system, a zero cost was considered since fertigation is a routine practice and there was an employee available for such function on the property. In the conventional case, the cost of the tractor was estimated at R$ 160.00 and of the four employees at R$ 45.00. The two costs, added together, indicated the cost of applying PBZ in the conventional way is R$ 205.00. The difference between the profitability of the non-conventional method (R$ 32,856.00) and the conventional method (R$ 27,323.00) shows that it is economically better to apply PBZ by irrigation system, increasing the profitability per hectare by R$ 5,328.00. It is worth mentioning, however, that the greatest effect is not simply on the reduction of production costs (tractor and labor) but on the higher productivity achieved and the greater efficiency in the application of the product in the area.

4. Conclusion and Suggestions

Paclobutrazol applied by irrigation system is more efficient than the conventional method, resulting in a higher production of 'Tommy Atkins' mango. The dose of 1.4 g i.a.$^{-1}$ linear canopy applied by irrigation system provides a gain in fruit production of 'Tommy Atkins' mango.

The highest content of total soluble solids in fruits was obtained at the dose 1.3 g a.i.$^{-1}$ linear canopy, and the acidity decreased as the applied dose of PBZ increased. From the point of view of profitability, the producer can increase its profitability by more than R$ 5,000.00 per hectare using the non-conventional system.

Future work should be carried out with other mango cultivars grown in the semi-arid region, as well as in other regions, highlighting the effect of handling the growth regulator application.

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Percentage of contribution of each author in the manuscript

Kalline Mendes Ferreira - 100%

Welson Lima Simões - 100%

Maria Aparecida do Carmo Mouco - 80%

Juliana Leite da Silva - 60%

Jucicléia Soares da Silva - 60%

Alessandro Carlos Mesquita - 100%