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## Research Article

# Paclobutrazol in the flowering management affects the quality of *Malpighia emarginata* fruits<sup>1</sup>

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## ABSTRACT

Floral management using the growth regulator paclobutrazol may be an alternative for promoting the uniformity of flowering and fruiting in West Indian cherry (*Malpighia emarginata* D.C.) plants. However, the effects of its use on fruit quality are still unknown. This study aimed to evaluate the effect of paclobutrazol doses on the fruit quality of *M. emarginata*. The experimental design was randomized blocks, in a 2 x 5 factorial arrangement, with three replications and three plants per plot, with the studied factors consisting of two *M. emarginata* cultivars ('Junko' and 'Flor Branca') and five paclobutrazol doses (0, 0.4, 0.8, 1.2 and 1.6 g a.i. m<sup>-1</sup> of canopy diameter). The following variables were evaluated: fruit mass, fruit transverse and longitudinal diameters, pH, soluble solids content, titratable acidity, soluble solids/titratable acidity ratio and vitamin C content. The use of paclobutrazol, to some extent, promoted the increase of fruit mass, longitudinal diameter and soluble solids contents. The 'Junko' cultivar presented a higher vitamin C content than that for 'Flor Branca', and the maximum vitamin C contents were obtained with the paclobutrazol doses of 0.64 and 0.81 g a.i. m<sup>-1</sup>, respectively for the 'Junko' and 'Flor Branca' cultivars. None of the studied factors promoted differences for pH and fruit acidity.

**KEYWORDS:** West Indian cherry, floral induction, growth regulator.

## RESUMO

Paclobutrazol no manejo da floração afeta a qualidade de frutos de *Malpighia emarginata*

O manejo floral com a utilização do regulador de crescimento paclobutrazol pode ser uma alternativa para promover a uniformização do florescimento e frutificação em aceroleiras (*Malpighia emarginata* D.C.). No entanto, os efeitos de seu uso na qualidade dos frutos ainda são desconhecidos. Objetivou-se avaliar os efeitos de doses de paclobutrazol na qualidade de frutos de *M. emarginata*. O delineamento experimental foi em blocos casualizados, em arranjo fatorial 2 x 5, com três repetições e três plantas por parcela, com os fatores estudados consistindo de duas cultivares de aceroleira ('Junko' e 'Flor Branca') e cinco doses de paclobutrazol (0; 0,4; 0,8; 1,2; e 1,6 g i. a. m<sup>-1</sup> de diâmetro de copa). As seguintes variáveis foram analisadas: massa dos frutos, diâmetro transversal e longitudinal dos frutos, pH, teor de sólidos solúveis, acidez titulável, relação sólidos solúveis/acidez titulável e teor de vitamina C. O uso de paclobutrazol, até certa medida, promoveu o aumento da massa, diâmetro longitudinal e teores de sólidos solúveis dos frutos. A cultivar 'Junko' apresentou teor de vitamina C superior ao da 'Flor Branca', e os máximos teores de vitamina C foram obtidos com as doses de paclobutrazol de 0,64 e 0,81 g i. a. m<sup>-1</sup>, respectivamente para as cultivares 'Junko' e 'Flor Branca'. Nenhum dos fatores estudados promoveu diferenças para pH e acidez dos frutos.

**PALAVRAS-CHAVE:** Acerola, indução floral, regulador de crescimento.

## INTRODUCTION

West Indian cherry (*Malpighia emarginata* D.C.) is a fruit species of the Malpighiaceae family, whose origin is undefined, although it has been reported to be native to the Caribbean and Antilles islands and commonly found in South America,

Central America and southern Mexico (Moura et al. 2018). In Brazil, it is present mainly in the Northeast region, where edaphoclimatic conditions are favorable to its development (Batista et al. 2018).

*M. emarginata* is widely used in the food and pharmaceutical industries as a natural source of vitamin C, with contents that may exceed 50-100 times

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those present in orange and lemon (Almeida et al. 2014), besides being rich in nutrients such as carotenoids, phenolic compounds, flavonoids and anthocyanins (Batista et al. 2018). Despite all the advantages associated with the nutraceutical properties of the fruit, its agronomic exploration faces some difficulties, mainly related to flowering and fruiting management. This plant presents an uneven and continuous flowering after outbreaks of vegetative growth, which provides a simultaneous presence of flowers and fruits in various stages of development, a factor that increases harvest and production costs (Almeida et al. 2014).

In this perspective, plant growth regulators, such as paclobutrazol (PBZ), have been studied as an alternative for the promotion of uniformity in flowering and production (Michelini & Chinnery 1988, Michelini & Chinnery 1989). However, the effects on the quality of *M. emarginata* fruits are still unknown.

Paclobutrazol [(2RS, 3RS)-1-(4-clorofenil)-4,4-dimethyl-2-(1H-1,2,4-triazole-1-il) pentan-3-ol] belongs to the triazoles group and acts by inhibiting the oxidation of ent-kaurene into ent-kaurenoic acid, in the second phase of gibberellin biosynthesis (Rademacher 2016), promoting the reduction of cell elongation and division in plants and, consequently, affecting growth, besides improving flowering uniformity.

Physiological changes in plants induced by the action of PBZ may cause modifications in the physicochemical quality of fruits (Barman & Mishra 2018). In avocado (*Persea americana*), Brogio et al. (2018) reported an increase of fruit mass and size; while, in 'Palmer' mango (*Mangifera indica* L.), Oliveira et al. (2015) observed a reduction in the soluble solids content. Oliveira et al. (2017), however, reported no effect of PBZ on the physical and chemical characteristics of 'Ubá' mango.

Therefore, the present study was developed to evaluate the fruit quality of the *M. emarginata* 'Junko' and 'Flor Branca' cultivars, as a function of PBZ doses on flowering management.

## MATERIAL AND METHODS

The experiment was conducted at an experimental orchard of the Universidade Federal do Vale do São Francisco (09°21'S, 40°34'W and 365 m above the sea level), in Petrolina, Pernambuco

state, Brazil, from January to May 2016. The climate of this region is classified as Bsh, semiarid, with mean annual rainfall of less than 500 mm (Alvares et al. 2013).

The *Malpighia emarginata* D.C. 'Junko' and 'Flor Branca' cultivars, propagated by grafting (with 'Junko' as rootstock) and with uniform vigor and canopy size, were used in this study.

The physical and chemical characteristics of the soil at the 0-20 cm and 20-40 cm depths were determined before the installation of the experiment (Table 1). The soil was classified as a typical cohesive Yellow Argisol (Silva et al. 2017).

The plants were spaced by 2.5 m between plants and 4.0 m between rows, and were daily irrigated using a micro-sprinkler system, with water supply equivalent to the daily evapotranspiration. Fertilization was performed weekly via fertigation, based on the results of the soil analysis (Table 1): 200 g of N and 150 g of K<sub>2</sub>O per plant were provided throughout the production cycle, in addition to foliar fertilizers with soluble compounds (10 % of N, 8 % of P<sub>2</sub>O<sub>5</sub>, 8 % of K<sub>2</sub>O, 0.5 % of Mg, 1 % of Ca, 2 % of S, 1 % of Zn, 0.5 % of B, 0.1 % of Fe, 0.1 % of Mo, 0.2 % of Cu and 0.5 % of Mn) at the dose of 1 mL L<sup>-1</sup>.

The adopted experimental design was randomized blocks, in a 2 x 5 factorial arrangement, with three replications and three plants per plot. The treatments consisted of two *M. emarginata* cultivars ('Junko' and 'Flor Branca') under floral management and five paclobutrazol doses (0, 0.4, 0.8, 1.2 and 1.6 g a.i. m<sup>-1</sup> of canopy diameter).

Table 1. Chemical and physical characteristics of the soil at the depths of 0-20 cm and 20-40 cm, before the experiment installation.

Soil characteristics	Value	
	0-20 cm	20-40 cm
pH (H <sub>2</sub> O)	6.20	5.40
Ca <sup>2+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	2.10	2.00
Mg <sup>2+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	1.40	1.20
Al <sup>3+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	0.00	0.00
K <sup>+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	0.74	0.63
Na <sup>+</sup> (cmol <sub>c</sub> dm <sup>-3</sup> )	0.11	0.19
P (mg dm <sup>-3</sup> )	207.00	58.00
Organic matter (%)	0.56	0.53
Sand (g kg <sup>-1</sup> )	95.00	11.00
Silt (g kg <sup>-1</sup> )	32.00	60.00
Clay (g kg <sup>-1</sup> )	870.00	774.00

P, K and Na: Melich 1; Ca, Mg and Al: KCl 1 M extractor.

Paclobutrazol was applied on January 27, 2016 (226 days after the seedling transplantation), in the morning, in four holes (10 cm in diameter and 10 cm in depth) per plant, at a distance of 30 cm from the stem, following the recommendation of Mendonça et al. (2001) for the mango crop. PBZ doses were defined according to the results of Michelini & Chinnery (1988), using as a source the commercial product Cultar™, whose doses were diluted in 1.0 L of water per plant. The reduction in the water supply began at 28 days after the paclobutrazol application and lasted for 15 days (Michelini & Chinnery 1988).

The harvest began at 44 days and finished at 125 days after the PBZ application. During this period, two harvests were conducted per week, between 7:00 a.m. and 9:00 a.m. The evaluated fruits were in the stage of commercial maturity, characterized by an external red color and sufficient firmness to support handling. The physicochemical quality analyses were performed on 15 fruits per plant, totaling 45 fruits per plot, with the total of evaluated fruits obtained from the successive harvests throughout the experimental period.

Fruit mass (g) was measured with a digital scale (0.5 g precision); the transverse and longitudinal diameters (mm) were determined with a digital caliper (Insize™ series 1108); the pH in a PHS-3E benchtop pH meter; the soluble solids contents (°Brix) in an Abbe benchtop refractometer; while the total titratable acidity (g 100 g<sup>-1</sup> of citric acid), soluble solids/titratable acidity ratio (SS/TA) and vitamin C (mg 100 g<sup>-1</sup>) were determined according to the Instituto Adolfo Lutz (IAL 2008).

The data were subjected to analysis of variance (Anova) by the F-test ( $p < 0.05$ ) and, if significant, the PBZ doses were subjected to regression analysis. The

statistical analyses were performed with the Assistat software (Silva & Azevedo 2016).

## RESULTS AND DISCUSSION

According to the results of the analysis of variance (Table 2), there was a significant effect of the cultivar factor on fruit mass, fruit transverse and longitudinal diameters, vitamin C and SS/TA ratio. The factor PBZ doses affected the fruit mass, fruit longitudinal diameter and soluble solids content, while the ‘cultivar x PBZ doses’ interaction was only significant for the vitamin C. No effect of the factors or the ‘cultivar x PBZ’ interaction was observed on pH and titratable acidity.

When analyzing the fruit mass as a function of the cultivars, it was observed that ‘Junko’ presented a result 35.27 % higher than that obtained for ‘Flor Branca’ (Table 2). In a survey conducted in the São Francisco Valley, the same region in which this study was conducted, Batista et al. (2015) reported that, for the ‘Flor Branca’ cultivar, the mean fruit mass was 4.09 g, a value 27.87 % lower than that obtained in the present study.

When evaluating the results of fruit mass, regarding the PBZ dose factor, an adjustment to the quadratic regression model was observed, with a positive effect on the estimated dose of 1.02 g m<sup>-1</sup> of the canopy and a maximum value of 7.07 g, with a decrease in this variable with higher PBZ doses (Figure 1).

Brogio et al. (2018), evaluating the effect of gibberellin inhibitors on ‘Hass’ avocado, observed that the PBZ dose of 1,750 mg L<sup>-1</sup>, via foliar spraying, provided an increase of 20.3 g in fruit mass, corroborating the results found by Barman & Mishra (2018), who observed that the application of 3.2 mL

Table 2. Analysis of variance for fruit mass (FM), fruit transverse diameter (TD), fruit longitudinal diameter (LD), pH, soluble solids content (SS), total titratable acidity (TA), soluble solids/titratable acidity ratio (SS/TA) and vitamin C content, as a function of cultivars and PBZ doses.

Source of variation	FM g	TD mm	LD mm	pH	SS °Brix	TA g 100 g <sup>-1</sup>	SS/TA	Vitamin C mg 100 g <sup>-1</sup>
Cultivar (C)	25.04*	33.45*	60.73*	0.34 <sup>ns</sup>	2.63 <sup>ns</sup>	3.03 <sup>ns</sup>	10.25*	30.91*
‘Junko’	7.67 a	24.92 a	21.40 a	3.15	6.39	1.24	5.17 b	1,842.03 a
‘Flor Branca’	5.67 b	21.61 b	18.52 b	3.17	6.92	1.11	6.41 a	1,372.81 b
PBZ (P)	1.24*	1.79 <sup>ns</sup>	1.25*	1.67 <sup>ns</sup>	0.42*	0.21 <sup>ns</sup>	0.55 <sup>ns</sup>	2.82 <sup>ns</sup>
C x P	0.85 <sup>ns</sup>	1.21 <sup>ns</sup>	0.51 <sup>ns</sup>	1.46 <sup>ns</sup>	1.10 <sup>ns</sup>	0.18 <sup>ns</sup>	0.35 <sup>ns</sup>	0.35*
CV (%)	16.35	6.72	5.08	3.06	13.48	17.32	18.34	14.38

<sup>ns</sup> Not significant; \* significant at 5 % of probability ( $p < 0.05$ ). Means with distinct letters in the column differ from each other by the F test. CV: coefficient of variation.

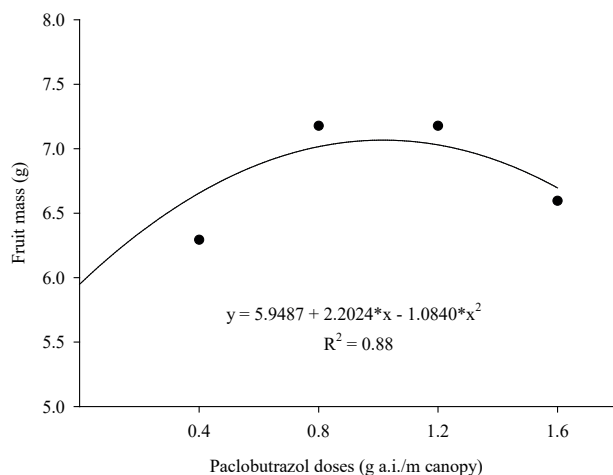


Figure 1. Mass of *Malpighia emarginata* fruits, as a function of paclobutrazol doses.

per linear meter of the canopy during floral induction, in 'Dashehari' mango, provided an increase in fruit weight, in relation to the control treatment.

Paclobutrazol is commonly used to reduce the vegetative growth in plants, thereby reducing the leaf area expansion and altering the source-drain balance, resulting in a greater allocation of photoassimilates to fruits (Reddy et al. 2013), what can favor their growth (Barman & Mishra 2018) and, consequently, lead to a higher accumulation of fresh matter. However, it is known that the effects caused by the use of plant regulators vary according to factors such as edaphoclimatic conditions, plant species, cultivar and application form.

For the fruit transverse diameter, 'Junko' presented results superior to those of the 'Flor Branca' cultivar, with a difference of 3.31 mm, although the PBZ application did not affect this variable (Table 2).

Regarding the longitudinal diameter, 'Junko' was also superior, with a result 2.92 mm higher than for 'Flor Branca' (Table 2). Menezes et al. (2018), evaluating nine different *M. emarginata* genotypes, observed measurements of transverse and longitudinal diameters ranging from 19.33 mm to 24.67 mm and from 17.51 mm to 21.25 mm, respectively, ranges that include the results obtained for the two cultivars evaluated in this study.

*M. emarginata* fruits may exhibit a diameter between 10 mm and 40 mm (Prakash & Baskaran 2018), and the differences observed in the present study are justified by the genetic characteristics of the

cultivars, since 'Junko' tends to present larger fruits than 'Flor Branca' (Souza et al. 2014).

For the isolated effect of the PBZ doses, the longitudinal diameter results adjusted to the quadratic regression model (Figure 2), with an increment up to the dose of 0.99 g a.i. PBZ m<sup>-1</sup>, estimating the best performance of 23.99 mm, followed by a reduction when increasing the PBZ doses.

Cavatte et al. (2012) observed that, for the 'Prata-Anã' banana cultivar, the use of PBZ reduced the fruit diameter; while, for the 'FHIA-01' cultivar, the responses to the different doses presented a quadratic behavior, with the highest recorded value of 0.92 g plant<sup>-1</sup>, exhibiting deleterious effects at higher doses. During the fruit growth process, cell division plays an essential initial role, with the later predominance of cell expansion for the increase of fruit volume (Chitarra & Chitarra 2005).

For the soluble solids content (Figure 3), the results adjusted to the quadratic regression model, as a function of the PBZ doses, with a maximum value of 6.85 °Brix at the dose of 0.38 g a.i. PBZ m<sup>-1</sup>, decreasing from this point and reaching the lowest value (6.2 °Brix) at the dose of 1.6 g a.i. PBZ m<sup>-1</sup>. However, the values obtained are above the minimum quality of 5.5 °Brix established by the Brazilian Ministry of Agriculture, Livestock and Supply (Brasil 2018).

Apparently, the effect of PBZ on soluble solids contents varies according to the crop and cultivar used. Oliveira et al. (2015) observed an increase in this variable, as a function of the use of PBZ

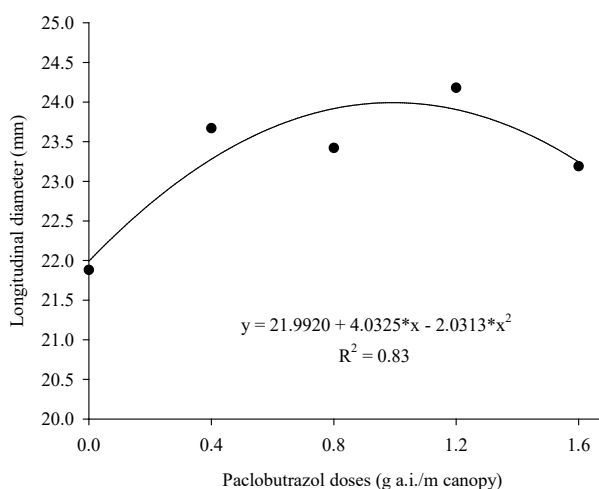


Figure 2. Longitudinal diameter of *Malpighia emarginata* fruits, as a function of paclobutrazol doses.



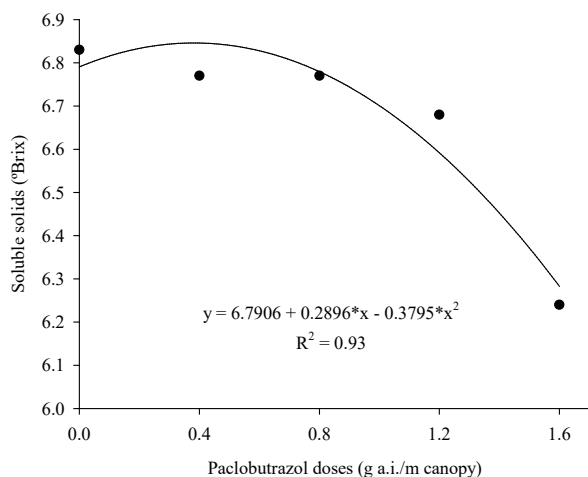


Figure 3. Soluble solids content of *Malpighia emarginata* fruits, as a function of paclobutrazol doses.

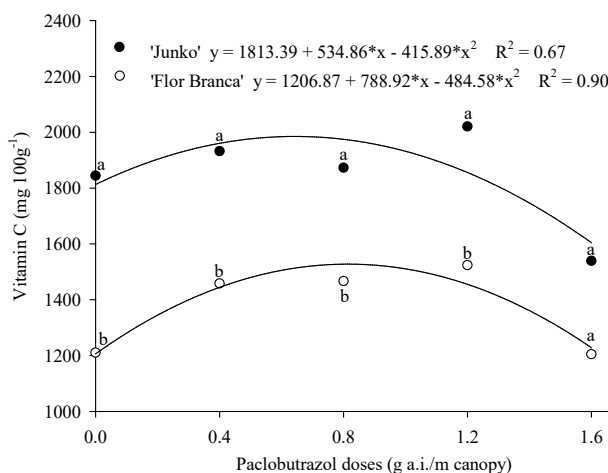


Figure 4. Vitamin C content of *Malpighia emarginata* fruits, as a function of cultivars and paclobutrazol doses.

in 'Palmer' mango, verifying a faster degradation in the postharvest period. However, Steffens et al. (1983) reported that PBZ may negatively affect alpha-amylase gene expressions, whose function is to catalyze the conversion of starch into sugars, justifying the linear decreasing behavior observed for soluble solids.

For the SS/TA ratio (Table 2), there was an increase of 1.24 for 'Flor Branca', when compared to 'Junko', justified by the higher soluble solids content and lower titratable acidity of 'Flor Branca', despite the non-significant difference for soluble solids and titratable acidity when evaluated separately. Menezes et al. (2018), studying the physical and chemical characterization of *M. emarginata* genotypes, observed values from 3.48 to 7.22, a range that includes the results in the present study. In contrast, Corrêa et al. (2017) obtained a 10.73 ratio in fruits of *M. emarginata* cv. 'Olivier', with the difference justified by the lower titratable acidity observed by the authors.

When analyzing the unfolding of the interaction for the vitamin C content (Figure 4), it is observed that, for all evaluated doses, 'Junko' provided better results than 'Flor Branca', with recorded differences of 634.21, 474.31, 405.91, 497.27 and 334.42 mg 100 g<sup>-1</sup>, respectively for the doses 0.0, 0.4, 0.8, 1.2 and 1.6 g a.i. PBZ m<sup>-1</sup>.

The vitamin C levels were affected by the PBZ doses, presenting a quadratic response in both cultivars (Figure 4). For 'Junko', the maximum estimated level was 1,985.34 mg 100 g<sup>-1</sup> of pulp at

the dose of 0.64 g a.i. PBZ m<sup>-1</sup>; whereas, for 'Flor Branca', a maximum value of 1,527.97 mg 100 g<sup>-1</sup> of pulp was observed at the dose of 0.81 g a.i. PBZ m<sup>-1</sup>. It is then noted that 'Junko' requires a 0.17 g a.i. PBZ m<sup>-1</sup> lower dose to obtain a pulp content greater than 457.34 mg 100 g<sup>-1</sup>, if compared to the 'Flor Branca' cultivar.

The vitamin C content of the 'Flor Branca' cultivar was also evaluated by Batista et al. (2018), who recorded a mean value of 1,713.28 mg 100 g<sup>-1</sup>; therefore, 341.18 mg 100 g<sup>-1</sup> higher than registered in this study for the same cultivar, but lower than the results obtained for the 'Junko' cultivar, which also presented a higher result than the values of 1,074.75 and 1,802.75 mg 100 g<sup>-1</sup> observed by Nasser et al. (2018), except for the result of 1.6 g a.i. PBZ m<sup>-1</sup>.

The effect of PBZ on the vitamin C content of fruit species present divergences in the scientific literature. Rehman et al. (2018), evaluating the effect of the pre-harvest application of prohexadione-calcium and PBZ on the fruit quality of 'M7' oranges (*Citrus sinensis* L. Osbeck), observed no significant effect on the vitamin C content, whereas a depressive effect on this variable was identified in fruits of the 'Red Delicious' apple cultivar (*Malus domestica* L.), in plants treated with PBZ via soil (Wani et al. 2007).

Apparently, gibberellin affects the anthocyanin content in the fruit, depending on the applied amount (Souza et al. 2017). Rosso & Mercadante (2007) affirm that anthocyanins may condense with vitamin C and promote an accelerated degradation of these compounds. In this sense, it is believed that PBZ

may have affected the total anthocyanin content of the fruit by promoting low endogenous gibberellin levels, fostering positive effects on the vitamin C content up to a certain dose.

For pH, the mean value observed for *M. emarginata* was 3.16, regardless of the cultivar; while, for titratable acidity, the mean value was 1.17 g 100 g<sup>-1</sup>, values higher than those established for the pulp quality standards of *M. emarginata*, which are 0.36 for pH and 0.37 g 100 g<sup>-1</sup> for titratable acidity (Brasil 2018).

## CONCLUSIONS

1. The 'Junko' cultivar presents higher physical quality and vitamin C contents than 'Flor Branca', although 'Flor Branca' has a higher soluble solids/ titratable acidity ratio;
2. The application of paclobutrazol in floral management affects the quality of *Malpighia emarginata* fruits. The dose of approximately 1 g a.i. m<sup>-1</sup> provides the highest fruit mass and longitudinal diameter; 0.38 g a.i. m<sup>-1</sup> the highest soluble solids content; and the maximum vitamin C contents were obtained with doses of 0.64 and 0.81 g a.i. m<sup>-1</sup>, respectively for the 'Junko' and 'Flor Branca' cultivars.

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