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Different rootstocks, irrigation, and nutritional management on the quality parameters of Montenegrina mandarins (*Citrus deliciosa* Tenore) cultivated in 'Vale do Caí' region, South Brazil

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SUMMARY

The objective of this work was to evaluate the qualitative parameters of Montenegrina mandarin fruits under different water and nutritional management, combined with two rootstocks, in the Vale do Caí region. The experiment was conducted in the city of São Sebastião do Caí, South Brazil, at UCS Campus. The experiment was bifactorial with two varieties of rootstocks (*Poncirus trifoliata* L. and Swingle citrumelo) and three cultivation systems (conventional, irrigated, and fertigated), completely randomized, with three replicates for each treatment. Fifty fruits were evaluated for average fruit mass (AFM), longitudinal and transverse diameters (Ø); 10 fruits for juice content (Jc), soluble solids content (SS), total titratable acidity (TA), ratio, and ascorbic acid content. The variables transversal Ø, AFM, Jc, SS, and ratio were not significantly influenced by the adopted treatments. Irrigated plants presented higher TA when compared to conventionally managed and fertigated plants. Swingle citrumelo presented greater longitudinal fruit Ø compared to *P. trifoliata*. Montenegrina fruits grafted to *P. trifoliata* presented a higher concentration of ascorbic acid compared to Swingle citrumelo fruits. For the conditions of Vale do Caí, with the climatic conditions of the years 2018/2019, would not be necessary to make use of irrigation and fertigation technologies to increase fruit quality.

Index terms: *Poncirus trifoliata*, Swingle citrumelo, fertigation, biometric parameters.

Efeito de diferentes porta-enxertos e manejos de irrigação e nutricional sobre os parâmetros de qualidade de mandarinas Montenegrina (*Citrus deliciosa* Tenore) cultivadas na região do Vale do Caí, Sul do Brasil

RESUMO

Este trabalho teve como objetivo avaliar os parâmetros de qualidade de mandarinas do tipo Montenegrina sob manejos de irrigação e nutrição diferentes, combinados com dois tipos de porta-enxertos, na região do Vale do Caí. O experimento foi conduzido na cidade de São Sebastião do Caí, Sul do Brasil, no Campus da UCS. O experimento foi do tipo bifatorial, com duas variedades de porta-enxerto (*Poncirus trifoliata* L. e citrumeleiro Swingle) e três formas de manejo (convencional, irrigado e fertirrigado), completamente casualizado, com três replicatas para

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cada tratamento. Cinquenta frutos foram utilizados na determinação da massa media de frutos (AFM) e diâmetros longitudinal e transversal (Ø); dez frutos foram utilizados para a determinação do teor de suco (Jc), sólidos solúveis (SS), acidez titulável total (TA), *ratio*, e teor de ácido ascórbico. As variáveis Ø, AFM, Jc, SS e *ratio* não foram influenciadas pelos tratamentos aplicados. As plantas irrigadas apresentaram frutos com maior TA do que as plantas conduzidas pelo manejo convencional e fertirrigado. Os frutos de plantas enxertadas sobre citrumeleiro Swingle apresentaram maior Ø longitudinal comparado ao *P. trifoliata*. Mandarinas do tipo Montenegrina enxertadas em *P. trifoliata* apresentaram maior concentração de ácido ascórbico comparativamente às frutas de plantas enxertadas sobre citrumeleiro Swingle. Para as condições do Vale do Caí, considerando os anos 2018/2019, não é necessário o uso de tecnologias de irrigação e/ou fertirrigação para incrementar a qualidade dos frutos.

Termos de indexação: *Poncirus trifoliata*, citrumeleiro Swingle, fertirrigação, parâmetros biométricos.

INTRODUCTION

In Rio Grande do Sul state, South Brazil, approximately 12,000 families cultivate some kind of citrus fruits for commercial purposes (Efrom & Souza, 2018). The edaphoclimatic conditions of the region allow the harvest of fruits with excellent color and flavor, highlighting the production of fruits for *in natura* consumption. According to Köppen's climate classification, the region has a Cfa (humid subtropical) climate (Alvares et al., 2013). Relative to mandarins, the state leads the national acreage ranking, with 11,758 ha and a total production of 148,432 t in 2019, corresponding to an average production of 12.678 $t \cdot ha^{-1}$ (IBGE, 2019).

The 'Vale do Caí' region highlights itself both in the production of *Citrus* fruits and of essential oil, processed by several industries of the region. Among the cultivated *Citrus* varieties, fruits of Montenegrina mandarin highlight themselves. The Montenegrina mandarin belongs to the species *Citrus deliciosa* Tenore and after the 'Valência' orange (*Citrus sinensis* Osb.), is the most cultivated *Citrus* with an acreage of 5,025 ha and raw production of 69,022 t in the Vale do Caí region in 2019, corresponding to an average productivity of 13.763 $t \cdot ha^{-1}$ (Efrom & Souza, 2018; IBGE, 2019).

Nowadays, the application of technologies that increase the overall efficiency of the agricultural productive system is of paramount importance, seeking to meet the worldwide increase in the demand for high-quality foods, associated with the growing integration of fruit consumption, to obtain more diverse and rich nutrition (Schneider, 2016). Besides, it is important to highlight the need for the rational use of natural resources. In this sense, water becomes increasingly important and determinant for successful production in the agricultural production units (Zanini et al., 1998; Otero & Goñi, 2009). To improve its use, irrigation and fertigation practices may be employed.

The water supply by irrigation provides better plant development, reduces flower and fruit drop, increases fruit quality, and also enhances the cultivation productivity (Bertonha et al., 2004; Pires et al., 2005). However, due to the climatic conditions of the Rio Grande do Sul state, the practice of irrigation is not commonly used, unlike in more arid regions, such as in Northeast Brazil, where the use of irrigation is an obligatory practice in *Citrus* cultivation and harvesting (Coelho et al., 2006; Koller, 2013).

Fertigation is a practice that consists of the addition of nutrients (fertilizers) in irrigation water (Quiñones et al., 2012). This is a rising practice in commercial orchard cultivations, in which the main advantage is the increase in overall absorption efficiency of the applied fertilizers, also being possible in some scenarios to reduce the amounts of fertilizers to be applied in the orchards without changes in the productivity and quality of *Citrus* (Gonçalves et al., 2017; Sravani et al., 2020). Moreover, fertigation allows a better arrangement of the nutrient supply according to the plants' demand, minimizing nutrient losses by leaching and also avoiding toxicity due to excessive accumulation in the soil. The use of fertigation also has a positive influence on the physiological parameters of plants, such as stomatic conductance, photosynthesis, and transpiration in periods of water deficit/drought during the harvest (Shirgure, 2012; Nirgude et al., 2016).

The use of rootstocks is a mandatory and very important practice in citriculture. Besides, it promotes resistance to serious illnesses, such as Citrus tristeza virus (CTV), *Phytophthora* spp., citrus blight, among others. The effect of the rootstock on the scion variety enables changes in its growth and size, provides adaption to some adverse edaphoclimatic contexts, and also influences plant productivity and fruit quality, among other characteristics (Bowman & Joubert, 2020). According to Souza et al. (2001), the interaction between the rootstock and the scion

becomes more significant when the plant undergoes water deficit, which may influence the degree of tolerance to drought of the scion cultivar.

Considering the status of citriculture in Rio Grande do Sul state, the resistance to low temperatures and frost are the most important factors for culture success (Efrom & Souza, 2018). As a result, most of the produced seedlings in South Brazil are grafted on the *Poncirus trifoliata* (L.) Raf. rootstock (Gonzatto et al., 2011; Carvalho et al., 2019). According to EMBRAPA (2008), this rootstock has as characteristics high resistance to cold, low tolerance to drought, and moderate tolerance to humid soils.

Besides, the *P. trifoliata* rootstock, the Swingle citrumelo [*C. paradisi* Macf. × *P. trifoliata* (L.) Raf.] also deserves a highlight in the citriculture of Rio Grande do Sul, once this rootstock also presents resistance to cold. This hybrid of the 'Duncan' pomelo (*C. paradisi* Macfad.) and *P. trifoliata* (Melgar et al., 2010; Gonzatto et al., 2011) is currently the most valued rootstock in Brazil because it is tolerant to *Citrus* sudden death (CSD), also having a high resistance to *Phytophthora* spp. gummosis. The fruits have good quality, with a longer ripening period (Oliveira et al., 2008; Koller, 2013).

In this sense, the present work aimed to evaluate the effect of the management kind (conventional, irrigation, and fertigation) and of the rootstock (*P. trifoliata* and Swingle citrumelo) on the quality parameters of Montenegrina mandarins cultivated in the 'Vale do Caí' region, South Brazil.

MATERIALS AND METHODS

Plant material characterization and cultivation conditions

The study was carried out in the Experimental Area of University of Caxias do Sul (UCS), located in the municipality of São Sebastião do Caí (29°37'03 S and 51°20'45 W), altitude of 18 m from sea level. The soil was classified as an arenic acrisol.

The orchard trees were evaluated at four years of age and were composed of Montenegrina mandarin trees, grafted on the rootstocks *Poncirus trifoliata* and Swingle citrumelo, with a spacing of 2.5 x 6.0 m. The treatments were the distinct management practices relative to irrigation and nutrition, being: conventional, irrigated, and fertigated. Irrigation was carried out by dripping, with a spacing of 0.5 m between drippers; two lines of drippers were used for each plant line. It was used an Aries Netafim® dripping system, with a pressure of 3.0 kgf·cm^{-2}. The irrigation flow rate was 2.0 L·h^{-1}, with 10 drippers per plant, totaling 20.0 L·h^{-1}·plant^{-1} and application intensity of 1.33 mm·h^{-1}.

In the conventional treatment, water was supplied only by rainfall (climatic conditions) and coverage fertilization was carried out, following the recommendations of CQFS (2016). In the irrigated treatment, the irrigations were carried out based on estimated crop evapotranspiration (EPT_c), calculated by the ETo method, proposed by Hargreaves and Samani, following the procedures described by Conceição & Mandelli (2005).

$$EPT_c = K_c \times 0.0135 \times K_t \times R_a \times (T_{max} - T_{min})^{0.5} \times (T + 17.8) \quad (1)$$

Being K_c the crop coefficient, K_t an empiric factor, R_a the radiation at the top of the atmosphere, T the average temperature, T_{max} the maximum temperature, and T_{min} the minimum temperature.

In fertigation treatment, water was supplied similarly as the irrigation treatment; nutrient supply was carried out in the same conditions recommended by CQFS (2016), being supplied in the irrigation water.

Analysis of the quality parameters of the fruits

The experiment was conducted from September 2018 to September 2019. Fruit harvest was carried out on August 22, 2019. Fifty fruits were selected randomly for the evaluation of the biometric parameters: longitudinal and transversal diameters (Ø) and average fruit mass (AFM). The longitudinal and transversal diameters were measured using a digital pachymeter (PD150, TMX, Brazil), with a measurement capacity of 150 mm and resolution of 0.01 mm. The AMF was determined by weighing the fruits using a semi-analytical balance (AS1000C, Marte, Brazil) with a measurement capacity of 1 kg and resolution of 0.01 g.

Ten fruits were selected randomly per replicate and have had their juice extracted using an electric juice extractor. The collected juice was homogenized and it was used in the determination of juice content (Jc), soluble solids content (SS), titratable acidity (TA), ratio, and ascorbic acid content.

Juice content was determined by measuring the volume of extracted juice with a glass graduated cylinder with a capacity of 1 L and resolution of 10 mL; its content was calculated using Equation 2.

$$Jc\left(\%\ v/m\right)=100\times\frac{V}{M} \quad (2)$$

Being 'V' the volume of juice extracted (mL) and 'M' the mass of fruits used in the extraction (g). The soluble solids content was determined using an analogic refractometer (RT-30ATC, Incoterm, Brazil), with a measuring range of 0-30 °Brix and a resolution of 0.25 °Brix. The titratable acidity was determined following the method 310/IV of the Instituto Adolfo Lutz (IAL, 2008). The ratio value was calculated as the quotient between the soluble solids content and the titratable acidity (ratio = SS/TA). The ascorbic acid content was determined following the method 364/IV of the Instituto Adolfo Lutz (IAL, 2008).

Experimental design and statistical analysis

The experimental design was bifactorial (2x3), with two rootstocks and three management practices, completely randomized, with five replicates for each treatment, being each replicate composed by five plants and each fruit parameter replicate was composed of 60 fruits (50 fruits for the biometric parameters and 10 for the quality parameters), chosen randomly.

The data underwent analysis of variance (ANOVA) and the means were compared by Tukey's multiple range test at 5% probability ($\alpha = 0.05$). The statistical analyses were carried out using the AgroEstat® software.

RESULTS AND DISCUSSION

The parameters of transversal diameter (Ø), average fruit mass (AFM), juice content (Jc), soluble solids content (SS), and ratio were not influenced by any of the treatments applied; their overall means and coefficient of variation are presented in Table 1.

Sartori et al. (2007), who evaluated the use of phytoregulators and pruning in Montenegrina mandarin trees, reported AFM values of 100.62 g whereas Petry et al. (2012), working with organic nutritional management, the AFM was 121.45 g. However, in the conditions of the present study, the AFM was 140 g.

Relative to the transversal Ø, the value observed in the present work (62.63 mm) is similar to the one reported by Schneider et al. (2011), in which the transversal Ø reported was 60.97 mm. Duenhas et al. (2005) reported a similar behavior when studied 'Valência' orange trees under conventional management, irrigated, and fertigated with different doses of NPK.

The Jc of all treatments was superior to 33% v/m (mean value was 47.23% v/m); this value is considered as the cutoff value for marketing in the European Union for this kind of mandarin (Campana, 2007).

In the present work, the average ratio observed was 11.57, which was superior to the cutoff value of 7.5, proposed by the international *Citrus* standard (OECD, 2010). Similar ratio values (13.70) were reported by Felipe (2013) in a work that involved the evaluation of the quality parameters of tangerines. The ratio is considered the main index to determine the stage of ripening of fruits. According to Sartori et al. (2002), ratio values in the range of 8-15 may be considered ripe and suitable for consumption *in natura*. Thus, it could be considered that the fruits evaluated in the present work were ripe when harvested.

Although there was no difference in AMF, Jc, SS, ratio, and transversal Ø of fruits relative to the treatments, the longitudinal Ø and ascorbic acid content were influenced by the rootstock, but not by the adopted management practices. The results for longitudinal Ø and ascorbic acid content are presented in Table 2.

The fruits from trees grafted on the Swingle citrumelo rootstock presented higher longitudinal Ø (68.36 mm) than the ones grafted on *P. trifoliata* (64.45 mm). This was an expected behavior because according to Schäfer et al. (2001) and Efrom & Souza (2018), the *P. trifoliata* rootstock induces a 'dwarfing' effect, which tends to propitiate the production of fruits of small size. Moreover, the fruits collected from plants grafted on Swingle citrumelo were classified as first category (> 65 mm), whereas the ones

Table 1. Overall means and coefficients of variation (CV) for the parameters of transversal diameter (Ø), average fruit mass (AFM), juice content (Jc), soluble solids content (SS), and ratio, which have not differed statistically relative to the treatments

Parameter	Transversal Ø (mm)	AFM (g)	Jc (% v/m)	SS (°Brix)	*Ratio*
Overall mean	62.63	140.91	47.23	10.62	11.57
CV (%)	6.00	9.53	7.15	4.06	4.67

Table 2. Effect of the rootstock on the parameters of longitudinal diameter and ascorbic acid content of Montenegrina mandarins

Rootstock	Longitudinal diameter (mm)	Ascorbic acid ($mg \cdot L^{-1}$)
P. trifoliata	64.45 b	239.72 a
Swingle citrumelo	68.36 a	219.17 b
CV (%)	5.32	7.40

Means in column followed by the same letter do not differ statistically by Tukey's multiple range at 5% probability ($\alpha = 0.05$).

from plants grafted on *P. trifoliata* were classified as second category (57-65 mm), according to Sartori et al. (2007) and Yehia et al. (2009).

Relative to the ascorbic acid content, little information is available in the literature regarding the ascorbic acid content as a function of both the scion cultivar and the rootstock used. However, there was a statistical difference in its content relative to the rootstock; on the other hand, the management has not influenced this parameter (Table 2). Montero et al. (2009), evaluating the effect of mechanical damage on Montenegrina mandarins (rootstock not specified) found ascorbic acid content of 210 $mg \cdot L^{-1}$, similar to the ones found in the present work (239.72 and 219.17 $mg \cdot L^{-1}$ for *P. trifoliata* and Swingle citrumelo rootstocks, respectively). Felipe (2013) commented that fruits from the group of tangerines have had an average ascorbic acid content of 286 $mg \cdot L^{-1}$, having a lower antioxidant activity than the sweet orange [*C. sinensis* (L.) Osbeck], whose average ascorbic acid content was 426.1 $mg \cdot L^{-1}$.

Relative to the titratable acidity (TA), the rootstock has not influenced this parameter. Relative to the management, irrigated plants had higher TA values than the ones managed under the conventional method and fertigation. Table 3 compiles the results of TA relative to each management kind.

This result was expected because according to Zanini et al. (1998), an increase in the irrigation depth tends to reduce the SS value and increases TA by a diluting effect, also reducing the ratio values. Yet, the observed TA values are similar to what is considered as 'normal' (0.93% m/v) for the Montenegrina mandarin (Efrom & Souza, 2018).

The results observed in this work differ from the ones of Duenhas et al. (2002, 2005), which studied 'Valência' oranges and reported no significant difference in TA under conventional, irrigated, and fertigated management with different doses of NPK. However, Navarro et al. (2010), who studied the effect of both the rootstock and the irrigation regime on 'Clemenules' mandarins, reported that irrigation regimes with slight water deficit had increased

Table 3. Effect of management kind on the parameter of titratable acidity of Montenegrina mandarins

Management	Titratable acidity (% m/v*)
Conventional	0.89 b
Irrigation	0.97 a
Fertigation	0.90 b
CV (%)	2.90

*As equivalent of citric acid. Means in column followed by the same letter do not differ statistically by Tukey's multiple range at 5% probability ($\alpha = 0.05$).

both the SS and TA values of the fruits; the rootstock did not affect any of the evaluated quality parameters. Also, there was no statistical difference relative to the different irrigation depths when other crops were evaluated, such as melon and watermelon (Medeiros et al., 2012; Silva et al., 2015). However, for pineapple, Souza et al. (2013) reported behavior that was the opposite to the one observed in the present work, in which an increase in the irrigation depth caused a decrease in TA.

To satisfy the water demand of *Citrus* plants, in general, 600-1300 $mm \cdot year^{-1}$ of rainfall is enough, being 1500 $mm \cdot year^{-1}$ considered as ideal, properly distributed (Koller, 2013; Böettcher et al., 2018). Relative to the 2018/2019 harvest, the total rainfall in the region was 1486 mm (INMET, 2019), an amount very close to the one considered optimal for this crop. The average daily temperature and rainfall for the period of September 2018 to September 2019 are presented in Figure 1.

By observing Figure 1, it was possible to see that rainfall was well distributed throughout the production cycle, most of it was below 30 mm, especially in the summer period (December 2018 to March 2019). This is an important aspect since regular rainfall avoids the water deficits that may have negative impacts on both plant productivity and fruit development and quality (Martínez-Ferri et al., 2013; Peddinti & Kambhammettu, 2019).

The need for irrigation varies with the cultivation region and can be higher or lower. Thus, it is expected

that both the need and the response to irrigation in humid regions may be economically unfeasible, where there is a small to absent hydric deficit throughout the year; small in sub-humid regions, in which irrigation may be a complement to avoid water deficit in specific periods of the year; and high in semiarid regions, where the orchards may only be viable by adopting an irrigation system (Marin & Angelocci, 2011; Carr, 2012).

Once *Citrus* plants have a high capacity to store water in their tissues due to the characteristics of the leaves, losses of water are minimized (Boman, 1996; Coelho et al., 2006). As observed in Figure 2, during most of the summer growing cycle (December 2018 to March 2019) there was a water deficit; however, this deficit was small (below 10 mm). Outside the summer period, there was mostly an excess of soil water, especially in the late stages of fruit development (from June on).

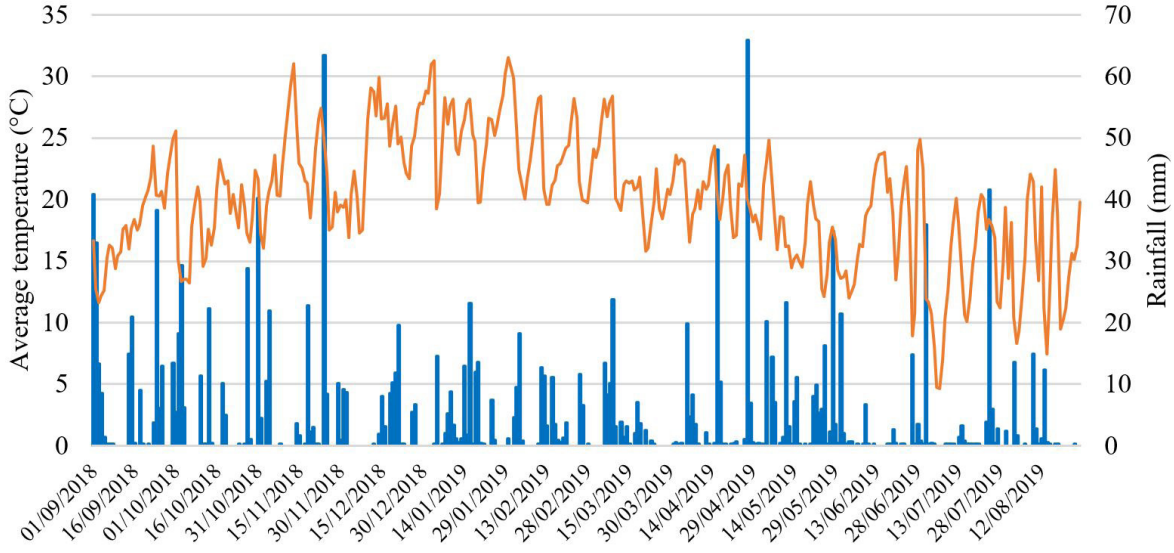

Figure 1. Average daily temperature (line) and rainfall (bars) for the 'Vale do Caí' region between September 2018 and September 2019. Source: adapted from INMET (2019).

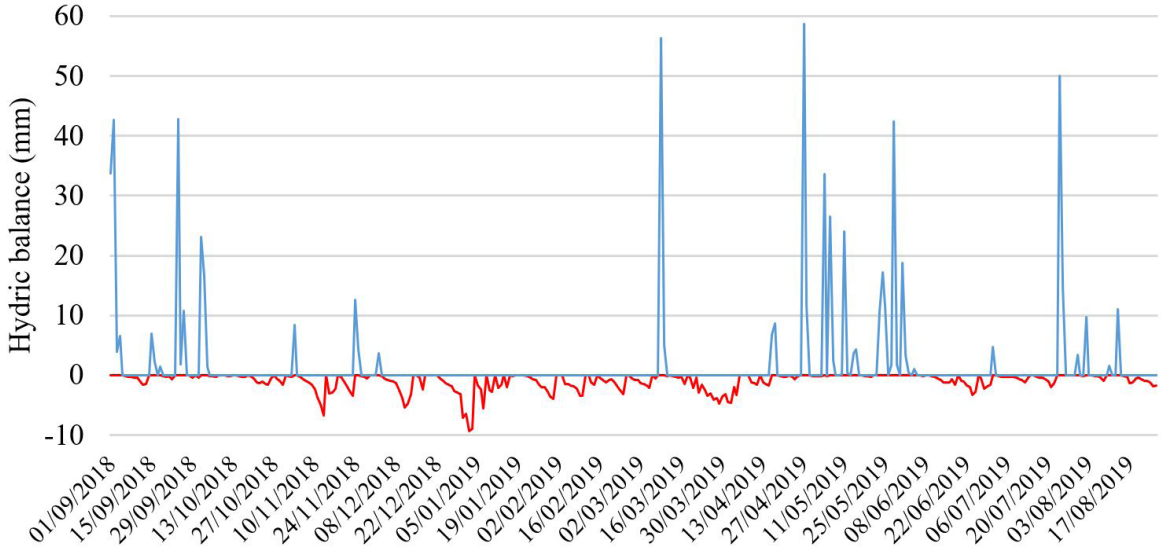

Figure 2. Hydric balance for the 'Vale do Caí' region relative to Citrus cultivations for the period between September 2018 and September 2019. Source: Adapted from INMET (2019).

Throughout the growing year, it was necessary to carry out the irrigation six times, all of them between December 2018 and January 2019. From February 2019 on the orchard was not irrigated anymore; this may justify the small differences between the treatments, once the hydric conditions were similar in the rest of the fructification period. It is also important to highlight that the studied orchard is a new one, with four years since planting, being this harvest the first productive year of the plants. More studies are needed relative to both fruit quality and orchard productivity to evaluate the need for irrigation and the productive performance of the plants, beyond quality, relative to fertigation.

CONCLUSION

The parameters of transversal diameter, average fruit mass, juice content, soluble solids, and ratio were not influenced by any of the treatments. The fruits from the plants grafted on the Swingle citrumelo presented a bigger longitudinal diameter. The fruits from the plants grafted on *P. trifoliata* have had a higher content of ascorbic acid. Irrigation and fertigation were not necessary, considering the fruit quality parameters evaluated.

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