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EFEITOS DA IRRIGAÇÃO DE NOGUEIRA-PECÃ NO RIO GRANDE DO SUL

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1 RESUMO

O cultivo de nogueira-pecã tem aumentado no Brasil, contudo pouco se conhece sobre a irrigação para essa cultura. Em climas semiáridos, a suplementação de água é obrigatória, e em climas úmidos, pesquisas indicaram resultados promissores na produção, porém com variedades e condições ambientais distintas daquelas presentes no Brasil. Por isso, este trabalho teve por objetivo avaliar os efeitos da irrigação na nogueira-pecã, em experimento conduzido em pomar com a variedade ‘Barton’ em Cachoeira do Sul, RS, entre as safras 2019-2020 e 2020-2021. Aplicaram-se doses de reposição da evapotranspiração da cultura (ETc) correspondentes a 0 (tratamento controle), 50, 100 e 150%, com microaspersão em blocos aleatorizados com três repetições. Avaliaram-se a circunferência do tronco, o tamanho, a quantidade e o peso de nozes e o peso e rendimento de amêndoas. Na primeira safra houve excedente de chuva na época de floração, e a irrigação não apresentou efeitos significativos. Por outro lado, na safra 2020-2021 houve incremento de circunferência do tronco das plantas irrigadas. Mesmo com maior quantidade de chuva no enchimento da amêndoa, a irrigação proporcionou maior tamanho e massa das nozes, com relação linear, indicando que as doses podem ser aumentadas para se obter a resposta máxima.

Palavras-chave: *Carya illinoinenses,* microaspersão, irrigação localizada.

SARETTA, E.
IRRIGATION EFFECTS ON PECAN NUTS TREE IN THE RIO GRANDE DO SUL

2 ABSTRACT

Pecan cultivation has been increasing in Brazil; however, little is known about the irrigation of this crop. In semi-arid climates, water supplementation is mandatory, and in humid climates, research indicated promising results in the production; although, with varieties and environmental conditions different from those present in Brazil. Therefore, the objective of this work was to evaluate the irrigation effects on pecan nut tree at an experiment conducted in an orchard with ‘Barton’ variety in Cachoeira do Sul, RS, between 2019-2020 and 2020-2021 growing seasons. Replacement doses of crop evapotranspiration (ETc) corresponding to 0 (control treatment), 50, 100, and 150% of were applied via microsprinkler in randomized blocks with three replicates. The trunk circumference, nut size, weight and quantity, and weight and percentage of kernel were evaluated. In the first harvest, there was an excess of rain during the flowering stage and the irrigation did not show significant effects. However, in the 2020-2021 harvest, there was an increase in the trunk circumference of the irrigated trees. Even with more rainfall during the kernel-filling stage, the irrigation

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contributed to enhancing the size and weight of nuts in a linear relationship, indicating that the doses can be increased to achieve the maximum response.

Keywords: *Carya illinoinenses*; microsprinkler; localized irrigation.

3 INTRODUCTION

In Brazil, pecan [*Carya illinoinenses* (Wangenh.) K. Koch)] is a growing crop with 8,000 hectares of planted area with more than 40 varieties registered for planting, with higher production in the South Region, especially in Rio Grande do Sul (INTERNATIONAL NUT AND DRIED FRUIT COUNCIL, 2021; MARTINS *et al.*, 2018; HAMANN *et al.*, 2018). However, irrigation remains unknown, as there are no studies on its effects on cultivation in the country. The species is native to the United States of America (USA), and in regions recognized as pecan producers, irrigation is essential, even with management often based on farmer experience (GANJEGUNTE; SHENG; CLARK, 2012; WELLS, 2015).

In general, the occurrence of water stress during the middle of the growing season (December and January in the Southern Hemisphere) tends to reduce size and cause nut drop; if it occurs later (February), it reduces almond filling and impairs epicarp opening (MIYAMOTO; HENGGELER; STOREY, 1995) . The southwestern region of the USA is one of the main global producers, and water is the productive element with the greatest demand, as it is a semiarid region, ~~with~~ annual rainfall of less than 250 mm and crop evapotranspiration (ETc) that can reach 1,400 mm in the cycle (SAMANI *et al.*, 2011; SAMMIS; MEXAL; MILLER, 2004) . In humid climates, irrigation also shows promising results both in the USA and in the USA (WELLS, 2015). as in other countries (DE MARCO *et al.*, 2021) . These are long-term research projects, as they involve long-lived trees, with production beginning three years after planting, if they are grafted.

In adult pecan trees of the 'Western Schley' variety, the average productivity can decrease by up to 20% if the amount of water supplied is 50% less than the maximum demand (GARROT JR. *et al.*, 1993) , and this reductive effect propagates both in the weight of the nuts and in the vegetative growth of the plant.

For young plants just beginning production, research has indicated that microsprinkler or subsurface drip irrigation had no effect on the 'Pawnee' variety over seven years in Oklahoma (USA) (SHALEKBRISKI *et al.*, 2019) . This study also revealed that irrigation was insufficient to increase trunk diameter, weight, and nut yield. On the other hand, seven-year-old young plants of the 'Success' variety responded positively to irrigated nut size and weight in Uruguay (DE MARCO *et al.*, 2021) . Notably, varieties respond differently in different environments, so local studies are needed.

Considering the need for research on pecan irrigation in Brazil due to the specific responses of varieties to the ~~environment~~, this work aimed to evaluate the effects of irrigation on the vegetative growth and production of this crop in young plants at the beginning of production.

4 MATERIALS AND METHODS

The experiment was conducted between 2019 and 2021 in an orchard with the 'Barton' variety in Cachoeira do Sul, RS (29.95° S; 52.98° W, average elevation of 100 m), on sandy loam soil with no drainage limitations. This variety occupies the largest area of Brazilian pecan orchards, mainly because of its good nut production ability and resistance to scab disease (USDA, [*nd*]) compared with other varieties grown in humid climates.

The orchard covered an area of three hectares and consisted of young trees that were five years old at the start of the experiment and were planted with a square spacing of 7 m. The treatments were applied to plots of 16 trees, with the four central plots used as the experimental unit, leaving those on the perimeter as the border.

The four treatments consisted of irrigation rates corresponding to 50, 100, and 150% of ETc and one without irrigation. The experiment was conducted in a randomized complete block design with three replicates. The rates were applied daily via a microsprinkler irrigation system, with one microsprinkler (RSB Plásticos Ltda.) per plant at a flow rate of 60 L/h.

ETc was determined from daily local measurements of Class A pan evaporation (ECA), converted to reference evapotranspiration (ETo), using a value of 0.70 for the pan coefficient (kp) in the expression ETo = ECA kp (CONCEIÇÃO, 2002; SENTELHAS; FOLEGATTI, 2003) . To estimate ETc, crop coefficient (kc) values adapted for the Southern Hemisphere were used: 0.39 in the initial period, 1.24 in the intermediate period and 0.84 in the final period (IBRAIMO *et al.*, 2016; SAMANI *et al.*, 2011), following plant phenology (FRUSSO, 2018).

Since this is localized irrigation, ETc was corrected for localized evapotranspiration (ETl) with a location factor (kl), considering the fraction of soil coverage (fc) by the plant canopy (FRIZZONE *et al.*, 2012), according to Equations (1) and (2).

$$ETl = ETc\ kl \qquad (1)$$

$$kl = fc + 0.5\ (1-fc) \qquad (2)$$

Notably, a study using remote sensing in pecan orchards with different values of fc obtained an expression for determining kc that provides results similar to those of Equations 1 and 2 (SAMANI *et al.*, 2011) . For ETc purposes, coverage can be considered complete when fc exceeds 65% (SAMMIS; MEXAL; MILLER, 2004; WANG *et al.*, 2007) , without the need for corrections. Orchards with spacings of up to 10 m in the central region of Rio Grande do Sul presented fc = 100% after approximately 10 years, depending on the management conditions. In the experiment, the fc value was approximately 10% in the first year and 19% in the second year.

Irrigation was applied from sprouting in September and stopped two weeks before harvest, at the beginning of epicarp opening in March (SHALEKBRISKI *et al.*, 2019) . Close to harvest, the trunk circumference of the trees was measured at a height of 1.2 m above the soil surface. All the nuts produced were collected, and their weight and total quantity were measured. The nuts were subsequently shelled to quantify the almond weight and yield (almond weight in relation to the total nut weight).

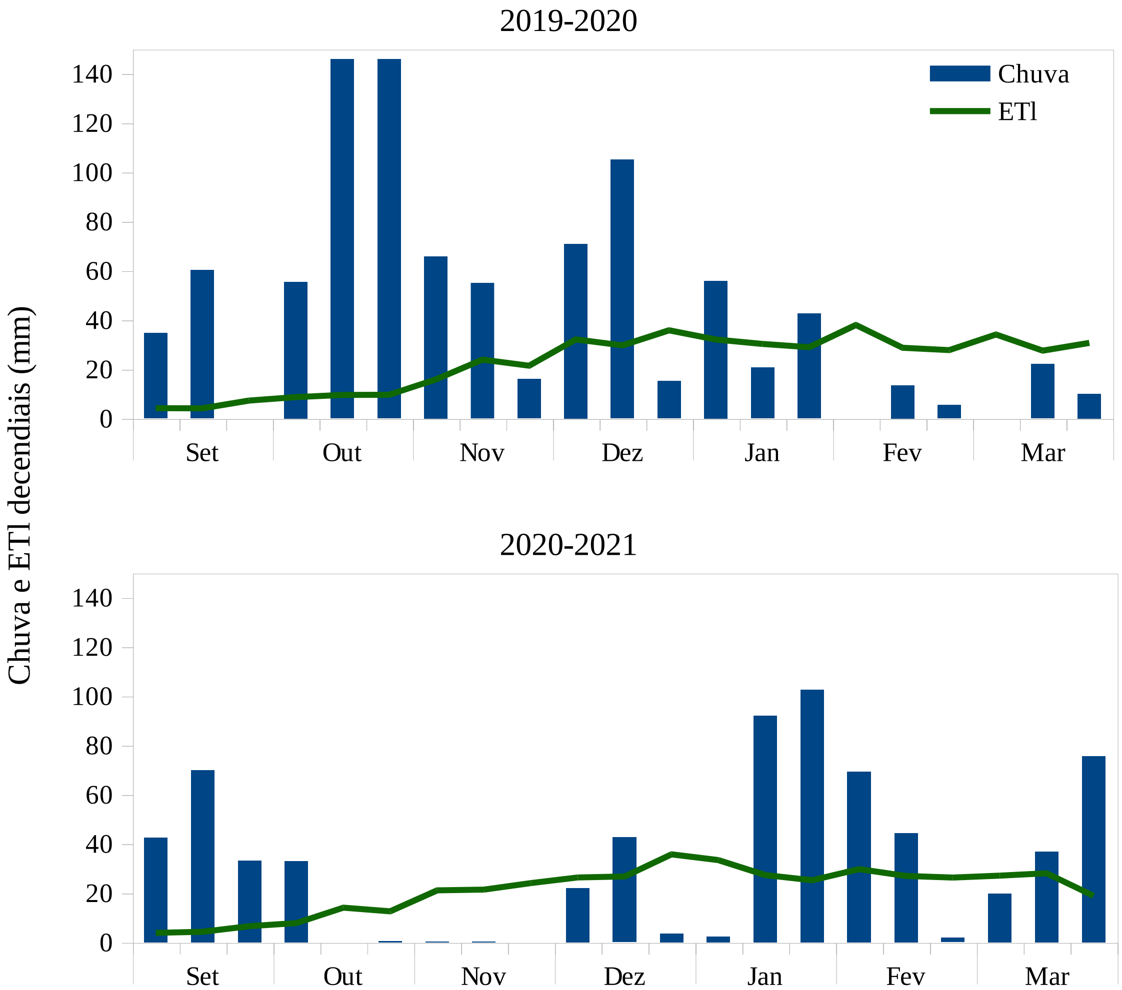
Measurements of nut length and diameter were taken by processing photographs of the nuts with ImageJ *software* (owned from the *National Institute of Health*). The area of the nuts in the image was also obtained via *software*, as it is related to size, since the fruits are elliptical in shape.

All variables were subjected to analysis of variance at the 5% probability level. When there was a significant treatment effect, regression analysis was used for the variable, also at the 5% probability level.

5 RESULTS AND DISCUSSION

In October 2019, there were two ten-day periods of rainfall greater than 140 mm, followed by two ten-day periods in November with more than 50 mm (**Figure 1**). In the state of Rio Grande do Sul, there is a possibility of a water surplus occurring in these months, which directly influences crop productivity, since flowering occurs during this period (ROVANI, 2016; ROVANI; WOLLMANN, 2019) .

Figure 1 Rainfall and crop evapotranspiration (ETc) corrected for localized irrigation in the two crop seasons**.**



During the 2019--2020 harvest, the total rainfall recorded was 939 mm, compared with 479 mm of ETl for walnut trees. Even though there was rain during the almond filling period in January and February, the amount was not enough to meet demand (**Figure 1**), and there was a dry period in early February.

With impaired flowering and fewer fertilized fruits, the crop's production potential was affected, even with irrigation replenishing ET1. This was one of the main reasons why the 2020 harvest was considered the smallest in recent years (INTERNATIONAL NUT AND DRIED FRUIT COUNCIL, 2020) .

In the 2020--2021 harvest, on the other hand, there was a dry period during the flowering period, which is also known in the state in years known as dry years (ROVANI; WOLLMANN, 2019) . The total rainfall throughout the harvest was 692.2 mm, which was less than that during the 2019--2020 harvest. The recorded ETl was 447 mm lower than that in the previous harvest, with greater replenishment by rainfall in January and February (**Figure 1**). Thus, the favoring of flowering due to drought and a greater amount of rainfall during the almond filling period provided the largest estimated walnut harvest (INTERNATIONAL NUT AND DRIED FRUIT COUNCIL, 2021) , since there are few irrigated orchards in Brazil.

During the 2019--2020 harvest, there was no significant difference in the analyzed variables between the treatments (**Table 1**). This was a result of both water surplus and deficit (**Figure 1**) (WELLS, 2015) and plant age. Some individuals start production with a small amount of nuts and therefore have development potential, which may even benefit from irrigation during subsequent harvests.

Table 1 Variables evaluated via analysis of variance.

Source of variation	**2019-2020 Harvest**							
	T	**THE**	**L**	**W**	**PPA**	**PM**	**PMA**	**R**
Block	0.0001	0.5739	0.5289	0.4714	0.1176	0.6870	0.0323	0.5675
Dose	0.1129	0.5813	0.4914	0.5359	0.1563	0.3833	0.2843	0.2650
	2020-2021 Harvest							
Block	0.0136	0.1097	0.0659	0.1058	0.0257	0.2821	0.2314	0.2302
Dose	0.0466	0.0354	0.0428	0.0207	0.5135	0.0467	0.0444	0.8051

Probability values less than 0.05 represent a significant difference. T: trunk circumference; A: Nut area; L: Nut width; C: Nut length; PPA: production per tree; PM: average nut weight; PMA: average kernel weight; R: kernel yield.

This variability in production during the 2019–20 harvest can be seen in the average nut yield per tree presented in **Table 2**These values are still considered low compared with those of adult plants, which can present productivity above 20 kg per plant (SAMMIS; MEXAL; MILLER, 2004; WANG *et al.*, 2007) , but the dimensional measurements of the nuts and the proportion of almonds in the fruits were consistent with those of a similar study (DE MARCO *et al.*, 2021).

Table 2 Averages of measured parameters and productivity during the 2019--2020 harvest.

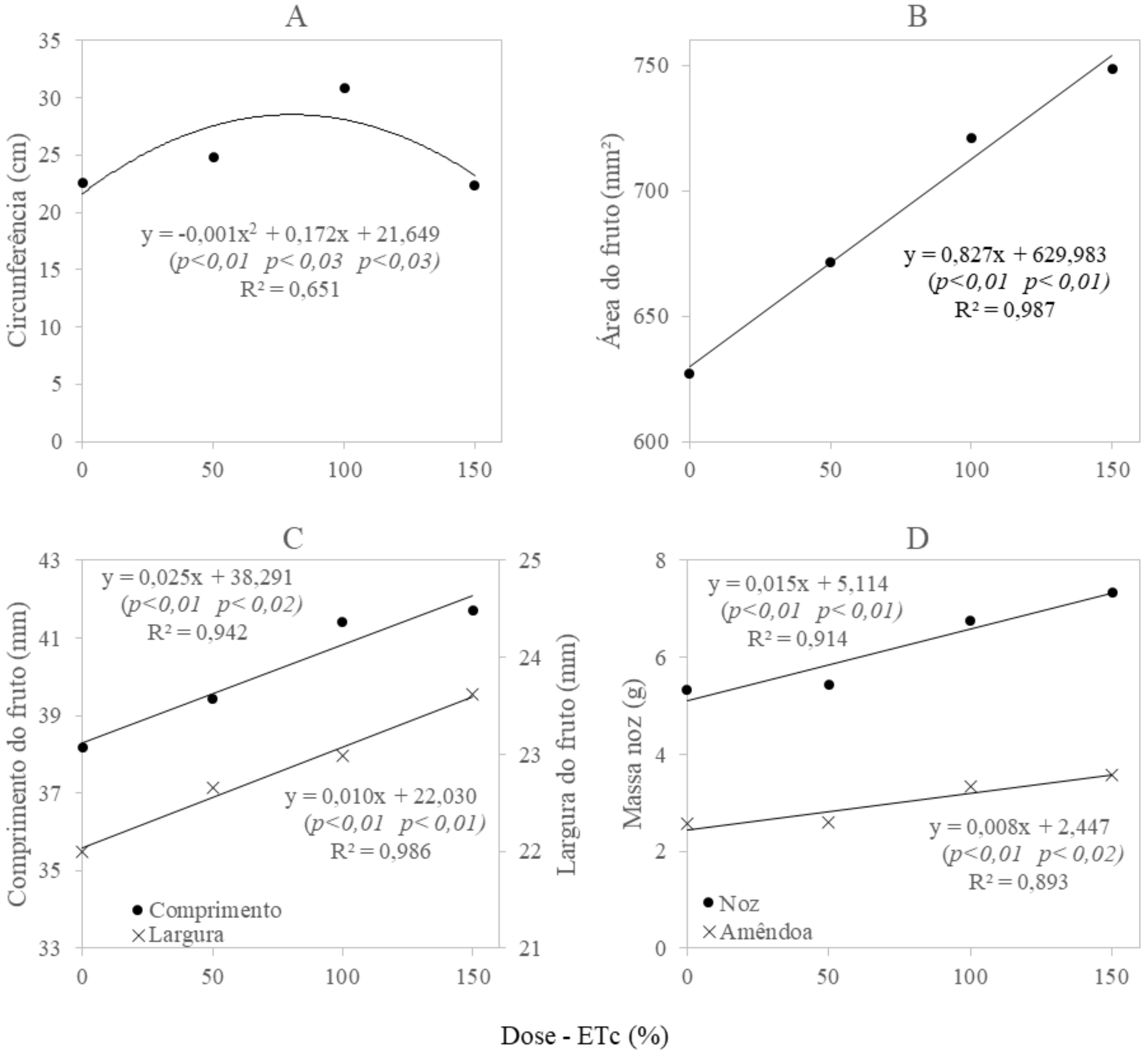
Dose (%ETc)	**T (cm)**	**THE (mm²)**	**L (mm)**	**W (mm)**	**PPA (g)**	**PM (g)**	**PMA (g)**	**R (%)**
0	20.78	561.45	20.72	34.43	34.98	4.96	2.06	41.5
50	22,23	603.43	21.00	36.18	227.98	5.15	2.07	40.2
100	23.21	597.03	20.83	36.07	171.15	5.08	2.01	39.6
150	19.86	592.63	21.41	35.13	21.04	6.09	3.14	51.6

T: trunk circumference; A: Nut area; L: Nut width; C: Nut length; PPA: production per tree; PM: average nut weight; PMA: average almond weight; R: almond yield; and ETc: crop evapotranspiration.

In the second evaluation season (2020--2021), irrigation significantly affected trunk circumference; nut width, length and area; and average and kernel weight (**Table 1**). Even with rainfall values higher than ETl during the kernel filling stage (**Figure 1**), irrigation increased tree trunk circumference, nut area, length and width, and average nut and kernel weights.

For these variables with a significant effect, the equations adjusted according to the irrigation dose are presented in **Figure 2**In terms of trunk circumference (**Figure 2**), nonirrigated plants had the lowest circumference value, 21.6 cm, compared with irrigated plants. The applied doses corresponding to 100 and 150% ETc did not maximize the circumference, but the dose of 86% ETl did, which resulted in a value of 29 cm. In adult plants, the application of only half the amount of water required can represent a 25% lower trunk circumference (GARROT JR. *et al.*, 1993).

Figure 2 Relationships between variables measured with irrigation and replacement doses of crop evapotranspiration (ETc) from the 2020–2021 harvest**.**



Note: Values in parentheses below the coefficients of the equations indicate their respective significance.

Even the 50% dose had positive results compared with nonirrigated walnut trees, indicating promising results in irrigated orchards, with doses considered minimal in this study. Thus, irrigation contributed to this increase and is an important factor in structuring crop production.

Growth models can use these results obtained for both productivity projections and management practices such as pruning (ANDALES *et al.*, 2006) and fertilization recommendations with respect to vegetative growth (BRAZILIAN SOCIETY OF SOIL SCIENCE. SOIL CHEMISTRY AND FERTILITY COMMISSION, 2004). In the case of the irrigation of young plants with groundwater or wastewater, care must be taken only with respect to salinity due to the susceptibility of the crop, which can significantly reduce trunk growth when the electrical conductivity is greater than 3.5 dS m^{-1} (DEB *et al.*, 2013).

The crop's response to irrigation can also be observed in the increase in nut size, both in area (**Figure 2**) and in length and width (**Figure 2**). The increases in these variables were linear with irrigation, indicating that the maximum was not reached and that the depths could be greater. In terms of nut area, the nonirrigated plants presented a value of 630 mm², with an increase of 0.827 mm² for a 1% increase in the irrigation depth, reaching 754 mm² for the largest depth used in the experiment.

The average length was 38.3 mm in the treatment without irrigation, increasing to 42.0 mm when the plants were irrigated with a blade with 150% ETc replacement, and the width increased from 22.0 mm to 23.5 mm. Under the conditions of the United States of America for the 'Barton' variety, the average length is 38.3 mm, and the width is 22.6 mm (USDA, [*sd*]). Similar results were found for the 'Success' variety, reinforcing the effects of increasing nut size with irrigation, which is an important attribute for fruit marketing (DE MARCO *et al.*, 2021).

With respect to nut size, irrigation significantly increased fruit and almond weights (**Figure 2**D). The highest values were obtained for the deepest water depth (150% ETc), with estimates of 7.4 g average nut weight and 3.6 g almond weight, in agreement with the conditions of the United States of America (USDA, [sd]). However, reported that yield was not significantly related to irrigation depth (**Table 1**and **Table 3**), as previously reported in other young (SHALEKBRISKI *et al.*, 2019) and adult (GARROT JR. *et al.*, 1993).

Table 3the 2020--2021 harvests as a function of irrigation with crop evapotranspiration (ETc) replacement doses, with no significant difference.

Dose (%ETc)	Production per tree (kg)	Almond yield (%)
0	0.64	48.0
50	0.67	47.3
100	0.71	49.2
150	0.43	48.3

Adult plants of the 'Western Schley' variety in Arizona (USA) also presented lower nut mass when the irrigation dose was reduced (GARROT JR. *et al.*, 1993) . In young plants, the response to irrigation can also be positive (DE MARCO *et al.*, 2021) or neutral (SHALEKBRISKI *et al.*, 2019) .

A recent study of the 'Success' variety in Uruguay reported that water application increased nut and kernel mass in young walnut trees (DE MARCO *et al.*, 2021) . The increases in these variables indicate that irrigation played a significant role in the orchard, even with greater rainfall during the kernel-filling period. In this context, small irrigation rates that do not replace the entire water requirement of the crop may have some positive results in the region and could be part of some irrigation strategies for the pecanist (FRIZZONE *et al.*, 2012) .

Even with the increase in nut and almond mass, the productivity per tree was not increased by irrigation (**Table 3**), with a general average of 0.61 kg. However, over time, higher irrigation doses tend to increase productivity, which occurs for adult orchards (GARROT JR. *et al.*, 1993) .

Pecan is known for alternating production between years, with intensity dependent on a number of factors in addition to the variety itself (ANDALES *et al.*, 2006; CONNER; WORLEY, 2000; WELLS, 2015) . During the 2020--2021 harvests, in addition to the effects of water deficit and surplus, this effect likely occurred. However, the crop recovered even after a disadvantageous harvest in 2019--2020, with irrigation contributing to the following harvest. Within the same harvest, if water stress occurs during the development period but irrigation is applied during the kernel filling period, productivity is not compromised (WELLS, 2015) .

Therefore, future studies could evaluate irrigation only during the almond filling period (DE MARCO *et al.*, 2021) , with an assessment of production characteristics. Furthermore, irrigation may be an important factor in reducing the intensity of alternating production, thus deserving in-depth studies in the region.

6 CONCLUSIONS

Excessive rainfall during the walnut flowering period negatively influenced production during the 2019--2020 harvest, and irrigation did not have a significant effect on the variables analyzed.

Irrigation led to an increase in nut size and mass from the 2020–2021 harvest, even with greater rainfall during the almond filling period and drought during the flowering period.

There was an increase in trunk circumference with increasing irrigation dose, with the maximum value obtained with a dose of 86% ETl.

For the variables nut width, length and area, in addition to the nut and almond mass, the increase was linear according to irrigation with increasing doses of crop evapotranspiration replacement, not reaching the maximum value even with the highest dose.

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