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Production of pear cv. 'Triunfo' under irrigation systems and depths in the sub-middle São Francisco region

Produção da pereira cv. Triunfo sob sistemas e lâminas de irrigação no submédio São Francisco

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ABSTRACT - Aiming at the search for a new alternative for the sustainability of the properties in the irrigated areas of the Brazilian Northeast, the objective of this study was to identify the ideal irrigation system and depth for a better yield and quality of pear fruits in the Sub-middle São Francisco region. The experiment was conducted in the commercial orchard of the Frutos do Sol farm, located in the municipality of Petrolina, PE, Brazil, from October 2016 to November 2017. The treatments consisted of four irrigation depths (60; 80; 100 and 120% of crop evapotranspiration - ETc), under two irrigation systems (drip and micro-sprinkler), in two crop cycles of 'Triunfo' pear. Yield, average fruit weight, water productivity, pulp firmness and titratable acidity, total soluble solids and lightness of the fruits were analyzed. Irrigation depths of 96.04% and 94.84% ETc promote, respectively, the highest marketable yields for the first (43.48 t ha^{-1}) and second (26.55 t ha^{-1}) cycle of 'Triunfo' pear in the Brazilian semi-arid region. Drip irrigation system in the warmer period promotes higher yield. The cultivation of 'Triunfo' pear irrigated by drip and micro-sprinkler promotes fruits with good commercial quality in the Brazilian semi-arid region.

Keywords: Drip. Micro-sprinkler. Crop evapotranspiration. *Pyrus* L.

RESUMO - Visando a busca de uma nova alternativa para sustentabilidade das propriedades dos polos irrigados do Nordeste brasileiro, objetivou-se com este estudo identificar o sistema e a lâmina de irrigação ideal para uma melhor produtividade e qualidade dos frutos da pereira, no Submédio São Francisco. O experimento foi conduzido no pomar comercial da fazenda Frutos do Sol, localizado no município de Petrolina – PE, no período de outubro de 2016 a novembro de 2017. Os tratamentos foram constituídos de quatro lâminas de irrigação (60; 80; 100 e 120% da evapotranspiração da cultura - ETc), sob dois sistemas de irrigação (gotejamento e microaspersão), em dois ciclos de cultivos da pereira 'Triunfo'. Analisou-se a produtividade, peso médio dos frutos, produtividade de água, bem como a firmeza de polpa e a acidez titulável, sólidos solúveis totais e luminosidade dos frutos. As lâminas de irrigação de 96,04% e 94,84% da ETc proporcionam, respectivamente, as maiores produtividades comerciais para o primeiro (43,48 t ha^{-1}) e segundo (26,55 t ha^{-1}) ciclo de cultivo da pereira 'Triunfo' no Semiárido brasileiro. O sistema de irrigação por gotejamento no período mais quente proporciona maior produtividade. O cultivo da pereira 'Triunfo' irrigada por gotejamento e microaspersão proporcionam frutos com boa qualidade comercial no Semiárido brasileiro.

Palavras-chave: Gotejamento. Microaspersão. Evapotranspiração da cultura. *Pyrus* L.

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INTRODUCTION

Pear production in Brazil has been lower than its demand by consumers, generating an import of about 133 thousand tons of fruits from the countries of South America and Europe in 2022 (MAPA, 2023).

Pear (*Pyrus communis* L.) cultivation in the country is concentrated in the South and Southeast regions, with a production of 13 thousand tons of fruits (IBGE, 2023). However, studies with cultivars that withstand low cold requirements ('Triunfo', 'Princesa', 'Housui' and 'Kousu') have demonstrated the socioeconomic viability of the production of this crop in the Brazilian semi-arid region, reaching yields above the national average (GOMES et al., 2023; OLIVEIRA; LOPES; SILVA-MATOS, 2015; OLIVEIRA et al., 2017; OLIVEIRA et al., 2022; BETTIOL NETO et al., 2014; LOPES et al., 2013).

However, a good production of pear crop in the region requires management practices that are adequate and adapted to it, in order to obtain a good production and with high quality (OLIVEIRA; LOPES; SILVA-MATOS, 2015). Thus, considering the climatic characteristics of the Brazilian semi-arid region, such as the high rate of evapotranspiration and the scarcity of water resources, searching for a correct irrigation management becomes a primary tool for the sustainability of the producing properties in the irrigated perimeters of the region (GOMES et al., 2023).

Although there are already values of crop coefficient (Kc) for pear, recommended by FAO, ranging from 0.45 to 1.2 in its phenological cycle (ALLEN et al., 2006), these numbers do not always match what a particular cultivar really needs in a given region, compromising its management (SILVA et al., 2013). Waller and Yitayew (2016) highlight the importance of good management of irrigated crops, since the low volume of water applied in irrigation can cause water deficit to the plant, and the excess leads to water percolation and leaching of nutrients.

The higher efficiency of water use by the crop may also be associated with its adaptability to the irrigation system used. Although localized irrigation in fruit crops in Brazil has expanded due to its greater application efficiency, when compared to other methods, the choice of using micro-sprinklers or drippers for irrigation has promoted difference in the production and quality of Keitt mango fruits in the Sub-middle São Francisco region (SIMÕES et al., 2018).

In view of the above and the competitiveness in the agricultural market, the objective of this study was to identify the ideal irrigation system and depth for a higher yield and fruit quality of 'Triunfo' pear in the Sub-middle São Francisco region.

MATERIAL AND METHODS

The experiment was conducted in the commercial orchard of the Frutos do Sol farm, in the Senador Nilo Coelho Irrigation District, Unit 5 (9°21'27.65" South latitude and 40°37'56.07" West longitude), located in the municipality of Petrolina, PE, Brazil. The predominant climate of the region is semi-arid, with an average annual temperature of 26.5 ºC.

Four-year old pear trees (*Pyrus communis*), propagated by grafting ('*P. calleryana* L.' rootstock and 'Triunfo' scion), with spacing of 3.5 x 1.25 m, was used in the study.

The experimental design was randomized blocks, in a 2x4 factorial scheme, with four replicates, with two localized irrigation systems (drip and micro-sprinkler) and four irrigation depths (60; 80; 100 and 120% of crop evapotranspiration - ETc), and the study was carried out in two crop cycles. Each plot consisted of 10 plants, and the three central plants were used for analysis, with a usable area of 13.125 m^2.

At the beginning of each evaluation season, a cleaning pruning of the plants was carried out, removing the unwanted, poorly positioned, diseased and excessively vigorous branches. The first cycle began in October 2016 and ended in April 2017, while the second cycle began in May 2017 and ended in November of the same year. Figure 1 shows the meteorological data regarding accumulated rainfall, reference evapotranspiration (ETo) and average air temperature during the experimental period.

During the first cycle, an average global radiation of 25.2 MJ m^{-2} day^{-1}, average air temperature of 29 °C, with minimum of 22 °C and maximum of 38.8 °C, and average relative air humidity of 47% were recorded. In the second cycle, the average global radiation was 20.1 MJ m^{-2} day^{-1}, the average temperature was 20 °C, with minimum of 14.4 °C and maximum of 36.3 °C, and the average relative humidity was 57.3%.

Table 1 presents the physical attributes of the soil of the experimental area: bulk density, particle density, total porosity, sand, silt and clay contents, field capacity and permanent wilting point. The textural classification of the soil of the experimental area is sandy, as described by Waller and Yitayew (2016).

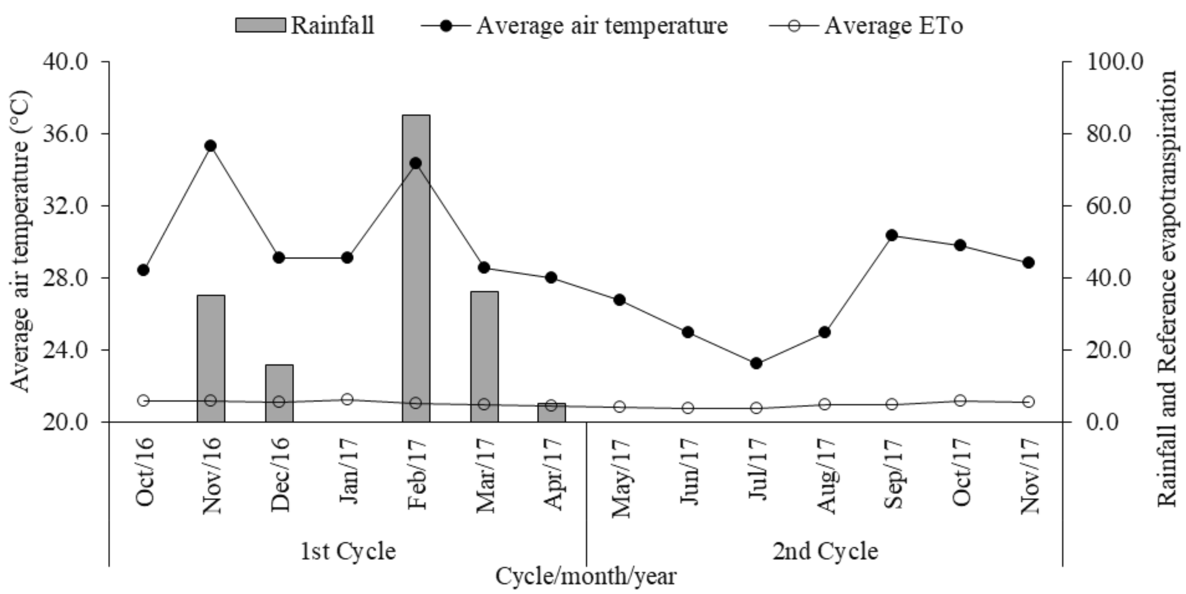

Figure 1. Rainfall, reference evapotranspiration (ETo) and average air temperature in the two cycles of 'Triunfo' pear in the Sub-middle São Francisco region.

Table 1. Physical analysis of the soil: bulk density (BD), particle density (PD), total porosity (Pt), sand, silt and clay contents, field capacity (FC) and permanent wilting point (PWP) of the experimental area cultivated with pear in the Sub-middle São Francisco region.

Depth	BD	PD	Pt	Sand	Silt	Clay	FC	PWP
m	----g cm^{-3}-----		--------------------%--------------------				-------g g^{-1}---------	
0-0.20	1.55	2.39	35.31	82.5	12.9	4.6	0.13	0.03
0.20-0.40	1.62	2.58	37.24	83.0	12.1	4.9	0.13	0.03
0.40-0.60	1.62	2.56	37.00	80.1	15.6	4.3	0.13	0.03

For drip irrigation, two lines of drippers were installed (application efficiency = 95%) per row of plant, spaced 1.0 m apart, with the plant in the center, and drippers spaced 0.5 m apart, with flow rate of 2 L h^{-1}, forming two continuous wet strips. In micro-sprinkler irrigation (application efficiency = 95%), the spacing between micro-sprinklers, which had a flow rate of 27.0 L h^{-1}, was 3.1 m.

Irrigations were performed daily, based on the ETc data, and the ETo values were estimated by the Penman-Monteith method, as described by Allen et al. (2006), obtained from a weather station installed 400 m away from the experimental area and the crop coefficient (Kc) indicated by the same authors (0.8, 1.2 and 0.85 of the vegetative, flowering and fruiting stages, respectively). The reduction coefficient (*Kr*) used to calculate the water requirements in both treatments (drip and micro-sprinkler) was 0.6, since the shaded area was larger than the wet area for both. Table 2 shows the amount of water that each treatment received during each cycle of the experiment.

Table 2. Amount of water that each treatment received in the cultivation of 'Triunfo' pear in the Sub-middle São Francisco region, under different irrigation depths in two crop cycles.

Cycle	Crop evapotranspiration (%)			
	60	80	100	120
	Amount of water (mm)			
1	288.6	384.8	481.0	477.1
2	433.1	385.0	488.2	577.5

The fruits of the usable plants of each treatment were collected, quantified and weighed when they reached their commercial physiological maturity. In addition, the fruits were classified into marketable and non-marketable according to the specification of the Agronomic Institute of Campinas (Instituto Agronômico de Campinas - IAC), and the mass of 'Triunfo' pear fruits oscillates between 180 and 250 g (NAKASU; FAORO, 2003).

Water productivity for total yield (WPTY) and water productivity for marketable yield (WPMY) were calculated using the equation described below:

$$\text{WP (kg m}^{-3}\text{)} = \frac{\text{Crop yield (kg)}}{\text{Crop total evapotranspiration (m}^{3}\text{)}}$$

The collected fruits were placed in plastic bags and sent to the post-harvest laboratory of Embrapa Semi-arid Region, where analyses of pulp firmness, content of soluble solids (SS), titratable acidity (TA), SS/TA ratio (ratio) and color of the epidermis of the fruits were performed. The analyses of SS, TA and SS/TA ratio were performed following the methodology described by the Adolf Lutz Institute (IAL, 2008). Pulp firmness was determined using a manual penetrometer with a 11-mm-diameter tip. Epidermis color was measured using a CR-400 colorimeter (Konica Minolta, Brazil) using the lightness (L), chroma (C) and hue angle (h) scales.

The results were subjected to analysis of variance, to study the interaction between the factors when significant, comparing the means by Tukey test for qualitative attributes and regression analysis for quantitative factors, at 5% probability level. In addition, non-orthogonal contrasts were performed using the Scheffé test at 5% probability level, where y = +1 and -1 for evaluation between the cycles studied.

RESULTS AND DISCUSSION

The analysis of variance showed, in the first and second cycles, significant difference caused by the irrigation depths in the variables total yield (t ha^{-1}), marketable yield (t ha^{-1}), water productivity for total yield (kg m^{-3}) and marketable yield (kg m^{-3}), average weight of marketable fruit (g), fruit resistance to penetration (N cm^{-2}), titratable acidity (%) and ratio, with no interaction between the irrigation systems and depths. In addition, there was no effect of irrigation depths on soluble solids (°Brix) and on variables related to fruit epidermis color: lightness (L), chroma (C) and hue angle (h).

Figures 2A and 2B show, respectively, the quadratic equation models for total yield and marketable yield for the two crop cycles. According to the models of fitted equations, the irrigation depths estimated at 93.62% and 96.04% ETc allowed the highest means of total yield (Figure 2A) and marketable yield (Figure 2B), with values of 50.03 and 43.48 t ha^{-1}, respectively, for the first cycle. In the second cycle, the irrigation depths estimated at 93.13% and 94.84% ETc allowed the highest means of total yield (Figure 2A) and marketable yield (Figure 2B), with values of 39.85 and 26.55 t ha^{-1}, respectively.

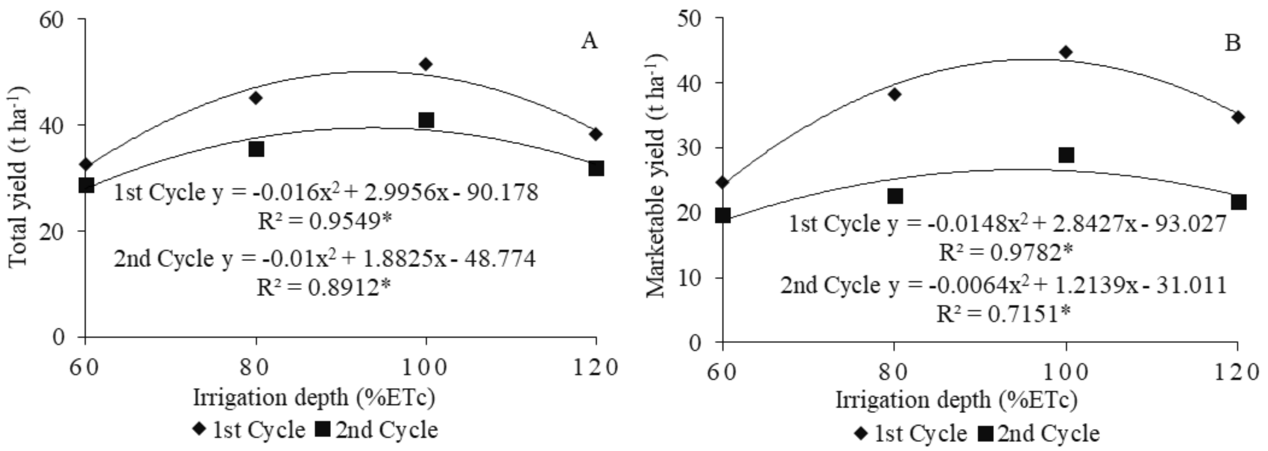

Figure 2. Total (A) and marketable (B) yield in 'Triunfo' pear cultivation in the Sub-middle São Francisco region, under different irrigation depths in two crop cycles. *Significant at 5% probability level by regression test.

The high yield of the crop, when compared to its average in the southern region of Brazil (14.89 t ha^{-1}) (IBGE, 2023), may be associated with the climatic conditions of the Brazilian semi-arid region, such as high solar radiation (between 17 and 21 MJ m^{-2} day^{-1}) (OLIVEIRA; LOPES; SILVA-MATOS, 2015), and daily frequency of irrigation, associated with the genetic potential of the pear cultivar 'Triunfo', adapted to tropical semi-arid zones. Thus, the interaction of these attributes acting together favors the sprouting of the pear tree (OLIVEIRA; LOPES; SILVA-MATOS, 2015), leading to increments in photosynthetic rates and consequently in the production of the crop (GOMES et al., 2023).

Regarding the difference between the irrigation depths, it should be noted that when the plant is under conditions of water availability in the soil, that is, close to field capacity or ideal irrigation depth (GOMES et al., 2023), there is no reduction in its metabolic activities, such as the production of photoassimilates, which influence the production of carbohydrates, favoring the increase in crop yield. These factors allow a high flux of carbon dioxide (CO_2) in the leaf, promoting the opening of the stomata, minimizing their resistance to CO_2 diffusion (SIMÕES et al., 2021; OLIVEIRA et al., 2020; TAIZ; ZEIGER, 2017).

Gomes et al. (2023), when working with the cv. 'Triunfo', evaluating its physiology and production under different irrigation managements in the region of the present study, found higher rates of production per plant (18.49 kg plant^{-1}), photosynthesis, stomatal conductance and transpiration with the irrigation depth close to 95% ETc. Lepaja et al. (2016), when studying different water regimes in pear crop in temperate climate regions, reported that the treatments subjected to full irrigation (100% ETc) had higher values of production per plant, when compared to treatments that received lower water depths.

The reductions in yield had a direct influence on soil water availability, given that both water excess and water deficit increase stomatal closure, which impairs the absorption of water and nutrients (GOMES et al., 2023; SILVA et al., 2015; SIMÕES et al., 2021). Thus, the observed results indicate that soils with inadequate water content, higher or lower, throughout the production cycle can result in reduced yield.

As described in Figures 2A and 2B, excess water reduced total and marketable yields, respectively, in the two crop cycles. In the first cycle, when comparing the highest means estimated with the 120% ETc depth, reductions of approximately 22.27% and 19.57% were observed for total yield and marketable yield, respectively. In the second cycle, this reduction was 16.86% and 15.25% in total and marketable yield, in that order.

The analysis of variance also showed a significant difference between irrigation systems in the second cycle for the total and marketable yields of the pear crop, with the drip irrigation system leading to the highest means for the evaluated characteristics, as shown in Figure 3.

The use of the drip irrigation system promoted increments of 34.48% and 45.93% in total and marketable yields, respectively, when compared to micro-sprinkler. This increase in the production aspects of the crop may be related to the greater efficiency of the drip system compared to micro-sprinkler, since evaporation losses are lower in drip systems (WALLER; YITAYEW, 2016).

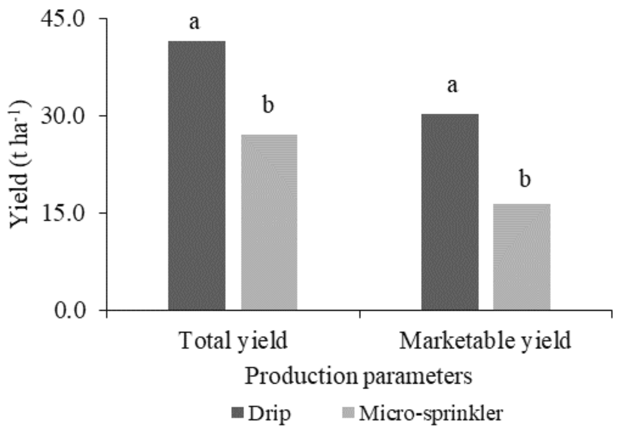

Figure 3. Total and marketable yield for 'Triunfo' pear under different irrigation systems in the second crop cycle in the Sub-middle São Francisco regions. Different letters indicate difference between irrigation systems.

The total and marketable yields, in the first cycle, were not influenced by irrigation systems, averaging 41.86 and 35.68 t ha^{-1}, respectively. The non-significant results in this cycle may be attributed to the meteorological conditions of this period, since the fruiting stage coincided with the rainy season of the region, with a total volume of 126.6 mm precipitated during this period (Figure 1), which probably allowed a uniform water distribution in the soil profile.

This same effect was reported by Vélez-Sánchez et al. (2021), who evaluated the regulation of irrigation deficit on fruit production and quality in the pear variety 'Triunfo de Vienna' under tropical conditions, and found that, due to rainfall, the production of fruits/plant was not significantly influenced by the treatments with and without water deficit.

In general, the yield values found in this study exceeded those obtained by Oliveira, Lopes and Silva-Matos (2015), who evaluated the phenological cycle of 'Triunfo' pear in the same region as the present study and found an average yield of 26.33 t ha^{-1}. In this context, it is observed that the adequate management of irrigation can contribute to increasing the production aspects of pear crop in the Brazilian semi-arid region.

Through the analysis of orthogonal contrasts, a significant difference was observed between crop cycles in total and marketable yield. The average total yield was 41.86 and 34.30 t ha^{-1}, in the first and second cycles, respectively, whereas the means for marketable yield were 35.68 and 23.28 t ha^{-1}, for the first and second cycle, respectively.

This increase in the production variables of the first cycle may be related to the environmental conditions of the period, when the evapotranspiration demand (Figure 1) was higher than in the second cycle, which may have caused an increase in photosynthesis, positively favoring crop yield.

The water productivity (WP) of the crop, which is measured by the relationship between the production of fresh fruits and the volume of water spent for that during the crop cycle, showed a significant difference between the irrigation depths, with no significant interaction between the studied factors.

The highest water productivity for total yield (WPTY) in the first crop cycle was achieved with a depth of 78.16% ETc, with an estimated value of 12.39 kg m^{-3}, as highlighted in Figure 4A. In the second cycle, the highest value of WPTY was obtained with the estimated depth of 87.53% ETc, with mean of 9.39 kg m^{-3} (Figure 4A).

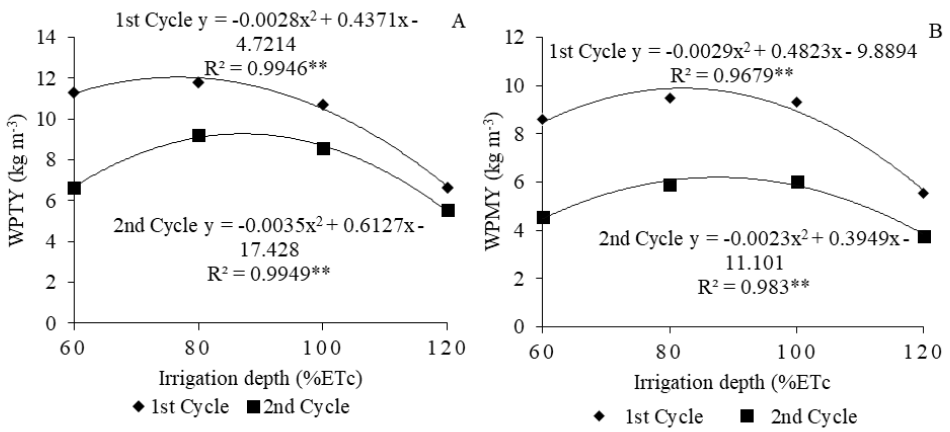

Figure 4. Water productivity for total yield (WPTY) (A) and water productivity for marketable yield (WPMY) (B) of 'Triunfo' pear in the Sub-middle São Francisco region, under different irrigation depths and two crop cycles. *Significant at 5% probability level by the regression test.

For the water productivity for marketable yield (WPMY) in the first cycle, the estimated depth of 83.16% ETc led to a value of 10.16 kg m^{-3} (Figure 4B). In the second cycle, the highest WPMY value (5.85 kg m^{-3}) was found with the estimated depth of 85.85% ETc. Although the highest total and marketable yields in the first and second cycle were achieved with depths between 93.62% and 96.04% ETc, the highest WP for pear cultivation in the Sub-middle São Francisco region occurred with the depths below 90% ETc. Vélez-Sánchez et al. (2021), when evaluating the controlled deficit (27% and 48% ETc) in pear crop under tropical climate conditions, found higher WP in treatments that received lower amounts of water.

The analysis of variance also indicated a significant difference between irrigation systems (Drip and Micro-sprinkler) for WPTY and WPMY (Figure 5). In the first cycle, there was no difference for WPTY, with mean of 10.09 kg m^{-3} between treatments.

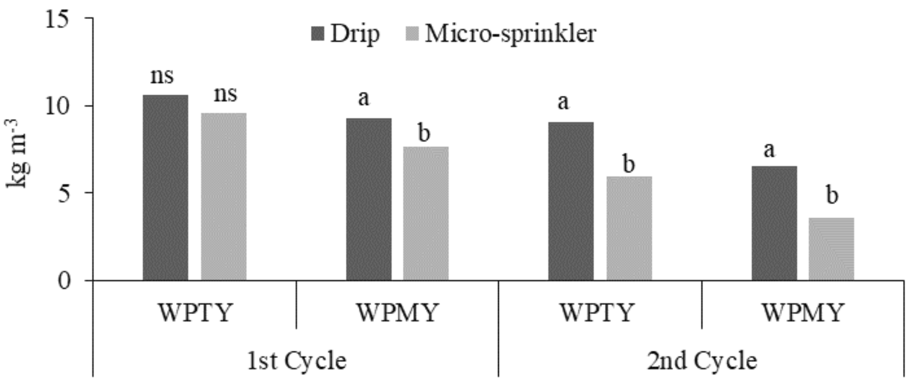

Figure 5. Water productivity for total yield (WPTY) and water productivity for marketable yield (WPMY) in the cultivation of 'Triunfo' pear under different irrigation systems in two crop cycles in the Sub-middle São Francisco region. Different letters indicate difference between irrigation systems.

However, in the first cycle there was a significant effect for WPMY (Figure 5), with values of 9.30 kg m^{-3} and 7.95 kg m^{-3}, for drip- and micro-sprinkler-irrigated treatments, respectively. In the second cycle, there was also an effect of irrigation systems on the variables WPTY and WPMY, whose highest means were recorded in drip-irrigated areas, with values of 9.04 kg m^{-3} and 6.58 kg m^{-3}, respectively. The higher water productivity (WP) in the drip system can be related to the higher efficiency in water application and absorption, when compared to the micro-sprinkler system.

In addition, the analysis of orthogonal contrasts showed a significant difference between the crop cycles for WPTY and WPMY. In the first cycle, the WPTY and WPMY values were higher than in the second cycle of the experiment, with means of 10.09 kg m^{-3} and 8.48 kg m^{-3}, respectively. In the second cycle, the observed means of WPTY and WPMY were 7.48 kg m^{-3} and 5.06 kg m^{-3}, respectively. The higher WP values in the first cycle are related to the higher means of yield found in this cycle, a factor that contributes to the optimization of water use in this period.

Effect of irrigation depths on the average weight of marketable fruits was also observed (Figure 6A). According to the regression models for this variable, the second-degree polynomial model showed the best fit in both crop cycles, estimating that the depths of 94.18% and 94.96% ETc were responsible for the highest weights of marketable fruit, with means of 236.17 g and 230.68 g, for the first and second cycle, respectively. In studies carried out with different irrigation regimes (60%, 80%, 100% and 120% ETo) with the apple crop in the region of the present study, it was found that the higher volumes of water (120% ETo depths) also favored an increase in average fruit weight (OLIVEIRA et al., 2017).

The reduction in the water volume applied during fruit growth, especially in phases 2 (cell elongation) and 3 (maturation), tends to reduce crop yield due to the reduction in the number and mainly the size and weight of the fruits (OLIVEIRA et al., 2017). On the other hand, as observed for marketable yield (Figure 2B), excess water also compromised the average weight of marketable fruit, which may also be associated with leaching of nutrients such as nitrogen, potassium and magnesium, responsible for photosynthesis, which affects fruit growth.

For pulp firmness, Figure 6B points to significant difference caused by irrigation depths, with best fit to the quadratic polynomial model for the first crop cycle, and this effect was not significant in the second cycle, with mean of 11.59 N cm^{-2}. The estimated depth of 104.97% ETc led to the lowest fruit pulp firmness (7.84 N cm^{-2}). This result may be associated with the fact that the concentration of cell wall materials and pulp firmness may decrease with the increase in fruit size, due to cell elongation (TAIZ; ZEIGER, 2017).

The results of the present study corroborate those reported by Oliveira et al. (2017), who studied with apple varieties and different water regimes, in the Sub-middle São Francisco region, and found reduction in pulp firmness as fruit size increased. The starch accumulation and turgor promoted by the adequate water availability favor pulp firmness (TAIZ; ZEIGER, 2017), enabling an advantage for harvest and post-harvest management procedures (SIMÕES et al., 2018). In addition, water restriction can limit cell division and expansion, increasing the density of the cell chain and the thickness of palisade tissue (ZHOU et al., 2017), justifying higher values for pulp firmness in less irrigated plots.

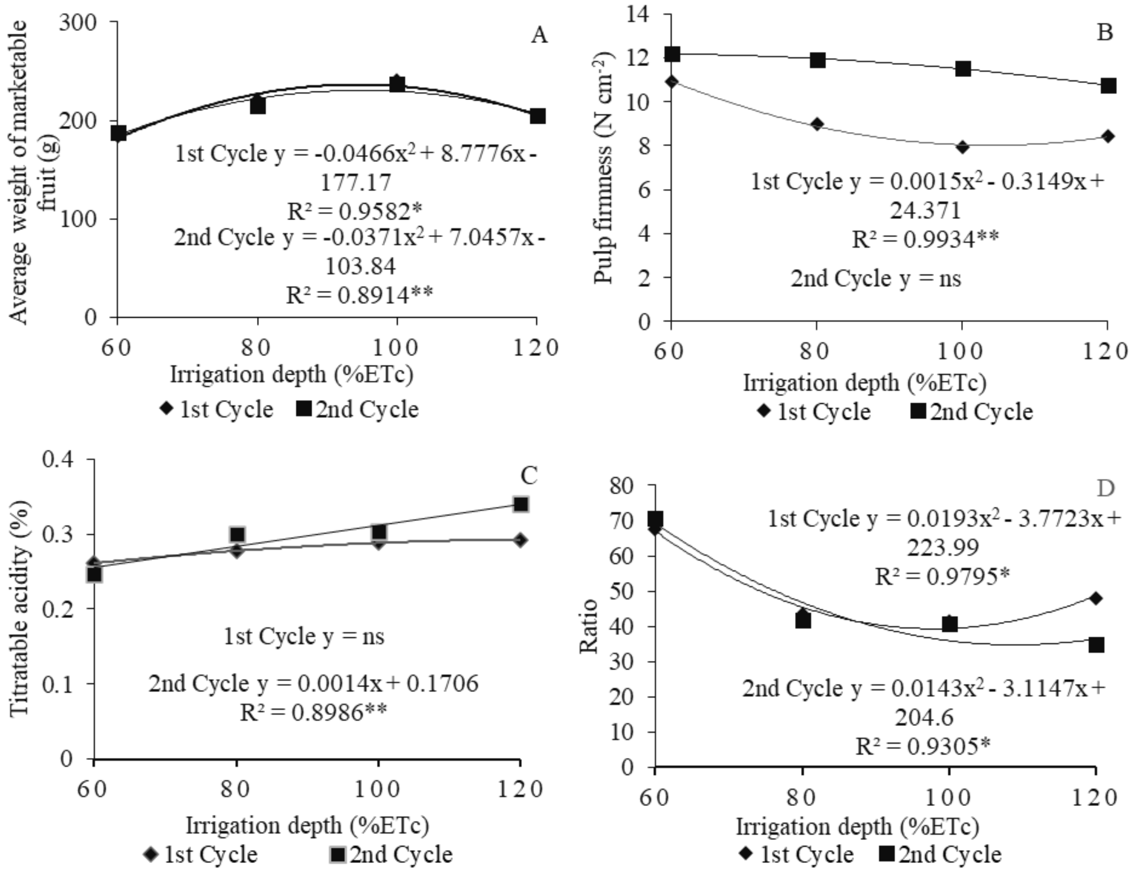

Figure 6. Average weight of marketable fruit (A), pulp firmness (B), titratable Acidity (C) and ratio (Soluble Solids/Titratable Acidity) (D) in fruits of 'Triunfo' pear under different irrigation depths in two crop cycles in the Sub-middle São Francisco region. [ns] Not significant; *Significant at 5% probability level; **Significant at 1% probability level.

Still regarding pulp firmness, significant difference was also observed between the crop cycles, by orthogonal contrast analysis, with higher values in the second cycle (11.59 N cm^{-2}) than in the first cycle (9.06 N cm^{-2}). The lower mean obtained in the first cycle may be linked to the occurrence of rainfall during the fruiting period, which allowed an increase in the water content of the fruits, reducing pulp firmness.

Although the water regime affected pulp firmness in the first cycle, the values obtained in the present study did not compromise the specifications of the Ministry of Agriculture, Livestock and Food Supply for marketing, which instructs that the minimum pulp firmness should be between 6.86 and 14.47 N cm^{-2} (BRASIL, 2006), and the results of this study are within this range.

In titratable acidity, a significant difference caused by the irrigation depths was observed in the first crop cycle (Figure 6C), when the increase in soil water content led to an increase in fruit acidity. This behavior was not significant in the second cycle, with mean of 0.30% for this variable. In agreement with the present study, Wu et al. (2013) reported that the water deficit at depths of 40% and 60% of the Class A Pan Evaporation, in the phases of cell division and fruit growth of pear crop, in the region of the Taklimakan Desert, China, showed no significant difference in the content of titratable acids in the studied treatments.

Titratable acidity indicates the quality in fruit flavor and can be directly related to the content of soluble solids, because as the °Brix increases the content of these organic acids decreases (CHITARRA; CHITARRA, 2005). Although the irrigation depths did not significantly influence the content of soluble solids, the titratable acidity in the fruit decreased as a function of water restriction.

Regarding the ratio variable (Soluble solids/Titratable acidity), there was a significant effect of the irrigation depths, with fit to the quadratic polynomial model (Figure 6D), which showed that the increase in irrigation depths up to 120% ETc caused a decrease in this variable, with minimum values of 39.41 and 40.76, in the first and second cycle, respectively.

Ratio is an index that indicates fruit maturity and flavor, and this parameter can be influenced by climatic attributes, such as luminosity and temperature, in addition to the water content in the soil (CHITARRA; CHITARRA, 2005; OLIVEIRA et al., 2017).

Although the results suggest that fruits under water restriction or subjected to the drip irrigation system have influenced fruit flavor (ratio), their values were higher than those found under subtropical condition in the Southeast of

Brazil by Bettiol Neto et al. (2014), who obtained an average ratio of 21.81 for 'Triunfo' pear.

For soluble solids, a significant difference was observed only between the irrigation systems in the second crop cycle, when the drip system led to the highest content of soluble solids (12.75 °Brix), an increase of 9.46% compared to plots subjected to the micro-sprinkler system (Figure 7A).

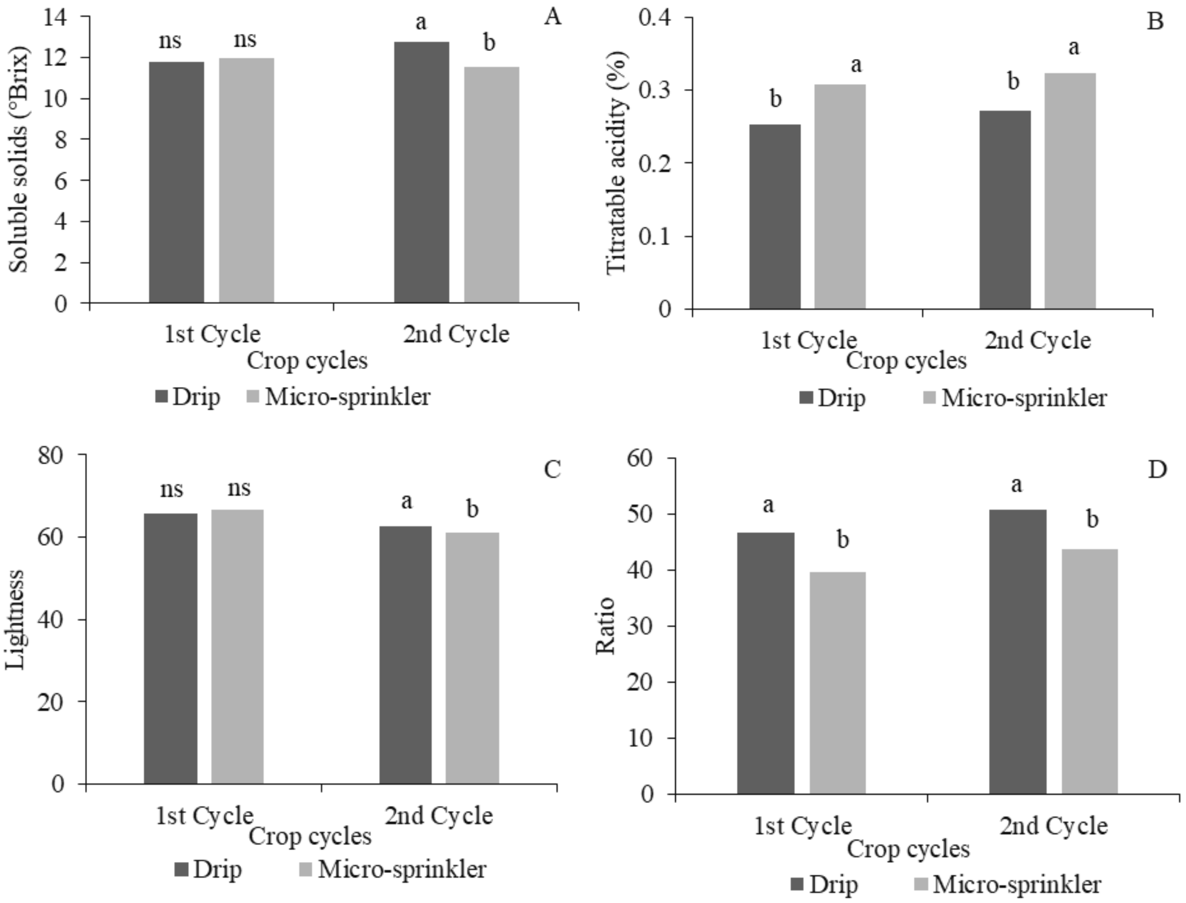

Figure 7. A – Soluble solids; B – Titratable acidity; C – Lightness D – Ratio (Soluble Solids/Titratable Acidity) in fruits of 'Triunfo' pear under two irrigation systems in two crop cycles in the Sub-middle São Francisco region. Different lowercase letters indicate difference between irrigation systems.

This effect can be justified by the fact that plants under irrigation systems of high application efficiency, as is the case of drip system, tend to have a higher water availability, stomatal conductance and photosynthetic rate, producing more sugars for the fruits than in situations where water application is less efficient (FALLAHI, 2017; TAIZ; ZEIGER, 2017).

The results found in the present study for soluble solids are superior to those found in a subtropical climate by Bettiol Neto et al. (2014), who obtained a content of 9.17 °Brix for 'Triunfo' pear. The soluble solids content can vary according to the variety, climate, position of the fruit in the crown, and time of harvest (BETTIOL NETO et al., 2014; FENG et al., 2014; FLORES-CANTILLANO; OTEIZA, 2003). The high solar radiation of the Brazilian semi-arid region may also be one of the factors that contributed to increasing the content of soluble solids. In general, the contents of soluble solids found for pear fruits in the present study are in accordance with the specifications for marketing standards, between 11 and 14 ° Brix (FLORES-CANTILLANO; OTEIZA, 2003).

The analysis of variance also showed that the irrigation system had an individual influence on the acidity content of the fruit, as shown in Figure 7B. Plots with micro-sprinkler system had higher concentrations of titratable acidity, with increases of 17.42% and 15.88% in the first and second cycle, respectively, compared to drip irrigation.

The higher values of titratable acidity obtained in the micro-sprinkler system may be related to its low efficiency of water application, when compared to the drip system. Simões et al. (2018) noticed this same effect in mango crop in the Brazilian semi-arid region, where the plots with micro-sprinkler system had higher acid contents in the fruits.

In general, the values of titratable acidity found in the present study were lower than those obtained by Bettiol Neto et al. (2014) for cv. 'Triunfo', with mean of 0.42%, in the Subtropical Zone of eastern São Paulo state. Hamadziripi et al. (2014) stated that fruits with greater exposure to sunlight tend to have a lower acidity content, thus justifying the results found in the present study.

For the characteristics related to the pear fruit epidermis color, only lightness was significantly different between the irrigation systems in the second crop cycle (Figure 7C). The drip system was the one that led to the highest mean (62.65), with an increase of 2.42% compared to the micro-sprinkler treatment.

Between crop cycles, the analysis of orthogonal contrasts for lightness and hue angle of the fruit epidermis (h) were influenced by the periods of the experiment, with mean values of 66.55 and 61.14 for lightness in the first and second cycle, respectively.

For the hue angle of the epidermis, the mean was higher in the second cycle, with a value of 109.73, while in the second cycle the mean was 106.21. For chroma, there was no significant response among the treatments, with mean of 45.43.

The higher lightness value in the first crop cycle may be associated with the occurrence of higher means of temperature and solar radiation, when compared to the second cycle, since lightness is related to the greater amount of chlorophyll pigments in the fruit (CHITARRA; CHITARRA, 2005).

As for the hue angle of the epidermis (parameter h), the lower value found in the first cycle may also be linked to environmental factors, since this characteristic measures the more yellowish shade of the epidermis (CHITARRA; CHITARRA, 2005), being an attribute that is inversely proportional to lightness.

In general, the values of lightness, chroma and hue angle of the epidermis in the present study are higher than those found by Bettiol Neto et al. (2014), who evaluated the production and post-harvest quality of 'Triunfo' pear under the subtropical conditions of eastern São Paulo.

In addition, effect of irrigation systems on the ratio (Figure 7D) was observed in the two crop cycles, and these values were higher for the drip system in both crop cycles. For the first cycle in the micro-sprinkler system there was a reduction of 15.34% in the ratio, when compared to the drip-irrigated plots, while in the second cycle this reduction was 15.89%. For all treatments, the values observed for these variables, as well as for the content of soluble solids, titratable acidity, ratio and pulp firmness, are consistent with the maturity stage of the fruits at the time of harvest.

CONCLUSIONS

Irrigation depths of 96.04% and 94.84% ETc promoted, respectively, the highest marketable yields in the first (43.48 t ha^{-1}) and second (26.55 t ha^{-1}) cycle of 'Triunfo' pear in the Sub-middle São Francisco region.

The drip irrigation system in the warmest period (between November and April) promoted the highest yield (41.45 t ha^{-1}).

Cultivation of 'Triunfo' pear under drip and micro-sprinkler irrigation promotes fruits with good commercial quality (soluble solids, titratable acidity, ratio and pulp firmness) in the Sub-middle São Francisco region.

Irrigation depths of 94.18% and 94.96% ETc promote, respectively, the highest average weight of marketable fruit in the first (236.17 g) and second (230.68 g) cycle of 'Triunfo' pear in the Sub-middle São Francisco region.

REFERENCES

ALLEN, R. G. et al. **Evapotranspiración del cultivo**. Guías para la determinación de los requerimientos de agua de los cultivos. Roma: Food & Agriculture Org. 2006. 298 p.

BETTIOL NETO, J. E et al. Produção e qualidade pós-colheita de cultivares de pereira nas condições subtropicais da região leste paulista. **Ciência Rural**, 44: 1740-1746, 2014.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Instrução Normativa n° 3 de 2 de fevereiro de 2006**. Decreta o Regulamento Técnico de Identidade e Qualidade da Pêra; as Disposições Complementares e a Amostragem, Conformação da Amostra e Análise, Brasília, DF, n° 3, 2 de fevereiro de 2006.

CHITARRA, M. I. F.; CHITARRA, A. B. **Pós–colheita de frutas e hortaliças: fisiologia e manuseio**. 2. ed. Lavras, MG: UFLA, 2005. 785 p.

FALLAHI, E. Long-term influence of irrigation systems on Postharvest fruit quality attributes in mature 'Autumn Rose Fuji'apple trees. **International Journal of Fruit Science**, 18: 1-11, 2017.

FENG, F. et al. Effects of location within the tree canopy on carbohydrates, organic acids, amino acids and phenolic compounds in the fruit peel and flesh from three apple (Malus x domestica) cultivars. **Horticulture Research**, 1: 1-7, 2014.

FLORES-CANTILLANO, R. F.; OTEIZA, E. Fisiologia e manejo pós-colheita. In: FLORES-CANTILLANO, R. F. et al. (Eds.). **Pêra: pós-colheita**. Brasília, DF: Embrapa Comunicação para Transferência de Tecnologia, 2003. v. 1. cap. 1, p. 12-35.

GOMES, V. H. F. et al. Production, gas and biochemical exchanges in pear cultivated in semi-arid region under different irrigation managements. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 27: 335-342, 2023.

HAMADZIRIPI, E. T. et al. Apple Compositional and Peel Color Differences Resulting from Canopy Microclimate Affect Consumer Preference for Eating Quality and Appearance. **Horticulture Science**, 49: 384–392, 2014.

IBGE - Instituto Brasileiro de Geografia e Estatística. **Sidra: produção agrícola municipal**. Disponível em: <https://sidra.ibge.gov.br/home/pnadcm/>. Acesso em: 6 jan. 2023.

IAL - Instituto Adolfo Lutz. **Métodos químicos e físicos para análise alimentos**. 4. ed. São Paulo, SP: Normas analíticas do Instituto Adolfo Lutz, 2008. 1020 p.

LEPAJA, L. et al. The ratio between leave and Fruit parameters on 'William' pear orchard affected by regulated deficit irrigation and mulching. **Agricultural University of Tirana**, 15: 8-12, 2016.

LOPES, P. R. C et al. Caracterização fenológica de pereiras 'Housui' e 'Kousui' cultivadas sob clima semiárido no Nordeste do Brasil. **Revista Brasileira de Fruticultura**, 35: 105-110, 2013.

MAPA – Ministério da Agricultura, Pecuária e Abastecimento. **AGROSTAT - Estatísticas de Comércio Exterior do Agronegócio Brasileiro**. Disponível em: <http://indicadores.agricultura.gov.br/agrostat/index.htm> Acesso em: 1 abri. 2023.

NAKASU, B. H.; FAORO, I. D. Pêra produção. In. NAKASU, B. H.; CENTELHAS-QUEZADA, A.; HERTER, F. G. **Cultivares**. Brasília, DF: Embrapa Informação Tecnológica, 2003. v. 1, cap. 5, p. 29-36.

OLIVEIRA, C. P. M. et al. Physiological and biochemical responses of apple trees to irrigation water depth in a semiarid region of Brazil. **Ciência e Agrotecnologia**, 44: 1-13, 2020.

OLIVEIRA, C. P. M. et al. Quality of irrigated apples in the Semiarid region of the Northeast of Brazil. **Revista Caatinga**, 30: 760-767, 2017.

OLIVEIRA, I. V. M.; LOPES, P. R. C.; SILVA-MATOS, R. R. S. Avaliação fenológica da pereira 'Triunfo' cultivada em clima Semiárido no nordeste do Brasil na safra de 2012. **Revista Brasileira de Fruticultura**, 37: 261-266, 2015.

OLIVEIRA, K. A. S. et al. Impact of paclobutrazol on gibberellin-like substances and soluble carbohydrates in pear trees grown in tropical semiarid. **Revista de la Facultad de Ciencias Agrarias**, 54: 46-56, 2022.

SILVA, F. G. D. et al. Trocas gasosas e fluorescência da clorofila em plantas de berinjela sob lâminas de irrigação. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 19: 946-952, 2015.

SILVA, V. P. R. et al. Evapotranspiração e coeficientes de cultivo simples e dual do coentro. **Horticultura Brasileira**, 31: 255-259, 2013.

SIMÕES, W. L. et al. Produção e qualidade da mangueira 'Kent' (Mangifera indica L.) submetida a diferentes lâminas de irrigação no semiárido nordestino. **Revista em Agronegócio e Meio Ambiente**, 14: 305-314, 2021.

SIMÕES, W. L. et al. Produção e respostas fisiológicas da mangueira cv. Keitt sob diferentes sistemas de irrigação no Submédio do São Francisco. **Revista Irriga**, 23: 34-43, 2018.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 6. ed. Porto Alegre, RS: Artmed, 2017. 858 p.

VÉLEZ-SÁNCHEZ, J. E. et al. Effect of regulated deficit irrigation (RDI) on the production and quality of pear Triunfo de Viena variety under tropical conditions. **Scientia Horticulturae**, 278: 1-8, 2021.

WALLER, P.; YITAYEW, M. **Irrigation and Drainage Engineering**. 1. ed. New York: Extra Materials, 2016. 742 p.

WU, Y. et al. Yield and growth of mature pear trees under water deficit during slowfruit growth stages in sparse planting orchard. **Scientia Horticulturae**, 164: 189-195, 2013.

ZHOU, H. et al. Peach yield and fruit quality is maintained under mild deficit irrigation in semi-arid China. **Journal of Integrative Agriculture**, 16: 1173-1183, 2017.