Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252023v36n418rc

Production of irrigated cherry tomatoes in economical planting beds with mulching

Produção de tomate-cereja irrigado utilizando canteiros econômicos com mulching

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ABSTRACT - Technologies that improve water use efficiency (WUE) and increase crop yields are essential for the development of a responsible and productive agriculture. Therefore, the objective of this study was to evaluate economical planting beds with the use of mulching and application of different irrigation water depths as a water-saving technology, and determine the irrigation water depth that promote the optimal plant development and fruit yield and quality of two cherry tomato cultivars. The experiment was conducted at the Federal Rural University of Pernambuco, Serra Talhada, PE, Brazil. A randomized block experimental design with split-plots (5×2) was used, with plots consisting of five irrigation water depths (25%, 50%, 75%, 100%, and 125% of the crop evapotranspiration - ET_c) and subplots consisting of two cherry tomato cultivars (Carolina and Yubi), with four replications, totaling 40 experimental units. The development of tomato plants was evaluated through biometric measurements of stem diameter, plant height, and canopy area. Additionally, the following variables were evaluated during fruit harvest: number of fruits, mean fruit weight, fruit diameter, fruit yield, WUE, titratable acidity, pH, and soluble solids content. The economical planting beds promoted increases in WUE. Irrigation water depths lower than 100% of ET_c resulted in better plant development and higher fruit yield, number of fruits, and WUE for the evaluated cherry tomato plants. The cultivar Carolina exhibited higher production performance compared to Yubi.

Keywords: Water use efficiency. Crop evapotranspiration. Semiarid.

RESUMO - Tecnologias que promovam o aumento da eficiência do uso da água (EUA) e incremento na produtividade é indispensável para o desenvolvimento de uma agricultura responsável e produtiva. Nesse sentido, objetivou-se avaliar ‘canteiros econômicos’ com a utilização de mulching, aplicando diferentes lâminas de irrigação para consolidar o uso desses canteiros como uma tecnologia que propicia a economia de água, da mesma forma que, encontrar a lâmina de irrigação que promova o melhor desenvolvimento, rendimento produtivo e qualidade de duas cultivares de tomate-cereja. A pesquisa foi conduzida na Universidade Federal Rural de Pernambuco em Serra Talhada – PE. Utilizou-se o delineamento experimental em blocos casualizados com parcelas subdivididas (5 x 2), onde foram consideradas parcelas cinco lâminas de irrigação (25, 50, 75, 100, e 125% da Evapotranspiração da cultura – ET_c) e subparcelas duas cultivares de tomate-cereja (Carolina e Yubi), com quatro repetições, totalizando 40 unidades experimentais. O desenvolvimento do tomateiro foi avaliado mediante coletas biométricas de diâmetro do caule, altura da planta e área da copa. Ademais, durante a colheita foi avaliado o número de frutos, massa média dos frutos, diâmetro dos frutos, produtividade, EUA, acidez titulável, potencial hidrogeniônico e sólidos solúveis dos frutos. Os canteiros econômicos promoveram aumento da EUA. Lâminas de irrigação inferiores a 100% da ET_c possibilitaram maior desenvolvimento, produtividade, número de frutos e EUA do tomate-cereja. A cultivar Carolina apresentou melhor desempenho produtivo comparado a Yubi.

Palavras-chave: Eficiência do uso da água. Evapotranspiração da cultura. Semiárido.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

Received for publication in: December 19, 2022.
Accepted in: June 12, 2023.

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INTRODUCTION

Low rainfall rates and variations in the spatial-temporal rainfall distribution result in severe droughts in the Semiarid region in the Northeast of Brazil, affecting agricultural production of water-demanding crops when cultivated under rainfed conditions (CASSIMIRO et al., 2019). In this sense, the use of irrigation enables increases in agricultural production in these regions (VALERIANO et al., 2016); however, inadequate irrigation practices can compromise the crop production process. Therefore, the appropriate use of irrigation through management practices and technologies that improve water use efficiency (WUE) is essential.

In this context, economical planting beds have emerged as a social technology aiming increases in WUE and providing conditions for expanding vegetable crop yields (CRUZ et al., 2015). According to Cassimiro et al. (2019), economical planting beds prevent water loss through infiltration by waterproofing the planting ground and reduce evaporation by using subsurface irrigation. Thus, combining this technology with mulching can result in even lower water losses, as mulching provides soil coverage, thus contributing to decreases in evaporation and occurrence of weeds (LI et al., 2013).

Tomato is one of the most grown and consumed vegetables worldwide and is economically and socially important in Brazil, where tomato crops are grown in several regions (GARCIA FILHO et al., 2017). Cherry tomatoes have stood out among tomato species due to an high consumer demand and rewarding prices for growers, often higher than those of other tomato cultivars (CANTELLI, 2018). These tomatoes are more rustic and tolerant to diseases and pests and present high yields (ZANIN et al., 2018; DIAS et al., 2019a), making them a great alternative for growing in economical planting beds.

Therefore, the objective of this study was to evaluate economical planting beds with the use of mulching and application of different irrigation depths as a water-saving technology and determine the irrigation depth that promotes the optimal plant development and fruit yield and quality of two cherry tomato cultivars.

MATERIAL AND METHODS

The experiment was conducted from January to May 2021, at an experimental area of the Federal Rural University of Pernambuco, in Serra Talhada, Pajeu Microregion, Pernambuco, Brazil (7°57'10"S and 38°17'43"W, and altitude of 429 m). The climate of the region is BSw'h', according to the Köppen classification, with a mean annual rainfall depth of 639 mm and a mean annual temperature of 25.2 °C (LAMEPE/ITEP, 2017).

The experiment was conducted in a randomized block design with a 5×2 split-plot arrangement, with plots consisting of five irrigation water depths (25%, 50%, 75%, 100%, and 125% of the crop evapotranspiration - ET_c) and subplots consisting of two cherry tomato cultivars (Carolina and Yubi), with four replications, totaling 40 experimental units with five tomato plants each.

Twenty planting beds with dimensions of 3.0 × 1.0 × 0.2 m (length, width, and depth, respectively) were implemented. The raising of the beds was performed firstly by leveling the ground in both the transverse and longitudinal directions to level the irrigation water depth and ensure a uniform water distribution throughout the bed. The beds were demarcated after land preparation, using ceramic blocks. Subsequently, a waterproofing was carried out using plastic films; then, a 40 mm pipe perforated every 0.2 m was installed on the film in the center of the bed. The beds were filled with a substrate composed of sand, soil, and well-aged bovine manure at a ratio of 2:3:4, which was subjected to chemical analysis after mixing (Table 1). Finally, the soil substrate in the beds was covered with mulching.

Table 1. Chemical analysis of the substrate used to fill the economical planting beds.

pH	EC	Al^{3+}	H+Al	K	Ca	Mg	Na	P	Fe	Cu	Zn	Mn	B
	dS m^{-1}	------------	------------	Cmolc dm^{-3}	------------	------------	------------	------------	------------	mg dm^{-3}	------------	------------	------------
7.2	5.84	0	0.2	1.15	9.3	3.5	0.47	520	22.6	1.7	3.1	14.4	3.6

EC = electrical conductivity of the saturation extract.

Soil fertilizer application was performed based on the substrate chemical analysis and soil fertilization recommendations for growing table tomato crops in the state of Pernambuco (IPA, 2008). Thus, 88 kg ha^{-1} of urea was applied at planting, and 266 kg ha^{-1} of urea was applied as topdressing at 30 days after planting (DAP). According to the manual, correction of other nutrients was not necessary.

Cherry tomato seedlings (cultivars Carolina and Yubi) were produced in 150 mL plastic cups containing substrate composed of soil and bovine manure at a ratio of 1:1, which was maintained moist. The seedlings were transplanted to the beds 30 days after sowing, distributed uniformly with spacing of 0.3 m, totaling 10 plants per bed (5 plants of each cultivar).

The irrigation water depth was calculated and applied underground, using microperforated pipes covered with ceramic tiles to protect them from clogging caused by soil particles. The system was individually assembled for each bed; the irrigation was based on the the crop evapotranspiration (ET_c), according to the equation described by Allen et al. (1998), which is the product of the reference evapotranspiration (ET_0) by the crop coefficient (K_c). ET_0 was obtained using the Penman-Monteith method, based on data of an automatic weather station (Campbell Scientific model CR1000/CFM100/OS100) near the experimental area. The Kc value used was that proposed by Doorenbos and Kassan (1994). The uniformity of water distribution in the economical planting beds was assessed by calculating its efficiency, which was 80%.

The effect of treatments on the development of cherry tomato plants was evaluated through measurements of stem diameter (SD; mm), plant height (PH; cm), and canopy area (CA; cm^2) from 15 to 60 days DAP. SD was obtained by measuring the stem base using a caliper; PH was measured from from the base to the apex of the plant using a measuring tape; and CA was determined by measuring the transverse diameters of the canopy and estimating it using the formula used to calculate the area of a circle.

The following variables were evaluated at the time of harvest: number of fruits per plant (NF) by counting; mean fruit weight (MFW; kg) by weighing on a semi-analytical balance; fruit diameter (mm), using a caliper; fruit yield (kg plant^{-1}); and water use efficiency (WUE; kg plant^{-1} m^{-3}), calculated by dividing the fruit yield by the applied water depth. Fruit quality was assessed by determining titratable acidity (AT), hydrogen potential (pH), and soluble solids content (°Brix), according to the methodology for food analysis of the Adolfo Lutz Institute – IAL (2008).

The obtained data were subjected to analysis of variance to evaluate the effects of the different irrigation water depths and cultivars; when significant, the means of irrigation water depths were evaluated through polynomial regression analysis and the means of cultivars were compared through the Tukey's test at 5% probability level, using the software R with the ExpDes.pt package (R Development Core Team, 2020).

RESULTS AND DISCUSSION

The accumulated rainfall depth, mean daily air temperature, mean relative air humidity, and mean daily solar radiation during the 110-day cycle of cherry tomato crops were 360 mm, 26.6 °C, 58.9%, and 19.8 MJ m^{-2} day^{-1}, respectively (Figure 1). These values are considered adequate for the development of cherry tomato plants, except the rainfall depth, which should accumulate between 400 and 600 mm to ensure a proper development for this crop (BRANDÃO FILHO et al., 2018). Therefore, the use of irrigation was essential.

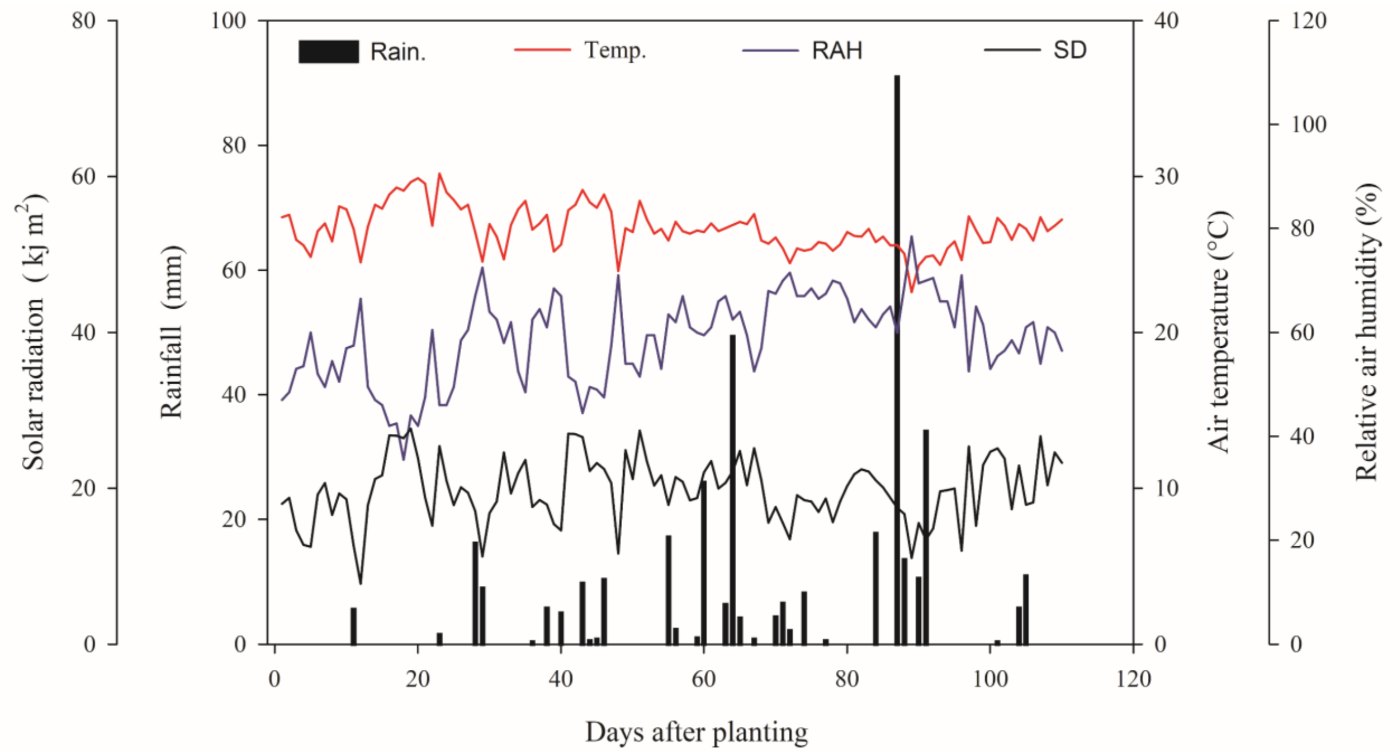


Figure 1. Climate data during the experimental period.

According to the analysis of variance (Table 2), the irrigation water depths had a significant effect on stem diameter and canopy area, but only in the final evaluation, at 60 DAP. The factor cultivar had a significant effect on plant height (except in the first evaluation), stem diameter (in all evaluations), and canopy area (in the last two evaluations). The interaction between irrigation water depth and cultivar had no significant effect on the growth-related variables.

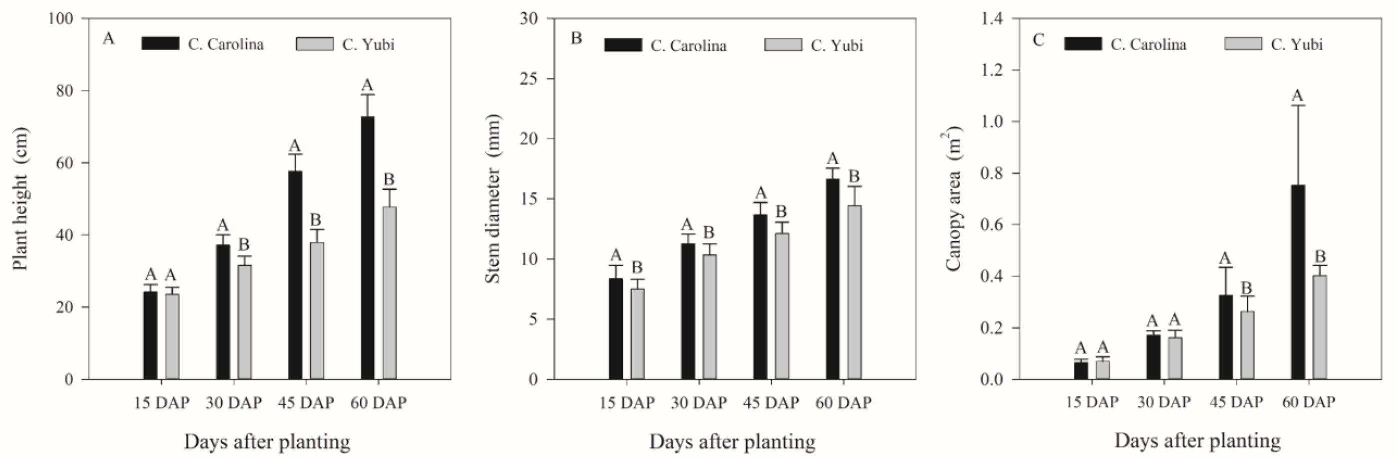
Paixão et al. (2020) and Santos et al. (2017) evaluated the effects of irrigation water depths on biometric variables of tomato plants by testing the water replenishment and found no significant effects on plant height. The difference found in the evaluated variables between the cultivars was expected, as the evaluated cherry tomato cultivars have distinct characteristics; however, the cultivar Carolina exhibited better performance compared to Yubi, as also found by Soares et al. (2022).

Table 2. Analysis of variance for plant height (PH), stem diameter (SD), and canopy area (CA) in cherry tomato plants of the cultivars Carolina and Yubi.

SV	DF	PH	SD	CA
		Mean square		
15 days after planting				
Block	3	13.906^{ns}	1.600^{ns}	0.0004^{ns}
ET_c (E)	4	4.155^{ns}	1.051^{ns}	0.0002^{ns}
Error 1	12	4.278	1.181	0.0003
Cultivar (C)	1.0	3.854^{ns}	7.041**	0.0001^{ns}
E×C	4	2.184^{ns}	1.009^{ns}	0.0003^{ns}
Error 2	15	2.071	0.5821	0.0001
CV 1 (%)	-	8.66	13.70	27.58
CV 2 (%)	-	6.02	9.62	14.32
30 days after planting				
Block	3	2.230^{ns}	0.354^{ns}	0.0002^{ns}
ETc (E)	4	3.550^{ns}	0.263^{ns}	0.0010^{ns}
Error 1	12	7.440	0.975	0.0072
Cultivar (C)	1.0	330.49**	8.957**	0.0009^{ns}
E×C	4	5.410^{ns}	1.191^{ns}	0.0008^{ns}
Error 2	15	9.130	0.546	0.0003
CV 1 (%)	-	7.91	9.12	16.14
CV 2 (%)	-	8.76	6.82	9.30
45 days after planting				
Block	3	16.400^{ns}	0.421^{ns}	0.003^{ns}
ETc (E)	4	6.300^{ns}	0.451^{ns}	0.010^{ns}
Error 1	12	21.400	1.283	0.007
Cultivar (C)	1.0	3868.100**	24.403**	0.038*
E×C	4	17.100^{ns}	0.620^{ns}	0.002^{ns}
Error 2	15	18.700	1.066	0.009
CV 1 (%)	-	9.67	8.78	29.19
CV 2 (%)	-	9.04	8.00	32.83
60 days after planting				
Block	3	24.100^{ns}	2.248^{ns}	0.056^{ns}
ETc (E)	4	35.800^{ns}	4.233*	0.181*
Error 1	12	25.700	1.085	0.041
Cultivar (C)	1.0	6271.700**	48.548**	1.228**
E×C	4	60.200^{ns}	1.491^{ns}	0.082^{ns}
Error 2	15	28.100	1.519	0.037
CV 1 (%)	-	8.40	6.70	35.09
CV 2 (%)	-	8.79	7.93	33.06

ns = not significant, ** and * = significant at 1% and 5% probability level by the F test, respectively; SV = source of variation; DF = degrees of freedom; CV = coefficient of variation; ET_c = irrigation water depth based on crop evapotranspiration percentages.

According to the Tukey's test for growth variables up to 60 DAP, plants of the cultivar Carolina showed better performance in all analyzed variables compared to those of the Yubi cultivar (Figure 2); only plant height at 15 DAP (Figure 2A) and canopy area at 15 and 30 DAP (Figure 2C) did not statistically differ between the cultivars. This difference in phenological variables denotes a distinction in the growth habits of the two cultivars, as plants of the cultivar Carolina have larger dimensions, indicating a higher production potential, considering that larger canopy areas promote greater solar radiation interception and, consequently, increases in photosynthesis and generation of assimilates, directly impacting crop yield (LADANIYA et al., 2021).



Means followed by the same letter in each evaluation are not significantly different from each other by the Tukey's test at 5% probability level.

Figure 2. Plant height (A), stem diameter (B), and (C) of cherry tomato plants (cultivars Carolina and Yubi) up to 60 days after planting (DAP).

According to Clarke, Danila, and Von Caemmerer (2021), photosynthetically active radiation is connected to leaf area and, consequently, canopy area. Fernandes et al. (2022) reported that crops with larger canopy areas are more exposed to wind and, therefore, have a higher CO_2 concentration. Therefore, considering that an adequate availability of solar radiation and CO_2 results in better crop performance, the results indicate that cherry tomato plants of the cultivar Carolina exhibit phenological characteristics for higher crop yield than those of the cultivar Yubi.

The high difference found in variables between the cultivars in the two last evaluations may be due to a high sensitivity of this crop to water stress during the flowering stage (BRITO et al., 2015), showing that plants of the cultivar Carolina are less affected by the amplitude of irrigation water depths applied.

Santos et al. (2017) found similar plant heights for the cultivar Carolina at 60 DAP to those found in the present study and higher than those found for the Yubi cultivar. However, the stem diameters found for both cultivars were smaller than those found in the present study.

The regression analysis showed that the linear and quadratic models best fitted the data of stem diameter (Figure 3A) and canopy area (Figure 3B), respectively. The largest stem diameter (16.1 mm) was found for the irrigation depth based on 125% of ET_c. Similarly, Lopes Sobrinho (2020) reported a linear result for stem diameter when testing irrigation depths, with the highest result (11.09 mm) found for the irrigation depth based on 125% of field capacity.

Contrastingly, the largest canopy area was found for the irrigation water depth based on 85% of ET_c, denoting that this variable is more sensitive to excess water. This result indicates that the use of economical planting beds minimizes evaporation, resulting in lower losses and accumulation of water in the beds, supplying water adequately to the crop with a low amount of water. The decrease found for canopy area may have occurred due to the soil saturation and filling pore spaces with water, thus reducing the oxygen availability in the root system.

Considering the correlation between canopy area and leaf area in cherry tomato crops, Silva et al. (2020) found the largest leaf area for irrigation depths close to 100% of ETc, reinforcing the importance of economical planting beds for improving crop performance and water use efficiency.

According to the analysis of variance (Table 3), the factor water depth affected significantly only the number of fruits, fruit yield, and water use efficiency (WUE), whereas the factor cultivar affected significantly the number of fruits, fruit diameter, mean fruit weight, and titratable acidity. The interaction between between the factors had no significant effect on the fruit-related variables.

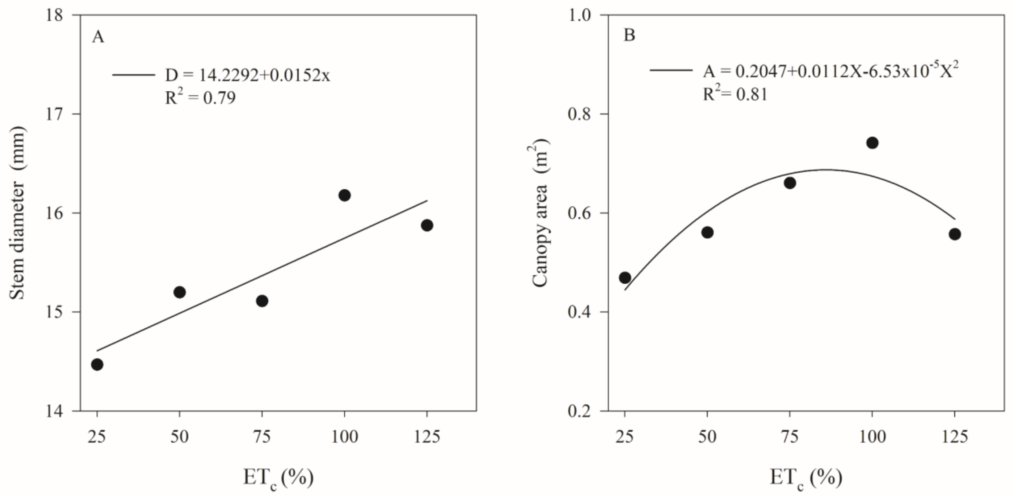


Figure 3. Regression analysis for stem diameter (A) and canopy area (B) of tomato cherry plants as a function of irrigation water depths (25%, 50%, 75%, 100%, and 125% of the crop evapotranspiration – ET_c).

Table 3. Analysis of variance for number of fruits (NF), fruit diameter (FD), mean fruit weight (FW), fruit yield (YIELD), water use efficiency (WUE), and fruit titratable acidity (TA), pH, and soluble solids content (°Brix) in cherry tomato plants.

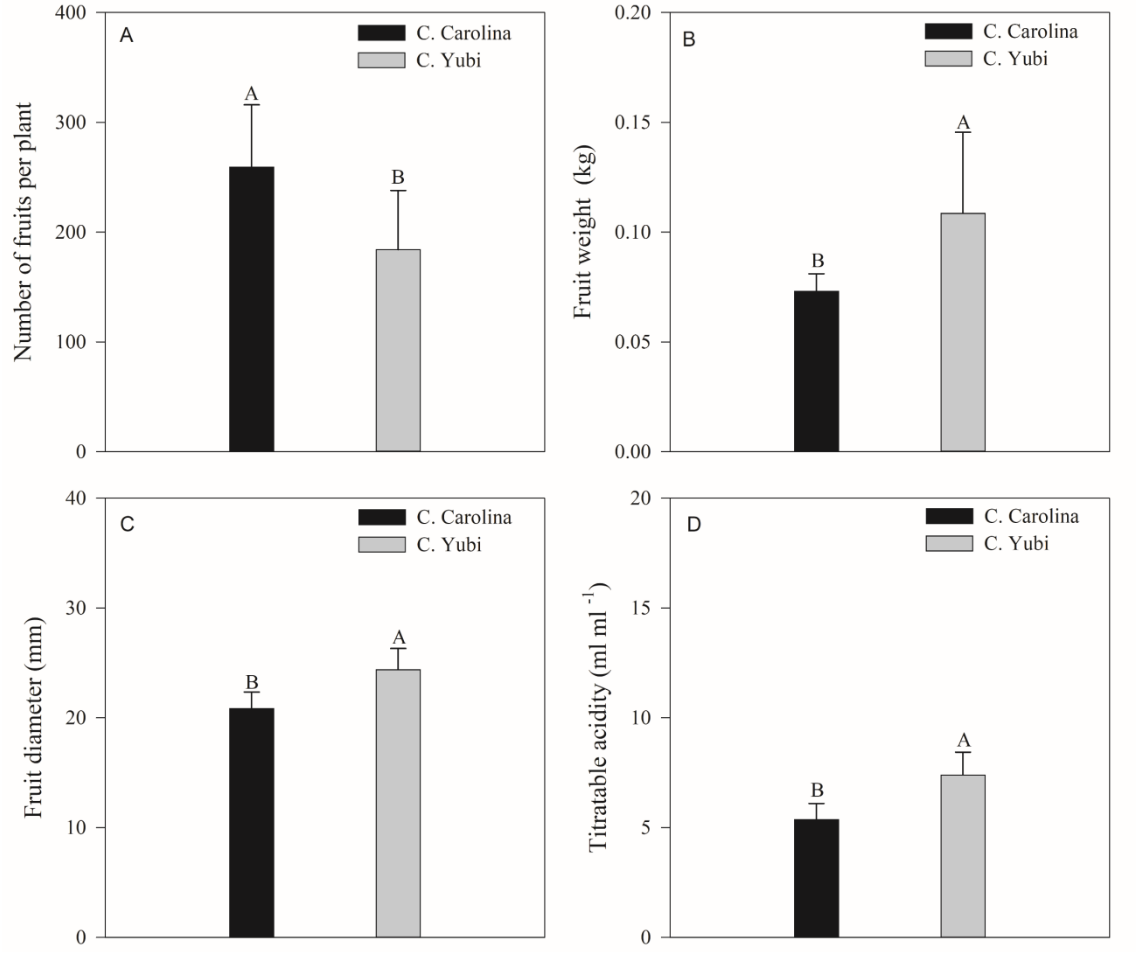
SV	DF	NF	FW	FD	YIELD	WUE	TA	pH	°Brix
		Mean square							
Block	3	31531^{ns}	0.0001^{ns}	2.935^{ns}	0.593^{ns}	21.33^{ns}	0.491^{ns}	0.327^{ns}	0.168^{ns}
ET_c (E)	4	368163**	0.0010^{ns}	5.316^{ns}	1.983*	695.88**	1.153^{ns}	0.151^{ns}	0.400^{ns}
Error 1	12	54479	0.0007	4.244	0.557	44.73	0.593	0.130	0.371
Cultivar (C)	1.0	1407000**	0.0126**	124.609**	0.044^{ns}	16.78^{ns}	41.168**	0.083^{ns}	0.001^{ns}
E×C	4	1763^{ns}	0.0003^{ns}	1.603^{ns}	0.040^{ns}	7.66^{ns}	0.833^{ns}	0.643^{ns}	0.102^{ns}
Error 2	15	45960	0.0008	1.697	0.246	64.55	0.926	0.350	0.187
CV 1 (%)	-	21.06	30.67	9.11	32.75	30.57	12.05	8.68	8.99
CV 2 (%)	-	19.35	31.53	5.76	21.78	36.72	15.06	14.24	6.39

ns = not significant and ** and * = significant at 1% and 5% probability level by the F test, respectively; SV = source of variation; DF = degrees of freedom; CV = coefficient of variation; ET_c = irrigation water depth based on crop evapotranspiration percentages.

According to the Tukey's test, plants of the cultivar Carolina showed better performance for number of fruits (259 fruits plant^{-1}) compared to plants of the cultivar Yubi (184 fruits plant^{-1}) (Figure 4A). Contrastingly, plants of the cultivar Yubi exhibited higher mean fruit weight (Figure 4B), (Figure 4C), and titratable acidity (Figure 4D). The number of fruits found for plants of both cultivars were higher than those reported in others studies with cherry tomato plants (MATOS et al., 2021; SHABBIR et al., 2020).

Similarly, the results found for mean fruit weight (FW) (Figure 3B) were higher than those reported in others studies (DIAS et al., 2019b; DU et al., 2017; PACHECO et al., 2018), indicating that these results were intensified by using economical planting beds, which provided better conditions for the crop development, denoting a possible positive impact of this technology. Additionally, Dias et al. (2019b) reported lower fruit weight (0.75 kg) for cherry tomatoes compared to those found in the present study. However, the fruit diameters found (Figure 4C) were similar to those reported by Matos et al. (2021), who found 18.8 to 27.6 mm.

Contrastingly, the results of titratable acidity (TA) found (Figure 4D) were lower than those reported by Dias et al. (2019b), who found TA higher than 15% in cherry tomatoes of the cultivar Fern. The lower the fruit acidity, the sweeter the fruit, and may be a characteristic that improves fruit quality; however, the preference for sweeter or more acidic tomatoes is subjective and varies depending on the food habits of consumers, which have regional variations (NASCIMENTO et al., 2013).



Means followed by the same letter are not significantly different from each other by the Tukey's test at 5% probability level.

Figure 4. Number of fruits per plant (A) and fruit weight (B) diameter (C), and titratable acidity (D) of cherry tomato plants.

According to the regression analysis, the quadratic model best fitted the results of number of fruits (Figure 5B) and fruit yield, whereas WUE presented a decreasing linear trend. The highest number of fruits (181 fruits) was found for the irrigation water depth of 94% ET_c, whereas the highest fruit yield (1.47 kg plant^{-1}) was found for the irrigation water depth of 86% ET_c, which is similar to the water depth that resulted in the largest canopy area.

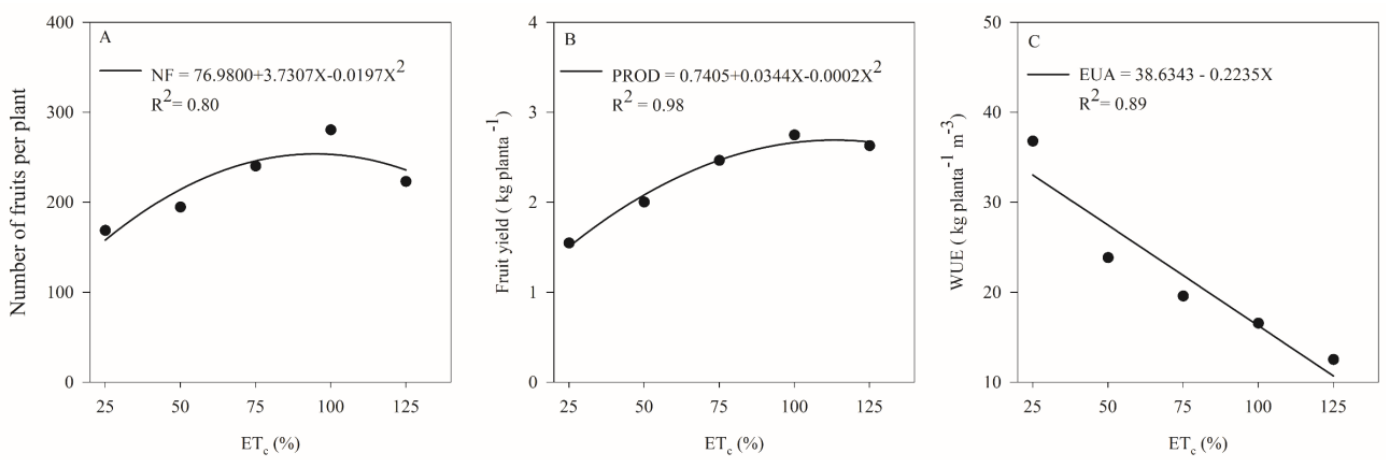


Figure 5. Regression analysis for number of fruits per plant (A), (B), and water use efficiency (WUE) (C) of cherry tomato plants as a function of irrigation water depths (25%, 50%, 75%, 100%, and 125% of the crop evapotranspiration – ET_c).

These results show that the use of economical planting beds enable water savings, as they provided a 14% decrease in water consumption, while promoting fruit yield, which was higher than those reported by Dias et al. (2019b) and Du et al. (2017), who found yields of 258.8 g plant^{-1} and 194.8 g plant^{-1}, respectively.

Cruz et al. (2022) evaluated different water replenishment levels for growing conventional tomato crops in economical planting beds and found that a water depth higher than 100% of ET_c was necessary to achieve the highest fruit yield. The different response found for cherry tomatoes plants in the present study may have been due to their rusticity and resistance to water stress, as table tomatoes subjected to water excess or deficit, mainly during the flowering and fruiting stages, exhibit low development, impacting fruit yield (SILVA et al., 2020).

The highest WUE (36.8 kg plant^{-1}) was found for the irrigation water depth of 25% ET_c. The WUE decreased to 12.53 kg plant^{-1} when increasing the water depth to 125% of ET_c. These results are consistent with those found by Du et al. (2017). Using an irrigation water depth of 86% of ET_c for growing cherry tomatoes in economical planting beds increase fruit yield and WUE due to the use of a reduced irrigation depth than 100% ETc, denoting that it is a great alternative for semiarid regions or other regions subjected to water restrictions.

CONCLUSION

The use of economical planting beds proved to be a technology that enables increases in water use efficiency (WUE) and consequently water savings. Irrigation water depths lower than 100% of ET_c enabled improvements in plant growth, fruit yield, number of fruits, and WUE in cherry tomato crops grown in economical planting beds with mulching. The cherry tomato cultivar Carolina exhibited a better production performance compared to Yubi under the same environmental conditions.

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