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IRRIGAÇÃO POR GOTEJAMENTO SUBSUPERFICIAL E FERTIRRIGAÇÃO DA CULTURA BRÓCOLIS*

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1 RESUMO

A irrigação eleva a produtividade e protege os cultivos da sazonalidade das chuvas, porém, sua aplicação deve estar embasada em critérios técnicos e operacionais. O objetivo deste trabalho foi avaliar o desempenho hidráulico de tubo gotejadores e o desenvolvimento da cultura brócolis submetida à irrigação por gotejamento em superfície e subsuperfície, com e sem fertirrigação. O experimento foi montado no esquema fatorial 3x2 em blocos casualizados (DBC), com quantro repetições. Os tratamentos foram constituídos da posição do tubo gotejador nas profundidades 0,00; 0,10 e 0,20 m; e a aplicação de fertilizantes, que foi realizada via fertirrigação e adubação manual. Em relação ao tubo gotejador, avaliou-se: vazão, coeficiente de variação de vazão (CVq), coeficiente de uniformidade de Christiansen (CUC), coeficiente de uniformidade de distribuição (CUD) e grau de entupimento (GE); em relação à resposta da cultura avaliou-se: diâmetro do pedúnculo floral, diâmetro da inflorescência, diâmetro perpendicular da inflorescência, altura da inflorescência, massa fresca da inflorescência, dias do transplante até a colheita e a produtividade da água. Não foram observadas alterações significativas nas características avaliadas do tubo gotejador e na produção da cultura brócolis quanto à profundidade do tubo e a forma de aplicação dos fertilizantes.

Palavras-chave: *Brassica oleracea* var. *itálica,* irrigação localizada, produtividade da água

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2 ABSTRACT

The use of irrigation increases yields and protects crops from the seasonality of precipitation; however, its application must be based on technical and operational criteria. This work aimed to evaluate the hydraulic performance of drip emitters and the development of the broccoli crop submitted to drip irrigation on surface and subsurface, with and without fertigation. The

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experiment was designed in randomized blocks (RBD), with four replications. The treatments were constituted of the positions of drip emitter at depths of 0.00; 0.10 and 0.20 m; and the application of fertilizers, that was made by fertigation and manual fertilizing. In relation to drip emitter, flow, flow variation coefficient (Cv), Christiansen uniformity coefficient (CU), distribution uniformity coefficient (DU) and degree of clogging of the emitter (Ec) were evaluated; regarding the crop response, the diameter of the flower stalk, the diameter of the inflorescence, the diameter of the inflorescence (perpendicular), height of the inflorescence, fresh mass of the inflorescence, days of transplantation until harvest and water productivity was analyzed. There were no significant changes in the characteristics evaluated of the drip emitter and in the production of broccoli crop in terms of the depth of the emitter and the way of application of the fertilizers.

Keywords: *Brassica oleracea* var. *itálica*, localized irrigation, water productivity

3 INTRODUCTION

The Food and Agriculture Organization (FAO) of the United Nations (2017) estimates that, by 2050, food consumption will be 70% higher than it is today; to meet this demand, the use of irrigation will be an indispensable strategy, allowing the intensification of global agricultural production.

Currently, Brazil has 7.3 million irrigated hectares (NATIONAL WATER AGENCY, 2019), with a prospect of 11.5 million hectares in 2024 (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2017). In this sense, the efficient use of water in agriculture is essential to guarantee the use of water resources by other sectors, nor does it meet the need for water for food production.

In Brazil, per capita broccoli consumption is low, approximately 1.04 kg year$^{-1;}$ in the United States of America, broccoli consumption is 3.8 kg year $^{-1;}$ and in Italy, it is 7.24 kg year^{-1} (PAIXÃO POR BRÓCOLIS BY SAKATA, 2017); however, they have shown an increasing trend. In the supply centers (Ceasas) in 2019, 40 thousand tons of broccoli were sold, representing 150 million reais (CONAB, 2019), to which the industrialized volume of broccoli must be added, mainly for the supply of frozen products in the market.

Irrigation, especially when associated with fertigation, is probably the agricultural practice that allows the greatest increase in agricultural productivity (MAROUELLI; SOUSA, 2011). Under current conditions, the future of irrigation involves productivity and profitability, with efficient use of water, energy and inputs and with management practices that respect the environment (MANTOVANI; BERNARDO; PALARETTI, 2013).

Satisfactory levels of productivity and quality of single-head broccoli can be obtained with the use of localized subsurface irrigation associated with fertigation, since these are techniques that allow the application of water and fertilizers directly to the root development zone, and according to Faria (2000), the adoption of this technique provides greater efficiency in the use of inputs, labor savings and better phytosanitary control.

However, the hydraulic network and drippers used in subsurface irrigation are susceptible to obstructions caused by the suction of soil particles into pipes, root intrusion, and the formation of organic and mineral precipitates or clay and silty sediments. Obstruction affects the uniformity with which water is distributed throughout the area; therefore, according to

Frizzone et al. (2012), some plots of land will be overirrigated, whereas others will be underirrigated.

The localized form of irrigation, which is characteristic of drip irrigation, according to Frizzone et al. (2012), can restrict roots to wet bulbs, limiting the volume of soil explored, which can lead to nutritional imbalance, in addition to water stress due to drought, especially during short dry periods. In this case, productivity and quality losses in broccoli crops could occur.

Given the above, the objective of this work was to evaluate the hydraulic performance of dripper tubes and the development of broccoli crops subjected to surface and subsurface drip irrigation, with and without fertigation.

4 MATERIALS AND METHODS

The experiment was carried out at the Federal Institute of Education, Science and Technology of Triângulo Mineiro (IFTM) - Uberaba *campus*, Minas Gerais, located at coordinates 19°45' south latitude, 47°55' west longitude and an altitude of 743 m.

The climate, according to the Köppen classification (1948), is hot and humid tropical, with cold and dry winters (Cwa), 1500 mm of precipitation and an average annual temperature of 21 °C.

Soil preparation was carried out via a subsoiler and levelling disc. The chemical characteristics of the soil samples were determined previously. The soil analysis results were interpreted, and fertilizer recommendations were made according to the recommendations of Bulletin 100 (VAIJ et al., 1997).

The single-head broccoli cultivar used was Avenger®, which was purchased from a reputable nursery in 128-cell trays and was transplanted into holes spaced 0.7 m between rows and 0.5 m between plants on 08/30/2019.

The irrigation system used was drip irrigation with TOP DRIP PC/AS emitters spaced 0.30 m apart, with a flow rate of 2.0 L h^{-1}. The filtration system consisted of a sand filter in series with a disc filter (120 mesh).

Randomized blocks (DBCs) with four replications were constructed in a factorial scheme (3 × 2), with the first factor being the burial depth of the dripper tube, which was 0.0, 0.10, and 0.20 m, and the second factor being fertigation and manual fertilization on the surface, for a total of six treatments.

Fertilization was carried out while maintaining the total amount of each nutrient as recommended by Bulletin 100, but the subdivisions were reorganized. Fertilization was carried out as follows: the planting dose was applied as a side dressing divided into two installments (one week apart), starting immediately after seedling establishment; the recommended side dressing dose was also applied in two installments, the first one week after the last planting fertilization and the other 15 days later. The total amount of each nutrient applied was 240 kg ha^{-1} of N, 200 kg ha^{-1} of P, 280 kg ha^{-1} of K, and 4 kg ha^{-1} of B, supplied in the form of urea (N), potassium chloride (K_2O), monoammonium phosphate (MAP) (P_2O_5), sodium molybdate (molybdenum), and boric acid (Boron), respectively.

The fertilizers were applied manually for conventional fertilization and injected with a hydraulic injection pump with a diaphragm for fertigation, whose brand and model are Amiad TMB 50 L. Three applications of molybdenum and boron were also carried out via foliar application.

A wide climate station equipped with precipitation, atmospheric pressure, temperature, and wind speed sensors was installed in the experimental area. Sensor readings were taken every 5 seconds, with average values compiled every 30 minutes. The collected climate data allowed climate monitoring and supported reference evapotranspiration (ETo) calculations.

The daily ETo was estimated via the method proposed by Penman–Monteith parameterized in FAO Bulletin 56 (ALLEN et al., 1998). The crop coefficient (Kc) values were adjusted daily by interpolating the values recommended by Doorenbos and Kassam (1979) for the crop development stages. The adjusted Kc values were as follows: from planting to 28 days after planting (DAP), Kc 0.37, increased daily by 0.015909; from day 29 to 62 DAP, Kc from the previous day increased by 0.009615; and from day 62 to harvest, Kc from the previous day decreased by 0.006250.

The net irrigation depth (LL) was calculated on the basis of the oasis evapotranspiration and the location coefficient, Equation 1:

$$LL = ETrl - P \quad (1)$$

In which,
LL is the net irrigation depth, mm;
P is the precipitation, mm; and
ETrl is the crop evapotranspiration for the localized irrigation condition, which is calculated via Equation 2:

$$ETrl = ETc \times K_L \times Kcl \times K_{ad} \quad (2)$$

In which,
ETc is the crop evapotranspiration, mm;
Kcl is the correction coefficient due to climatic variations, 1.2 (FARIA, 2000);
Kad is the correction coefficient due to advection, which is 1 (DOORENBOS; PRUITT, 1977);
K_L is the correction factor due to location, depending on the wet area or the shaded area, whichever is larger.

OK $_L$ was calculated according to the Keller equation (1978), since it is a horticultural plantation, Equation 3.

$$K_L = \frac{P}{100} + 0,15\left(1 - \frac{P}{100}\right) \quad (3)$$

In which,
P is the percentage of wet area or percentage of shaded area, always the larger value, in %.

The values adopted for P were 50% from transplantation to the 43rd day and 75% from the 44th day to harvest.

The gross irrigation depth (LB) was calculated via Equation (4):

$$LB = \frac{LL}{Ea} \quad (4)$$

In which,
LB is the gross irrigation depth, mm;
LL is the liquid blade, mm;
Ea is the application efficiency, with an adopted value of 90%.

In the first 10 days after transplanting, the soil surface was wetted to restructure it.

4.1. Hydraulic assessment

The initial evaluation of the drip system was carried out according to the methodology proposed by Keller and Kameli (1974), in which the drip lines located in the following positions were selected: first, 1/3, 2/3 and last, and in each of them, the drippers positioned at the beginning, 1/3, 2/3 and last in the irrigation line were selected.

After the experiment, the evaluation was repeated in a line of each plot following the same criteria as the initial evaluation to determine the emitters in which the flow was collected.

Hydraulic evaluations were performed before and after the experiment in accordance with NBR ISO 9261 (ABNT, 2006). For this purpose, the drippers were tested to determine the flow rate, flow rate variation coefficient (CVq) (Equation 5), Christiansen's uniformity coefficient (CUC) (Equation 6), distribution uniformity coefficient (CUD) (Equation 7) and degree of emitter clog (GE) (Equation 8).

$$CV_q = \left(\frac{S_q}{\bar{q}}\right) \times 100 \quad (5)$$

In which,
CVq is the coefficient of variation of flow, %.
Sq is the sample standard deviation, L h $^{-1}$.
where $\bar{q}$ is the average sample flow rate, L h $^{-1}$.

$$CUC = 100 \times \left(1 - \frac{\sum|q_i - \bar{q}|}{n \times \bar{q}}\right) \quad (6)$$

In which,
CUC is Christiansen's uniformity coefficient, %;
q_i is the flow rate of each dripper, L h $^{-1}$;
$\bar{q}$ is the average flow rate of the drippers, L h $^{-1}$;
n represents the number of drippers sampled.

$$CUD = 100 \times \left(\frac{\bar{q}_{25}}{\bar{q}}\right) \quad (7)$$

In which,
CUD is the coefficient of uniformity of distribution, %.
$\bar{q}_{25}$ is the average flow rate of the 25% smallest flows, L h $^{-1}$;
where $\bar{q}$ is the average flow rate of the drippers, L h $^{-1}$.

$$GE = \left(1 - \frac{q_{usado}}{\bar{q}_{novo}}\right) \times 100 \quad (8)$$

In which,
GE is the degree of clogging, %;
q is the flow rate of the dripper used, L h $^{-1}$;
$\bar{q}_{new}$ is the average flow rate of new drippers, L h $^{-1}$;

In terms of the evaluation of the characteristics of the dripper tube, i.e., flow, CUC, CUD and Cvq, the experimental design was 2 × 3 ± 1, with treatments with and without fertigation in a factorial scheme with the position of the dripper tube: on the surface, subsurface 0.10 and 0.20 m, and the additional one, which is the initial evaluation, was considered a control.

For the EG evaluation, the experimental design was 2 × 3, with the same sources of variation as for the tube evaluation, except for the addition of the control. Since EG can be a positive or negative value, the mean EG of each plot, for analysis of variance purposes, was calculated using the mean flow rate of the plot after use instead of the flow rate of each emitter, as per Equation 8.

The observed values of flow, CVq, CUC, and CUD were compared via the F test, both for the treatments and for the control. The data were subjected to analysis of variance via the F test at 1% and 5% probability.

4.2 Culture assessment

To evaluate the crops, 12 central plants from each plot were used; the plot consisted of 32 plants distributed in 4 lines.

The harvest was carried out between 10/30/2019 and 11/15/2019, when the central head or lateral branches presented well-developed flower buds, with a dark green color, but before the flowers opened, as recommended by Filgueira (2008).

The characteristics evaluated were floral peduncle diameter, inflorescence diameter, perpendicular inflorescence diameter, inflorescence height, inflorescence fresh weight, and days from transplantation to harvest.

Water productivity was determined by the relationship between commercial production and the volume of water applied via irrigation.

The data were subjected to analysis of variance via the F test at 1% and 5% probability.

5 RESULTS AND DISCUSSION

5.1 Dripper flow rate and uniformity

Christiansen's uniformity coefficient (CUC), distribution uniformity coefficient (CUD) and flow rate variation coefficient, as a function of the treatments regarding the use of fertigation and dripper pipe installation position, are represented in Table 1.

Table 1. Results of the analysis of variance of the flow rate, Christiansen uniformity coefficient (CUC), distribution uniformity coefficient (CUD) and flow rate variation coefficient (CVq).

FV	Flow rate (Lh^{-1})	CUC (%)	CUD (%)	CVq (%)
Fertilization (A)				
Fertigation	2.02	94.14	91.29	7:30
Manual fertilization	1.96	92.67	88.20	9.59
F Test	1.55 ^{ns}	0.72 ^{ns}	0.75 ^{ns}	0.96 ^{ns}
Burial depth (P)				
0.00 m	1.99	93.79	90.51	7.89
0.10 m	1.96	92.56	87.24	9.75
0.20 m	2.02	93.86	91.48	7.70
F Test	0.72 ^{ns}	0.24 ^{ns}	0.52 ^{ns}	0.32 ^{ns}
A*P Interaction				
F Test	0.99 ^{ns}	1.88 ^{ns}	1.88 ^{ns}	1.53 ^{ns}
Factorial x Witness				
F Test	4.25 ^{ns}	0.12 ^{ns}	0.36 ^{ns}	3.39 ^{ns}

^{ns} not significant according to the F test at 5% probability

Among the proposed treatments, the interaction effect between the fertilization method (manual or via fertigation) and the drip irrigation type (surface or subsurface) did not result in significant differences in the dripper flow, CUC, CUD, or CVq (Table 1). Therefore, fertigation and drip irrigation, both on the surface and subsurface, can be used without affecting emitter performance. According to the observed results, the dripper line model used can be used for irrigation and fertigation via surface and subsurface drip.

The average flow rate of the emitters before use (2.1 h^{-1}) was 5% higher than that indicated by the manufacturer (2 L h^{-1}), and after use (1.99 L h^{-1}), it was 0.5% lower. Fischer Filho et al. (2016), who evaluated a dripper of the same model after 100 hours of use, obtained a relative flow rate of 99.02%, that is, a flow rate 0.08% lower, corroborating the results reported here.

The average CUC after use was 93.40%, and before use, it was 92.60%. Thus, the sample was classified as excellent according to Mantovani (2002). Santos et al. (2016), in an experiment with drippers and fertigation, also obtained results classified as excellent for CUC. Berça, Mendonça and Souza (2019), under irrigation with dripper tubes for cabbage cultivation, obtained a CUC of 94.1%, which is consistent with the value reported in this work.

The CUD after use was 89.74%, and before use, it was 92.56%. Thus, this result can be classified as good for the used pipe and excellent for the new pipe, according to the classification proposed by Merriam and Keller (1978). Cunha et al. *(2014), evaluating* subsurface drippers with and without fertigation, reported that, one month after fertilizer application, the CUD was 93.1% and 95%, respectively, for the treatments with and without fertigation, and 12 months after application, values of 75% and 81%, respectively, were found for the treatments with and without fertigation., respectively.

The average CVq after use was 8.45%, and before use, it was 2.79%. According to the Brazilian standard NBR ISO 9261:2006 (ABNT, 2006), this result should not differ by ±7%, which occurred with the dripperlines after use, which presented an average CVq higher than this value. However, it should be noted that according to the statistical tests, fertigation or subsurface irrigation was not the cause of the variation in flow.

Therefore, it is recommended that the uniformity and flow rate of the emitters be monitored periodically, as these factors compromise water distribution and, consequently, can affect crop productivity due to the uneven distribution of water in the area.

The average degree of clogging of the emitters (GE) of the plots according to the treatments is presented in Table 2.

Table 2. Summary of the analysis of variance of the degree of clogging of the emitters (GE).

FV	**GE (%)**
Fertilization (A)	
Fertigation	4.08
Manual Fertilization	6.50
F Test	1.39 [ns]
Depth (P)	
0.00 m	5.23
0.10 m	6.74
0.20 m	3.90
F Test	0.65 [ns]
A*P Interaction	
F Test	0.89 [ns]

[ns] not significant according to the F test at 5% probability, FV variation factor

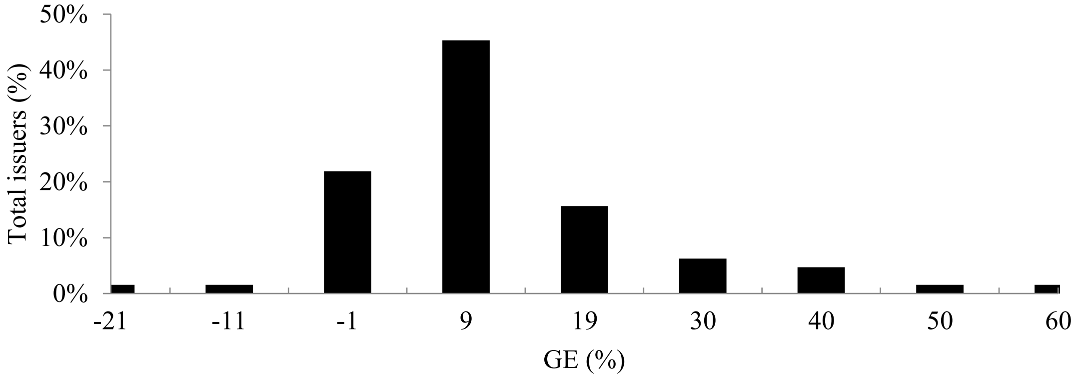
The average degree of clogging (GE) in the plots ranged from -4.83% to 20.53%. A negative GE value results from some obstructions causing increased flow, whereas a positive GE value refers to a reduction in flow. In most plots, the degree of clogging was positive, meaning that the flow was reduced. According to the classification proposed by Dantas et al. (2014), the average GE of the dripperline according to the treatments is low (<10%).

An increase in the flow rate may occur in the initial stage of material accumulation within the emitter, even affecting the flow regime (NASCIMENTO et al., 2016). Similar results were also reported by Fischer Filho et al. (2016). In this study, self-compensating drippers presented both positive and negative GEs, demonstrating that obstructions decrease or increase the flow rate. These same authors suggest that solids, microorganisms, and chemical substances such as iron and sodium can interfere with the compensation membrane of drippers.

According to Frizzone et al. (2012), emitter clogging is one of the most important problems in microirrigation and is the factor that most affects the CVq of emitters in the field. Emitter clogging can be minimized by improving emitter sensitivity and irrigation water quality.

The percentage of emitters according to the degree of clogging is shown in Figure 1.

Figure 1. Percentage of emitters according to the degree of clogging.



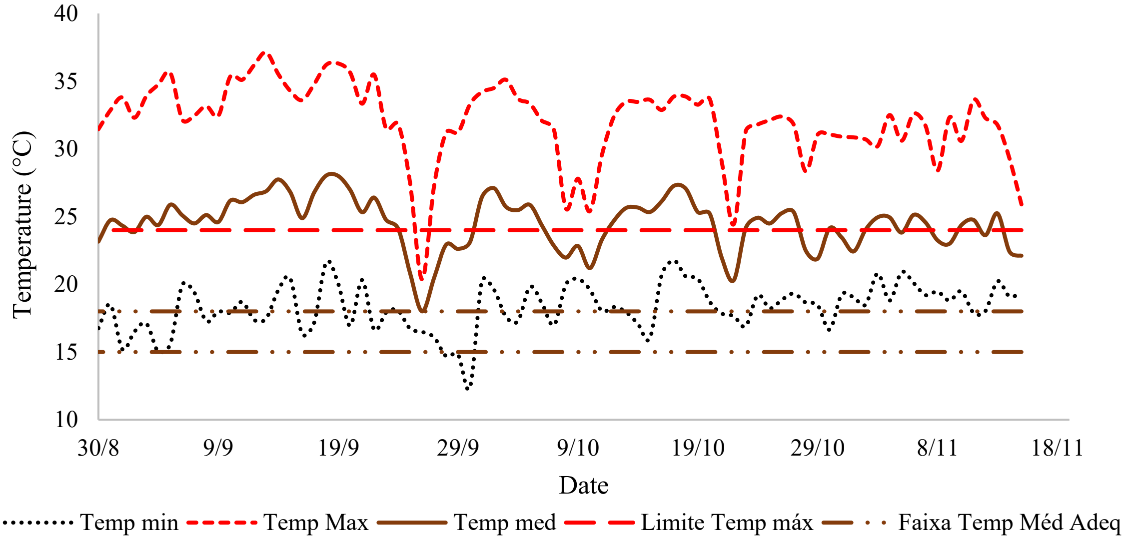
Most emitters had GEs of -1--9 and were classified as having a low degree of clogging. Nine percent of the emitters had a GE greater than 40% and are therefore considered to have a high degree of clogging, according to Dantas et al. (2014).

Similar to these results, only a small number of emitters with GEs greater than 10% were described by Dalri et al. (2014) in a subsurface irrigation system for sugarcane. Cunha et al. (2016) reported the degree of emitter clogging after 3 months of use, with GE results equal to 8.48% when 50% of the required irrigation depth was replaced and 31.17% when 100% was replaced. They also highlighted that partial clogging has the aggravating factor of not being easily visualized.

5.2 Crop assessment

The maximum, minimum and average daily temperatures observed during the experimental period were 32.03 °C, 18.30 °C and 24.50 °C, respectively. An average temperature of 18 °C was recorded only on one day; on the other days, the values remained above 20 °C; and on 53 days of observation, the average temperature was above 24 °C (Figure 2).

Figure 2. Behavior of maximum, minimum, and average daily temperatures measured; upper and lower limits of the optimum average temperature for the crop; and upper limits of the maximum temperature for broccoli crops. Uberaba, Minas Gerais, 2019.

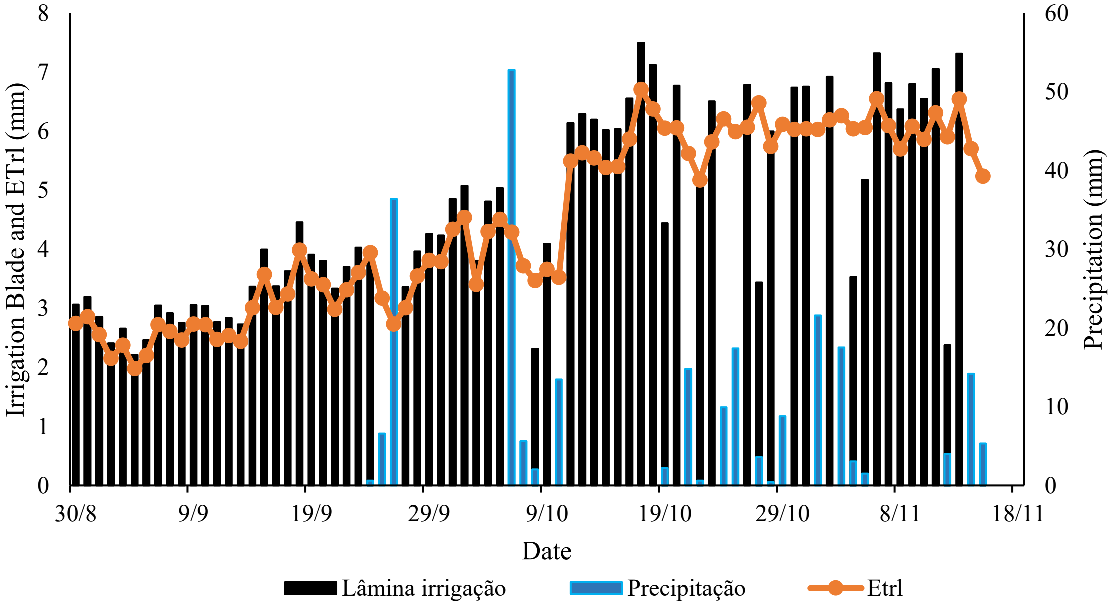


Under average temperatures of 15 to 18 °C and a maximum of 24 °C, there is better productive and qualitative development of the plants (TREVISAN et al., 2003). Therefore, during the study period, the local temperature was above the recommendation for broccoli cultivation.

Seabra Júnior et al. (2014) reported that for the Avenger cultivar, there was an average production of 886 g of fresh inflorescence mass, at average temperatures of 33.4°C for the maximum; 26.3°C for the average; and 19.2°C for the minimum. On the other hand, the authors reported disturbances in the plants, such as bracts in the inflorescences and lateral shoots.

The estimated crop evapotranspiration for the localized irrigation condition (ETrl) was 4.48 mm day $^{-1}$, totaling 349.32 mm in the cycle. The total irrigation depth applied was 300.23 mm, and the total accumulated precipitation during the period was 242.41 mm (Figure 3).

Figure 3. Daily irrigation depth, crop evapotranspiration for localized irrigation conditions (ETrl) and precipitation from August 30 to November 15, 2019. Uberaba, Minas Gerais, 2019.



Silva et al. (2019) reported that for broccoli crops, with accumulated evapotranspiration values of 393.4 mm, 284.95 mm of irrigation depth and 246.8 mm of precipitation, the authors estimated evapotranspiration (ETo, Kc and KL) according to the same methods used in this work; therefore, when comparing the evapotranspiration values, it is possible to infer that the dissimilarity between them is related mainly to the differences in climatic factors between the works.

Importantly, Silva et al. (2019) reported that although the accumulated evapotranspiration was greater at 44.08 mm, the applied irrigation depth was lower at 15.05 mm, considering the greater volume of precipitation, highlighting the importance of irrigation management with daily local data.

The application of fertilizers manually or through fertigation and the position of the drip tube did not promote significant changes in the characteristics evaluated for the broccoli crop (Table 3).

Table 3. Analysis of variance of broccoli: head diameter, stem diameter, fresh mass, head height, and days from transplanting to harvest (DAT).

FV	Diam . (mm)	Diameter (mm)	Fresh mass (g)	Head Height (mm)	DAT
Fertilization (A)					
Fertigated	155.50	43.47	434.47	140.69	71
Conventional fertilization	159.66	44.18	467.65	141.12	70
F Test	1.25 ns	0.49 ns	2.61 ns	0.01 ns	1.52 ns
Depth (P)					
0.00 m	159.85	43.64	460.37	140.17	69
0.10 m	156.29	43.99	454.36	146.18	70
0.20 m	156.59	43.84	438.45	136.36	71
F Test	0.42 ns	0.054 ns	0.129 ns	0.62 ns	1.49 ns
A*P Interaction					
F Test	1.96 ns	3.27 ns	0.83 ns	1.01 ns	2.26 ns
CV (%)	5.67	5.32	14.03	12.67	3.3

ns not significant according to the F test at 1% probability; FV = variation factor; Diam. = diameter; Alt. = height;

The total productivity was 12.88 t ha $^{-1}$, approximately 28,570 broccoli heads per hectare, with an average broccoli weight of 0.45 g. The average head diameter was 15.80 cm, the height was 14.1 cm, and the stem diameter was 4.40 cm. The average period from transplanting to harvest was 71 days, with a 16-day period between the first and last harvests. There were no heads weighing less than 100 g or with defects that would have rendered them unmarketable.

The market for *fresh consumption* prefers single inflorescences, which are dark green in color, compact, with good granulometry, an average size of 300--400 g in weight and diameters between 12 and 15 cm (SCHIAVON et al., 2015).

The cultivar was avoided under high-temperature conditions, with a fresh mass of 327.50 g, a head diameter of 11.43 cm and a productivity of 10.07 t ha $^{-1}$. In this work, the authors reported that the temperature was higher than the optimal temperature for crop development, which consequently affected production performance, diameter and head mass. Melo, Madeira and Peixoto (2010) reported a productivity of 13.2 t ha^{-1}, a fresh mass of 458 g and a head diameter of 15.3 cm for the same cultivar, corroborating the results of the present work.

Silva et al. (2019), evaluating nitrogen doses via fertigation in localized drip irrigation in the Avenger cultivar, reported an average fresh mass of 344.95 g plant $^{-1}$ without nitrogen application, which increased significantly to 511.13 g for a nitrogen dose of 240 kg ha^{-1}, with productivity ranging from 6.90 to 9.73 t ha^{-1}, similar to the findings of this work, in which fertigation and localized irrigation enabled the adequate development of the broccoli crop.

Silva et al. (2019) presented a harvest period between 85 and 99 DAT; in this study, the harvest period ranged from 61 to 77 DAT; therefore, the period for crop development in the field was slightly shorter. Harvest homogeneity is influenced by the climate and, mainly, by the cultivar used (SCHIAVON et al., 2015). A shorter harvest duration is associated with a lower incidence of disease, fewer injuries, and lower labor costs because fewer people enter the area.

The drip line used in this study can be buried up to 20 cm deep without harming broccoli growth under conditions similar to those used in this experiment. Owing to the fertilizer application method, fertigation can also be used to fertilize broccoli without compromising production.

The water productivity was 0.43 kg m^{-3}, requiring 232 L of water to produce 1 kg of broccoli. Geisenhoff et al. (2015) used 200 L of water to produce 1 kg of broccoli in a subsurface drip system, a value close to that used in this study. Water productivity expresses the benefit derived from water use by crops, as it relates the economic product of the crop to the volume of water applied via irrigation (LIMA et al., 2012) .

6 CONCLUSIONS

The hydraulic performance of the dripper pipe evaluated in this experiment by CUC, CUD, CVq, GE and flow rate was not affected by fertigation or burial.

On average, after use, the values were CUC (93.40%), CUD (89.74%), CVq (8.45%), GE (5.29%) and Flow (1.99 L h^{-1}).

There was no effect of the fertilizer application method (manual or fertigation) or dripper tube depth (0.00, 0.10 or 0.20 m) on crop productivity, which was 12.88 t ha^{-1}, or on water productivity, which was equal to 0.43 kg m^{-3}.

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