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Agricultural Engineering

Thermal, hydric, and physiological effects on watermelon due to wetted area variation

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ABSTRACT

The objective of this research was to evaluate leaf temperature, and watermelon yield components under wetted area percentages (PW) in irrigation located in the Agreste region of Northeastern Brazil. Two experiments were carried out in 2018 and 2019. The adopted statistical design was randomized blocks, with six replications and four treatments, in 2018: P1 = 13%, P2 = 14%, P3 = 19%, and P4 = 22%, in 2019: P5 = 12%, P6 = 15%, P7 = 16%, and P8 = 21% of PW. The meteorological variables analyzed were: air temperature (Ta) and rain. The experimental evaluations consisted of measuring the temperature of the plant's vegetative canopy, tensiometry, mass, and BRIX. Air temperature was not a limiting factor for watermelon growth and development. The average was 195.88 mm, and the average leaf temperature of watermelon is 29.5 °C, a value lower than Ta. There was no statistically significant difference for fruit mass and BRIX, where the overall mean was 10.82 and 10.46 kg, respectively. Therefore, it is feasible to irrigate watermelon with wetted area percentages ranging from 12 to 22%, in localized irrigation systems, without generating physiological damage and reducing agricultural productivity and fruit quality.

Keywords: *Citrullus lanatus*; PW; evapotranspiration; fruit mass; BRIX.

INTRODUCTION

The watermelon (*Citrullus lanatus*) is one of the main vegetables in tropical countries and is considered important in human and animal nutrition. Due to its relatively simple handling, it is an agricultural crop explored by small, medium, and large producers, which highlights its socioeconomic importance for generating income in the countryside (Erdem & Yuksel, 2003).

In the 2021 harvest, world agricultural production of watermelon was 101.63 million tons, in an area of 3.03 million hectares, which resulted in an average yield of 33.54 t ha-1 (FAO, 2023). Brazil produced 2.14 million tons in the same season, with a yield of 23.30 t ha-1. The Northeast region is the largest watermelon producer in the country, responsible for 37% of national production. Among the Brazilian states, Rio Grande do Norte is the largest national producer, with production and yield of 341 thousand tons and 23.17 t ha-1, respectively. Alagoas is the 19th largest producer, with a production of 29.33 thousand tons and average productivity of 20.22 t ha^{-1} (IBGE, 2021). In Alagoas, watermelon is traditionally cultivated by small producers under a low technological index. Therefore, crops have been carried out under rainfed conditions or with empirical irrigation management, which generates wastage of water, which is generally scarce, and the low agricultural productivity observed in the region.

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In this context, increasing efficiency in irrigation management becomes important, as it reduces water waste and tends to increase agricultural productivity, consequently, the income of producers. One way to increase the efficiency of water use in watermelon crops is to obtain the ideal percentage of wetted soil area (PW) in localized irrigation for the development and growth of the plant, which favors the achievement of its potential productivity when combined with fertilization and proper phytosanitary management and makes crops more sustainable. The percentage of wetted area is the ratio between the area of the soil moistened by the emitter and the area occupied by the plant (Keller & Karmelli, 1975), in which the wetted area is really necessary to supply the water demand of the plant. Keller & Karmelli (1975) proposed that the ideal PW value, in crops from regions with a dry climate, is at least 33% to obtain the potential productivity of agricultural crops. This value is recommended by several researchers in irrigation projects (Bernardo *et al.*, 2006; Frizzone *et al.*, 2012; Mantovani *et al.*, 2007).

Other researchers (Nair *et al.*, 2013; Abdulhadi & Alwan, 2020) claim that the PW in localized irrigation of agricultural crops, such as watermelon cultivation, may vary depending on the edaphic conditions of each region and that the adoption of values less than 33% can generate water savings and maintain high agricultural yields of plants. However, if greatly reduced, water deficit may occur in crops and affect production components and physiological aspects (leaf temperature, transpiration, stomatal conductance, and photosynthetic rate) of plants.

In view of the above, despite the existence of studies on watermelon cultivation in response to irrigation levels (Hong *et al.*, 2021; Nisha *et al.*, 2020), there is no information on productive and physiological responses of watermelon irrigated under different percentages of wetlands in the Agreste of Northeast Brazil. For this reason, the objective of this study was objective to evaluate leaf temperature and watermelon yield components under wetted area percentages (PW) in irrigation located in the Agreste region of Northeastern Brazil.

MATERIAL AND METHODS

The research was carried out in Arapiraca (9°46'07"S; 36°33'41"W; 324 m), state of Alagoas, Agreste of Northeast Brazil, planting was done on October 5Th, 2018, and November 18th, 2019 (two cultivation cycles). According to the Köppen climate classification, the local climate is AS, tropical, with a rainy period from April to August and a dry period from September to March. Average annual rainfall and temperature are 800 mm and 25 °C, respectively (Barros *et al.*, 2012).

The soil in the experimental area is classified as Red-Yellow Argisol (Embrapa, 2018). The physico-hydric and chemical properties of the soil, from the layers of 0 – 0.20, 0.20 – 0.40, and 0.40 – 0.60 m, are shown in Table 1.

Soil preparation was carried out five days before planting. The no-tillage spacing was 2.0 x 2.0 m. The watermelon cultivar used was Olímpia, characterized by an early cycle, intense red fruits, and high productivity. Fruit thinning was carried out in order to eliminate deformed, damaged, and small fruits, in the end, two fruits were left per plant. The foundation and cover fertilization was carried out according to Ribeiro *et al.* (1999). In the foundation fertilization, 160 kg ha^{-1} of P2O5, 40 kg ha^{-1} of K2O, and 40 kg ha^{-1} of nitrogen were applied. In the topdressing fertilization, 50 kg ha^{-1} of K2O and 80 kg ha^{-1} of N were applied in two applications, at 20 and 40 days after germination (DAG).

The adopted statistical design was in randomized blocks, with six replications and four treatments, which totaled 24 experimental plots. Each plot was composed of three plants, the central plant constituted the useful area of the plot. The treatments studied were wetted area percentages (PW) of the area occupied by the plant (4.0 m²), in 2018: P1 = 13%, P2 = 14%, P3 = 19%, and P4 = 22%, in 2019: P5 = 12%, P6 = 15%, P7 = 16% and P8 = 21% PW (Figure 1)

The irrigation system adopted was drip irrigation. The emitters used to form the different PW were spaced 0.2 m apart in 2018, with flows of 1.39 and 1.92 L h^{-1}. In 2019, emitters were spaced 0.3 m apart, with flows of 3.75 and 8.0 L h^{-1}. The number of emitters ranged from three to twenty units per plant, in which plants with higher flow emitters had a smaller number of emitters. The PW, of the treatments studied, were measured on the soil surface, after irrigation, with the aid of a tape measure, obtaining the wet width and length, consequently, its area was obtained. Subsequently, the PW was determined by the ratio between the wet area measured in the soil and the area occupied by the plant.

Treatments P2, P4, and P6 used double drip lines to obtain higher PW values. P1, P2, P3, P4, and P5 formed a wetted trip. In 2018 there was a difference between the volumes of water applied per plant and in 2019 the volume of water applied was similar.

Table 1: Chemical and physical-hydric properties of the soil in the research area

Physical-Hydric Properties	Unit	Soil Layers (m)		
		0-0.2	0.2-0.4	0.4-0.6
Sand	g kg-1	70.35	62.30	58.24
Silt	g kg-1	11.71	26.80	30.85
Clay	g kg-1	17.94	10.90	10.91
Soil Density (g cm³)	g cm³	1.29	1.43	1.31
Particle Density (g/cm³)	g cm³	2.68	2.68	2.71
Porosity (%)	%	51.86	46.64	51.66
θS	m3 m^{-3}	0.518	0.466	0.516
θR	m3 m^{-3}	0.077	0.070	0.083
a	-	0.371	0.313	0.271
n	-	1,542	1,523	1.627
m				

Chemical properties	Unit	Soil Layers (cm)	
		0 – 20	20 – 40
pH	-	6.05	5.74
Calcium + Magnesium	cmolc dm³	2.70	2.11
Calcium	cmolc dm³	1.94	1.54
Aluminum	cmolc dm³	< 0.08	< 0.08
Sodium	mg dm³	47.9	73.0
Potassium	mg dm³	80.0	116.0
Phosphor	mg dm³	29.4	28.9
SB	cmol dm³	3.12	2.73
CTC	cmol dm³	4.36	4.16
V	%	71.60	65.60

Irrigation management was carried out as a function of crop evapotranspiration (ETc), which was estimated by Equation 1. The ETo was estimated diary by the method of Hargreaves & Samani (1985), Equation 2. ETo data were collected at each irrigation to estimate ETc. With the station, data on meteorological variables (rainfall and air temperature) were obtained.

$$ET_C = ET_0 \cdot K_C \cdot K_R \quad (1)$$

$$ETo = a \times \frac{Ra}{2,45} \times (Tmáx - Tmín)^b \times (Tméd + c) \quad (2)$$

Where ETc is crop evapotranspiration (mm day-1); ETo is the reference evapotranspiration estimated by the Hargreaves & Samani method (mm day-1); Tmax – maximum air temperature (°C); Tmin – minimum air temperature (°C) and Tmed – average air temperature (°C); Ra –extraterrestrial solar irradiance (MJ m-2 s-1); a, b and c coefficients were 0,004344, 0,532201 and -6,056 (Barros *et al.,* 2019).

$$R_a = 37,6(d/D)^2\left[(\pi/180°)hnsen\Phi sen\delta + cos\Phi cos\delta senhn\right] \quad (3)$$

$$(d/D)^2 = 1 + 0,033cos(NDA360/365) \quad (4)$$

Where Φ – local latitude (degrees); δ – solar declination (degrees); hn – the hour angle at sunrise (degrees); d/D – Earth-Sun relative distance and NDA – day number of the year or Julian day.

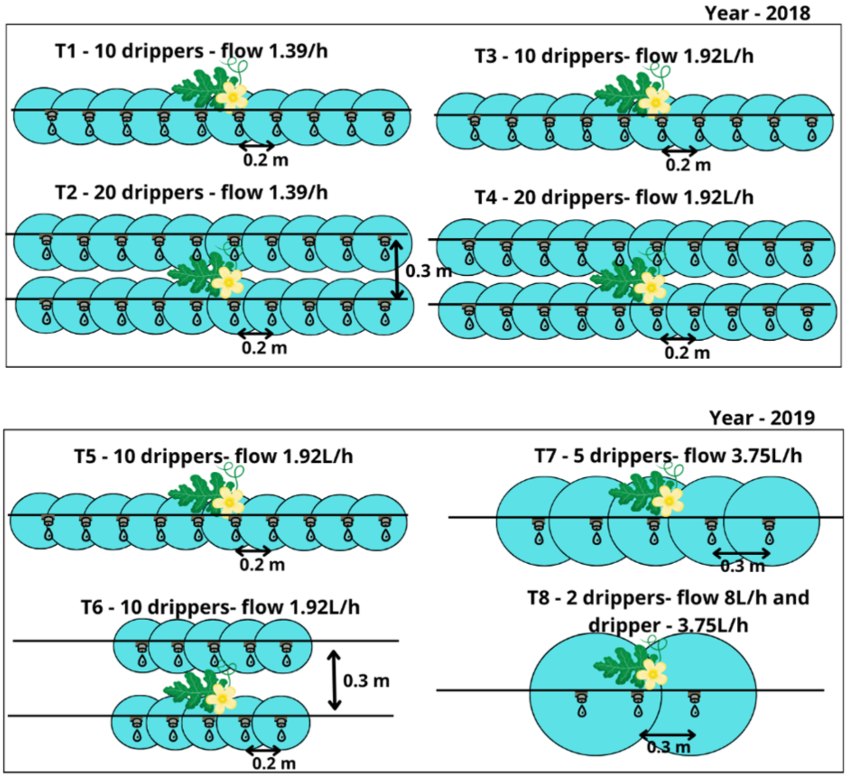

Figure 1: Details of treatments and drippers distribution.

According to the phenological stages of the crop, the KC and Kr proposed by Ferreira *et al.* (2015) were adopted, as shown in Table 2.

The watermelon harvest in 2018 and 2019 was carried out at 65 and 62 days after sowing (DAS), respectively. The experimental evaluations consisted of measuring the temperature of the plant's vegetative canopy (Tc), tensiometry, mass, and BRIX of fruits. To obtain the plant canopy temperature (Tc) a Minipa thermometer (MT - 320) was used two batteries of tensiometers were installed, per treatment, at depths of 0.2, 0.4, and 0.6 m, and the readings were taken with a digital tensiometer, obtaining the matrix potential of the soil. The matrix potential was related to the soil water retention curve, which determined the percentage of soil moisture. The tensiometry and thermometry readings were performed daily, before irrigating, at 12:00 am. Fruit mass was obtained by weighing on a precision scale equivalent to 0.001 kg (Todelo, Prix 3 Plus, São Bernardo do Campo, Brazil). The soluble solids content was determined in a refractometer (Vodex, VX0-90).

Data were submitted to analysis of variance ($p < 0.05$) and, when significant, to regression analysis, according to Ferreira (2018). The SAS (2002) was used for the analyzes.

RESULTS AND DISCUSSION

The general average air temperature, during the experimental period in 2018 and 2019, was 27.7 (±1.1) °C. Hamad *et al.* (2022) state that regions with average air temperatures between 18 and 30 °C are ideal for the growth and development of cucurbits, such as watermelon. Therefore, it is confirmed that the Agreste region of Alagoas has adequate thermal availability for watermelon cultivation. Total rainfall during cultivation was only 29 and 19 mm in 2018 and 2019, respectively, which makes clear the need for irrigation incrops in the region from September to January.

The total reference evapotranspiration (ETo), during the experimental period in 2018 and 2019, was 301 and 347 mm, with a daily average of 4.7 (±1.4) and 5.5 (±1.1) mm day^{-1}, respectively. Therefore, the overall mean ETo in the region during the experiment was 5.1 (±1.2) mm day^{-1}. Total crop evapotranspiration (ETc) in 2018 was 177.35 mm, with a daily average of 2.86 (±0.9) mm day^{-1}, while in 2019 it was 214.41 mm, with a daily average of 3.01 (±1.0) mm day^{-1}. Figure 2 shows the average daily air temperature, total rainfall, and daily reference and crop evapotranspiration during the experimental period.

Table 2: Crop coefficient (KC) and coefficient of wetted area reduction (Kr) for the watermelon crop

Stadiums	Intervals (days)	KC	kr
Emergence and growth	0-20	0.39	0.39
Flowering	21-35	0.80	0.53
Fructification	36-56	1.14	0.69
Fruit ripening	56-70	0.59	0.89

The analysis of water and thermal relations can be done in Figure 3 and 4. The overall mean canopy temperature (Tc) of watermelon was 28.4 (±0.6) °C under the different percentages of the wetted area and remained below the air temperature (Ta) average which was 30.8 (± 0.6) °C.

The lowest temperatures of the Canopy, Tc, in year 1 (Figure 1), occurred in the drippers with the highest flow (P1 = 23 °C, P2 = 22.9 °C; P3 = 21.55 °C and P4 = 21.2 °C) and the highest in treatments with the lower flow (P1 = 36.2 °C, P2 = 36.55 °C; P3 = 34.8 °C and P4 = 34 .5 °C), this result is corroborated by year 2 (Figure 3), when the same volume of water was applied per plant, resulting in almost similar minimum temperatures (Tc-minimum of P5 = 27.15 °C, P6 = 27.1 °C; P7 = 26.95 °C and P8 = 27.00 °C and Tc-maximum of P5 = 4 2.5 °C, P6 = 41.75 °C; P7 = 41.5 °C and P8 = 44, 5 °C), demonstrating that the Tc-minimum is more related to the volume of water applied as a function of time than its fraction of the wetted area. In the second year of planting, the highest temperature founded was due to P8, probably due to the higher percolated volume, leaving fewer ecological entrails.

During almost the entire cycle of the crop, situation of Tar < Tc occurs, indicating that there was no indication of stress in the crop. The reduction in the amplitude between Tc and Tar, for year 1, occurs from DAS45, where the end of the fruiting phase occurs (DAS36 to DAS50), this movement is accompanied by the reduction of the applied water layer, visually more felt in the P1 treatments and P3 in the 3 depths (0.20 – 0.40 – 0.60 m). Another factor that could indicate this increase in Tc could be the increase

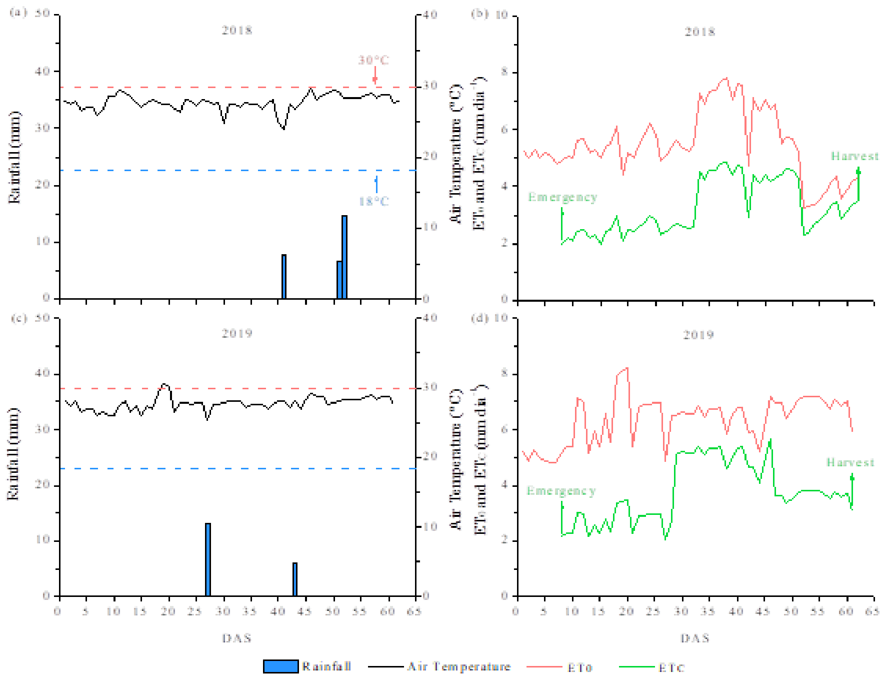

Figure 2: Rainfall (mm) and mean air temperature (°C) (a e c) and reference and crop evapotranspiration (ETo, ETc – mm day-1) (b e d), during watermelon cultivation in Arapiraca, Alagoas, in 2018 and 2019, and ideal thermal range for watermelon growth and development.

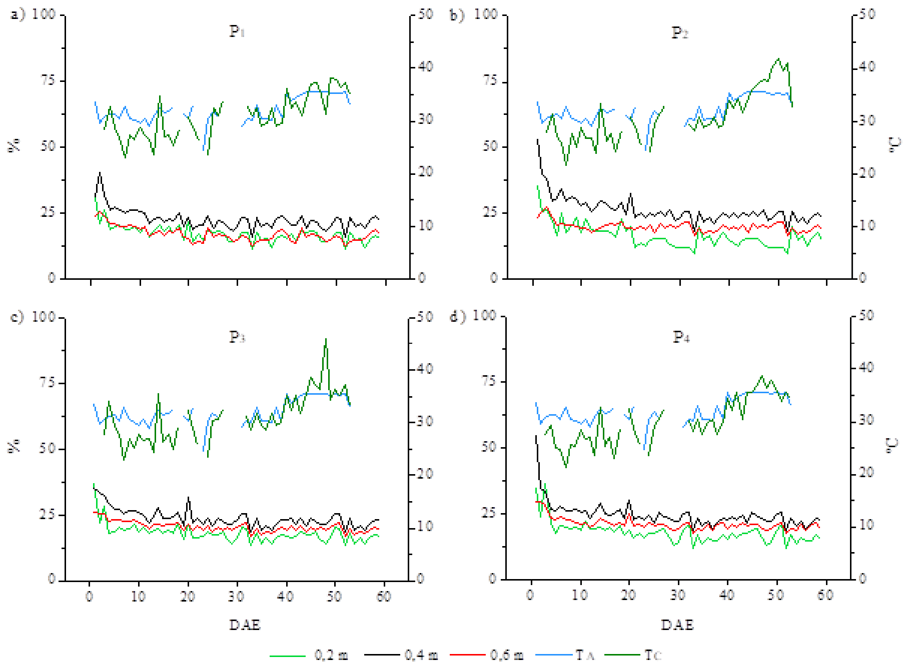

Figure 3: Air temperature (Ta) and canopy (Tc) (°C) of watermelon and soil moisture (θ%) under wet area percentages in the Arapiraca region, Alagoas, Brazil, in 2018.

in nutrient extraction in the soil and accumulation in the plant, the macronutrients nitrogen, phosphorus, potassium, calcium, and magnesium, have this peak in the watermelon crop between days 45 and 55 after planting according to Aguiar Neto *et al.* (2016).

Analyzing the humidity in the first year of planting, it is observed that the humidity in the 0.20 m layer was lower in all treatments and throughout the cycle, with some points with higher humidity compared to the deeper layers. Moisture at 0.20 shows a slight reduction between the beginning and end of the planting cycle. When double drip lines are used (P2, P4 and P5), it is observed that the difference in moisture in the 0.40 and 0.60 layers is lower than in the P1 and P3 treatments, which may have occurred due to the greater search for water in the root system of the watermelon in treatments with less surface water availability.

The average moisture content in 0,22m was very close between treatments (17.9; 18.7; 17.65 and 18.81% in treatments, P1, P2, P3 AND P4, respectively), with slightly higher values (+- 1%) in treatments with a greater number of laterals. The same occurred at a depth of 0.60m, in which the average moisture values were similar between P2, P3, and P4 and lower in P1, in a proportion of 19; 15 and 22%, once again confirming the search for moisture in greater depth when there is a reduction in the wetted area.

Sharma *et al.* (2018) studied the pattern of water absorption in different watermelon cultivars (Mission, Da Vinci, and Super Necta) and observed that greater water consumption occurs at depths of 0.15 and 0.30 m and that when there is water stress, the crop consumes water at a greater depth (0.60 m), in addition, it is possible to notice different consumption patterns depending on the cultivars.

In the second year of planting (Figure 3), the moisture lines at depths of 0.20, 0.40 and 0.60 m, with less variation in moisture between them in treatments P6, P7 and P8. At times, it is possible to verify moisture contours at a depth of 0.40 m, which may have been caused by the Bt textural horizon, classified as an abrupt textural change, in which the clay is translocated from the upper horizon to the lower one, therefore, reduces the hydraulic conductivity of the soil, causing a temporary increase in moisture at these points.

The percentages of the wetted area did not generate significant differences ($p < 0.05$) in the variables fruit mass and BRIX content. The analysis of variance is shown in Table 3.

Table 4 shows the mass and BRIX content of watermelon fruits under percentages of the wetted area from 12 to 22%, with localized irrigation, in the region of Arapiraca, Alagoas.

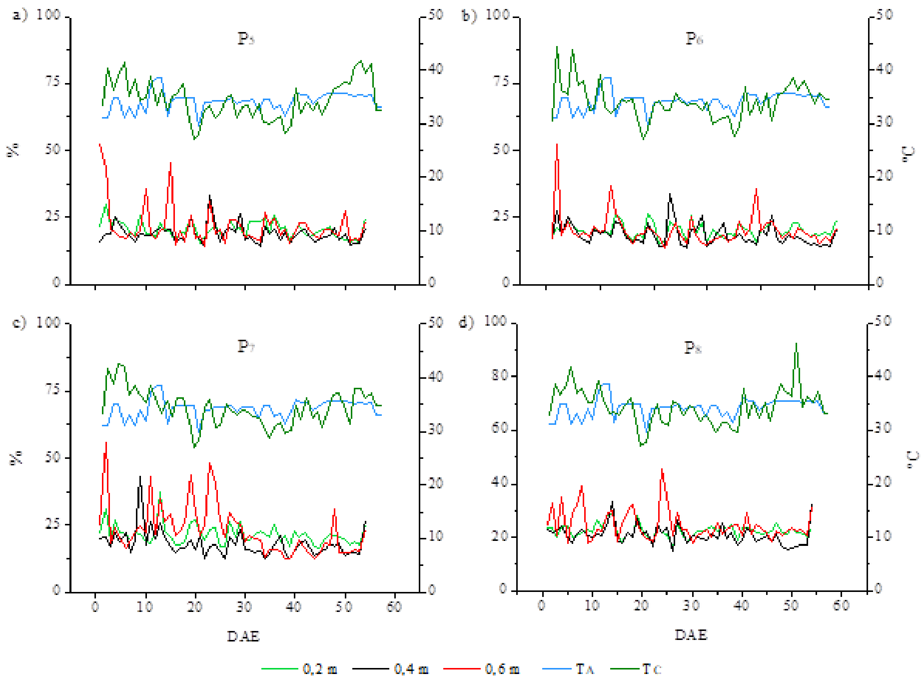

Figure 4: Air temperature (Ta) and canopy (Tc) (°C) of watermelon and soil moisture (θ%) under wetted area percentages in the Arapiraca´s region, Alagoas, Brazil, in 2019.

The lowest fruit mass value (10.20 kg) was observed under the lowest PW (P1 – 13%, P2 – 14%, and P5 – 12%). The highest value (11.20 kg) was obtained in areas with the highest PW (P4– 22%), which represents an increase of only 9.8% in the value of fruit mass. Keller & Karmelli (1975) stated that the ideal PW value, in tropical climate regions, such as Arapiraca, should be at least 33% to reach the potential productivity of agricultural crops, such as watermelon. This value is still recommended by several researchers (Mantovani *et al.*, 2007; Frizzone *et al.*, 2012) as a standard for sizing irrigation projects. Çamoğlu *et al.* (2010) and Hama-Aziz *et al.* (2023) obtained productivity

Table 3: Analysis of variance of fruit mass (MF) and BRIX content of watermelon cultivated under different percentages of wetted area Arapiraca's region, Alagoas, Brazil

CAUSE OF VARIATION	GL	MEAN SQUARE	
		MF	BRIX
Wet area percentages1	3	2,225^{NS}	0.197^{NS}
Block	5	2,387^{NS}	0.466^{NS}
Reg. Linear	1	2,079^{NS}	0.085^{NS}
Reg. quadratic	1	3,982^{NS}	0.024^{NS}
Residue	15	2049	0.627
CV		13.28	6.94
Overall Average		10.47 kg	11.42%
Wet area percentages2	3	0.657^{NS}	0.939^{NS}
Block	5	0.195^{NS}	0.153^{NS}
Reg. Linear	1	1,294^{NS}	0.337^{NS}
Reg. quadratic	1	0.121^{NS}	1,272^{NS}
Residue	15	0.083	0.413
CV		2.76	6.30
Overall Average		10.45 kg	10.22%

CV is coefficient of variation; 1 referring to 2018; 2 referring to 2019; * is significant at 5% and NS is not significant by the F test ($p < 0.05$).

Table 4: Average values of mass and BRIX content of fruits observed under percentages of wetted area (PW), during the watermelon production cycle, in the region of Arapiraca, Alagoas, Brazil, in 2018 and 2019

PW - 2018	Fruit Mass	BRIX
%	kg	%
P1 – 13	10.20	11.20
P2 – 14	10.20	11.60
P3 – 19	10.30	11.50
P4 – 22	11.20	11.40
PW - 2019	**Fruit Mass**	**BRIX**
%	kg	%
P5 – 12	10.20	10.50
P6 – 15	10.50	9.70
P7 – 16	10.60	10.70
P8 – 21	10.40	10.00

of watermelon fruits of 60 and 62 t ha-1, respectively, under full irrigation, this value is, on average, only 16% higher than the general mean value obtained in this research, 52.3 t ha-1, which confirms that under PW values lower than 33%, such as the P5 treatment (12%), the watermelon crop is able to maintain its high productive potential and make the crop more sustainable, since there are water savings to reach the smaller wetland area.

Studies show that the greater the volume of water applied per plant, the greater the crop response, as in the work of Nisha *et al.* (2020) with a reduction of Eto by 40 and 20%, demonstrating greater productivity in the smallest reduction. However, when there is sufficient soil moisture for plant development, this water effect becomes non-significant, as occurred with Li *et al.* (2018) evaluating water effects on watermelon (Nongkeda no. 11), the authors observed that the two largest depths, under two types of mulching, did not cause a significant effect on the variables: individual fruit weight, productivity, amount of soluble sugars.

Thus, the Pw variations submitted in this experiment only provided a greater evaporative area, since the water demand was contemplated in all situations. In addition, some crops can also adapt to a smaller wet area, as occurred with Vellame *et al.* (2015) who, studying the effect of different Pw on the orange crop, observed that when the treatment was applied (Pw of 12.5 and 100%) there was a reduction in transpiration in plants with lower Pw, but this effect was reversed over time and there was no variation in vegetative development.

It was observed that the watermelon cultivated under percentages of wetted areas smaller than 33% is able to maintain its high productive potential and fruit quality. This highlights that watermelon can be cultivated in regions with poor rainfall distribution, such as the northeast of Brazil since the reduction in the area to be watered in localized irrigation tends to reduce the need for water in crops and watermelon is able to maintain its high yield under such conditions.

Air temperature is not a limiting factor for watermelon growth and development in Arapiraca, Agreste in Northeast Brazil. And, crop evapotranspiration (ETc) average total, during the period of the experiment, in the region was 324 mm.

CONCLUSIONS

The canopy temperature was more related to the volume of water applied as a function of time than its fraction of the wetted area.

To irrigate watermelon with percentages of wetted area ranging from 12 to 22% is feasible, in localized irrigation systems, without generating physiological damage and reducing agricultural productivity.

The lowest BRIX value (9.7%) was obtained in fruits of plants cultivated with P6 (15%), this value is only 16% lower than the highest value (11.6%) verified in areas irrigated with P2 (14%).

REFERENCES

Abdulhadi JS & Alwan HH (2020) Evaluation the existing drip irrigation network of Fadak Farm. Kerbala Journal for Engineering Science, 0:01-13.

Aguiar Neto P, Souza RAG, Maracajá PB, Medeiros AC, Pimenta TA & Lima TS (2016) Crescimento e absorção de macronutrientes na cultura da melancia no estado de Pernambuco. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 11:17-25.

Barros AC, da Silva FF, Araujo PHV, Medeiros PRF & Lelis Neto JA (2019) Estimativa diária da evapotranspiração de referência por Hargreaves-Samani e ajuste de parâmetros para Alagoas. Irriga, 24:527-537.

Barros AHC, Araújo Filho JC, Silva AB & Santiago GACF (2012) Climatologia do Estado de Alagoas. Recife, Embrapa Solos. 32p.

Bernardo S, Soares AA & Mantovani EC (2006) Manual de Irrigação. 8ª ed. Viçosa, Editora UFV. 625p.

Çamoğlu G, Aşık Ş, Genç L & Demirel K (2010) The effects of water stress on evapotranspiration, water use efficiency, yield and quality parameters in watermelon irrigated by drip irrigation. Ege Üniversitesi Ziraat Fakültesi Dergisi, 47:135-144.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2018) Sistema Brasileiro 395 de Classificação do Solo. 5ª ed. Brasília, Embrapa. 356p.

Erdem Y & Yuksel AN (2003) Yield response of watermelon to irrigation shortage. Scientia Horticulturae, 98:365-383.

FAO – Food and Agriculture Organization (2023) Crops and livestock proocducts. Available at: https://www.fao.org/faostat/en/#data/QCL Accessed on: May 25th, 2023.

Ferreira PV (2018) Estatística experimental aplicada às Ciências Agrárias. Viçosa, UFV. 588p.

Ferreira VM, Klar AE, Andrade Júnior AS, Bastos EA & Oliveira SEM (2015) Evapotranspiração e coeficiente de cultura da melancia na microrregião de Teresina, PI, Brasil. Comunicata Scientiae, 6:488-494.

Frizzone JA, Freitas PSL, Rezende R & Faria MA (2012) Microirrigação: gotejamento e microaspersão. Maringá, Eduem. 356p.

Hama-Aziz ZQ, Mustafa RA & Neima HA (2023) Water productivity of mulched and drip irrigated watermelon in Kurdistan Region of Iraq. Research Square [Preprint]. Available at: https://doi.org/10.21203/rs.3.rs-2887425/v1. Accessed on: May 25th, 2023.

Hamad AO, Kai KH, Kijazi A, Khamis SA, Abdalla AH, Ame HK & Ali FA (2022) The Influence of Climate Variability on the Watermelon Production in Zanzibar. Atmospheric and Climate Sciences, 13:44-61.

Hargreaves GH & Samani ZA (1985) Reference crop evapotranspiration from temperature. Applied Engineering in Agriculture, 1:96-99.

Hong T, Cai Z, Zhao R, He Z, Ding M & Zhang Z (2021) Effects of water and nitrogen coupling on the yield, quality, and water and nitrogen utilization of watermelon under CO2 enrichment. Scientia Horticulturae, 286:110213.

IBGE - Instituto Brasileiro de Geografia e Estatística (2021) Produção Agrícola Municipal. Available at: https://sidra.ibge.gov.br/tabela/5457#resultado. Accessed on: May 25th, 2023.

Keller J & Karmeli D (1975) Trickle irrigation design. Glendora, Rain Bird. 133p.

Li H, Yang X, Chen H, Cui Q, Yuan G, Han X, Wei C, Zhang Y, Ma J & Zhang X (2018) Water requirement characteristics and the optimal irrigation schedule for the growth, yield, and fruit quality of watermelon under plastic film mulching. Scientia Horticulturae, 241:74-82.

Mantovani EC, Bernardo S & Palaretti LF (2007) Irrigação: Princípios e Métodos. Viçosa, UFV. 322p.

Nair S, Johnson J & Wang C (2013) Efficiency of irrigation water use: A review from the perspectives of multiple disciplines. Agronomy Journal, 105:351-363.

Nisha SK, Sreelathakumary I & Vijeth S (2020) Effect of fertigation and drip irrigation on yield and quality of watermelon [Citrullus Lanatus (THUNB.) Matsum. & Nakai]. Journal of Applied Horticulture, 22:67-70.

Ribeiro AC, Guimarães PTG & Alvarez VVH (1999) Recomendações para o uso de corretivos e fertilizantes em Minas Gerais: 5ª aproximação. Viçosa, Comissão de fertilidade do solo do estado de Minas Gerais. 359p.

SAS Institute Inc. (2002) Statistical Analysis System user's guide. Version 9.0. Cary, Statistical Analysis System Institute. 513p.

Sharma SP, Leskovar DI, Volder A, Crosby KM & Ibrahim AMH (2018) Root distribution patterns of reticulatus and inodorus melon (Cucumis Melo l.) Under subsurface deficit irrigation. Irrigation Science, 36:301-317.

Vellame LM, Fraga Júnior EF & Coelho RD (2015) Effect of partial soil wetting on transpiration, vegetative growth and root system of young orange trees. Scientia Agricola, 72:377-384.