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Microclimate under the Cup of Papaya Planted in the North-South and East-West Directions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work was to evaluate the variations of environmental factors under the canopy of papaya planted in a north-south and east-west orientation. Two areas were studied, one oriented north-south and the other east-west, both planted with a spacing of 3.20 mx 2.40 m, planted in April 2015. The distances from the papaya line (levels of shading) and a place in full sun, where it was evaluated, in the North-South direction: in the papaya planting line, at 40 cm west side, 40 cm east side and in full sun; in the East-West direction: In the papaya planting line, at 40 cm on the north side, 40 cm on the south side and in the planting line in full sun. The following atmospheric variables were determined: temperature, irradiance and relative humidity. Tukey's test was used to compare means at a confidence level of 95%. Papaya planted in the east-west direction, under the conditions studied, provided lower incident irradiation, reduced temperature and higher values of relative humidity under its canopy, compared to papaya planted in the north-south direction. It is possible to intercrop papaya planted in the east-west direction with other agricultural crops, including conilon coffee.

Keywords: Carica papaya L.; planting guidelines; intercropping.

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1. INTRODUCTION

Papaya (*Carica papaya* L.) is widely cultivated in tropical regions. In Brazil, climatic conditions are favorable for its economic exploitation and high productivity, making the country stand out as the third largest producer of papaya in the world, with about 1,161,808 tons produced in 2019, corresponding to approximately 8.5% of world production of this fruit [1]. The State of Espírito Santo stands out with a production of 403,278 tons in 2019, corresponding to more than a third of the national production [2].

Regarding the microclimate in papaya crops, most studies focus on the influence of planting spacing [3], mainly to achieve an optimal condition between number of plants and light absorption by plants [4,5], resulting in high yields. When cultivated in consortium with another agricultural crop, the crops have a more efficient use of solar energy, in addition to benefits such as weed control and increased productivity [6]. Several cultures are used in intercropping with papaya [7,8], including conilon coffee [9].

Despite being widely cultivated in full sun, conilon coffee is a species originally adapted to partially shaded environments [10]. According to Damatta and Ramalho [11], adequate shading can allow the coffee plantation to receive sufficient and adequate solar radiation, improve microclimatic conditions by reducing temperature extremes, create conditions for soil moisture conservation, reduce evapotranspiration and possible damage by the winds.

Studies have shown that attenuation of climatic variables occurs in coffee trees in wooded crops [12,13,14], in addition to providing greater sustainability to the systems [15]. In consortium with papaya, coffee is planted when the papaya trees are between eight and twelve months old. This period is due to the fact that the coffee tree can etiolate when planted simultaneously. Thus, the intercropping system of these two crops appears as a promising alternative and an option for producers in the face of constant fluctuations in the price of products on the market.

An important factor that influences the microclimate of a crop is the orientation of the crop, normally being in the east-west alignment [16] or north-south [17]. To reduce photorespiration and possible burns on the leaves, in addition to the shading caused by the consortium, variations in the solar zenith angle throughout the day must be observed. This occurs because the different conditions of climatic variables, such as radiation, temperature and relative humidity, between the North-South and East-West sides of the canopy of the plants, will certainly determine a different microclimatic response between both sides. The knowledge of the microclimatic behavior segmented under the papaya tree canopy may provide information for a better management of the cultures that are in consortium, through the attenuation of climatic variables.

Thus, the objective of this work was to evaluate the variations of environmental factors under the papaya tree canopy, planted in the North-South and East-West orientation, in the four seasons of the year.

2. MATERIALS AND METHODS

The study was conducted on a private property located in the municipality of Sooretama, Espírito Santo State, Brazil (19º11'S, 40º05'W), at an altitude of 59 m and flat relief. The region has a tropical climate with dry winter, classified as Aw according to the Koppen-Geiger classification [18]. The average annual temperature is 23 ºC, and the average annual precipitation is 1250 mm.

Two papaya areas were used, one planted in the North-South orientation and the other in the East-West orientation, with approximately 1 year of age, implanted at a spacing of 3.20 x 2.40 m, both planted in April 2015, if one next to the other.

Four points were evaluated, being three distances (locations) of shading with papaya, and a place in full sun, where it was evaluated, in the North-South direction: T1: located in the papaya planting line; T2 O: located 40 cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full planting line. East-West: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row. The experimental plot consisted of three replications.

The microclimatic characterization was carried out by obtaining the irradiance, temperature and relative humidity of the air. Measurements were carried out with HOBO U12

Temp/RH/Light/External Data Logger devices, fixed to 1 m high wooden slats and placed in the field below the papaya tree canopy, which were previously programmed to perform readings at intervals of 10 minutes throughout the day. Three HOBOS equipment were placed at each distance, featuring three replications per treatment. The microclimatic data were collected on 02/03/2016 (Summer), 04/21/2016 (Autumn), 08/08/2016 (Winter) and 12/15 (Spring), starting measurements before sunrise. sun and remaining until sunset, on days with few clouds. In this period, the solar declination was -16.47° in summer, 12.26° in autumn, 15.8° in winter and -23.

The microclimatic data were subjected to analysis of variance and the means were compared by the Tukey test at 5% error probability, using the Assistet program [19].

3. RESULTS AND DISCUSSION

The results observed in the present study showed that papaya planted in the East-West direction provided lower incident irradiation under its canopy, in relation to papaya planted in the North-South direction (Fig. 1 and Fig. 2). The average irradiance in papaya planted in the North-South direction showed higher values than in the papaya planted in the East-West direction, in the evaluated periods, with variations being observed as a function of the distance from the planting line, of the North/South and East/ West of the line and time of day (Fig. 3 and Fig. 4).

In summer (Fig. 1A), a lower incidence of irradiance was observed in the papaya line (T1), with an average interception of 60% of the incident irradiance in the area under full sun (T4 Sun). The other treatments (T2 O and T3 L) showed interception of 16 and 30%, respectively. Observing the daily behavior of the irradiance in summer (Fig. 3A), note lower values throughout the day for the treatment located in the papaya line (T1). It is observed that the highest irradiance value was obtained in the full sun treatment (T4 Sun) at 13:30 h, presenting a value of 2499 µmol $m^{-2}s^{-1}$ and an irradiance of 846.8 µmol $m^{-2}s^{-1}$ was recorded at the same time in the treatment located on the papaya line (T1), thus presenting an attenuation of 42%.

The distance located at 40 cm on the east side (T3 L) showed higher irradiance values during the morning, and after noon, the irradiance value decreased. On the other hand, the treatment located at 40 cm West (T2 O), had an opposite behavior to that presented in T3 L, with lower irradiance value in the morning, with an increase after noon, until the end of the day. This variation in behavior observed throughout the day at different distances and east and west orientations is due to the diurnal movement of the sun, which is from east to west, the point on the east horizon where the sun rises and the point on the horizon west in which it sets. On the other hand, in papaya planting in the east-west direction (Fig. 2A), in summer, the lowest irradiance was observed in treatments in the papaya line and at 40 cm north and south (T1, T2 N and T3 S).

Observing the daily behavior of irradiance in summer (Fig. 4A), note similar irradiance values for treatments T1, T2 N and T3 S, and higher values for the treatment in full sun, throughout the day. It is observed that the highest irradiance value was obtained in the full sun treatment (T4 Sun) at 13:30 h, presenting a value of 2498.9 µmol $m^{-2}s^{-1}$ and an irradiance of 1167 µmol $m^{-2}s^{-1}$ was recorded at the same time in the treatment located on the papaya line (T1), thus presenting an attenuation of 61%.

In autumn (Fig. 1B), in papaya planted north-south, lower irradiance values were observed in the treatment located in the papaya line (T1) and in the treatments located at 40 cm east (T3 L), with an average interception of 20 % and 17%, respectively, of incident irradiance in full sun treatment (T4 Sun).

Observing the daily behavior (Fig. 3B), note higher values of irradiance in the treatment at 40 cm east (T3 L) in the morning and lower values from noon to the end of the day. The treatment at 40 cm west, on the other hand, had lower values in the morning and higher values in the afternoon, until the end of the day. In the treatment located on the papaya line (T1), note higher values of irradiance in the morning, a reduction in the hottest times of the day, again an increase in the early afternoon and, in the late afternoon, a reduction in the values. It is observed that the highest irradiance value was obtained in the full sun treatment (T4 Sun) at 12:00 h, presenting a value of 2498.9 µmol $m^{-2}s^{-1}$ and an irradiance of 1527 µmol $m^{-2}s^{-1}$ was recorded at the same time in the treatment located on the papaya line (T1), thus presenting an attenuation of 38%.

In the papaya tree planted in the East-West direction (Fig. 2B), in autumn, the lowest irradiance was observed in the treatments in the papaya line and at 40 cm north and south (T1, T2 N and T3 S), it presented an average interception of 51, 34 and 47%, respectively. Observing the daily behavior (Fig. 4B), note lower irradiance values in the treatments located in the papaya row, 40 cm north south (T1, T2 N and T3 S). It is observed that the highest irradiance value was obtained in the full sun treatment (T4 Sun) at 12:30 h, presenting a value of 2498.9 µmol $m^{-2}s^{-1}$ and an irradiance of 1141 µmol $m^{-2}s^{-1}$ was recorded at the same time in the treatment located on the papaya line (T1), thus presenting an attenuation of 54%.

In winter and spring, in papaya planted in the North-South direction (Fig. 1C and 1D), it was observed that in all treatments, the irradiance values were similar, not differing statistically from each other. Observing the daily behavior of irradiance (Fig. 3C and Fig. 3D), note that at the hottest time of day, 12 h, all treatments obtained similar behaviors. In papaya planted in the East-West direction (Fig. 2C), lower irradiance values can be observed in the treatment located in the papaya line and at 40 cm south side (T1 and T3 S), with attenuation of 26 and 16%, respectively, in relation to the treatment in full sun (T4 Sun).

In spring, in papaya planted in the East-West direction (Fig. 2D), a lower irradiance value is observed in the treatment located in the papaya line (T1), with attenuation of irradiance of 11%, in relation to the treatment in full sun. Observing the daily behavior (Fig. 4D), note that the highest irradiance value was obtained in the full sun treatment (T4 Sun) at 11:50 h, presenting a value of 2498.9 µmol $m^{-2}s^{-1}$ and an irradiance of 2176.5 µmol $m^{-2}s^{-1}$ was recorded at the same time in the treatment located in the papaya line (T1), thus presenting an attenuation of 12.8%.

It was observed in the seasons of the year, Summer, Autumn, Winter and Spring, average interception of 35.7, 16.6, 5, and 2.7% of the incident irradiance in the North-South direction, and 54.47, 44 .33, 17 and 10%, in the East-West planting direction, respectively, with average interception of 15.1 and 31.45% in the four evaluated times, in the North-South and East-West directions, respectively. Analyzing the treatment located in the papaya line (T1), note that the interception was 60.5, 20, 7.7 and 3.9% in the North-South planting direction and 68.75, 34.13, 26 .3 and 11.1%, in the East-West planting direction, in Summer, Autumn, Winter and Spring, respectively.

The attenuation of the irradiance promoted by the different planting orientations of papaya can favor the microclimate for the planting of other species in your planting line. In studies of coffee trees with rubber trees, Araújo et al. [20] found a lower amount of radiation received in coffee trees in trees, compared to planting in full sun, with interception of 88.04% in winter and 72.49% in summer, which promoted greater etiolation of the branches and greater leaf expansion in the year. shaded coffee. However, in studies with 40 to 50% irradiance interception, coffee plant growth, coffee bean maturation, grain yield and size were not altered [21].

Papaya planted in the North-South and East-West direction provided a reduction in the average daily temperature under its canopy at all evaluated times (Fig. 5 and Fig. 6). Variations can be observed depending on the distance from the planting line, the North-South and East-West positions of the line and the time of day (Fig. 7 and Fig. 8).

In summer and spring, in papaya planted in the north-south direction (Fig. 5A and Fig. 5D), it was observed that in all treatments, the temperature values were similar, not differing statistically from each other. Observing the daily behavior of temperature (Fig. 7 A), note that the highest value was obtained in the full sun treatment (T4 Sun) at 1:30 pm, with a value of 42.60°C and a temperature of 37. 42°C was recorded at the same time in the treatment located in the papaya line (T1), thus presenting an attenuation of 5.18°C. In spring (Fig. 7 D), the highest temperature value was recorded in the full sun treatment, at 12:20 h, with a value of 40.23°C and, at the same time, a temperature of 38.93°C was recorded in the treatment located in the papaya line, thus having an attenuation of 1.3°C.

In the papaya tree planted in the East-West direction (Fig. 6 A), the lowest temperature was observed in the treatments in the papaya line and at 40 cm north (T1 and T2 N), it presented an average attenuation of 1.7 and 1.3°C, respectively. Observing the daily behavior (Fig. 8 A), it is noted that the highest temperature value was obtained in the full sun treatment (T4Sun) at 1:30 pm, presenting a value of 41.40°C and a temperature of 36.15°C was recorded at the same time in the treatment located in the papaya line (T1), presenting an attenuation, therefore, of 5.35°C.

In autumn, in papaya planted in the North-South direction (Fig. 5 B), lower temperature values were observed in the treatments in the papaya line and at 40 cm East, with mean attenuation of 0.60 and 0.40°C. Observing the daily behavior of temperature (Fig. 7 B), note that the treatment located at 40 cm East obtained the highest temperature values in the morning, in the afternoon, the treatment located at 40 cm to the West and the treatment at full sun, showed the highest temperature values. In papaya planted in the East-West direction (Fig. 6 B), the highest temperature was observed in the full sun treatment (T4 Sun), the other treatments did not differ statistically from each other. Observing the daily behavior (Fig. 7 B), note that the highest temperature value was obtained in the full sun treatment (T4 Sun) at 13:40 h, presenting a value of 36.9°C and a temperature of 35°C was recorded at the same time in the treatment located in the papaya line (T1), thus presenting an attenuation of 1.9°C. The variations in behavior throughout the day are due to the diurnal movement of the sun, which is from east to west, the point on the east horizon where the sun rises and the point on the west horizon where it sets.

In winter, papaya planted in the North-South direction (Fig. 5 C) showed a higher temperature value in the treatment located in full sun, the other treatments did not differ statistically from each other. Observing the daily behavior of temperature (Fig. 7 C), note that the highest temperature value was obtained in the full sun treatment (T4 Sun) at 11:30 h, presenting a value of 36.4°C and a temperature of 34.7°C was registered at the same time in the treatment located in the papaya line (T1), presenting an attenuation, therefore, of 1.7°C. In the papaya tree planted in the East-West direction (Fig. 6 C), the lowest temperature was observed in the treatment located in the papaya line and at 40 cm East (T1 and T3 L), with an attenuation of 1.6 and 1°C, respectively. Observing the daily behavior (Fig. 8 C).

In spring, in papaya trees planted in the East-West direction (Fig. 6 D), lower temperature values are observed in treatments located in the papaya line and at 40 cm north (T1 and T2 N), presenting an attenuation of 1 and 0, 8°C, respectively. Observing the daily behavior (Fig. 8 D), it is noted that the treatment at 40 cm south (T3 S) has the highest temperature values in the morning, after midday until late afternoon, the highest values of temperature are observed. temperature in full sun treatment. Note also that the highest temperature value was obtained in the full sun treatment (T4 Sun) at 12:20 h, presenting a value of 40.4°C and a temperature of 35.5°C was recorded at the same time in the treatment located on the papaya line (T1), thus presenting an attenuation of 4.9°C.

It is known that high temperature combined with high irradiation can result in leaf damage, by hindering several leaf metabolic processes and increasing the yield of highly reactive chlorophyll and oxygen molecules [22,11]. In this way, temperature attenuation, especially in the hottest months of the year, becomes an important technique for mitigating climatic variables for some crops, especially coffee, which coincides with its fruiting season and, with higher rates of vegetative growth [23,24].

Papaya planted in the North-South and East-West direction promoted an increase in the Relative Humidity of the air in some of the evaluated times, with the coffee treatment in full sun (T6 Sun) showing lower values (Fig. 9 and Fig. 10). Variations can be observed depending on the distance from the papaya line, the north or south position of the line, the time of day and the time of year. Observing the daily values of relative humidity (Fig. 11 and Fig. 12), note a trend of behavior inversely proportional to temperature, with higher values in the early morning, decreasing throughout the day with increasing temperature, and increasing again at the end of the day pm.

In summer, autumn and spring, in papaya planted in the North-South direction (Fig. 9 A, Fig. 9 B and Fig. 9 D), it was observed that in all treatments, the Relative Humidity values were similar, not differing statistically from each other, this result may be related to temperature and irradiance, which were also statistically similar in some evaluated times. In winter (Fig. 9 C) the lowest value of relative humidity was registered in the full sun treatment (T4 Sun), since the other treatments did not differ statistically from each other.

Observing the daily behavior of relative humidity in summer (Fig. 11 A), it is noted that in the morning the lowest value is observed in the treatment at 40 cm east (T3 L), and increases in the afternoon until the end of the day. On the other hand, the treatment located at 40 cm west (T2 O) has a higher relative humidity value in the morning and after midday until late afternoon, the values decrease, this behavior is a function of the diurnal movement of the sun., where it rises in the east and moves and sets in the west. Note that the lowest value of relative humidity was recorded in the full sun treatment, at 12:10 h, presenting 29.48%, already at the same time, in the treatment located in the papaya line, it presents a value of 41.27%, there being, therefore, an increase of 11.79% of relative humidity.

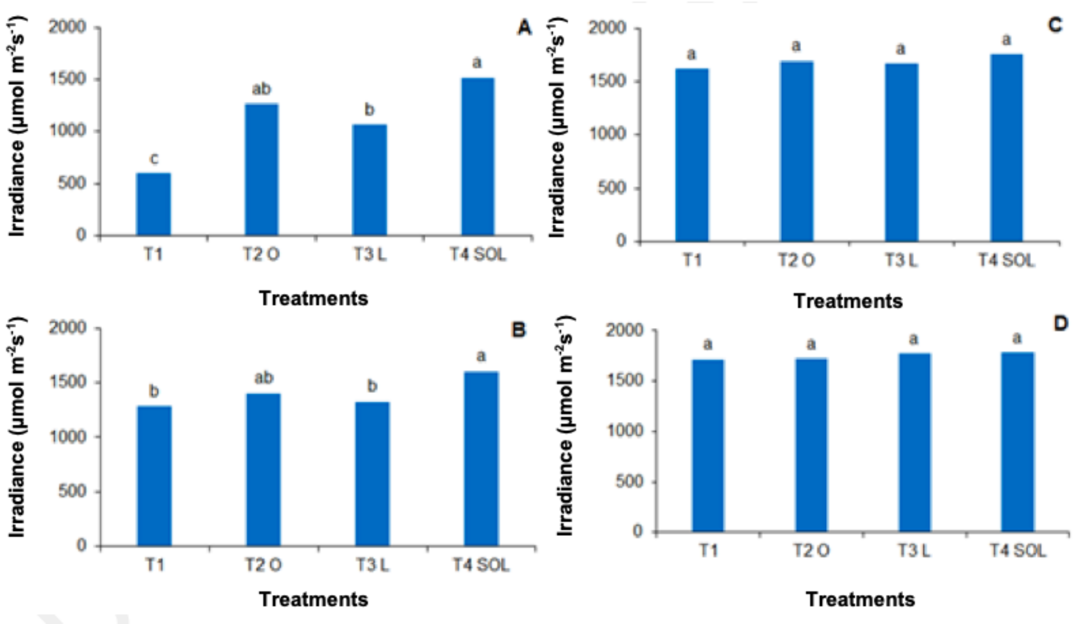

Fig. 1. Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40cm from the planting line on the west side; T3 L: located 40cm from the planting line on the east side; T4 Sun: located in the full planting line. CV%= Summer: 11.74; Autumn: 7.7; Winter: 6.72 and Spring: 4.13

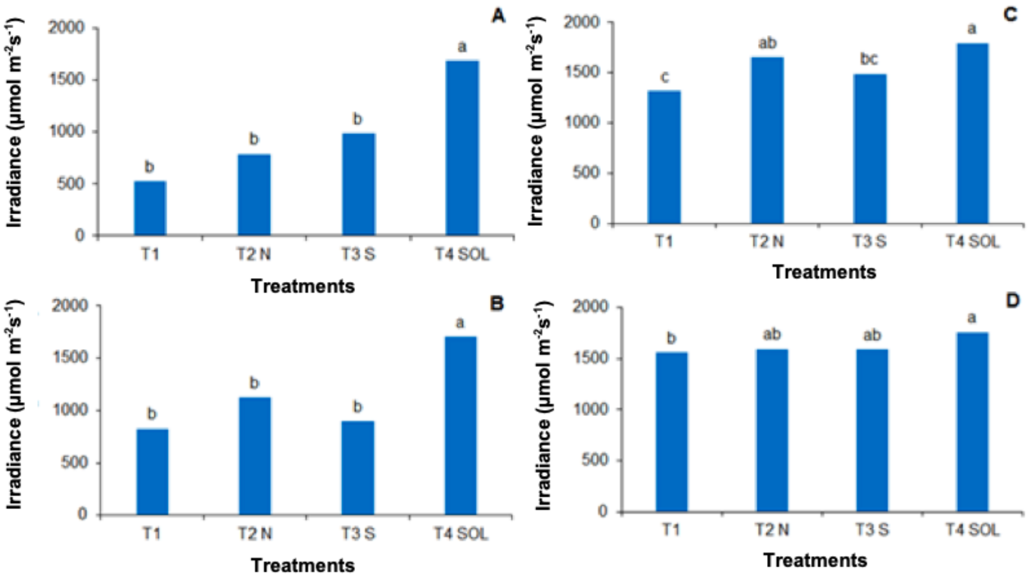

Fig. 2. Average daily values of Irradiance in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row. CV%= Summer:19.5; Autumn: 18.81; Winter: 5.84 and Spring: 4.37

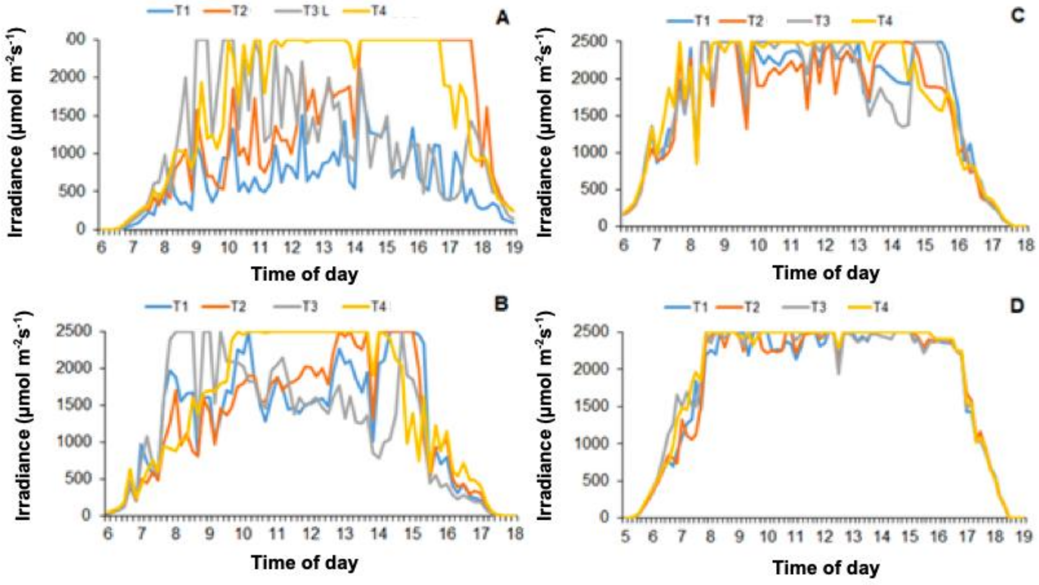

Fig. 3. Daily values of Irradiance in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full sun planting row

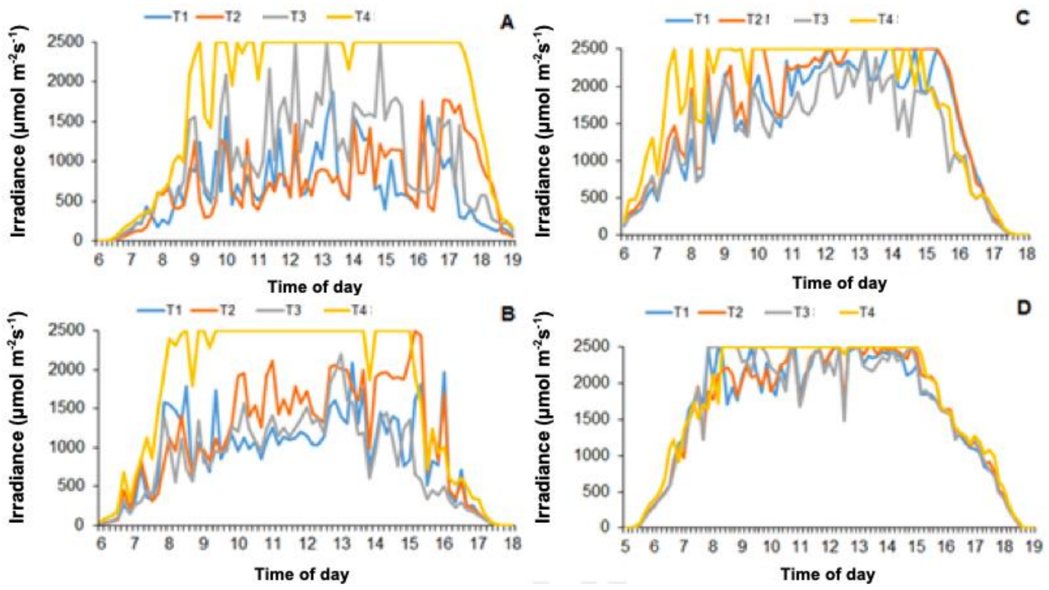

Fig. 4. Daily values of Irradiance in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row

In Autumn, Winter and Spring (Fig. 11 B, Fig. 11 C and Fig. 11 D), the lowest values of relative humidity were also recorded in the full sun treatment, at 12:40, 11:20 and 11:50 h, presenting 41.68, 33 and 33.42% relative humidity, and in the treatment located in the papaya line (T1), at the same times, they presented 47.2, 37.63 and 39.93% of relative humidity, thus having an increase in humidity of 2.52, 4.63 and 6.51%, in autumn, winter and spring, respectively.

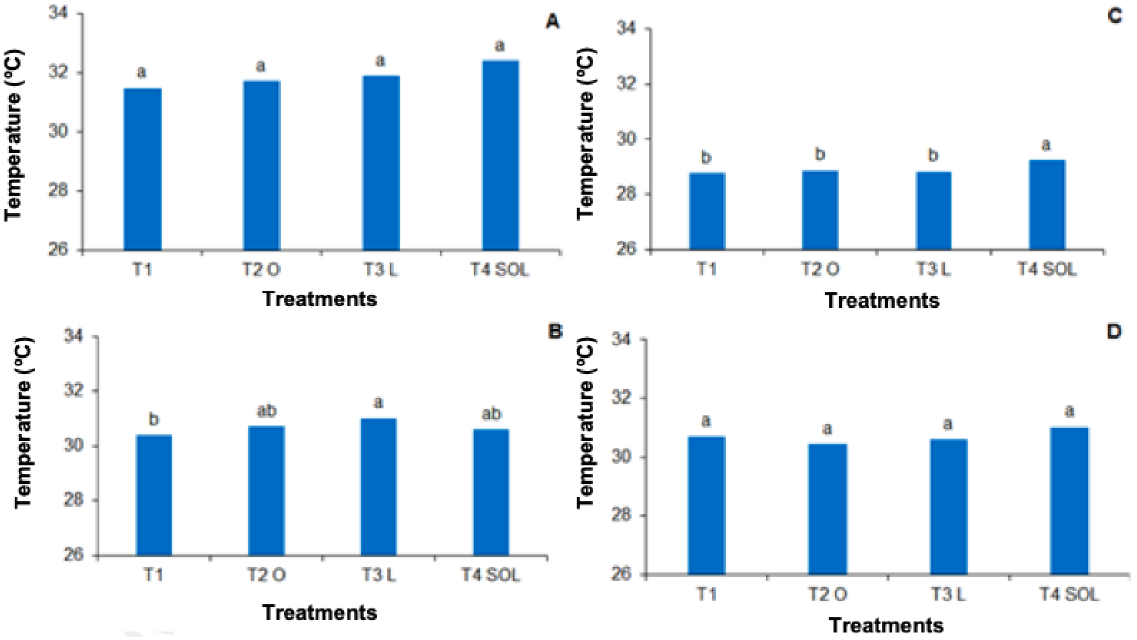

Fig. 5. Average daily temperature values in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40 cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full sun planting row. CV%= Summer: 1.21; Autumn: 0.58; Winter: 0.50 and Spring: 1.61.

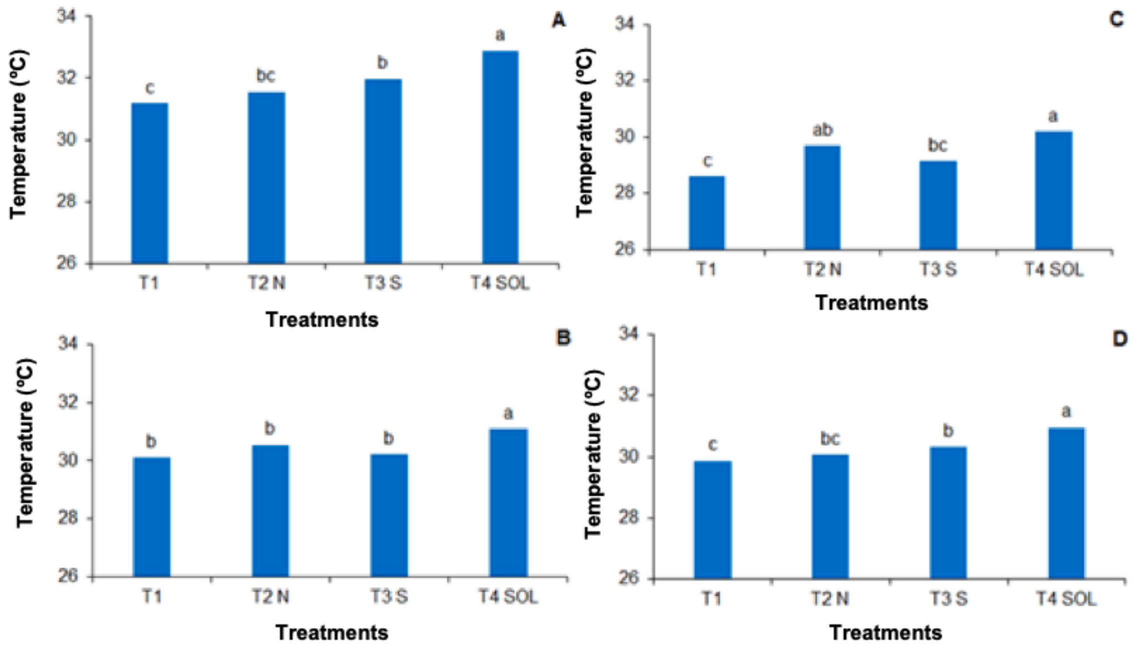

Fig. 6. Average daily temperature values in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row. CV%= Summer: 0.70; Autumn: 0.67; Winter: 0.83 and Spring: 0.47.

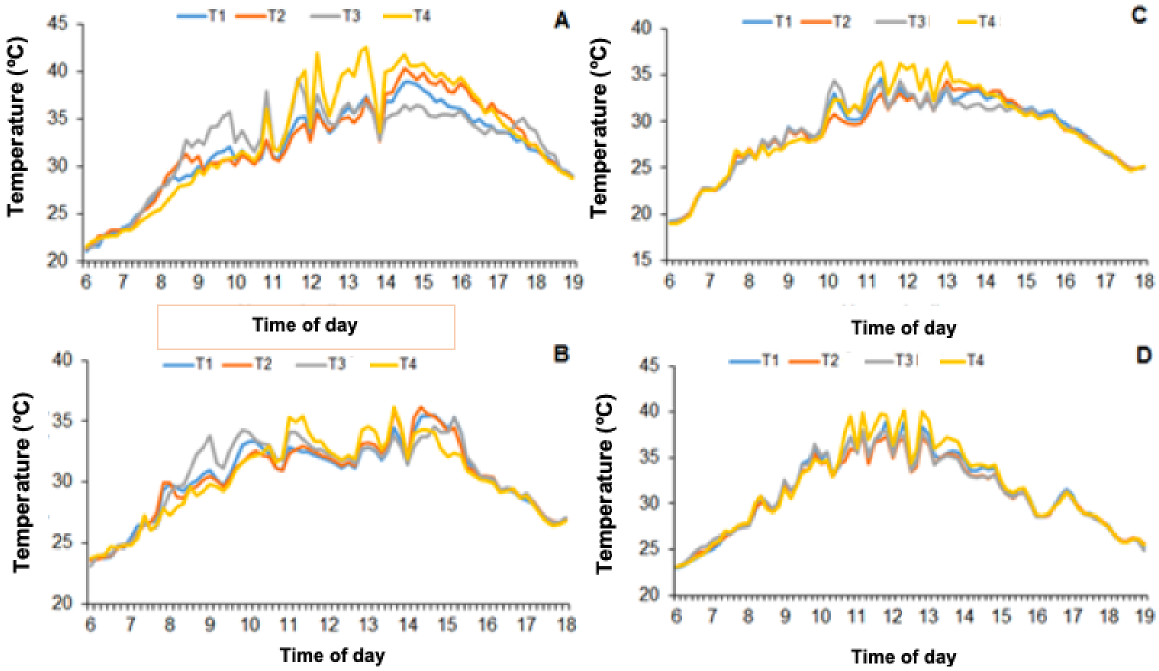

Fig. 7. Daily Temperature values in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40 cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full sun planting row.

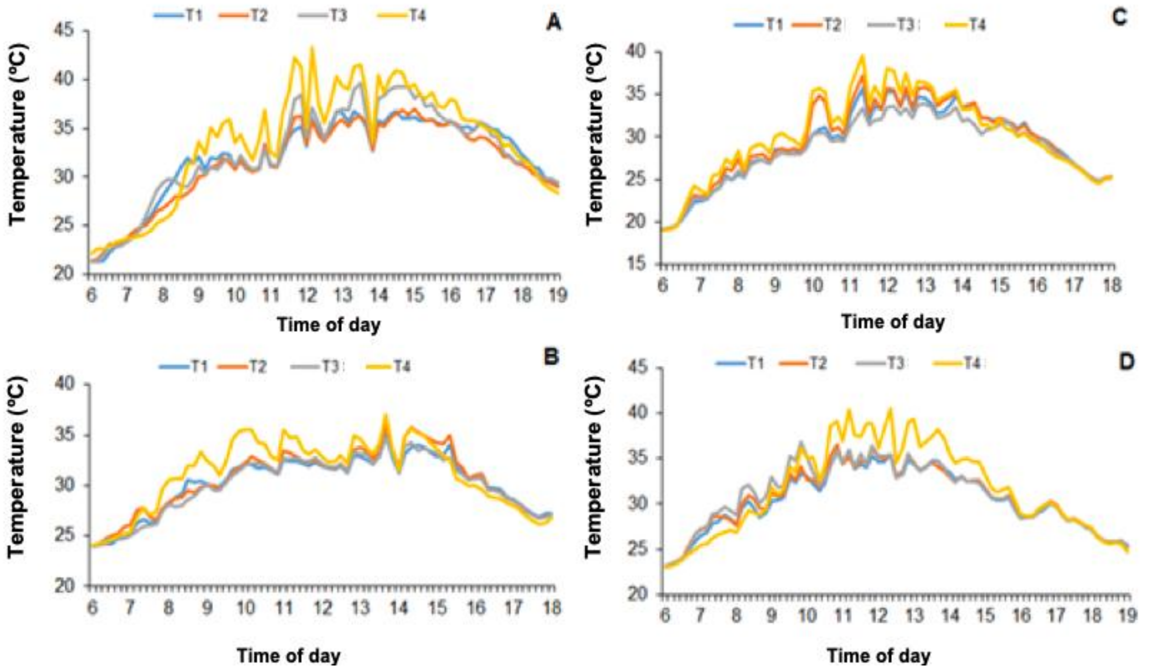

Fig. 8. Daily Temperature values in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row

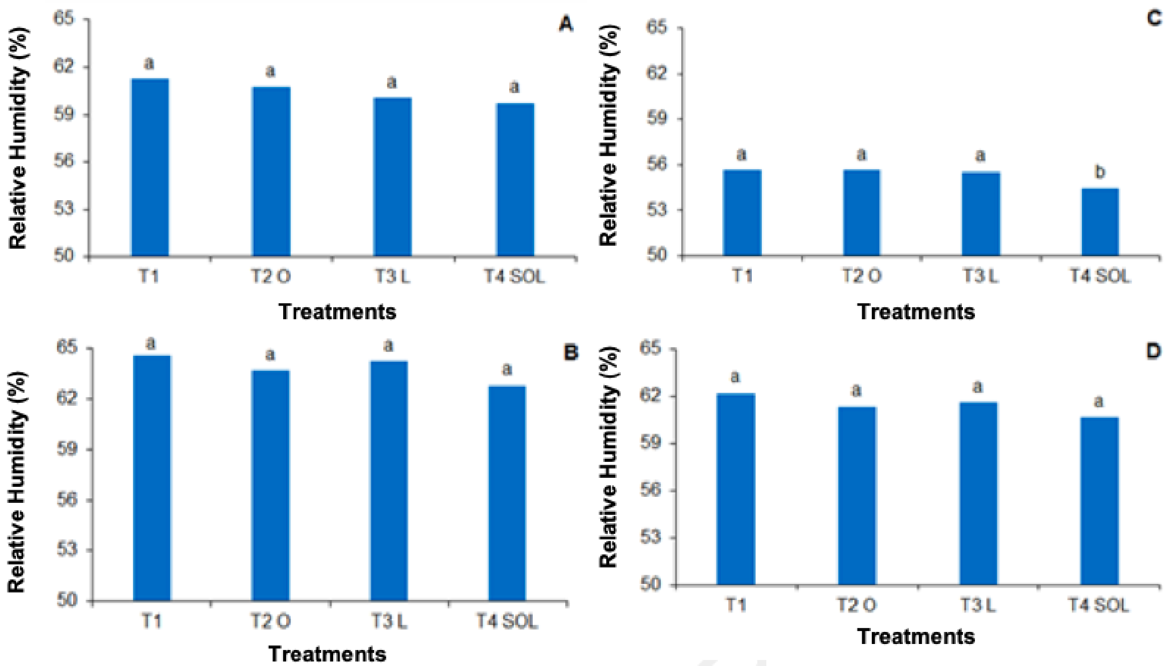

Fig. 9. Average daily values of Relative Humidity in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40 cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full sun planting row. CV%= Summer: 1.64; Autumn: 1.13; Winter: 0.59 and Spring: 1.89

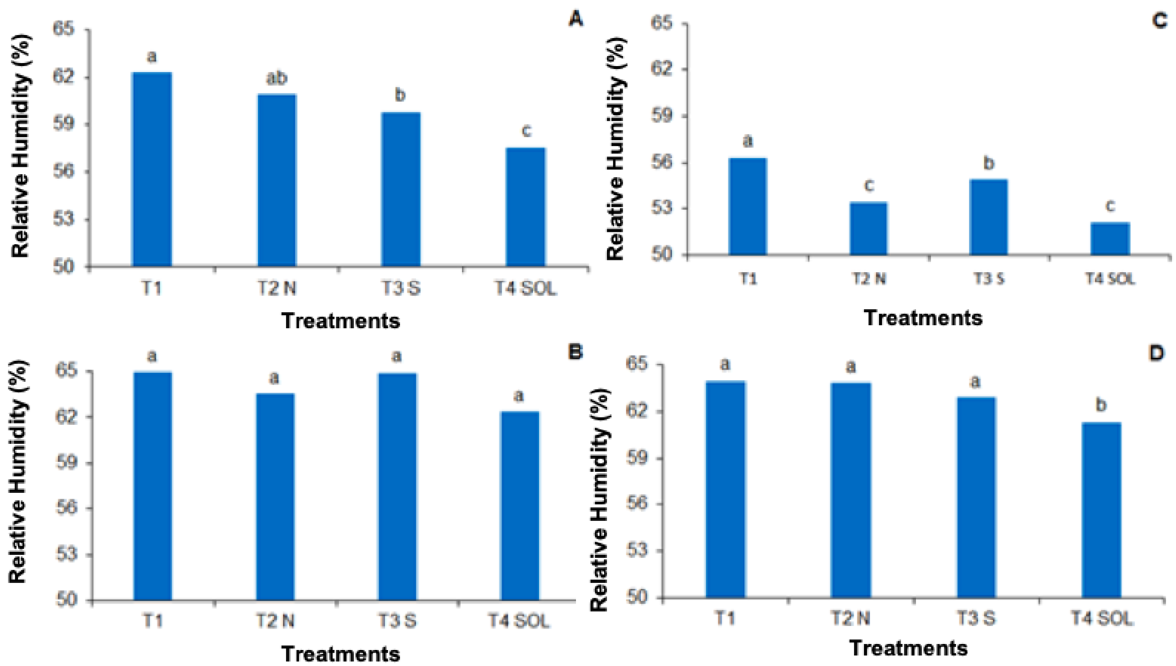

Fig. 10. Average daily values of Relative Humidity in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row. CV%= Summer: 1.09; Autumn: 1.70; Winter: 1.0 and Spring: 0.83

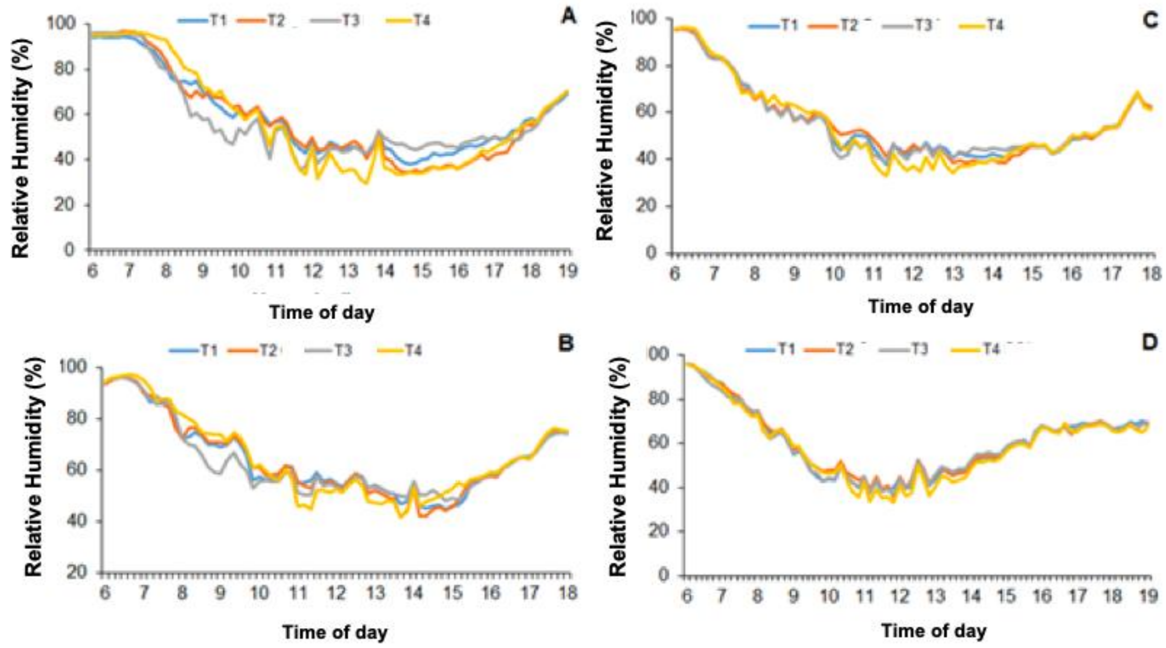

Fig. 11. Daily values of Relative Humidity in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the North-South direction

where: T1: located in the papaya planting line; T2 O: located 40 cm from the planting line on the west side; T3 L: located 40 cm from the planting line on the east side; T4 Sun: located in the full sun planting row

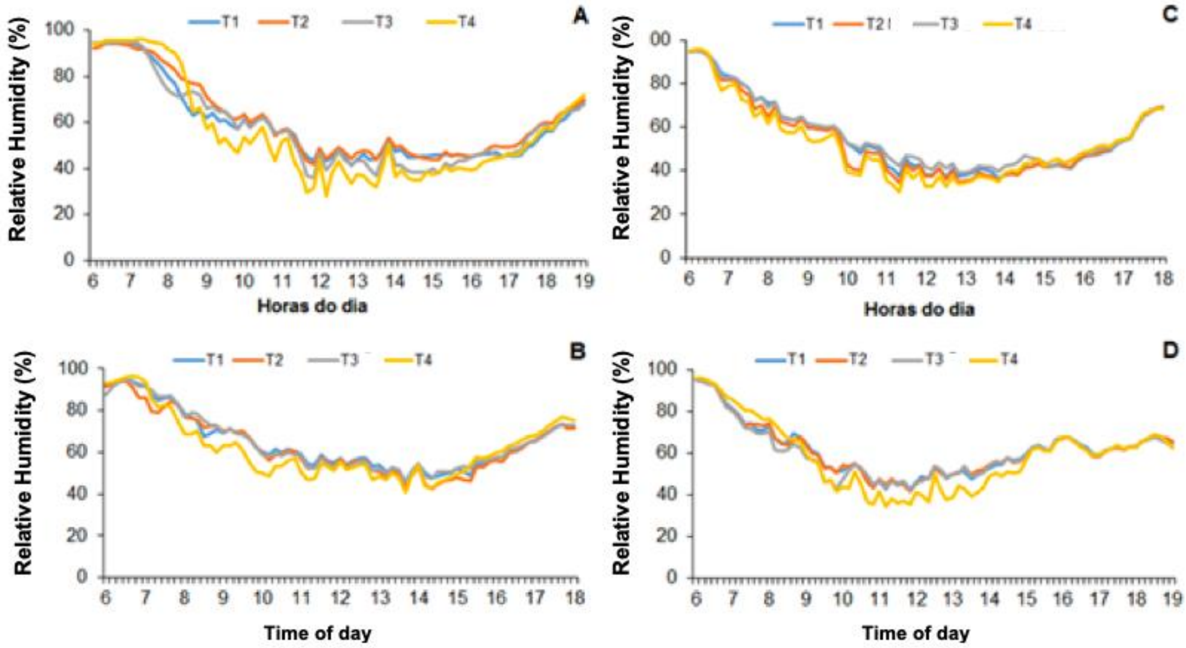

Fig. 12. Daily values of Relative Humidity in Summer (A), Autumn (B), Winter (C) and Spring (D), in Papaya planted in the East-West direction

where: T1: located in the papaya planting line; T2 N: located 40 cm from the planting line on the north side; T3 S: located 40 cm from the planting line on the south side; T4 Sun: located in the full sun planting row

In papaya planted in the East-West direction (Fig. 10), it was observed that in all the evaluated times (Fig. 10 A, Fig. 10 B, Fig 10 C and Fig 10 D), the highest value of relative humidity was registered in the treatment located in the papaya line (Fig. 10). T1), and the lowest value, in the full sun treatment (T4 Sun). Observing the daily behavior of relative humidity in the summer (Fig. 12 A), note that the lowest value of relative humidity was recorded in the full sun treatment, at 12:10 h, presenting 28.25%, already at the same time, in the treatment located in the line of papaya, presents a value of 43.30%, with, therefore, an increase of 15% of relative humidity. In winter and spring (Fig. 11 C and Fig. 11 D), the lowest values of relative humidity were also recorded in the full sun treatment, at 11:20h and 11:10h, with 37.56 and 42.81% relative humidity.

The maintenance of high atmospheric humidity on hot days, combined with the maintenance of higher rates of relative humidity and low wind speed, reduces the deficit of water vapor between the leaves and the atmosphere, reducing the loss of water from the plant by transpiration [25]. To this benefit obtained in shaded systems, there are also lower levels of irradiance at the leaf level, reducing the probability of over-excitation and photoinhibition of the components of the photosynthetic system. These occur mainly in the hottest and most radiant hours of the day, when plants are exposed to full sun, either considering shorter periods, of hours [26], or longer periods, of days [27].

4. CONCLUSION

Papaya planted in the East-West direction under the conditions studied provided a decrease in incident irradiation and temperature, and higher values of relative humidity under its canopy, in relation to papaya planted in the North-South direction.

It is possible to combine the papaya tree planted in both directions, as the shading provided was mild, promoting attenuation of climatic variables.

Of the times of the year evaluated, in the summer the greatest attenuation of the climatic variables was obtained.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. Food and Agriculture Organization of the United Nations. FAOSTAT. Disponível em:
   Available:http://www.fao.org/faostat/en/#data/QC
   (Acesso em: 8 setembro de 2020).
2. IBGE. Instituto Brasileiro de Geografia E Estatística. Produção agrícola municipal: Área plantada ou destinada à colheita, área colhida, quantidade produzida, rendimento médio e valor da produção das lavouras temporárias e permanentes. 2018. Disponível em
   Available:http:/www.sidra.ibge.gov.br
   Acesso em 6 de setembro de 2020.
3. Santos EM, Silva Junior GB, Cavalcante IHL, Marques AS, Albano FG. Planting spacing and NK fertilizing on physiological indexes and fruit production of papaya under semiarid climate. Bragantia. 2016; 75:63–69.
4. Campostrini E, Glenn DM. Ecophysiology of papaya: A review. Brazilian Journal of Plant Physiology; 2007.
5. Silva JR, Rodrigues W, Ruas KF, Paixão JS, Lima RSN, Machado Filho JA, Garcia J. AC, Shaffer B, Gonzalez JC, Campostrini E. Light, photosynthetic capacity and growth of papaya (*Carica papaya* L.): A short review. Australian Journal of Crop Science. 2019;13:1835–2707.
6. Olubode OO, Odeyemi OM, Olatokunbo Aiyelaagbe IO. Influence of environmental factors and production practices on the growth and productivity of pawpaw (*Carica papaya* L.) in south western Nigeria – A review. Fruits. 2016;71:341–361.
7. Arunachalam V, Vaingankar JD, Kevat N. Foliar Traits in Papaya Plants Intercropped in Coconut. National Academy Science Letters, 2020:1–4.

8. Vincent C, Schaffer B, Rowland DL, Migliaccio KW, Crane JH, Li Y. Sunn hemp intercrop and mulch increases papaya growth and reduces wind speed and virus damage. Scientia Horticulturae. 2017;218: 304–315.
9. Khusnul K, Suratno, Asuah N, Hariyadi S. Analysis of the effect of several types of shade on the productivity of robusta coffee. Journal of Physics. Conference Series. 2021;1751:012060.
10. Rodrigues VGS. Arborização de café Robusta e implicações na formação de liteira e no estabelecimento de plantas companheiras. Porto Velho: Embrapa Rondônia; 2007. (Circular Técnica, 91).
11. Damatta FM, Ramalho JDC. Impacts of drought and temperature stress on coffee physiology and production: A review. Brazilian Journal of Plant Physiology. 2006;18:55-81.
12. Araújo AV, Partelli FL, Oliveira MG, Pezzopane JRM, Falqueto AR, Cavatte PC. Microclima e crescimento vegetativo do café conilon consorciado com bananeiras. Coffee Science. 2015;10:214-222.
13. Oliosi G, Giles JAD, Rodrigues WP, Ramalho JC, Partelli FL. Microclimate and development of Coffea canephora cv. Conilon under different shading levels promoted by Australian cedar (toona ciliata M. Roem. Var. Australis). Australian Journal of Crop Science. 2016;10: 528-538.
14. Partelli FL, Araújo AV, Vieira HD, Dias JRM, Menezes LFT, Ramalho JC. Microclimate and development of 'Conilon' coffee intercropped with rubber trees. Pesquisa Agropecuária Brasileira. 2014; 49:872-881.
15. Pezzopane JRM, Pedro Júnior MJ, Gallo PB. Caracterização microclimática em cultivo consorciado café/banana. Revista Brasileira de Engenharia Agrícola e Ambiental (Online). 2007;11:256-264.
16. Bis APP, Partelli FL, Rodrigues WP, Falqueto AR, Espíndula MC, Martins LD. Microclimatic characterization of conilon coffee cultivated in north-south alignment in northen Espírito Santo state, Brazil. Coffee Science. 2019;14:427–437.
17. Bis APP, Partelli FL, Falqueto AR, Rodrigues WP, Vieira HD. Microclimatic characterization of a conilon coffee plantation grown in an east-west orientation. Australian Journal of Crop Science. 2020;14(03):1835–2707.
18. Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. 2013;22(6): 711–728.
19. Silva FAS. ASSISTAT - Statistical Assistance.Versão 7.6 beta. Campina Grande, UFCG, 2017. Disponível em: Available:http://www.assistat.com/indexi.html
(Acesso em: 15 mar. 2020).
20. Araújo AV, Partelli FL, Oliosi G, Pezzopane JRM. Microclimate, development and productivity of robusta coffee shaded by rubber trees and at full sun. Revista Ciência Agronômica. 2016; 47:700-709.
21. Pezzopane JRM, Marsetti MMS, Ferrari WR, Pezzopane JEM. Alterações microclimáticas em cultivo de café conilon arborizado com coqueiro-anão-verde. Revista Ciência Agronômica. 2011;42: 865-871.
22. Ramalho JC, Campos PS, Teixeira M, Nunes MA. Nitrogen dependent changes in antioxidant systems and in fatty acid composition of chloroplast membranes from *Coffea arabica* L. plants submitted to high irradiance. Plant Science. 1998;135: 115-124.
23. Partelli FL, Vieira HD, Silva MG, Ramalho JC. Seasonal vegetative growth of different age branches of Conilon coffee tree. Semina: Ciências Agrárias. 2010;31:619-626.
24. Partelli FL, Marré WB, Falqueto AR, Vieira HD, Cavatti PC. Seasonal vegetative growth in genotypes of Coffea canephora, as related to climatic factors. Journal of Agricultural Science. 2013;5:108-116.
25. Lin BB. The role of agroforestry in water conservation: The effect of shade on evapotranspiration in coffee agroecosystems, mitigation of microclimate variation through agroforestry: Protecting coffee agriculture from the impacts of climate change. Agricultural and Forest Meteorology. 2007; 144:85-94.
26. Ramalho JC, Pons TL, Groeneveld HW, Nunes MA. Photosynthetic responses of *Coffea arabica* L. leaves to a short-term high light exposure in relation to N availability. Physiologia Plantarum. 1997; 101:229-239.

27. Ramalho JC, Pons TL, Groeneveld HW, Azinheira HG, Nunes M. A. Photo-synthetic acclimation to high light conditions in mature leaves of *Coffea arabica* L.: Role of xanthophylls, quenching mechanisms and nitrogen nutrition. Australian Journal of Plant Physiology. 2000;27:43-51.

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