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CROP PRODUCTION

Physiological and productive characteristics of the banana 'Prata-Anã' subjected to different irrigation intervals and emitter heights

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ABSTRACT. This study aimed to evaluate the productive characteristics, gas exchange and water use efficiency of the banana 'Prata-Anã' clone Gorutuba under different irrigation intervals associated with different emitter heights. Therefore, a field experiment was conducted in a 2 x 4 factorial scheme: two irrigation intervals (daily and every two days) and four emitter heights (50, 70, 90, and 110 cm) in a completely randomized design with four replicates. The irrigation depths applied by the microsprinkler irrigation system were calculated as a function of crop evapotranspiration. The gas exchanges were evaluated during the period of greatest climatic stress, and the productive characteristics were evaluated at harvest. The economic water use efficiency was determined indirectly by considering the production divided by the applied irrigation depth, which was the same in all the treatments. The instantaneous water use efficiency was estimated with an infrared gas analyzer in the critical climatic period. There was no interaction between the irrigation intervals and emitter heights. The two-day irrigation interval resulted in lower values of leaf temperature and photosynthetically active radiation incident on the leaves, resulting in a higher fruit weight and, consequently, higher yields and a higher water use efficiency. The highest fruit weights were obtained at heights of 70 and 90 cm.

Keywords: water use efficiency; irrigation management; gas exchanges.

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Introduction

Brazil is the fourth largest banana producer in the world (FAOSTAT, 2016), and more than 50% of its production is in the semiarid region (IBGE, 2016), where irrigation is indispensable, especially due to the high water requirements of crops (Kissel, van Asten, Swennen, Lorenzen, & Carpentier, 2015).

The type of irrigation system affects the yield of banana crops, regardless of the use of the same cultivars and similar growing conditions (Sant'ana, Coelho, Faria, Silva, & Donato, 2012), due to differences in the uniformity of water distribution associated with factors such as the emitter position, irrigation angle, working pressure, type of vegetation and emitter height, which affect both the area and volume of wet soil, the intensity and frequency of application, the spatial distribution of the root system, the chemical attributes, and nutrient flux in the soil. It can also generate changes in phenotypic characteristics (Donato et al., 2010).

Higher plants are those that can generate physiological and phenotypic changes, thus increasing their water use efficiency (WUE). This attribute can be expressed in several ways: leaf WUE or instantaneous WUE, which is the ratio between the gross carbon fixed by photosynthesis per unit of water transpired for a reduction of 1 kPa of vapor pressure deficit; the WUE of the plant, which corresponds to the ratio between the dry mass produced and the transpiration depth; or, from an economic point of view, WUE considers the ratio between fresh mass production (kg) per unit of transpired water (Donato, Coelho, Marques, & Arantes, 2016).

The increase in irrigation interval implies a greater amount of water applied per irrigation event and a larger volume of wet soil, which affects the distribution of roots in the soil (Donato et al., 2016).

Given the above, the objective of this work was to evaluate the productive characteristics, gas exchanges and water use efficiency in the banana 'Prata-Anã' clone Gorutuba crop under different irrigation intervals associated with different emitter heights.

Material and methods

The experiment was carried out at Fazenda São Francisco, which is owned by Grupo Banarica, located in Matias Cardoso, Minas Gerais State, Brazil, with central geographic coordinates corresponding to 14º56'49" S and 43º57'21" W and an elevation of 461 m. The soil texture is sandy, and the relief is flat to slightly undulated; the chemical and physical composition of the soil are described in Table 1. The climate of the region is type Aw (tropical with a dry winter) according to the Köppen classification.

Table 1. Results of the soil analysis of the experiment site.

Chemical Characteristics																					Phys. Char.		
Identif.	pH[1]	OM[2]	P[3]	K	Ca[4]	Mg[4]	Al[4]	H+Al[5]	BS	t	T	V	m	B[6]	Cu[3]	Fe[3]	Mn[3]	Zn[3]	Prem[8]	EC	Sand	Silt	Clay
		dag kg^{-1}	m dm^{-3}	---------- cmol$_c$ dm^{-3} ----------								--- % ---			--- mg dm^{-3} ---				mg L^{-1}	dS m^{-1}	-- dag kg^{-1} --		
B4-5	6.6	0.7	84.6	82	2	0.6	0	2.9	2.9	2.9	4.1	72	0	0.2	0.6	36.9	40.2	5.3	47.8	0.5	86	6	8

[1]pH in water; [2]Colorimetry; [3]Extractor: Mehlich-1; [4]Extractor: KCl 1 mol L^{-1}; [5]pH SMP; [6]Extractor: $CaCl_2$; [7]Extractor: $Ca(H_2PO_4)_2$, 500 mg L^{-1} of P in HOAc 2 mol L^{-1}; [8]Balance solution of P; SB: Sum of bases; t: effective CEC; T: CEC in pH 7; V: Base saturation; m: Aluminum saturation; P-rem: Phosphorus remaining; EC: Electrical conductivity. dag kg^{-1} = %; mg dm^{-3} = ppm; cmol$_c$ dm^{-3} = meq 100 cm^{-3}.

The planting of the crop was carried out between April 1st and 6th, 2016. Tissue culture seedlings of the cultivar 'Prata-Anã', clone Gorutuba, were used (Rodrigues, Librelon, Nietsche, Costa, & Pereira, 2012) at a spacing of 3 x 2 m. The planting and cultivation followed the practices commonly adopted on the property.

For irrigation, microsprinklers were used, which had a nominal flow rate of 102 L h^{-1}, a working pressure of 201 kPa, and a wet diameter of 9.4 m. They were spaced 6 m apart and 6 m between the lateral lines. The irrigation depths were calculated and applied based on the reference evapotranspiration (ETo), which was determined daily by the Penman-Monteith method (Allen et al., 2006), based on data collected from an automatic weather station installed 500 m from the experiment. The crop coefficients (Kc) used for determining the crop evapotranspiration (ETc) were defined according to the phenological phases of the crop according to Silva, Coelho, and Coelho Filho (2015). The total soil water storage capacity (TWSC) was determined with the values of the field capacity (FC) and the permanent wilting point (PWP) obtained from the soil retention curves (Equations 1, 2, and 3) shown in Table 2, along with the soil global density values (D_g). The available water storage capacity (AWSC) was obtained by integrating the TWSC values for each layer of soil and multiplying the value obtained by the availability factor (f), 0.3 (Allen et al., 2006). The minimum irrigation frequency or maximum irrigation interval (II_{max}) was determined by dividing the AWSC by the maximum ETc. The values of FC, PWP, AWSC, ET_{Cmax}, and II_{max} are shown in Table 3.

Table 2. Soil retention curves of the three soil layers (0 - 20, 20 - 40, and 40 - 60 cm) at the experiment site.

Curve*	R^2	D_g
$\theta_{0-20} = 0.0383 + \frac{(0.1250 - 0.0383)}{[1 + (0.0745 * \tau)^{1.8489}]^{0.4591}}$	0.9888	1.84
$\theta_{20-40} = 0.0442 + \frac{(0.1200 - 0.0442)}{[1 + (0.0820 * \tau)^{1.8240}]^{0.4518}}$	0.9810	1.82
$\theta_{40-60} = 0.0526 + \frac{(0.1250 - 0.0526)}{[1 + (0.1117 * \tau)^{2.1801}]^{0.5413}}$	0.9952	1.86

*Data fit van Genuchten Model (van Genuchten, 1980); θ = Soil moisture (g g^{-1}); τ = soil water pressure (kPa); D_g = soil global density (decimal).

Table 3. Field capacity (FC), permanent wilting point (PWP), soil global density (Dg), total soil water storage capacity (TWSC), available water storage capacity (AWSC), maximum ETc (ET_{Cmax}) and maximum irrigation interval (II_{max}).

Layer depth (cm)	FC (%)	PWP (%)	Dg (g cm^{-3})	TWSC (mm)	AWSC (mm)	ET_{Cmax} (mm dia^{-1})	II_{Max} (dias)
0 - 20	10.9	4.0	1.84	25.392			
20 - 40	10.4	4.6	1.82	21.112	19.1	8.4	2.3
40 - 60	9.9	5.3	1.86	17.112			

The treatments, two irrigation intervals (daily and every two days) and four emitter heights (50, 70, 90, and 110 cm) were arranged in a completely randomized experimental design (CRD) in a 2 x 4 factorial scheme with four replications and plots consisting of four measurement plants.

The evaluations of gas exchange, leaf temperature and leaf radiation were always carried out on the third or fourth leaf (leaf three or four) from the apex to the base using the infrared gas analyzer (IRGA) model Lcpro+® Portable Photosynthesis System (ADC BioScientific Limited, UK) with ambient temperature and irradiance, air flow of 200 mL min.$^{-1}$, and with the shield of radiation always facing the sun (Arantes, Donato, Siqueira, Coelho, & Silva, 2016). In the treatments with two-day intervals between irrigations, the evaluations were performed on the day without irrigation. Data collection was carried out from September 2016 to February 2017, which corresponds to the season of greatest climatic stress (Donato et al., 2016), until flowering in the first production cycle.

The productive characteristics were evaluated at the time of harvest. The number of hands per bunch, the weight of the peduncle, the total weight of fruits per bunch and the number of leaves per plant were evaluated. The economic water use efficiency was calculated by the total weight of fruits divided by the total water applied, which was the same for all treatments.

The data were subjected to analysis of variance, and the means were compared to one another by the Tukey test ($p < 0.1$). Ten percent was adopted to meet the production dynamics, in which the factors that can influence the development of the crop are diverse and uncontrollable, allowing the occurrence of type II errors due to greater rigor in the Tukey test to identify significant differences between the treatments (Ferreira, 2011).

Results and discussion

The maximum and minimum temperature and relative humidity values recorded during the crop cycle are shown in Figure 1. The evapotranspiration, precipitation and gross irrigation depth are shown in Figure 2.

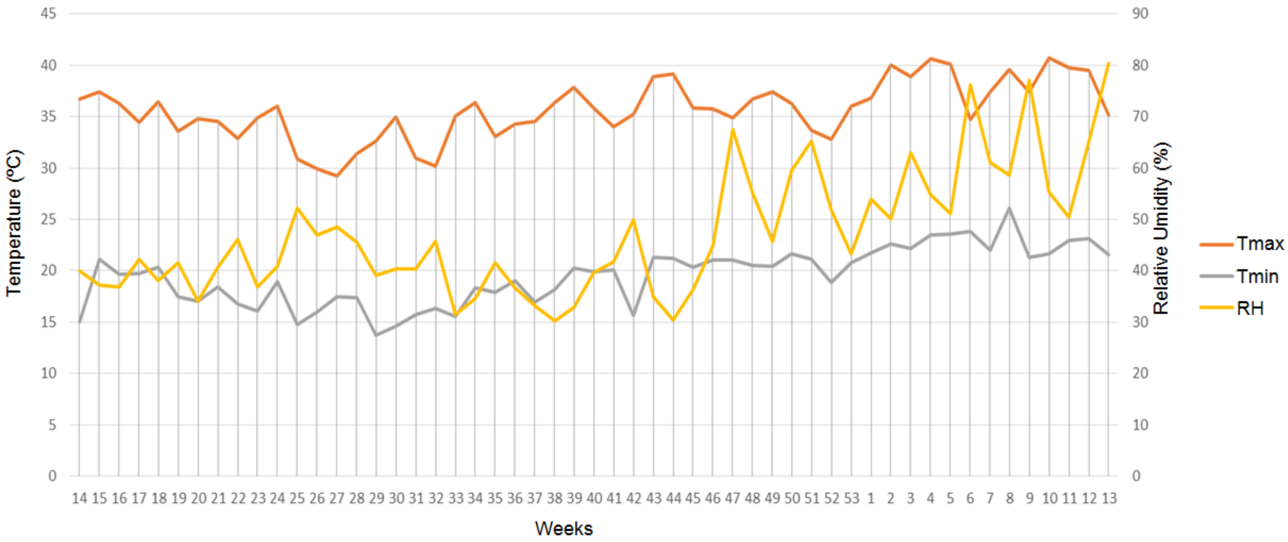

Figure 1. Weekly averages of maximum temperature (Tmax), minimum temperature (Tmin), and relative humidity (RH) recorded during the experimental period, from April 2016 to May 2017, at the experiment site.

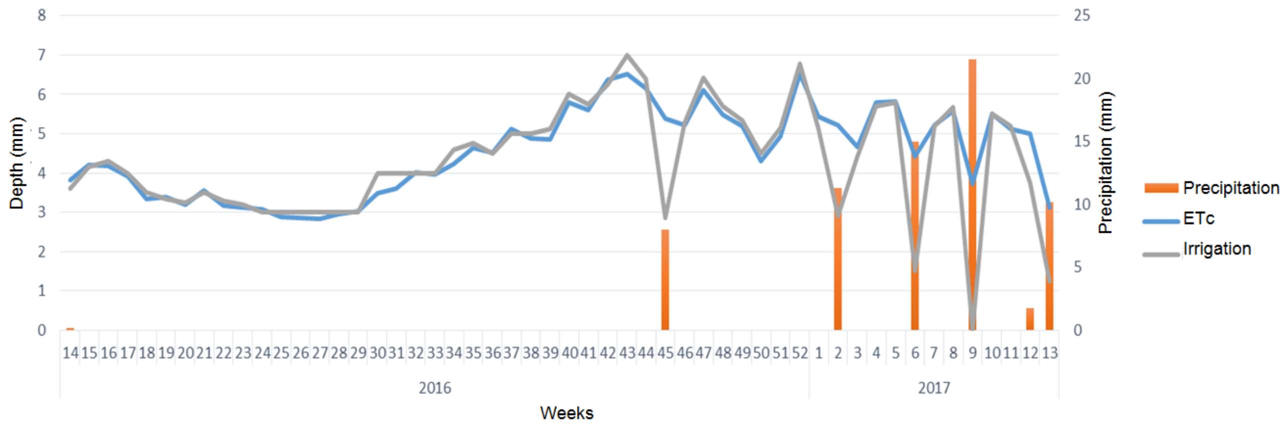

Figure 2. Weekly measurements of crop evapotranspiration (ETc) and total precipitation observed and the gross irrigation depth applied during the experimental period from April 2016 to May 2017.

The fluctuations in the meteorological data suggest that during the majority of the cycle, the conditions were not ideal for the vegetative development of the banana plant. According to Robinson and Galán Saúco (2012), the optimal temperature for the carboxylation of CO_2 (A/C_i) in plants with a C_3 photosynthetic mechanism is approximately 22°C, and the optimal temperature for growth metabolism is 27°C.

There was no influence of the irrigation interval on the agronomic variables evaluated: the number of hands per bunch, peduncle weight and the number of leaves per plant, but there was an influence on the total weight of fruits per bunch, which contrasted with the results presented by Silva et al. (2015). These authors found that even with six-day irrigation intervals, the final yield was not influenced despite different soil characteristics between the experiments. This result may be associated with the subdivision of the irrigation depth in the three applications during the irrigation day, even in the two-day irrigation interval, making it possible to optimize the operational management of irrigation system maintenance, which is considered one of the critical points of production.

Concerning gas exchanges, which was evaluated in October 2016, the period of greatest climatic stress (Donato et al., 2016), there was no significant effect in the interaction between the emitter height and irrigation interval neither of the emitter height alone for the variables analyzed, indicating that the effects of each action are not complementary. However, there was a significant effect of the irrigation interval on leaf radiation (Q_{leaf}) and leaf temperature (T_{leaf}). The values collected resemble those presented by Arantes et al. (2016) for the banana 'Prata-Anã', reiterating the common behavior for the clone in semiarid regions.

Table 4 shows the rates of radiation incident on a leaf (Q_{leaf}), liquid photosynthesis (A), the stomatal conductance (g_s), the CO_2 concentration (C_i), the leaf temperature (T_{leaf}), and the evapotranspiration (E) of the banana 'Prata-Anã' Gorutuba clone in two periods of the day under different irrigation intervals.

Table 4. Rates of radiation incident on a leaf (Q_{leaf}), net photosynthesis (A), stomatal conductance (g_s), CO_2 concentration (C_i), leaf temperature (T_{leaf}) and evapotranspiration (E) of the banana 'Prata-Anã' Gorutuba clone in two periods of the day under different irrigation intervals.

Irrigation interval (day)	Q_{leaf} (µmol photons m^{-2} s^{-1})		A (µmol CO_2 m^{-2} s^{-1})		gs (mmol H_2O m^{-2} s^{-1})		Ci (µmol CO_2 mol^{-1})		T_{leaf} (°C)		E (mmol H_2O m^{-2} s^{-1})	
	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm
1	2039.5 Aa	2037.5 Aa	26.78 Aa	16.66 Ba	0.53 Aa	0.30 Aa	220.62 Aa	237.14 Aa	35.52 Aa	39.59 Aa	7.74 Aa	7.63 Aa
2	1988.2 Ab	1653.9 Ab	26.10 Aa	17.12 Ba	0.48 Aa	0.34 Aa	211.72 Aa	212.20 Aa	36.08 Ba	38.36 Ab	7.70 Aa	7.79 Aa
CV	0.242		0.212		0.382		0.138		0.050		0.260	

Means followed by the same uppercase letter in a column and lowercase letter in a row do not differ significantly from each other ($p < 0.1$) by the Tukey test.

The photosynthesis rates presented a significant difference between the schedules, which was already expected since it is directly influenced by T_{leaf} and C_i, an effect reiterated by Arantes et al. (2016), which is characterized by the effect of the climate in semiarid regions. There were no significant differences between the schedules to transpiration and stomatal conductance despite the increase in the temperature of the air, which is associated with the radiation not used in photosynthesis (decreasing from 32°C) as the plant maintains transpiratory flow, also allowing the entry of CO_2. Ramos, Donato, Arantes, Coelho Filho, and Rodrigues (2018) observed that the photosynthetic rates, carboxylation efficiency, and instantaneous water use efficiency were higher at 8:00 am due to meteorological conditions while the foliar temperature and transpiration were higher at 2:00 pm due to the elevation of air temperature and low humidity.

Concerning the irrigation intervals, there was a significant effect on T_{leaf} in the afternoon, in which lower values for the two-day irrigation interval were observed (Table 4), suggesting an adaptive behavior of the plant, allowing a lower incidence of radiation on the leaf lamina and consequently greater heat dissipation and a lower leaf temperature. This may be associated with leaf laminae flexion.

The Q_{leaf} values did not vary significantly between schedules; however, it differed between irrigation intervals. The highest values of Q_{leaf} in the banana leaf were observed with the daily irrigation interval, between 2,037 and 2,039 µmol photons m^{-2} s^{-1}, values above the ideal described by Robinson & Galán Saúco (2012); they considered the ideal values to be between 1,500 and 2,000 µmol photons m^{-2} s^{-1} since there is no increase of photosynthesis as a function of radiation when values are above 1,500 µmol photons m^{-2} s^{-1}. In the two-day irrigation interval, the Q_{leaf} values (1,653 - 1,988 µmol photons m^{-2} s^{-1}) remained above the ideal for the maximum net photosynthetic rate (1,500 µmol photons m^{-2} s^{-1}), which probably shows adaptability to the climate when compared to the daily irrigation interval. This behavior is probably associated with the flexion of the leaf lamina without necessarily considering the camber of the central midrib because there was maintenance of the transpiration (E), which was similar to the daily-irrigated plants. Raven, Evert, and Eichhorn (2001) affirmed that this movement is a mechanism associated with turgor changes and concomitant contractions and expansions of the parenchyma due to the exit of potassium ions to the apoplast and the accumulation of sucrose from the phloem.

In the daily irrigation interval, the water-soil-plant-atmosphere flow probably remained constant. Thus, the plant remained with greater exposure of the leaf, increasing the incidence of radiation in the afternoon, causing an increase in leaf temperature. In this case, the daily frequency of irrigation may be conditioning the plant to a stress condition at high Q_{leaf} values (2,039.48 - 2,037.5 μmol photons m^{-2} s^{-1}), absorbing heat at the level of thermal damage (T_{leaf} = 39.59°C), close to 40°C (Donato et al., 2016), contributing to physiological derangements.

According to Surendar, Devi, Ravi, Jeyakumar, and Velayudham (2013), early signs of stress activate response mechanisms to restore homeostasis and protect and repair damaged proteins and membranes. This reinforces the idea that the accumulation of ions in the shoot of banana plants occurs as a function of the synthesis of abscisic acid (ABA), which is triggered by initial and/or partial signs of stress, such as the pre drying of the soil surface horizon in the two-day interval between irrigations.

Sant'Ana et al. (2012) concluded that a longer irrigation interval leads to a greater horizontal expansion of the root system, in which roots that effectively contribute to the absorption of water and nutrients reach a greater distance from the plant. In this context, lower moisture loss on the soil surface could trigger ABA synthesis and its transport via the xylem from root to shoot, altering the hormonal balance and the assimilation within the root and shoot, promoting the downward growth of roots, the accumulation of salts in the shoot, and regulating the stomatal movement.

Based on the data observed in Table 4, it can be inferred that there was maintenance of the soil and plant moisture for the two-day irrigation interval since there was no significant difference among the frequencies in the rates of E, A, C_i, and g_s as well as for the relationships among them, confirming that the soil moisture did not reach the critical level, as two sequential days with a maximum ETc without irrigation did not bring the soil moisture to the AWSC value (Table 3). This does not eliminate the hypothesis of the loss of moisture in the soil surface horizons. According to Donato et al. (2016), gas exchanges are influenced by climatic factors, physiological processes, and soil moisture.

Table 5 presents the values of instantaneous water use efficiency (WUEi), carboxylation efficiency (A/C_i) and photochemical efficiency of photosynthesis (A/Q_{leaf}) in two periods (8:00 am and 2:00 pm) under irrigation intervals of 1 and 2 days.

Table 5. Instantaneous water use efficiency (WUEi), carboxylation efficiency (A/C_i) and photochemical efficiency of photosynthesis (A/Q_{leaf}) in two periods (8:00 am and 2:00 pm) under irrigation intervals of 1 and 2 days.

Irrigation interval	WUEi (A/E) (μmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1})		A/C_i (μmol CO_2 m^{-2} s^{-1}/μmol CO_2 mol^{-1})		A/Q_{leaf} (μmol CO_2 m^{-2} s^{-1}/μmol photons m^{-2} s^{-1})	
(day)	8:00 am	2: 00 pm	8:00 am	2:00 pm	8:00 am	2:00 pm
1	3.46 Aa	2.18 Ba	0.12 Aa	0.078 Aa	0.013 Aa	0.008 Aa
2	3.39 Aa	2.20 Ba	0.12 Aa	0.072 Aa	0.013 Aa	0.010 Aa
CV	0.197		0.214		0.535	

Means followed by the same uppercase letter in a column and lowercase letter in a row do not differ significantly from each other ($p < 0.1$) by the Tukey test.

The carboxylation rate of CO_2 (A/C_i) did not differ between the treatments. It expresses the ratio between the rate of photosynthesis (A) and the internal CO_2 concentration (C_i), which is a measure of the carboxylation efficiency of the rubisco enzyme.

The efficiency of leaf water use or the instantaneous water use efficiency, represented by the relationship between photosynthesis and transpiration (A/E), presented significant variation between the schedules, which is similar to the data of Arantes et al. (2016). The treatments did not influence the instantaneous water use efficiency. The values were influenced directly by the photosynthetic rate, which presented the same behavior. As observed by Arantes et al. (2016), there is a relationship between the instantaneous water use efficiency and T_{leaf}, as it is one of the main factors that influences the photosynthetic rate and transpiration in semiarid regions, a fact also corroborated by Arantes, Donato, Siqueira, and Coelho (2018) and Ramos et al. (2018). On the other hand, Ramos et al. (2018) verified that the BRS Princesa banana cultivar in months with a higher radiation and intermediate temperature provided higher rates of photosynthesis and a higher efficiency of carboxylation and photochemistry of photosynthesis.

The photochemical efficiency of photosynthesis (A/Q_{leaf}) did not differ between the treatments. It expresses the ratio between A and Qleaf, which is a measure of the efficiency of assimilation of the radiation in the photosynthetic process. In addition to the aforementioned differences, there was no difference in the photochemical efficiency since the values were above the ideal for the maximum net photosynthetic rate (1,500 μmol photons m^{-2} s^{-1}) obtained by Soto Ballestero (2008).

Table 6 shows the mean number of hands per bunch (N hand), peduncle weight, the total fruit weight and the number of leaves per plant in the harvest (N leaves) at different irrigation intervals.

Table 6. Mean number of hands per bunch (N hand), peduncle weight, total fruit weight and number of leaves per plant in the harvest (N leaves) in different irrigation intervals.

Irrigation interval (day)	N hand	Peduncle weight (g)	Total fruit weight (g)	N leaves
1	6.98 A	1,130.65 A	11,080.81 B	9.53 A
2	7.27 A	1,098.51 A	11,638.06 A	9.20 A

Means followed by the same uppercase letter in a column and lowercase letter in a row do not differ significantly from each other (p <0.1) by the Tukey test.

There were significant differences between the irrigation intervals regarding the total fruit weight. The two-day irrigation interval exhibited the highest total fruit weight and, consequently, a higher yield despite the fact that the number of hands per bunch, peduncle weight and number of leaves did not differ between the treatments, indicating a greater accumulation of daily net photosynthesis as a function of higher values of photochemical efficiency, which is probably associated with root development promoted by the higher volume of water applied and the higher volume of wet soil. In contrast, Silva et al. (2015) found that irrigation frequencies did not influence yield but rather the fruit diameter.

Because there was no difference in the number of hands per bunch and weight of peduncles, the difference in fruit weight is related to fruit density as a result of the effect of ABA synthesis and the allocation of salts in the shoot, justifying the increase in fruit density.

Although there was no difference in the instantaneous water use efficiency, it could be observed that with the same water depth, there was a higher yield in the two-day irrigation interval, that is, a greater water use efficiency. This reinforces the argument of greater tolerance and adaptability to climatic stress, which keeps the plant physiologically active longer during the day, resulting in a greater amount of daily net photosynthesis. Considering that leaf laminae flexion could be visually observed during the experiment, this result could be more easily explained if more than two daily evaluations had been performed.

Table 7 shows the same agronomic and productive variables (N hand, peduncle weight, total fruit weight, and N leaves) in relation to the emitter height. A significant effect was expected because the higher the emitters, the longer the radius of application, thus increasing the uniformity coefficients of the applications. The microsprinklers applied larger water depths when they were installed between 0.5 and 1.35 m from their base with the radius of application varying from 4.0 to 5.7 m, as presented by Silva, Coelho, and Miranda (2013). They demonstrated a concentration of water next to the emitter even with good values of the uniformity coefficients owing to the uniformity of moisture to the movement of water in the soil. In this situation, there is a concentration of roots or a change in the direction of root growth toward where there is a greater water content in an uneven way in the soil, as demonstrated by Silva et al. (2015). As expected, there was a significant difference in the productive variables, corroborating the expectation of improvement of applied water depth distribution.

Table 7. Mean number of hands per bunch (N hand), peduncle weight, total fruit weight, and number of leaves per plant in the harvest (N leaves) in different emitter heights.

Emitter height (cm)	N hand	Peduncle weight (g)	Total fruit weight (g)	N leaves
50	7.09 AB	1,073.44 A	10,807.81 B	9.26 AB
70	7.27 A	1,130.00 A	11,840.00 A	8.52 B
90	7.28 A	1,137.50 A	11,935.94 A	9.88 A
110	6.97 B	1,115.71 A	10,964.57 B	9.57 A

Means followed by the same uppercase letter in a column and lowercase letter in a row do not differ significantly from each other (p < 0.1) by the Tukey test.

Table 7 shows that the height of the emitters influenced the total weight of the fruits, the number of hands per bunch and the number of leaves. A height of 90 cm provided higher values of fruit weight and the number of leaves, although it did not differ statistically from the height of 70 cm when considering the fruit weight and from heights of 50 and 110 cm when considering the number of leaves. This result is probably associated with the improvement of the distribution of the irrigation water depth as the height of the emitters increases due to the behavior of the emitters described by Silva et al. (2013), as overlapping is required to reach higher values of the distribution coefficients. By allowing a higher application efficiency, it is possible to increase soil exploration by the roots as a result of the higher root distribution through the increased wet area and due to moisture uniformity, as stated by Silva et al. (2015). This provides greater capacity for the absorption of nutrients and increases in the yield capacity of the plant.

Regarding the height of 110 cm, the expected effect did not occur, which was probably related to the greater interception of the emitter's jet by the leaves of the banana plant, which may have occurred at this emitter height, decreasing the watering range and the uniformity of distribution.

Conclusion

There was no interaction between the irrigation intervals and emitter height.

The two-day irrigation interval resulted in lower values of leaf temperature and photosynthetically active radiation incident on a leaf.

The two-day irrigation interval resulted in a higher total fruit weight and, consequently, higher yield and higher water use efficiency.

The highest rates of photosynthesis and momentary water use efficiency occurred in the morning as opposed to the leaf temperature, whose highest values occurred during the afternoon.

Emitter heights of 70 and 90 cm provided the highest total fruit weight and, consequently, a higher yield and higher water use efficiency.

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