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Evaluation of gas exchanges and production of genotypes of maçã banana type cultivated in the semi-arid region of Bahia

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Abstract - The objective of this study was to evaluate gas exchange and production of Maçã bananas type, at different times of the year and the day in semi-arid environment. Seven genotypes genotypes were used: Maçã, Caipira, BRS Tropical, BRS Princesa, YB42-03, YB42-17 and YB42-47, arranged in a completely randomized experimental design with five replicates and four useful plants per plot. For the physiological characteristics, a factorial arrangement 7x7x2 was considered (seven genotypes, seven evaluation periods, two reading times, 8:00 a.m. and 2:00 p.m.). Photosynthetic rates, carboxylation efficiency, and instantaneous water use efficiency are higher at 8:00 a.m., due to meteorological conditions, while foliar temperature and transpiration are higher at 2:00 p.m., due to the elevation of air temperature and low humidity. Months with higher radiation and intermediate temperature provided higher rates of photosynthesis, higher efficiency of carboxylation and photochemistry of photosynthesis. In general, genotype YB42-47 was the most productive, with higher water use efficiency and photosynthesis rates.
Index terms: *Musa* spp, climate, physiology, hybrids.

Avaliação de trocas gasosas e produção de genótipos de bananeira tipo maçã cultivados em região semiárida da Bahia

Resumo - O objetivo deste estudo foi avaliar as trocas gasosas e a produção de bananeiras tipo Maçã, em diferentes épocas do ano e horários, em ambiente semiárido. Foram utilizados sete genótipos: Maçã, Caipira, BRS Tropical, BRS Princesa, YB42-03, YB42-17 e YB42-47, dispostos em delineamento experimental inteiramente casualizado, com cinco repetições e com quatro plantas úteis por parcela. Para as características fisiológicas, foi considerado um arranjo em esquema fatorial 7x7x2 (sete genótipos, sete épocas de avaliação, duas leituras diárias: às 8 e 14 horas). As taxas fotossintéticas, a eficiência de carboxilação e a eficiência instantânea do uso da água são maiores às 8 horas, devido às condições meteorológicas, enquanto a temperatura foliar e a transpiração são mais altas às 14 horas, decorrentes da elevação da temperatura do ar e da baixa umidade. Meses com maior radiação e temperatura intermediária proporcionaram maiores taxas de fotossíntese, maior eficiência de carboxilação e fotoquímica da fotossíntese. De forma geral, o genótipo YB42-47 foi o mais produtivo com maior eficiência de uso da água e taxas de fotossíntese.
Termos para indexação: *Musa* spp., clima, fisiologia, híbridos.

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Introduction

Banana (*Musa spp.*) is a millenarian and widely consumed fruit, originated in Southeast Asia, with indications of its cultivation from 8.000 B.C., and it is currently distributed in several tropical regions of the world (CARVALHO et al., 2011). It has great economic importance and is well appreciated by the taste, easy consumption, good source of energy, vitamins and minerals, besides the low cost. According to Sena (2011), in Brazil, bananas are grown in all states, being the second most consumed fruit in the country, with orange in the first place.

Banana cv. Maçã belongs to the AAB genomic group. The fruit stands out for having delicate palate, and it is considered the noblest by most consumers, reaching high prices in the market, being one of the most planted banana cultivars in the country (SILVA et al., 2006; CARVALHO et al., 2011). However, the extreme susceptibility to Panana disease has made it unfeasible to cultivate in different producing regions.

Due to the expressiveness of banana cultivation in agricultural systems of different regions of the tropics, the Brazilian Program for Genetic Improvement of Banana Crop, coordinated by Embrapa Cassava and Fruits, has continuously sought, in partnerships, to evaluate and recommend banana cultivars for the different producing regions, respecting their adaptation to the local edaphoclimatic characteristics (DONATO et al., 2009; ROQUE, 2013; SILVA JUNIOR et al., 2014), considering, besides phytotechnical characteristics, the physiological characteristics of banana cultivars (ARANTES et al., 2016).

For recommendation of banana cultivars, Turner et al. (2007) pointed out that the evaluation of physiological characters is of great importance because it allows to establish genotype x environment relations, since variations in locality and in planting season can exert effects on the speed of metabolic processes, influencing vegetative cycle and photosynthetic and respiratory cycle of a cultivar (MELO et al., 2010).

Evaluation of gas exchange is based on the efflux of water and the influx of CO_2; they are instantaneous and punctual measures, which serve as a basis in the determination of important physiological parameters, such as photosynthesis and correlates with rates of transpiration and stomatal conductance, serving as basis for determining the productive potential of cultivars in breeding programs (ARANTES, 2014).

According to Veríssimo et al. (2010), some studies are carried out with the purpose of discovering the physiological bases that explain yield differences between varieties of the same species. The estimation of gas exchange through equipment is a fast, non-destructive, and precise technique for characterizing the momentary physiological behavior of the plant, which can be used by breeding and development of techniques programs, although, as state by Lucena (2013) and Arantes et al. (2016), because the variation of atmospheric conditions and soil moisture at the moment of measurement, they may not reflect the management history to which the plant is submitted.

Therefore, studies involving evaluation of physiological characteristics are quite common in banana cultivars (ROBINSON; GÁLAN SAÚCO, 2012; LUCENA, 2013; ARANTES et al., 2016), yet still scarce in some cultivars, such as Maçã cultivar. Thus, the objective of this work was to evaluate gas exchange and production of seven genotypes of Maçã bananas type, at different times and at different times of evaluation in semi-arid conditions.

Material and methods

The experiment was implemented in the area of the Instituto Federal Baiano, Guanambi *Campus*. The original soil classified as Dystrophic Red-Yellow Latosol, A weak, medium texture, caatinga hyperxerophilic phase, flat to smooth wavy relief. The region presents annual averages of precipitation and temperature of 680 mm and 26 °C, respectively.

Meteorological data: relative humidity; mean, maximum, and minimum temperatures (Figures 1); vapor pressure deficit (VPD) (Figures 2) and daily rainfall (Figures 3), from February to November 2011, were collected in an automatic weather station Vantage Pro Integradet Sensor (Davis Instruments, Wayward, CA, USA), installed at 100 meters from the experimental area.

Using meteorological data, saturation pressure of water vapor in the air was determined, according to Tetens (1930) methodology, and the partial pressure of water vapor, by the difference between the two pressures, allowed the calculation of vapor pressure deficit (VPD) (Figure 2), helping to understand the physiological performance of banana plants.

Planting was carried out on 2010-11-05, and micropropagated seedlings were used, in spacing of 3.0 x 2.5 m. Implantation and crop management followed the recommendations for the crop according to Rodrigues et al. (2015). Plants were irrigated by micro-sprinkler, with Netafim® self-compensating emitters, 120 L h^{-1} flow rate, 7.4 m wet diameter, 1.57 mm red nozzle, spacing 6 m between lateral lines and 5 m between emitters. In addition to irrigation, the plants received 562.4 mm of precipitation from February to November 2011 (Figure 3).

Irrigations were carried out based on evapotranspiration of the crop, considering the evapotranspiration of reference (Eto) daily determined by the modified Penman-Monteith method, based on data collected by meteorological station. The cultivation coefficients for ETc determination were defined according to the phenological stages of the crop, according to Coelho et al. (2015).

The experimental design was completely randomized (CRD), with seven treatments represented by Maçã banana type genotypes: Maçã (AAB), Caipira (AAA) known as Yangambi Km-5 and hybrids (AAAB) derived from Yangambi, BRS Tropical (YB42-21), BRS Princesa (YB42-07), YB42-03, YB42-17 and YB42-47, with five replicates, containing four useful plants per plot.

The following physiological characteristics were evaluated: leaf incident radiation (Q_{leaf}) expressed in µmol photons $m^{-2}s^{-1}$; foliar temperature (T_{leaf}), °C; internal concentration of CO_2 (C_i), µmol CO_2 mol^{-1}, stomatal conductance (g_s), mol H_2O $m^{-2}s^{-1}$, transpiration (E), mmol H_2O $m^{-2}s^{-1}$, net photosynthesis (A), µmol CO_2 $m^{-2}s^{-1}$, instantaneous water use efficiency (A/E), µmol CO_2 $m^{-2}s^{-1}$/mmol H_2O $m^{-2}s^{-1}$, carboxylation efficiency (A/C_i), and quantum or photochemical efficiency of photosynthesis (A/Q_{leaf}), µmol CO_2 $m^{-2}s^{-1}$/µmol photons $m^{-2}s^{-1}$. At the time of harvesting, agronomic production parameters were evaluated: number of leaves per plant (units), mass of hands (kg), and net or hands yield estimated by area (t ha^{-1}).

Evaluations of all physiological parameters were always performed on the third or fourth leaf (leaf three or four) from the apex to the base (LUCENA, 2013; ARANTES et al., 2016) with the aid of the infrared gas analyzer (IRGA) model Lcpro$^{+®}$Portable Photosynthesis System (ADC BioScientific Limited, UK), with ambient temperature and irradiance and airflow of 200 ml min^{-1}, always with the radiation shield facing the sun. A total of 14 monthly evaluations were carried out , from February to April, and in July, August, September, and November 2011; corresponding to the flowering of the first cycle until the flowering of the second cycle, at two reading times, at 8 a.m. and 2 p.m., contrasting schedules that allow the conditions nearer and farther, respectively, from the physiological optimum for banana crop (TURNER et al., 2007; ROBINSON; GALÁN SAÚCO, 2012; ARANTES et al., 2016; DONATO et al. 2016). However, for yield data, observations of harvest of the second cycle were still considered.

For statistical analyzes of data of the evaluated characteristics, the arrangement was arranged in a factorial scheme 7x7x2, seven genotypes, seven evaluation periods (months), and two reading times in each season, arranged in a completely randomized design. Data were submitted to analysis of variance and then the unfolding of the interactions according to their significance. The means of these variables were compared by the F test ($p < 0.05$) for reading time factors; and grouped by the Scott-Knott criterion ($p < 0.05$) for genotype and evaluation periods (months) factors using the statistical software SAEG (RIBEIRO JR.; MELO, 2009).

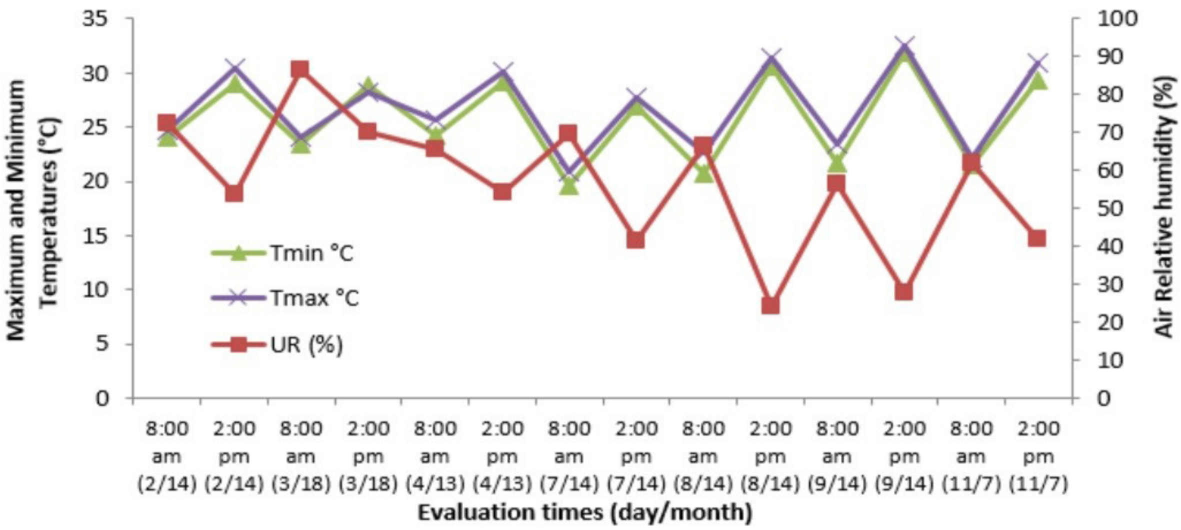

Figure 1 - Averages of air relative humidity, maximum and minimum temperatures at the time of evaluations, from February to November 2011, Guanambi - BA.

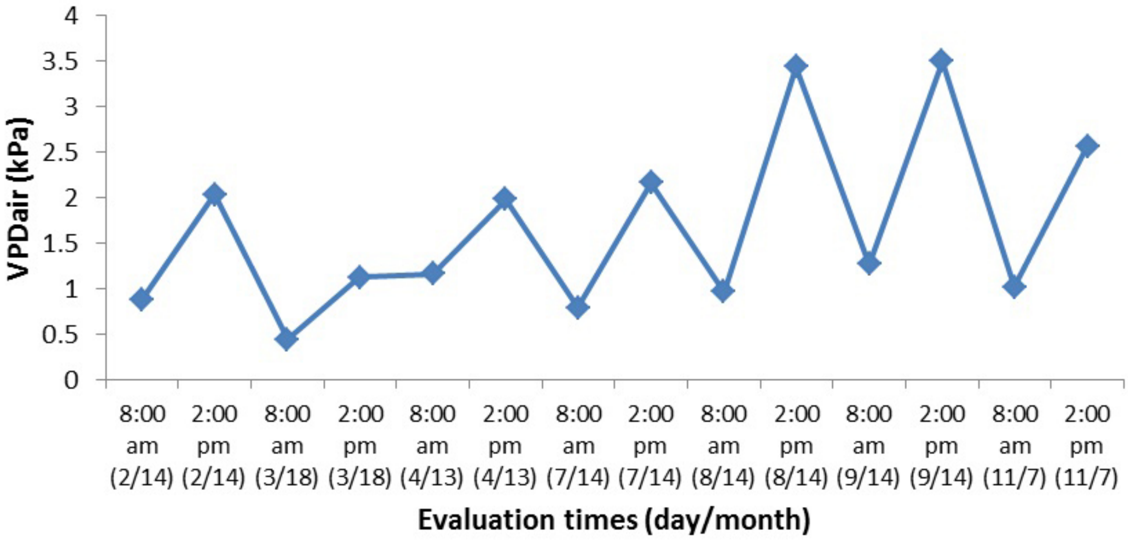

Figure 2. Vapor pressure deficit (VPD) determined at the time of physiological evaluations, from February to November 2011, Guanambi - BA.

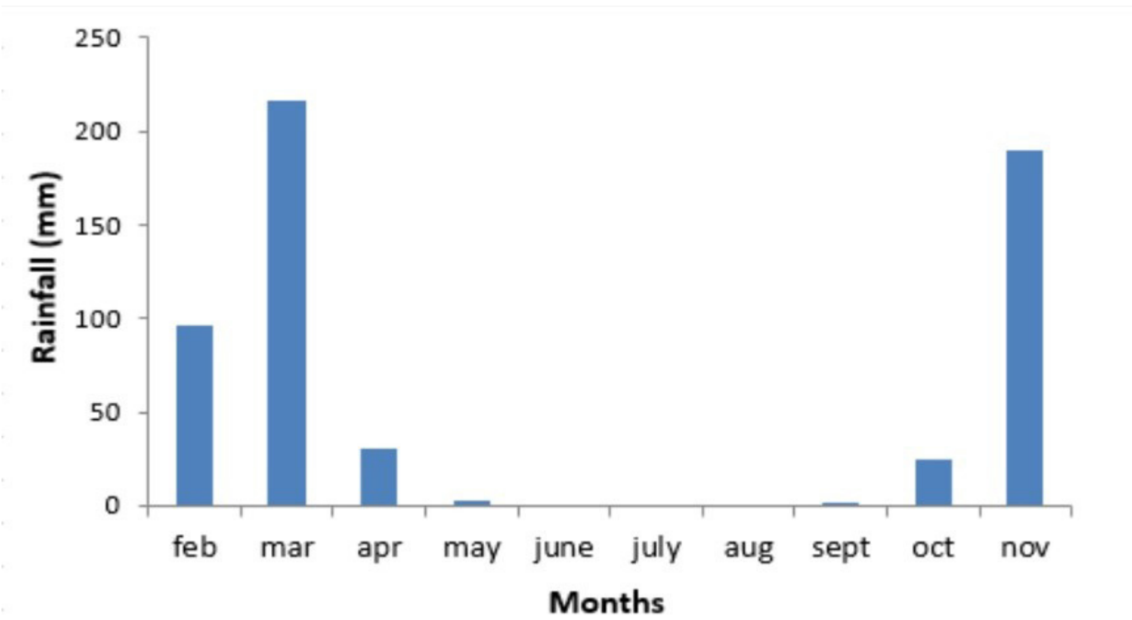

Figure 3. Rainfall (mm) from February to November 2011, Guanambi - BA.

Results and discussion

For all physiological characteristics evaluated in Maçã banana type, interactions between the periods and the evaluation times were verified (Tables 1 and 2). Photosynthesis (*A*), transpiration (*E*), instantaneous water use efficiency (*A/E*) and foliar temperature (T_{leaf}) varied with Maçã banana type genotypes, regardless of periods and time of evaluation (Table 3).

By the Scott-Knott criterion, Table 1 shows that there was formation of three groups for photosynthesis evaluated at 8 a.m.. The first group formed by the photosynthesis rates recorded in February, March, and April with lower values; the second, formed by the rates expressed in July, August, and September (24.05, 24.00, 24.98 µmol CO_2 m^{-2} s^{-1}, respectively), with higher values, and the third, intermediate group, in November. In the afternoon evaluation, the grouping with the highest values of *A* was repeated, July, August and September, however, greater variation was observed among the other groups formed. The combination of some factors such as high radiation (Q_{leaf}), high temperatures, favored gas exchange, such as the high transpiration rates (Table 2), which may have contributed to the higher *A* values of the banana crop at these periods (July, August and September), at both times of evaluation.

With the exception of March and April, the lowest *A* values were recorded predominantly in the afternoon. According to Donato et al. (2016) photosynthesis can be beneficial in the morning, as the predominant radiation at 8:00 in the morning shows a wavelength in the range of red and distant red, which have better effect for photosynthesis, while the predominant radiation from of 10:00 a.m., have higher energy and may cause photoinhibition (TAIZ et al., 2017).

The lowest photosynthetic rates recorded in February, March, and April at 8:00 a.m. (Table 1) are associated to the lowest Q_{leaf}, 531.79 e 515.80 µmol photons m^{-2} s^{-1} (Table 2), for February and March (TURNER et al., 2007), respectively, and to the highest T_{leaf}(Table 2) for April (ARANTES et al., 2016; DONATO et al., 2016), as well as the high VPD (1.16 kPa) for the morning period (Figure 2).

In February and March at 8:00 am, low values of Q_{leaf} were measured, reflecting reduced photosynthetic rates, 15.51 and 15.23 µmol of CO_2 m^{-2} s^{-1}, respectively (Table 1), corroborating with Turner et al. (2007), who state that bananas subjected to photosynthetically active radioation (Q_{leaf}) between 1,500 and 2,000 µmol photons m^{-2} s^{-1} present higher photosynthetic efficiency, whereas very low Q_{leaf} values (<1,000 µmol photons $m^{-2}s^{-1}$) severely affect photosynthesis. On the other hand, the low value of *A*, recorded in April, 15.12 µmol of CO_2 m^{-2} s^{-1}, is associated with a possible thermal stress. According to Robinson and Gálan Saúco (2012), photosynthesis can be affected when leaf temperature is above optimum (28-30 °C) as observed in the month above, much higher (34.57 °C) (Table 2).

Regardless of the evaluation schedule, the months of February, March, April, and November had the lowest photosynthetic rates (Table 1). Possibly, these results are associated to the occurrence of cloudiness in this period, as observed in Table 2 and Figure 3. They were months with low photosynthetically active radiation and great rainfall occurrence. These facts corroborate with the arguments of Lucena (2013), Santos et al. (2013) and Arantes et al. (2016) on the influence of atmospheric conditions and soil moisture at the moment of measurement, which may not reflect the management history to which the plant is subjected, influencing the photosynthetic rates.

These facts also show the variability of the meteorological elements between years, since it is expected that in this time and in this region, higher values of solar radiation incident on the leaf would be verified (DONATO et al., 2016), in this case blocked by the presence of clouds. In Brazil, the highest levels of photosynthetically active radiation occur during spring on Northeast and Center-West regions, and during the summer, in South and Northeast regions (PEREIRA et al., 2006). However, in the North and Central regions of the country, the highest incidences of this radiation occur during the dry seasons (autumn and winter), where there are days with low rainfall and low cloudiness.

The values of *A* obtained in July, August, and September, around 24.00 µmol of CO_2 m^{-2} s^{-1} at 8:00 a.m. (Table 1) corroborate with Arantes et al. (2016) that verified in banana type Prata, rates varying from 8.28 to 27.10 µmol of CO_2 m^{-2} s^{-1}. This suggests that banana plants present average rates of photosynthesis above most C_3 plants, with values up to 35 µmol of CO_2 m^{-2} s^{-1} (TURNER et al., 2007). While in most C_3 plants the photosynthetic rates vary between 10 and 20 µmol of CO_2 m^{-2} s^{-1} (TAIZ et al., 2017) as observed in the present work for the other months. Which reinforces the need to study the physiological behavior of genotypes, in different environments, as a basic tool to determine the best management, aiming to express the maximum of their productive potential.

Transpiration (*E*) of banana plants recorded at 8:00 a.m. formed four groups by the Scott-Knott criterion (Table 1), with the highest value in September (6.94 mmol H_2O m^{-2} s^{-1}), and the lowest value in April. At 2:00 p.m., 9.04 mmol H_2O m^{-2} s^{-1} was the highest value, determined in August (Table 1). Variations in *E* values were observed between months at both times of evaluations, regardless of genotype. However, for all months, transpiration was always higher in the afternoon, which was expected.

At 8:00 a.m., the lowest value of *E* (Table 1) was verified in April (2.27 mmol H_2O $m^{-2}s^{-1}$). For the afternoon (2:00 p.m.), the months of February, March, and April presented the lowest values.

There is a direct linear relationship between leaf temperature and transpiration (*E*), as indicated by Arantes et al. (2016). The increase in T_{leaf} (Table 2), due to the elevation of air temperature in the afternoon (Figure 1), corroborating with Donato et al. (2017), increases *E* and decreases instantaneous water use efficiency (LUCENA, 2013; ARANTES et al., 2016). The high transpiration rates in the afternoon in response to the increase of air temperature and, consequently, of the leaf, favored by the moisture of the soil due to irrigation, evidences the activation of this mechanism of cooling of the plant to reduce thermal stress, even under low conductance.

For April at 8:00 a.m., when Q_{leaf} was 1,600.23 µmol photons $m^{-2}s^{-1}$ (Table 2), in the optimal range for banana plant (TURNER, 2013), the lowest value of *E* can be attributed to the occurrence of photorespiratory process, from the high radiation combined with low internal concentration of CO_2, and low availability of water in the soil, causing the closure of the stomata and consequently reduction in sweating.

For March and April, reduced values of photosynthetically active radiation at the leaf surface (606.95 and 858.56 µmol photons m^{-2} s^{-1}, respectively) (Table 2) may have limited plant transpiration (TURNER, 2013), associated with reduction in carboxylation efficiency and increase in the internal concentration of CO_2, thus interfering with stomatal opening (TAIZ et al., 2017). What is in agreement with Turner et al. (2007) who argue that plant transpiration is regulated by biological characteristics and environmental parameters such as solar radiation, relative humidity, and air temperature.

Banana plants presented significant variation of *A/E* between the months and the times of evaluation (Table 1). However, April presented the highest values for both 8:00 a.m. and 2:00 p.m. (6.81 and 3.97 µmol CO_2 $m^{-2}s^{-1}$/(mmol H_2O $m^{-2}s^{-1}$), respectively). High rates of morning radiation (Q_{leaf}), high foliar temperature, and lower daytime variation of humidity may have contributed to the reduction of *E* and *gs* of banana plants in April, directly interfering with these results.

Water use efficiency in irrigated plantations is directly related to crop and irrigation management, and, consequently, to the soil-water-plant-atmosphere system (COELHO et al., 2015). In general, farmers exceed the amount of water supplied to banana crop, due to unfamiliarity or negligence, implying losses through percolation without increasing of yield (DONATO et al., 2015).

When comparing the times of evaluation, higher water use efficiency (*A/E*) was observed for all months in the 8:00 a.m. evaluation (Table 1), suggesting that for optimization of irrigation system functioning, this time should be more appropriate.

It is also observed in Table 1 that for the carboxylation efficiency (*A/Ci*), three groups were formed, regardless of the time of evaluation. In both schedules, the months July, August, and September presented the highest values of *A/Ci*. The lowest values of this variable for 8:00 a.m. were verified in February, March, and April, whereas for 2:00 p.m., only the months February and April were grouped in this range.

In the afternoon evaluation, there was reduction in instantaneous carboxylation efficiency (Table 1), possibly due to the increase in the foliar temperature of banana plants (Table 2), which indicates an increase in rubisco oxygenase activity and, consequently, reduction in the synthesis of ATP. According to Taiz et al. (2017), the increase in temperature under environment CO_2 concentration, an increase in temperature modifies the kinetic constants of rubisco and increases the rate of oxygenation, preferentially to carboxylation, elevates photorespiration, reducing the rate of net photosynthesis, besides altering the permeability of membranes. The photochemical efficiency of photosynthesis (A/Q_{leaf}) of Maçã banana type plants presented variation between the months and the times of evaluations (Table 1). However, for both 8:00 a.m. and 2:00 p.m. evaluation times, the highest values were recorded in September (0.088 µmol CO_2 $m^{-2}s^{-1}$/µmol photons $m^{-2}s^{-1}$ and 0.071 µmol CO_2 $m^{-2}s^{-1}$/µmol photons $m^{-2}s^{-1}$, respectively). For most months *A/* Q_{leaf} did not differ between times of evaluations.

It is observed that the photosynthetically active radiation on the leaf surface (Q_{leaf}) of the genotypes varied between the months and the times of evaluation (Table 2). These variations, according to Andrade et al. (2014), are basically related to the climatic characteristics of each evaluated period (month x time), since each one can present differences of cloudiness, precipitation (dry or rainy period) or even differences in the distance of the sun in relation to the local zenith.

Several researchers have already established associations between climate and gas exchange of vegetables, for example: Silva et al. (2015) with eggplant, Amarullah et al. (2016) with cassava, Arantes et al. (2016) and Santos et al. (2017) with banana plants, indicate that studies of the same nature reveal the effects of the interaction between plant physiology, the environment, and management, with positive correlations between these responses and climatic factors.

It was observed that the highest values of Q_{leaf} (Table 2) in the Maçã banana type were verified in April, July and August for evaluation at 8:00 a.m., 1,600.23; 1,444.73 e 1,455.05 µmol photons $m^{-2}s^{-1}$, respectively, while for the 2:00 p.m. evaluation, the highest value was obtained in July, 1,479.26 µmol photons $m^{-2}s^{-1}$.

In tropical rainforest regions there was great seasonality in the photosynthetically active radiation, where the highest values are generally observed in the dry season and the lowest in the rainy season (XIAO et al., 2005). In the study region, the highlighted months (April, July, and August) with higher Q_{leaf} are characterized by milder temperature, with low or no precipitation, corroborating with this author, even though it is not a forest site (Figure 1).

T_{leaf} recorded in the banana plants varied between the times of evaluation, in all months, except in April (Table 2). In the majority of evaluations (85.7%), genotypes showed foliar temperatures higher at 2:00 p.m. in relation to the morning evaluation (8:00 a.m.) as a reflection of the higher air temperature in the afternoon (DONATO et al., 2017). At 8:00 a.m., the lowest T_{leaf} (29.59 ºC) was observed in July, while the highest temperatures were obtained in the February, August, and November evaluations at 2:00 p.m. (39.19 ºC, 39.93 ºC, and 39.05 ° C, respectively). Lower foliar temperatures in the morning evaluation were also verified by Donato et al. (2016) and Arantes et al. (2016) in studies with banana plants in the same locality.

The morning high photosynthetic active radiation (Q_{leaf}) observed in banana leaves in April (Table 2), coupled with low conductance values (*gs*), resulted in lower transpiration rates (2.27 mmol H_2O m^{-2} s^{-1}) which may be associated with the increase in foliar temperature in this month and period. Although Arantes et al. (2016) and Donato et al. (2017) show increase in transpiration data with the increase leaf of temperature to about 40 °C. Which agrees with Kumar and Portis Júnior (2009), that states that the control of the stomatal opening, which transpiration is the mechanism involved, acts on the regulation of foliar temperature due to the dissipation of latent heat.

In Table 2 can be observed the formation of two groups for internal CO_2 concentration (C_i) evaluated at 8:00 a.m., with March presenting the highest value of C_i (232.53 µmol CO_2 mol^{-1}), and another group with other months. In the afternoon evaluation, the grouping with the highest values formed by the rates of C_i in March and April (225.60 and 231.58 µmol CO_2 mol^{-1}, respectively) and a second group with the lowest values of C_i with the remaining months.

Maçã banana type plants had the highest values of internal CO_2 concentration (C_i) in the morning, for most cases except in April. Higher values of C_i observed in the morning are usually related to the higher g_s in this period, as well as, may be associated to the higher concentration of CO_2 in the environment, next to the canopy, due to the absence of carboxylation at night and respiratory CO_2 (TAIZ et al., 2017).

The lower values of *gs* verified in the afternoon may be related to the increase of the VPD, to the decrease of the water potential of leaf due to the low humidity measured at 2:00 p.m., or to the combined effect of these factors, implying a reduction of *Ci* in banana plants in this period. In addition, according to Donato et al. (2016), higher values of g_s are verified in the morning due to higher occurrence of winds in this period, which ends up contributing to the removal of the border layer and, consequently, reduction of resistance in the surface of the leaf limb, increasing the losses.

The lowest values of photosynthesis (*A*) and transpiration (*E*), and higher water use efficiency (*A/E*) were observed in genotypes YB42-03 and BRS Princesa (Table 3). There were also high *A/E* values for the genotypes Maçã and YB42-47. The highest values of *A* and *E* were recorded in 'Caipira', 'YB42-17', and BRS Tropical, but with low water use efficiency. The genotypes BRS Tropical and YB42-17 presented the highest values of foliar temperature (T_{leaf}), all above 35ºC.

A high instantaneous water use efficiency may indicate greater tolerance to possible water stresses or longer irrigation periods, as well as greater economic efficiency of water use, dry mass production per gram of transpirated water (DONATO et al., 2015), when under ideal conditions of management. However, in this study, the genotypes with the highest instantaneous water use efficiency did not appear as the most productive ones.

In Table 4, it can be observed that in the first cycle of production, yields of hands were similar, with maximum variation of 4.07 Mg ha^{-1}. While in the second cycle, YB42-17 and BRS Tropical genotypes stand out with yields of 18.82 Mg ha^{-1} and 18.75 Mg ha^{-1}, respectively, but below the potential for Maçã bananas type, which may reach more than 30 Mg ha^{-1}. These genotypes, even though presenting high rates of photosynthesis and transpiration, but with low water use efficiency, were those that obtained higher yield.

Yield recorded for Maçã bananas type was low. However, they corroborate the gross yield of looted bunches obtained by Lucena (2013) with 'BRS Tropical', 13 Mg ha^{-1} in the same place and inferior to that obtained by Donato et al. (2003) for 'Caipira', 24.3 Mg ha^{-1}, in the same region, but in Eutrophic Flubic Neosol and with higher plant density.

According to Zhengbin et al. (2011), the most efficient plants in the use of water are those that present better osmotic adjustment, maintaining the stability of plasma membrane and active antioxidant enzymes, that is, improvement of physiological functions, with less water, implying greater photosynthetic efficiency, accumulation of dry matter, and chlorophyll content.

According to Donato et al. (2015) the use of cultivars more tolerant to water deficit are more environmentally acceptable and possibly predominant in hybrids (AAAB), which can be submitted to irrigation strategies with controlled and partial root-zone deficit, due to greater water use efficience (*A/E*). Moreover, increasing the water use efficiency in a cultivar is fundamental to reduce the waste of this resource, compared to the current production systems of irrigated agriculture.

The elevation of temperature accompanied by a decline in relative humidity, which characterizes a ondition of high vapor pressure deficit of the atmosphere, increases the evapotranspirometric demand and directly influences all the metabolic and physiological processes of the plant. According to Robinson and Galán Saúco (2012), in C_3 plants the quantum productivity of photosynthesis is elevated up to around 30 ºC and decreases considerably, particularly in banana plants, above 34 ºC. In contrast, with BRS Tropical and YB42-17 genotypes, despite high foliar temperatures, they still presented higher photosynthetic rates.

The concentration of CO_2 in the environment determines the internal concentration of CO_2 in the plant (*Ci*), this gas moves from the most concentrated medium to the least concentrated by diffusion, being regulated by stomatal opening and closure (ARANTES et al., 2016; et al., 2017). Higher *Ci* favors photosynthesis, whereas lower *Ci* can cause change in the activity of rubisco enzyme from carboxylase to oxygenase, that is, increase of photorespiration and decrease of net photosynthesis (MARENCO et al., 2014).

In general, the highest values of g_s were observed in July, August, and September, and the lowest in February. In Table 2 it can be seen that February was characterized by low photosynthetic radiation incident on leaves of banana plants (Q_{leaf}), which directly influenced low values of photosynthesis and transpiration for that month (Table 1), which compromised the control of opening stomata and, consequently, g_s reduction, in addition to a possible cultivar x environment response, by restricting or not stomatal opening in periods of thermal and soil stress as discussed by Donato et al. (2015; 2016) and Arantes et al. (2016).

Table 1 - Photosynthetic rate (*A*), transpiration rate (*E*), instantaneous water use efficiency (*A/E*), carboxylation efficiency (*A/Ci*), μmol CO_2 $m^{-2}s^{-1}$/μmol CO_2 mol^{-1}, photochemical efficiency of photosynthesis (A/Q_{leaf}), μmol CO_2 m^{-2} s^{-1}/μmol photons m^{-2} s^{-1} evaluated in the third leaf of Maçã banana type plants, between flowering of first and second cycle at different months and times of evaluations. Guanambi, BA, 2010-2011.

Months	*A* (μmol CO_2 $m^{-2}s^{-1}$)		*E* (mmol H_2O $m^{-2}s^{-1}$)		*A/E*		A/C_i		A/Q_{leaf}	
	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
Feb	15.51 Ca	11.64 Db	3.14 Cb	5.11 Da	5.00 Ba	2.29 Db	0.073 Ca	0.056 Cb	0.031 Ba	0.014 Cb
Mar	15.23 Ca	15.74 Ba	2.91 Cb	4.78 Da	5.20 Ba	3.36 Bb	0.067 Ca	0.071 Ba	0.030 Ba	0.027 Ca
Apr	15.12 Ca	13.72 Ca	2.27 Db	4.00 Da	6.81 Aa	3.97 Ab	0.070 Ca	0.060 Cb	0.016 Ba	0.021 Ca
Jul	24.05 Aa	19.19 Ab	4.51 Bb	7.65 Ba	5.39 Ba	2.57 Cb	0.110 Aa	0.090 Ab	0.021 Ba	0.015 Ca
Aug	24.00 Aa	18.03 Ab	4.78 Bb	9.04 Aa	5.05 Ba	2.03 Db	0.114 Aa	0.083 Ab	0.024 Bb	0.049 Ba
Sep	24.98 Aa	18.06 Ab	6.94 Ab	7.57 Ba	3.70 Ca	2.56 Cb	0.114 Aa	0.085 Ab	0.088 Aa	0.071 Aa
Nov	18.28 Ba	15.55 Bb	3.60 Cb	6.28 Ca	5.20 Ba	2.53 Cb	0.084 Ba	0.072 Bb	0.031 Ba	0.018 Ca
CV(%)	21.49		24.78		23.33		23.19		106.48	

*Averages followed by uppercase letters, in the columns for months, belong to the same grouping by the Scott-Knott criterion at 5% probability; and lowercase letters in the lines do not differ significantly by F-test at 5% probability.

Table 2 - Photosynthetically active radiation on leaf surface (Q_{leaf}), foliar temperature (T_{leaf}), internal concentration of CO_2 (*Ci*), and stomatal conductance (g_s), evaluated in the third leaf of Maçã banana type, between flowering of first and second cycle of production, at different months and times of evaluations. Guanambi, BA, 2010-2011.

Months	Q_{leaf} (μmol fótons m^{-2} s^{-1})		T_{leaf} (°C)		C_i (μmol CO_2 mol^{-1})		*gs* (mol 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
Feb	531.79 Cb	1,106.86 Ba	31.36 Cb	39.19 Aa	217.64 Ba	210.51 Bb	0.278 Ca	0.215 Cb
Mar	515.80 Ca	606.95 Da	31.88 Cb	35.68 Ca	232.53 Aa	225.60 Ab	0.354 Ca	0.421 Ab
Apr	1,600.23 Aa	858.56 Cb	34.57 Aa	35.01 Ca	216.40 Bb	231.58 Aa	0.298 Ca	0.337 Ba
Jul	1,444.73 Aa	1,479.26 Aa	29.59 Db	37.30 Ba	217.76 Ba	212.52 Ba	0.499 Ba	0.381 Ab
Aug	1,455.05 Aa	1,069.07 Bb	31.08 Cb	39.93 Aa	213.55 Ba	216.45 Ba	0.509 Ba	0.381 Ab
Sep	990.71 Ba	845.75 Cb	33.58 Bb	37.53 Ba	219.65 Ba	210.21 Bb	0.611 Aa	0.356Ab
Nov	655.68 Cb	915.23 Ca	31.49 Cb	39.05 Aa	218.54 Ba	216.64 Ba	0.327 Ca	0.309 Ba
CV (%)	38.97		4.98		6.66		35.04	

*Averages followed by uppercase letters, in the columns for months, belong to the same grouping by the Scott-Knott criterion at 5% probability; and lowercase letters in the lines do not differ significantly by F-test at 5% probability.

Table 3. Photosynthesis rate (*A*), transpiration rate (*E*), instantaneous water use efficiency (*A/E*), ((µmol CO_2 m^{-2} s^{-1}) ((mmol H_2O m^{-2} s^{-1})$^{-1}$), and foliar temperature (T_{leaf}) evaluated in the third leaf Maçã banana type genotypes, between flowering of first and second cycle of production. Guanambi, BA, 2010-2011.

Genotypes	*A* (µmol CO_2 $m^{-2}s^{-1}$)	*E* (mmol H_2O $m^{-2}s^{-1}$)	*A/E*	T_{Leaf} (°C)
Caipira	18.77 A	5.56 A	3.92 B	34.77 B
YB42-17	17.92 A	5.48 A	3.76 B	35.34 A
BRS Tropical	17.80 A	5.65 A	3.66 B	35.43 A
YB42-03	17.20 B	4.82 B	4.16 A	34.58 B
BRS Princesa	16.63 B	4.83 B	3.98 A	34.75 B
Maçã	17.85 A	4.89 B	4.23 A	34.37 B
YB42-47	18.38 A	5.08 B	4.12 A	34.38 B
CV (%)	21.49	24.78	23.33	4.98

*Averages followed by same letters in the columns belong to the same group by the Scott-Knott criterion at 5% probability.

Table 4. Yield of genotypes of Maçã banana type between flowering of the first and the second production cycle. Guanambi, BA, 2010-2011.

Genotypes	Number of hands (unit)		Mass of hands (kg)		Yield of hands (Mg ha^{-1})	
	1° cycle	2° cycle	1° cycle	2° cycle	1° cycle	2° cycle
Caipira	6.50 A	8.98 A	8.47 A	11.10 B	11.29 A	14.79 B
YB42-17	6.52 A	9.67 A	10.68 A	14.12 A	14.23 A	18.82 A
BRS Tropical	6.40 A	8.37 B	10.30 A	14.07 A	13.72 A	18.75 A
YB42-03	5.98 A	7.60 B	8.88 A	10.72 B	11.83 A	14.28 B
BRS Princesa	7.23 A	9.73 A	9.23 A	12.22 B	12.30 A	16.28 B
Maçã	7.35 A	8.08 B	11.53 A	12.07 B	15.36 A	16.08 B
YB42-47	6.40 A	8.13 B	10.50 A	11.20 B	13.99 A	14.92 B
CV (%)	17.56		15.98		9.08	

*Averages followed by same letters in the columns belong to the same group by the Scott-Knott criterion at 5% probability.

Conclusions

Photosynthetic rates, carboxylation efficiency, and the instantaneous water use efficiency are higher at 8:00 a.m., while foliar temperature and transpiration are higher at 2:00 p.m., due to the elevation of the air temperature and low humidity.

Months with higher radiation and intermediate temperature provided higher rates of photosynthesis, higher efficiency of carboxylation and photochemistry of photosynthesis.

Genotype YB42-47 is most promising for water use efficiency, photosynthetic rates, and yield.

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