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GAS EXCHANGE IN DIFFERENT VARIETIES OF BANANA PRATA IN SEMI-ARID ENVIRONMENT[1]

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ABSTRACT - This study aimed to evaluate gas exchange of banana Prata in two production cycles in semiarid environment. Six cultivars were used as treatments arranged into a completely randomized design with five replications and four plants per plot. For physiological characteristics, it was considered a factorial arrangement of 6x14x2, six cultivars, 14 periods (months), two readings, 8h and 14h in each period. The rates of gas exchange, the carboxylation efficiency and the instantaneous efficiency of water use were higher at 8h and lower at 14h, with rare exceptions. The 'BRS Platina' had a higher leaf temperature, higher transpiration and lower water use efficiency. 'Prata-Anã', 'FHIA-18' and 'Maravilha' expressed lower leaf temperature and lower transpiration. The 'Maravilha' is the most efficient in water use. Transpiration increases linearly with the leaf temperature, while the instantaneous efficiency of water use decreases linearly.
Index terms: *Musa* spp., AAB and AAAB, physiological variables.

TROCAS GASOSAS EM DIFERENTES CULTIVARES DE BANANEIRAS TIPO PRATA EM AMBIENTE SEMIÁRIDO

RESUMO - Objetivou-se com o presente trabalho avaliar as trocas gasosas de bananeiras tipo Prata, em dois ciclos de produção em ambiente semiárido. Utilizaram-se seis cultivares como tratamentos dispostos em um delineamento experimental inteiramente casualizado, com cinco repetições e quatro plantas úteis por parcela. Para as características fisiológicas, considerou-se um arranjo em esquema fatorial 6x14x2, seis cultivares, 14 épocas de avaliação (meses) e dois horários de leitura (8h e 14h), em cada época. As taxas de trocas gasosas, a eficiência de carboxilação e a eficiência instantânea do uso da água foram maiores às 8h e menores às 14h, com raras exceções. A 'BRS Platina' apresentou maior temperatura foliar, maior transpiração e menor eficiência de uso da água. 'Prata-Anã', 'FHIA-18' e 'Maravilha' expressaram menor temperatura foliar e menor transpiração. A 'Maravilha' é mais eficiente no uso da água. A transpiração aumenta de maneira linear com o aumento da temperatura foliar, enquanto a eficiência instantânea do uso da água decresce linearmente.
Termos para indexação: *Musa* spp., AAB e AAAB, variáveis fisiológicas.

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INTRODUCTION

The cultivation of banana tree is significant in agricultural systems in the agro-ecological zones of the tropics (AZEVEDO et al., 2010) with great economic and social importance. In Brazil, the ‘Prata’, ‘Pacovan’ and ‘Prata-Anã’ cultivars are the most widespread. In the Southwest of Bahia (DONATO et al., 2009) and in the North of Minas Gerais, the most planted cultivar is the ‘Prata-Anã’ that despite the high commercial value, it is susceptible to the yellow and black sigatoka, and Panama disease.

In the search of solutions, the Brazilian Program for Banana Plant Improvement, coordinated by Embrapa Mandioca e Fruticultura, developed banana ‘Prata’ hybrids with different degrees of commercial acceptance.

The physiological characters evaluation may be important for recommending cultivars because it allows establishing a genotypic variation of physiological responses of banana to the environment (TURNER et al., 2007). The existence of this variation would infer on changes in transpiration rates, stomatal conductance and photosynthesis as physiological indicators of the presence of stress (LUCENA, 2013); in addition it contributes to the identification and the selection of superior individuals. The extrapolation of these results may subsidize specific production systems for various cultivars.

Additionally, physiological characteristics studies are quite common in cultivars of Cavendish type (ROBINSON; GÁLAN SAÚCO, 2012), however they are scarce in cultivars of ‘Prata’ type prevalent in Brazil. Given the above, the aim of this study was to evaluate the physiological characteristics of six ‘Prata’ type bananas in two production cycles in semi-arid environment.

MATERIAL AND METHODS

The experiment was established in the area of Instituto Federal Baiano, Campus Guanambi, in the State of Bahia, Brazil. The original soil is classified as typical dystrophic Red-Yellow Latosol, weak A, medium texture, hypoxerophytic caatinga phase, flat to mildly hilly relief, with annual average of precipitation and temperature, 680 mm and 26 °C respectively.

In planting, on 05/11/2010, we used seedlings that were acclimatized in plastic bags, 30 cm tall, and planted in 3.0 x 2.5 m spacing. The introduction and cultivation followed the recommendations for the crop (RODRIGUES et al., 2008). The plants were irrigated by micro sprinkling with Netafim® self-compensating emitters, flow 120 L h^{-1}, wet diameter of 7.4 m, with red nozzle of 1.57 mm, spacing of 6 m between side lines and 5 m between emitters.

The irrigations were based on the evapotranspiration reference (ETo) determined daily by the Penman-Monteith method, and on the data from an automatic weather station Vantage Pro Integrated Sensor (Davis Instruments, Wayward, CA, EUA) located 100 m from the area. The crop coefficients to determine the ETc were defined according to the phenological stages of the crop.

The experimental design was completely randomized, with six treatments represented by ‘Prata’ type banana cultivars: ‘Prata-Anã’ (AAB) and the hybrids (AAAB), FHIA-01 (‘Maravilha’); FHIA-18; BRS FHIA-18; ‘BRS Platina’ (PA42-44) derivatives from ‘Prata-Anã’ x M53 (AA); and JV42-135, derivatives from ‘Prata de Java’ x M53. We used five replications and four plants per plot.

We evaluated the gas exchanges, the leaf temperature and incident radiation on the third or fourth leaf (leaf three or four) counting from the apex to the base, with the help of Lcpro+® Portable Photosynthesis System (ADC BioScientific Limited, UK) infrared gas analyzer (IRGA), always with the radiation shield facing the sun, with ambient temperature and irradiance, and airflow of 200 ml min^{-1}.

There were 14 monthly evaluations in two reading times, 8h and 14h, covering the period from October 2010 to November 2011, corresponding to the early flowering of the first cycle to the beginning of the harvest of the second production cycle.

We measured the incident radiation in the leaf (Q_{leaf}) expressed in μmol photons $m^{-2}s^{-1}$; leaf temperature (T_{leaf}), ºC, internal CO_2 concentration (C_i), μmol CO2 mol^{-1}, stomatal conductance (*gs*), 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 efficiency of water use (A/E), μmol CO_2 $m^{-2}s^{-1}$/mmol H_2O $m^{-2}s^{-1}$, carboxylation efficiency (*A/Ci*), quantum efficiency or photochemistry of photosynthesis (*A/Qleaf*), μmol CO_2 $m^{-2}s^{-1}$/μmol photons $m^{-2}s^{-1}$.

For statistical analysis of the data of the characteristics evaluated, we adopted the following: a) For the vegetative and yield characteristics, we used six treatments, the cultivars arranged in a randomized design. The data were submitted to variance analysis and the averages compared by Tukey test at 5% error probability ($p < 0.05$)

in SAEG software (SAEG, 2009). b) For the physiological characteristics, we adopted the arrangement in factorial 6x14x2, six cultivars, 14 evaluation periods (months) and two reading times each period, arranged in a completely randomized design. The data were submitted to analysis of variance and proceeded to the split of interactions according to their significance. The F and Turkey test compared the averages from those variables ($p<0.05$) for reading time factor and cultivars factor, respectively; and the Skott-Knott criterion grouped them for the evaluation period factor (months). We also realized correlation studies between the different variables and the adjusted linear models for those significant and of greater magnitudes.

RESULTS AND DISCUSSION

The differences in physiological characteristics evaluated in several months did not allow a grouping of the averages by the Scott-Knott criterion ($p<0.05$) according to the periods of the year. The grouping was random; probably because of the assessments made with devices are pointwise values, influenced by weather conditions of the moment (SANTOS et al., 2013). These results contradict the expectation of obtaining physiological differences grouped according to the periods, to the two times of reading, which would make it possible to compare the physiological responses of different cultivars in months with similar climatic characteristics.

The physiological variables, leaf temperature (T_{leaf}), transpiration rate (E) and instantaneous efficiency of water use (A/E) varied with the cultivar regardless of the month and reading time (Table 1).

The 'BRS Platina' showed higher Tleaf (37.39 ^oC) and 'Prata-Anã' showed the lower (35.90 ^oC), with a small percentage variation of 4.15%. The transpiration rate (E) varies similarly to Tleaf, with the higher value (7.04 mmol H_2O $m^{-2}s^{-1}$) measured on the 'BRS Platina' and the lower 6.19; 6.40 and 6.41 mmol H_2O $m^{-2}s^{-1}$ on the 'Prata-Anã', 'Maravilha' and 'FHIA-18', respectively. The instantaneous efficiency of water use (A/E) in leaf was higher (3.45 µmol CO_2 $m^{-2}s^{-1}$/mmol H_2O $m^{-2}s^{-1}$) in the 'Maravilha' and lower (2.96 µmol CO_2 $m^{-2}s^{-1}$/ mmol H_2O $m^{-2}s^{-1}$) in the 'BRS Platina'. There is a tendency of direct relation between the T_{leaf} and E and a contrary relation between the T_{leaf} and the A/E, proven by the correlation study (Figure 1).

The higher A/E observed in 'Maravilha' indicates the highest cultivar efficiency regarding the use of water resource, which is the main obstacle in banana production. Productive efficiency and better use of water do not contradict the recommendation for a new cultivar that requires other desirable characteristics, such as market acceptance despite of the observation meets the research needs to understanding the mechanisms of tolerance to drought (VANHOVE et al., 2012; MUTHUSAMY et al., 2014; KISSEL et al., 2015).

The photosynthetically active radiation incident on the leaf surface (*Qleaf*), leaf temperature (*Tleaf*), transpiration rate (E), the instantaneous efficiency of water use (A/E), and the quantum efficiency of photosynthesis (A/Q_{leaf}) also varied with periods and reading times regardless of the cultivar (Table 2).

The Q_{leaf} varied between times in most of the months (64.28%) and the higher values were recorded in the morning. Significant changes were observed between the months in the two times of evaluation. The higher value (1.650,94 µmol photons $m^{-2}s^{-1}$) was recorded in February 2011 and the lower (485.65 µmol photons $m^{-2}s^{-1}$) was recorded in October 2010 coincident with a cloudy day and presence of rain because it is a typical month of high radiation. The higher value recorded is between the radiation recommended, 1.500 and 2.000 µmol photons $m^{-2}s^{-1}$, and the lower value is in the range where photosynthesis is severely reduced, below 1.000 µmol photons $m^{-2}s^{-1}$ (TURNER et al., 2007).

The Tleaf recorded in 'Prata' type banana varied between times, in all the evaluated months, regardless of the cultivars, except in January and May 2011 (Table 2).In all cases, the lower Tleaf occurred at 8h and the higher occurred in the afternoon, as observed by Donato et al. (2013). Significant differences were also observed between the months in the two times, regardless of the cultivar. The Tleaf had a percentage variation of 43.23%, the lowest value was 30.60 ° C and the highest value was 43.83 ^oC.

The transpiration rates evaluated in 'Prata' type banana differ between times in every evaluation month, regardless of the cultivar (Table 2), with the occurrence of lower values in the morning and of higher values in the afternoon at 78.57% of the cases. Variations were also observed between the months in both times, regardless of the cultivar. In October 2010, at 14h, the lowest transpiration rate was recorded (3.58 mmol H_2O m^{-2}s-1), coincident with cloudy and rainy day illustrated by the lower radiation (485.65 µmol photons $m^{-2}s^{-1}$) (Table 2). The highest transpiration (11.96 mmol H_2O $m^{-2}s^{-1}$) occurred in November 2010 at 14h.

The efficiency of water use (A/E) in the leaf of 'Prata' type banana ranged between times in every month except for January 2011 that always presented the higher values in the morning (Table 2) because of the higher photosynthetic rates registered at 8h (Table 4) and the lower transpiration (Table 2). There was also significant variation between the months in both times.

The photochemical efficiency of photosynthesis represented by the relation between photosynthesis and photosynthetically active radiation (A/Q_{leaf}) incident on the third leaf of 'Prata' type banana, showed little variation between the months evaluated at 8h (Table 2). In the second time the variation was higher. No significant differences were recorded between times in most months.

In all cases, the highest photochemical efficiency was observed at 8h, except in October 2011. In C3 plants, the quantum photosynthesis productivity is raised close to 30 °C and decreases a lot, particularly in banana trees above 34 oC (ROBINSON; GALÁN SAUCO, 2012), which explains the lower quantum efficiency at 14:00 attested by higher leaf temperature values that were measured at this time.

The stomatal conductance (*gs*), photosynthetic rate (*A*) and carboxylation efficiency (*A/Ci*) showed significant interaction ($p < 0.05$), considering the three factors studied (cultivars, seasons and times), shown in Tables 3, 4, 5, respectively.

All the cultivars showed significant variation in gs between the months and in the two times evaluated (Table 4). The stomatal conductance differed between times in 47.61% of the cases. These differences were observed for all cultivars in October and November 2010, and in January and May 2011 in most cases, probably because these were the hottest months of the evaluated period (Table 2).

In most of the cases, the highest values of gs occurred in the morning and the lowest in the afternoon, which can be justified by the occurrence of winds in the morning (DONATO et al., 2012) that contributes to the removal of the boundary layer and consequently decreases resistance. The stomatal conductance is the inverse of stomatal resistance to the steam. Its value refers to the potential amount of water that could flow over the leaf surface and it is different from steam flow (or transpiration). The reduction of gs in the afternoon can also be related to the stomatal sensitivity to the air aridity, strongly influenced by temperature. Its values decrease with the increasing of steam pressure deficit and temperature. Factors that influence gs interfere in the acquisition of carbon in plants.

The cultivars did not express differences in gs values in both times every month evaluated, with the exception of November 2010, September and November 2011, at 8h, and November 2011, at 14h (Table 5).

Ekanayake et al. (1994) argue the cultivars that restrict the stomatal conductance in drought conditions are considered "water economic." Thus obtaining cultivars with increased tolerance to abiotic stresses passes the identification of characteristics that grants drought tolerance (RAVI et al., 2013) as transpiration efficiency (KISSEL et al., 2015).

It is unlikely that the soil water content may change significantly between measurements, but the leaf steam pressure difference to the air will increase as the temperature increases. Therefore, the variation in stomatal conductance between cultivars is a strategy for the detection of stomatal sensitivity to the steam pressure deficit, which may or may not be related to drought tolerance. Turner et al. (2007), in their review, state that the gas exchange of the leaf is a more sensitive method for determining the response of banana tree to water deficit compared to traditional volumetric or thermodynamic measurements of leaf water status, such as the relative water content.

The change in gas exchange in banana leaves due to the stomatal response to water deficit, steam pressure deficit, leaf temperature and the intensity and quality of solar radiation have been reported in several studies. Different studies show that the stomatal of banana trees can respond to low relative humidity, as well as the reduction of soil moisture, and there is a genetic variation among cultivars, in relation to this feature (EKANAYAKE et al., 1994; THOMAS et al., 1998; KISSEL et al., 2015).

Recorded changes in stomatal conductance (*gs*) (Table 3), photosynthesis rate (*A*) (Table 4), carboxylation efficiency (*A/Ci*) (Table 5), transpiration rate (*E*) and efficient use of water (*A/E*), due to the change of the radiation (Q_{Leaf}) and leaf temperature (T_{leaf}) (Table 2) were also reported by Donato et al. (2013).

The photosynthetic rate of all cultivars was different between the months in both reading times (Table 4). The values were higher at 8:00 and lower at 14h in most months (66%), except for the 'Prata-Anã' in November 2011 (Table 5).

The cultivars showed the same rate of photosynthesis in each reading time in all evaluation periods, except in October 2010 and in November

2011, at 8h, and in June and in November 2011 at 14h (Table 5).

The photosynthetic rate, stomatal conductance (gs) and the efficiency of water use (*A / E*), in November 2010, July, August, September and November 2011 were lower at 14:00 than at 8h, despite subjected to the same radiation (Q_{leaf}). Even with the difficulty of separating the effect of the radiation changing (Q_{leaf}) and leaf temperature (T_{leaf}) in gas exchange in field experiments (LUCENA, 2013), the present study data allow us to state that the decrease in rates, observed at 14h, is the reflection of increasing temperature, as observed by Donato et al. (2013). The leaf temperature varied a percentage of 43.23%, the highest value, 43.83 °C recorded in November 2010 at 14h, to the lowest, 30.60 °C, in September 2011 at 8h (Table 2).

The rise in temperature increases evapotranspiration demand and directly influences all metabolic and physiological processes of the plant. Probably, the rise in temperature affects the functioning of the enzyme system at a higher intensity than the stomatal closure because the transpiration rate (*E*) increased at 14h for all cultivars in most of the months (Table 2). However, the ecophysiological behavior results from the balance of the various environmental factors (DONATO et al., 2013). This is also proven by the decrease of A/E and the increase of the transpiration on linear basis with the increase of temperature (Figure 1). If transpiration increased, logically there would not be stomatal restriction.

The ratio *A/Ci* is a measure of the rubisco carboxylation efficiency and its decrease expresses a shift toward oxygenized activity. This characteristic varies between months, in both times for all cultivars (Table 5). The relation *A/Ci* of the cultivars was similar between reading times, in most of the evaluation months (60.72%). In 39.28% of the cases, the values were always higher at 8:00 and lower at 14h, except for the 'BRS Platina' in December 2010. Proof of the Rubisco carboxylase activity change to oxygenize, with the temperature increase observed from 8:00 to 14:00, is in the reduction of ration between photosynthesis and internal CO_2 concentration (*A/Ci)* observed in 39.28 % of the cases. Considering the percentage difference, regardless of differences detected by the Tukey test ($p < 0.05$), they increase this variation to 67.85% for all cultivars and months.

The cultivars evaluated showed similar A/*Ci* relation. The averages did not differ between the evaluated times and month, except in October 2010 and June 2011 (Table 5). The highest value (0.13 μmol CO_2 $m^{-2}s^{-1}$/μmol CO_2 mol^{-1}) was recorded in 'BRS Platinum' in January 2011 at 8h and the lowest (0.04 μmol $CO_2 m^{-2}s^{-1}$/μmol CO2 mol^{-1}) in JV42-135 evaluated in February and May 2011 at 14h. This relation may clarify the factors that limit the photosynthesis, analyzing the adjusted curve of *A/Ci*.

The great temperature for carboxylation of the prevailing CO_2 in plants with C_3 photosynthetic mechanism, such as the banana, is around 22 °C, while the great temperature for growth and development is approximately 27 °C (ROBINSON; GALÁN SAÚCO, 2012). The balance between carboxylase and oxygenize activities of Rubisco is ruled by its kinetics, temperature and concentration of CO_2 and O_2 substrates. Under environmental CO_2 concentration, the increase in temperature modifies the kinetic constants of rubisco, and increases oxygenation rate preferably to carboxylation, consequently increases photorespiration and decreases net photosynthesis.

The plant can respond differently to environmental conditions, proved by the maintenance of the photosynthesis rate (*A*) (Table 4) and stomatal conductance (*gs*) (Table 3), in the evening, most of the cultivars, in December 2010, March, April and June 2011. Despite the increase in leaf temperature (T_{leaf}), the transpiration rate (*E*) and the reduction in water use efficiency (*A/E*) (Table 2), we did not observe decrease in carboxylation efficiency (*A/Ci)* at 14h for most cultivars, which shows the greatest effect on the intensity of the radiation (*Qleaf*) in gas exchange.

Seneviratne et al. (2008) also found a reduction in photosynthesis rate when the radiation level decreased while studying the different levels of shading and Photoinhibition under conditions of high intensity of light. Probably the same happened in this study, in February 2011, when all cultivars were subjected to a higher radiation Qleaf (1650.94 μmol photons $m^{-2}s^{-1}$) at 8h they had minor photosynthetic rates for the period, except the 'Prata-Anã' (Table 4).

The photosynthesis rate is increased by the presence of growth organs in the plant and reduced with the increase of shadowing or senescence (age) of the leaf. The lowest value of A (8.28 μmol CO_2 $m^{-2}s^{-1}$) was recorded in May 2011 at 14h in JV42-135 and the highest (27.10 μmol CO_2 $m^{-2}s^{-1}$) recorded in January 2011 at 8h in 'Maravilha'. The photosynthesis showed a variation of 227.29%, proving that the photosynthetic rates of banana trees can reach values of 25 to 30 μmol CO_2 $m^{-2}s^{-1}$ (TURNER et al., 2007; ROBINSON; GÁLAN SAÚCO, 2012).

The studied cultivars expressed the same photosynthetic rate at 8h and 14h on all evaluated months, with the exception of October 2010 at 8h, June 2011 at 14h and November 2011 at 8h and 14h (Table 4).

Several authors established associations between gas exchange of plants and the weather. Field studies reveal the integrated effects of environmental conditions on the physiology of banana trees, so correlations between these answers and climatic factors indicate trends, since there is influence of unmeasured factors. Higher precision in the associations between gas exchange and climatic factors is obtained in environments with controlled conditions (ROBINSON; GÁLAN SAÚCO, 2012). Nevertheless, Vanhove et al. (2012) state that experiments conducted in vitro and in greenhouse increase the experimental control, but it has lower physiological relevance compared to field studies.

The banana trees type ‘Prata’ presented, in November 2010, higher photosynthetic rates, stomatal conductance and transpiration compared to other months, regardless of the cultivar. The higher transpiration values (*E*), 10.11 and 11.96 mmol H_2O m-^{2}s^{-1}, in the two times, 8h and 14h, respectively, were due probably to the higher volume of rainfall recorded in the month (276.50 mm) that consequently increased soil moisture. The maximum Tleaf, 39.23^{o}C and 43.83 ° C, observed at 8h and 14h, respectively, are a result of the ambient temperature above 34 ºC, stressful for the banana tree (ROBINSON; GÁLAN SAÚCO, 2012), as well as the second highest radiation level (Q_{leaf}) 1298.11 µmol photons m^{-2}s^{-1} and 1212.36 µmol photons m^{-2}s^{-1} recorded in the morning and afternoon respectively. The high transpiration rates illustrate the plant cooling mechanism to relieve the heat stress caused by higher soil moisture.

The correlation study between the variables showed direct association, significant and of high magnitude, only between the rate of transpiration and leaf temperature of banana trees type ‘Prata’ cultivated in semi-arid environment (Figure 1). The adjusted linear models estimate an increase of 0.70; 0.47; 0.48; 0.42; 0.50 and 0.44 units in transpiration for each additional unit on the leaf temperature of cultivars ‘Maravilha’, BRS FHIA-18, FHIA-18, BRS Platina, ‘Prata-Anã’ and JV42-135 respectively.

The correlation study also established an inverse association, significant and high magnitude, only between the relation A/E and the Tleaf (Figure 1). The adjusted linear regression models predict a decrease of 0.26; 0.26; 0.37; 0.32; 0.29 and 0.28 units in the relation (A/E) for each increase of one unit in Tleaf in the cultivars ‘Maravilha ‘,’ BRS FHIA-18 ‘,’ FHIA-18 ‘,’ BRS Platinum ‘,’ Prata-Anã’ and JV42-135 respectively.

The increase in leaf temperature, due to the air temperature rise, increases transpiration and reduces water use efficiency for all crops, as reported by Donato et al. (2013). Changes in transpiration rates show stomatal opening as a cooling mechanism and showed that the reduction in photosynthetic rates in warmer times was more influenced by enzymatic involvement caused by temperature increase than by stomatal closure.

Lucena (2013) found a high, positive and significant correlation ($p < 0.05$) between transpiration and the air temperature to ‘BRS Platina’ and ‘Prata-Anã’. The author also found a high correlation, inverse and significant ($p < 0.05$) between the A/E and the air temperature. In his study, without water limitation, ‘BRS Platinum’ and ‘Prata-Anã’ had the same productivity (14,375 kg.ha^{-1}) in the first cycle and maximum values for the next 20.6 and 22.2 µmol CO_2 m^{-2}s^{-1}, respectively. In this study under the same conditions (local, level, population, spacing and original soil class), but with higher soil fertility and better management of plants, the maximum values of A for ‘BRS Platinum’ and ‘Prata-Anã ‘were higher, 26.44 and 25.52 µmol CO_2 m$_{-2}$s$_{-1}$, respectively. The yield in the first cycle was higher, 25.4 and 21.3 t.ha^{-1}, respectively.

For DaMatta (2007), the reduction of production is associated with a decline in photosynthetic rates induced by low water availability in the soil, either by a direct effect of dehydration in the photosynthetic apparatus or by an indirect effect through stomatal closure, which restricts the absorption of CO_2. Santos et al. (2013) evaluated ‘Tommy Atkins’ mangos under different irrigation regimes in the same region of this study and concluded that the gas exchange influenced the growth, development and production and they were related to water conditions of the plant, depending on the soil water status and weather conditions.

The showed data highlight the significant influence of temperature on gas exchange, either in a direct way with protein denaturation or indirectly by the sensitivity of stomatal to the effect of steam pressure deficit. However, correlations between these characteristics are not always found.

TABLE 1- Leaf temperature (Tleaf), ºC; transpiration rate (E), mmol H2O $m^{-2}s^{-1}$; instantaneous efficiency of water use (A/E), µmol CO2 $m^{-2}s^{-1}$/(mmol H_2O $m^{-2}s^{-1})^{-1}$; evaluated in the third leaf of Prata type , in the first and second production cycle in Guanambi, BA, 2010-2012.

Banana trees cultivars	T_{leaf}	*E*	*A/E*
Maravilha	36.19 BC	6.40B	3.45 A
BRS FHIA-18	36.57 B	6.57AB	3.26 AB
FHIA-18	36.28 BC	6.41B	3.32 AB
BRS Platina	37.39 A	7.04A	2.96 C
'Prata-Anã'	35.90 C	6.19B	3.35 AB
JV42-135	36.65 B	6.52AB	3.16 BC
CV (%)	5.30	26.12	22.10

* Averages followed by the same letter in columns do not differ from each other by Tukey test, 5% probability of error.

TABLE 2 - Radiation incident on the leaf surface (Qleaf), leaf temperature (Tleaf), transpiration rate (E), water use efficiency (A/E), and photochemical efficiency of photosynthesis (A/Qleaf), evaluated on the third leaf of banana trees type 'Prata' in the first and second production cycle, at 8h and 14h in Guanambi, BA, 2010-2012.

Months	Q_{leaf} (µmol photons $m^{-2}s^{-1}$)		T_{leaf}(ºC)		*E* (mmol H_2O $m^{-2}s^{-1}$)		*A/E*((µmol CO_2 $m^{-2}s^{-1}$)(mmol H_2O $m^{-2}s^{-1})^{-1}$)		A/Q_{leaf} (((µmol CO_2 $m^{-2}s^{-1}$)(µmol photons $m^{-2}s^{-1}$))	
	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00
Oct 2010	927.93Ca	485.65Db	32.45Eb	34.96Fa	5.01Ca	3.58Gb	4.42Ca	3.52Ab	0.028Aa	0.028Ca
Nov 2010	1298.11Ba	1212.36Ba	39.23Ab	43.83Aa	10.11Ab	11.96Aa	2.61Fa	1.52Db	0.022Ba	0.017Da
Dec 2010	543.72Db	1381.90Aa	31.02Fb	40.94Ba	3.91Db	9.20Ca	4.83Ba	2.30Cb	0.037Aa	0.015Db
Jan 2011	1496.91Aa	1184.55Bb	37.53Ba	36.98Ea	6.95Ba	5.43Fb	3.54Da	3.36Aa	0.016Ba	0.016Da
Feb 2011	1650.94Aa	1286.52Bb	36.08Cb	41.12Ba	5.64Cb	7.22Da	3.08Ea	1.80Db	0.010Ba	0.012Da
Mar 2011	1012.32Cb	1579.54Aa	35.27Cb	39.22Da	4.09Db	6.91Ea	4.22Ca	2.72Bb	0.021Ba	0.013Da
Apr 2011	605.24Db	1088.84Ba	31.85Eb	38.45Da	3.35Db	6.23Ea	5.30Aa	2.44Cb	0.030Aa	0.015Db
May 2011	975.25Ca	663.90Db	35.85Ca	35.73Fa	6.80Ba	4.68Fb	3.10Ea	2.74Bb	0.021Ba	0.022Ca
Jun 2011	1229.08Bb	1460.66Aa	30.66Fb	38.86Da	4.71Cb	8.08Da	4.82Ba	2.26Cb	0.020Ba	0.011Db
Jul 2011	1425.66Aa	1428.27Aa	30.46Fb	37.25Ea	4.80Cb	7.55Da	4.92Ba	2.50Cb	0.017Ba	0.017Da
Aug 2011	1492.15Aa	1421.62Aa	33.50Db	41.29Ba	6.09Bb	10.70Ba	4.10Ca	1.74Db	0.016Ba	0.013Da
Sep 2011	1334.12Ba	1196.86Ba	30.60Fb	40.04Ca	5.11Cb	9.40Ca	4.41Ca	1.80Db	0.028Aa	0.034Ba
Oct 2011	1271.75Ba	849.87Cb	31.20Fb	38.96Da	4.24Db	6.77Ea	5.35Aa	2.33Cb	0.020Bb	0.056BAa
Nov 2011	1037.72Ca	1081.65Ba	37.40Bb	41.22Ba	6.49Bb	7.55Da	3.23Ea	2.06Cb	0.024Aa	0.017Da
CV (%)	33.28		5.30		26.12		22.10		77.72	

* Averages followed by capital letters equal in the column for months, they belong to the same group by the criterion of Skott-Knott at 5% probability of error and lower case in line for hours did not differ significantly by F test at 5% probability of error.

TABLE 3- Stomatal conductance (gs), mol H_2O $m^{-2}s^{-1}$ evaluated on the third leaf of banana tree type 'Prata' in the first and second production cycle, at 8h and 14h in Guanambi, BA, 2010-2012.

Months	Maravilha		BRS FHIA-18		FHIA-18		BRS Platina		'Prata-Anã'		JV42-135	
	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00
Oct 2010	0.58Aa	0.15Bb	0.69Ba	0.16Bb	0.61Aa	0.14Bb	0.45Ba	0.14Bb	0.49Ca	0.18Bb	0.43Ba	0.17Bb
Nov 2010	0.71Aa	0.38Ab	1.01Aa	0.40Bb	0.75Aa	0.34Bb	0.72Aa	0.43Ab	0.86Aa	0.42Ab	0.73Aa	0.32Ab
Dec 2010	0.43Ba	0.43Aa	0.35Ca	0.54Aa	0.38Ba	0.56Ab	0.44Ba	0.47Aa	0.49Ca	0.48Aa	0.39Ba	0.38Aa
Jan 2011	0.65Aa	0.45Ab	0.58Ba	0.31Bb	0.46Ba	0.32Ba	0.52Ba	0.25Bb	0.63Ba	0.40Ab	0.62Aa	0.35Ab
Feb 2011	0.32Ba	0.27Ba	0.31Ca	0.26Ba	0.31Ba	0.28Ba	0.42Ba	0.25Ba	0.37Ca	0.24Ba	0.39Ba	0.19Bb
Mar 2011	0.34Bb	0.56Aa	0.31Ca	0.39Ba	0.44Ba	0.47Aa	0.34Bb	0.55Aa	0.33Ca	0.42Aa	0.30Bb	0.50Aa
Apr 2011	0.32Ba	0.23Ba	0.37Ca	0.40Ba	0.57Aa	0.42Aa	0.41Ba	0.43Aa	0.34Ca	0.28Ba	0.33Ba	0.30Ba
May 2011	0.51Aa	0.26Bb	0.55Ba	0.22Bb	0.53Ba	0.22Ba	0.56Ba	0.27Bb	0.44Ca	0.24Bb	0.47Ba	0.12Bb
Jun 2011	0.50Aa	0.32Ba	0.57Ba	0.29Bb	0.48Ba	0.50Ab	0.49Ba	0.30Ba	0.43Ca	0.45Aa	0.60Aa	0.45Aa
Jul 2011	0.46Ba	0.34Ba	0.55Ba	0.36Bb	0.70Aa	0.41Aa	0.43Ba	0.39Aa	0.46Ca	0.32Bb	0.55Aa	0.39Aa
Aug 2011	0.60Aa	0.54Aa	0.61Ba	0.62Aa	0.60Aa	0.51Ab	0.55Ba	0.35Bb	0.52Ca	0.52Aa	0.75Aa	0.50Ab
Sep 2011	0.38Ba	0.41Aa	0.54Ba	0.35Ba	0.45Ba	0.26Ba	0.65Aa	0.29Bb	0.33Ca	0.39Aa	0.42Ba	0.47Aa
Oct 2011	0.53Aa	0.38Aa	0.53Ba	0.31Bb	0.42Ba	0.35Ba	0.41Ba	0.35Ba	0.47Ca	0.28Ba	0.56Aa	0.26Bb
Nov 2011	0.58Aa	0.26Bb	0.40Ca	0.35Ba	0.48Ba	0.23Ba	0.81Aa	0.28Bb	0.29Cb	0.55Aa	0.45Ba	0.34Aa
CV (%)	36.08											

* Averages followed by capital letters equal in the column for months, they belong to the same group by the criterion of Skott-Knott at 5% probability of error and lower case in line for hours did not differ significantly by F test at 5% probability of error.

TABLE 4- Photosynthesis rate (A), µmol CO_2 $m^{-2}s^{-1}$, evaluated on the third leaf of 'Prata' type banana in the first and second production cycle, at 8h and 14h in Guanambi, BA, 2010-2012.

Months	Maravilha		BRS FHIA-18		FHIA-18		BRS Platina		'Prata-Anã'		JV42-135	
	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00
Oct 2010	26.21Aa	13.02Bb	26.67Aa	11.91Bb	23.16Aa	11.07Bb	18.02Ba	12.44Bb	20.25Aa	13.38Bb	17.05Ba	13.66Ba
Nov 2010	24.47Aa	17.45Ab	26.21Aa	18.30Ab	24.23Aa	17.92Ab	22.93Aa	18.77Aa	25.52Aa	20.07Ab	22.89Aa	15.23Bb
Dec 2010	18.79Ba	19.88Aa	19.50Ba	20.56Aa	18.26Ba	21.76Aa	14.92Ba	19.30Aa	20.92Aa	19.65Aa	19.72Ba	16.80Aa
Jan 2011	27.10Aa	20.95Ab	24.68Aa	17.15Ab	21.81Aa	18.09Aa	25.51Aa	15.70Bb	22.25Aa	19.81Aa	24.62Aa	18.29Ab
Feb 2011	14.77Ba	14.11Bb	15.65Ba	12.88Ba	15.60Ba	14.75Ba	20.54Ba	12.19Bb	19.01Aa	12.60Bb	18.64Ba	10.20Cb
Mar 2011	19.20Ba	21.72Aa	16.15Ba	15.75Ba	19.41Ba	17.90Aa	18.77Ba	21.19Aa	13.53Ba	15.89Ba	16.78Ba	17.30Aa
Apr 2011	16.25Ba	11.66Ba	16.87Ba	15.74Ba	16.73Ba	17.21Aa	19.44Ba	18.84Aa	15.81Ba	13.34Ba	16.51Ba	14.76Ba
Mai 2011	20.16Ba	14.14Bb	21.29Aa	12.76Bb	21.04Aa	12.02Bb	21.17Ba	14.64Bb	19.41Aa	13.26Bb	20.55Ba	8.28Cb
Jun 2011	20.69Ba	16.96Aa	23.83Aa	12.94Bb	22.14Aa	21.00Aa	21.85Aa	14.15Bb	21.07Aa	19.84Aa	23.21Aa	19.65Aa
Jul 2011	21.82Ba	18.54Aa	25.16Aa	18.03Ab	25.74Aa	19.46Ab	21.00Ba	19.47Aa	22.34Aa	17.32Ab	24.19Aa	18.88Ab
Aug 2011	24.22Aa	14.74Bb	24.34Aa	20.82Aa	24.14Aa	19.07Aa	23.09Aa	17.06Ab	23.27Aa	20.56Aa	26.53Aa	18.38Ab
Sep 2011	20.70Ba	19.44Aa	25.11Aa	14.71Bb	22.91Aa	13.43Bb	26.44Aa	15.50Bb	19.23Aa	17.20Aa	19.84Ba	19.99Aa
Oct 2011	25.52Aa	1872Ab	25.44Aa	15.67Bb	20.32Ba	14.24Bb	19.92Ba	15.19Ba	22.80Aa	12.99Bb	22.27Aa	13.87Bb
Nov 2011	21.44Ba	12.56Bb	18.00Ba	16.74Aa	19.82Ba	11.65Bb	23.13Aa	13.20Bb	14.38Ab	19.60Aa	19.87Ba	14.95Bb
CV (%)							22.26					

* Averages followed by capital letters equal in the column for months, they belong to the same group by the criterion of Skott-Knott at 5% probability of error and lower case in line for hours did not differ significantly by F test at 5% probability of error.

TABLE 5 - Efficiency of carboxylation (A/Ci), μmol CO_2 $m^{-2}s^{-1}$/μmol CO_2 mol^{-1}, evaluated on the third leaf of ‘Prata’ type banana in the first and second production cycle, at 8h and 14h, in Guanambi, BA, 2010-2012.

Months	Maravilha		BRS FHIA-18		FHIA-18		BRS Platina		‘Prata-Anã’		JV42-135	
	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00	08:00	14:00
Oct 2010	0.12Aa	0.06Bb	0.11Aa	0.05Bb	0.09Aa	0.05Bb	0.07Ca	0.06Ba	0.08Aa	0.06Ba	0,07Ba	0.07Aa
Nov 2010	0.10Aa	0.08Aa	0.11Aa	0.08Aa	0.10Aa	0.08Aa	0.10Aa	0.09Aa	0.11Aa	0.09Aa	0.09Aa	0.06Ab
Dec 2010	0.08Ba	0.09Aa	0.09Ba	0.09Aa	0.07Ba	0.10Aa	0.05Cb	0.09Aa	0.09Aa	0.09Aa	0.08Ba	0.07Aa
Jan 2011	0.13Aa	0.10Ab	0.12Aa	0.08Ab	0.11Aa	0.09Aa	0.13Ba	0.08Ab	0.10Aa	0.10Aa	0.10Aa	0.09Ab
Feb 2011	0.06Ba	0.06Ba	0.07Ba	0.06Ba	0.07Ba	0.07Ba	0.09Ba	0.05Bb	0.09Aa	0.06Bb	0.07Ba	0.04Bb
Mar 2011	0.08Ba	0.10Aa	0.07Ba	0.07Ba	0.08Ba	0.08Aa	0.09Ba	0.10Aa	0.05Ba	0.07Ba	0.08Ba	0.07Aa
Apr 2011	0.07Ba	0.05Ba	0.07Ba	0.06Ba	0.07Ba	0.07Aa	0.09Ba	0.08Aa	0.06Ba	0.06Ba	0.07Ba	0.07Aa
May 2011	0.09Ba	0.06Ba	0.09Aa	0.06Bb	0.09Aa	0.05Bb	0.10Ba	0.07Bb	0.09Aa	0.06Bb	0.07Aa	0.04Bb
Jun 2011	0.08Ba	0.07Aa	0.10Aa	0.05Bb	0.10Aa	0.09Aa	0.10Ba	0.06Bb	0.09Aa	0.09Aa	0.08Aa	0.08Aa
Jul 2011	0.09Ba	0.08Aa	0.11Aa	0.08Ab	0.11Aa	0.08Aa	0.09Ba	0.09Aa	0.09Aa	0.08Aa	0.09Aa	0.08Aa
Aug 2011	0.10Aa	0.06Bb	0.11Aa	0.09Aa	0.10Aa	0.08Aa	0.10Ba	0.08Aa	0.10Aa	0.09Aa	0.09Aa	0.08Ab
Sep 2011	0.09Ba	0.09Aa	0.11Aa	0.06Bb	0.10Aa	0.06Bb	0.12Aa	0.07Bb	0.09Aa	0.07Aa	0.08Ba	0.09Aa
Oct 2011	0.11Aa	0.08Ab	0.12Aa	0.07Bb	0.08Ba	0.06Bb	0.09Ba	0.06Ba	0.10Aa	0.05Bb	0.08Ba	0.06Ab
Nov 2011	0.09Ba	0.05Bb	0.07Ba	0.07Aa	0.08Ba	0.05Bb	0.09Ba	0.05Bb	0.06Ba	0.08Ab	0.07Ba	0.06Aa
CV (%)	25.20											

* Averages followed by capital letters equal in the column for months, they belong to the same group by the criterion of Skott-Knott at 5% probability of error and lower case in line for hours did not differ significantly by F test at 5% probability of error.

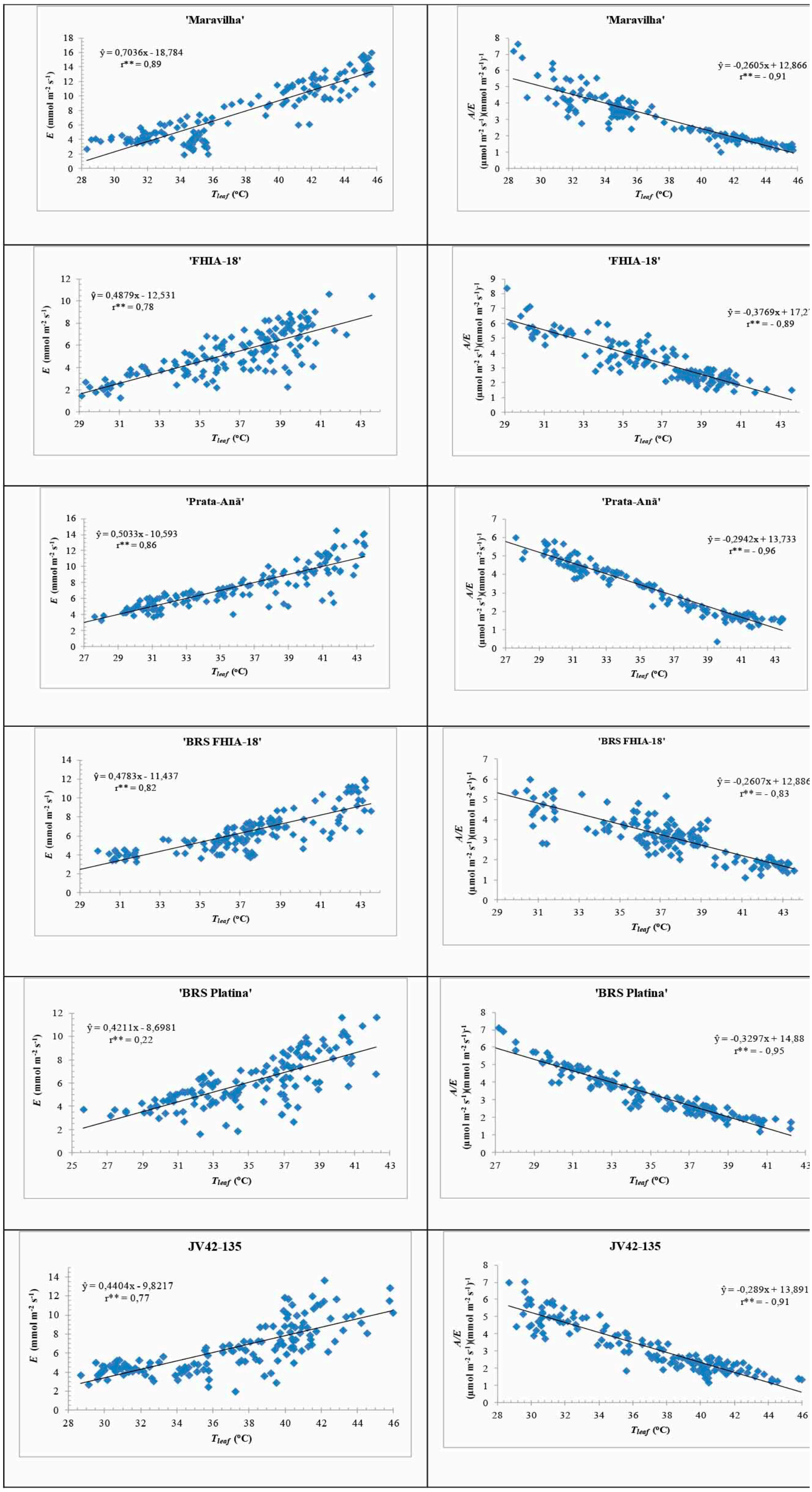

FIGURE 1- Correlation between transpiration rate (E), mmol H_2O $m^{-2}s^{-1}$, and leaf temperature (Tleaf), ºC, and between the instantaneous efficiency of water use (A/E), µmol CO_2 $m^{-2}s^{-1}$/(mmol H_2O $m^{-2}s^{-1})^{-1}$, and the leaf temperature (Tleaf), ºC, evaluated in the third leaf of 'Prata' type banana, in the first and second production cycle in Guanambi, BA, 2010-2012.

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