REVISTA BRASILEIRA DE
FRUTICULTURA
Published by the Brazilian Society of Fruit Crops
ISSN 0100-2945

Botany And Physiology

Original Article - Edited by: Juliana Domingues Lima

Gas exchange and leaf area requirement for yield in Cavendish and Gros Michel Bananas

Sérgio Luiz Rodrigues Donato[1], Alessandro de Magalhães Arantes[1], Alex Rodrigues Silva Soares[1], Marcelo Rocha dos Santos[1], Maria Geralda Vilela Rodrigues[2]

[1] Federal Institute of Education, Science and Technology Baiano, Guanambi Campus, Agriculture Sector. Guanambi-BA, Brazil.
[2] Agricultural Research Company of Minas Gerais - Epamig Norte. Nova Porteirinha-MG, Brazil.
* Corresponding author: *sergio.donato@ifbaiano.edu.br*

Abstract: The objective was to evaluate gas exchange and the leaf area requirement for yield in Cavendish and Gros Michel bananas. The cultivars Grande Naine, Calipso, Bucaneiro, FHIA-17 and FHIA-23, and two production cycles, were arranged in a completely randomized experimental design, in a factorial scheme, with five replicates. For the physiological characteristics, a 5x9x2 factorial arrangement was considered, with cultivars, evaluation periods and reading times. Cultivars Bucaneiro and Calipso require larger leaf area per unit produced and FHIA-23, smaller, which suggests a greater photosynthetic efficiency per leaf unit for FHIA-23, confirmed by the higher masses of bunches and hands and greater numbers of hands and fruits. Gas exchange varies with cultivars, evaluation periods and reading times. Cultivars FHIA-17 and Calipso, Gros Michel type, respectively showed higher photosynthesis and transpiration rates than Grande Naine, Cavendish type. Net photosynthesis, stomatal conductance, quantum efficiency of photosynthesis, instantaneous water use efficiency and carboxylation efficiency are higher at 8:00 h than at 14:00 h. The month of June allowed the cultivars to express the highest values of photosynthesis rates, incident radiation on leaves, carboxylation efficiency and stomatal conductance.

Index terms: *Musa* spp., physiology, climate, production, vigor.

Revista Brasileira de Fruticultura, v.45, e-079. DOI: *https://dx.doi.org/10.1590/0100-29452023079*
Received 18 Jul, 2022 ● Accepted 07 Nov, 2022 ● Published Jan/Feb, 2023.

Trocas gasosas e requerimento em área foliar para rendimento de bananeiras Cavendish e Gros Michel

Resumo: Objetivou-se avaliar trocas gasosas e requerimento em área foliar para rendimento de bananeiras Cavendish e Gros Michel. As cultivares, Grande Naine, Calipso, Bucaneiro, FHIA-17 e FHIA-23, e dois ciclos de produção foram dispostos em delineamento experimental inteiramente casualizado, em esquema fatorial, com cinco repetições. Para características fisiológicas, considerou-se arranjo fatorial 5 x 9 x 2, com cinco cultivares, nove períodos de avaliação e dois horários de leituras. As cultivares Bucaneiro e Calipso requerem maior área foliar por unidade produzida, e a FHIA-23, menor, o que sugere maior eficiência fotossintética por unidade de folha para esta, comprovada pelas maiores massas de cachos e de pencas, e maiores quantidades de pencas e frutos. As trocas gasosas variam com as cultivares, épocas de avaliação e horários de leitura. As cultivares FHIA-17 e Calipso, tipo Gros Michel, expressaram, respectivamente, maiores taxa de fotossíntese e de transpiração, que a Grande Naine, tipo Cavendish. A fotossíntese líquida, condutância estomática, e as eficiências quântica da fotossíntese, instantânea de uso da água e de carboxilação são maiores às 8 horas comparada às 14 horas. O mês de junho possibilitou às cultivares expressarem os maiores valores de taxas de fotossíntese, radiação incidente nas folhas, eficiência de carboxilação e condutância estomática.

Termos para indexação: *Musa* spp., fisiologia, clima, produção, vigor.

Introduction

Banana (*Musa* spp.) cultivation is carried out in different climatic zones, from cold subtropics to semi-arid tropics, where periods in the year with low temperatures or stress caused by heat and lack of water, respectively, are frequent, which limits the production potential of the plant (DONATO et al., 2021). Thus, studies involving management practices, cultivars and gas exchange in specific environments provide greater understanding of soil-water-plant-atmosphere interactions to support the proposition of improvements in production.

Adverse conditions, whether abiotic, such as the occurrence of high-speed winds (DONATO et al., 2006a; FARIA et al., 2010), or biotic, such as the presence of pathogens that cause leaf diseases, accelerate senescence and contribute to reductions in the leaf area of banana (DONATO et al., 2021) and, consequently, in its photosynthesis. Under these conditions, certain cultivars may show, at the time of flowering, a number of leaves below the functional requirement to ensure high yield. Thus, it is interesting to use cultivars with lower leaf area requirements per unit quantity of bananas produced, which may suggest greater photosynthetic efficiency.

In the phytotechnical characterization of cultivars, vegetative traits that reflect plant vigor, plant height and pseudostem diameter and yield traits, such as masses of bunches, hands and fruits, fruit length and diameter (ARANTES et al., 2017), as well as susceptibility to certain pathogens (RODRIGUES FILHO et al., 2014), are usually evaluated.

From the ecophysiological point of view, there is an adjustment of the species to the site, climate and soil. Thus, the banana plant performs its gas exchange at appropriate rates when the environment is favorable (ARANTES et al., 2016; DONATO et al., 2021). In this context, the study of gas exchange is based on the efflux of water and influx of CO_2, a process that can be measured, especially in leaves, in a precise and nondestructive way, with instantaneous and time-point measurements, through devices that assist in the identification of cultivars adapted to different environments.

Photosynthesis, transpiration, respiration, growth and development of banana are interdependent and influenced by site, soil and climate conditions (DONATO et al., 2021) and management. Thus, they may be associated with the yield differences between cultivars (TURNER et al., 2007; ARANTES, 2016; RAMOS et al., 2018), when subjected to different irrigation systems (ARANTES et al., 2018), irrigation management strategies (SANTOS et al., 2017), irrigation intervals and emitter heights (LAGE et al., 2020), fertilization with fertilizers for organic management (MARQUES et al., 2018), or to different planting densities (RODRIGUES FILHO et al., 2020), which lead to variations in the total leaf area and leaf area index (LAI). This is important because there is a relationship between LAI and photosynthesis (TURNER et al., 2007), leaf area and yield with varietal specificity for Cavendish (SOTO BALLESTERO, 2008; RODRÍGUEZ GONZÁLEZ et al., 2012), Prata (RODRIGUES et al., 2009) and plantains (CAYÓN SALINAS, 2004).

These variations between cultivars, managements and weather conditions throughout the day and year make it possible to understand changes in the rates of photosynthesis, transpiration, stomatal conductance, water use efficiency and carboxylation efficiency, leaf temperature, which is a consequence of air temperature (DONATO et al., 2021), and their effects on the vigor and yield of banana plants. These changes constitute physiological indicators of the presence of stress and allow extrapolation of these results to promote managements in specific production systems and for cultivars in similar environments (ARANTES et al., 2016). Thus, the objective of this work was to evaluate the gas exchange and leaf area requirement for yield of five banana cultivars, one Cavendish (Grande Naine) and four Gros Michel (Calipso, Bucaneiro, FHIA-17 and FHIA-23), under semi-arid conditions and irrigation.

Material and methods

The experiment was carried out in the experimental area of the Federal Institute of Education, Science and Technology Baiano, Guanambi Campus, located in the Ceraíma district, in the municipality of Guanambi, Bahia, Brazil (14°17’38”S, 42°41’42”W). The soil, whose original classification is *Latossolo Vermelho-Amarelo distrófico* (SANTOS et al., 2018), which corresponds to Oxisol (SOIL SURVEY STAFF, 2014), before the crop was planted, showed high fertility, improved by anthropic actions (Table 1). The climate is hot and dry semi-arid, with an average annual temperature of 25.9 ºC and average annual precipitation of 664.7 mm, average of the last 39 years. The meteorological data of the experimental period are shown in Figure 1 (A, B and C); precipitation data encompassed the entire experimental period, from planting to the harvest of the second production cycle (Figure 1A), while temperature, relative humidity (Figure 1B) and vapor pressure deficit (Figure 1C) data corresponded to the period of gas exchange measurement.

Planting was carried out using micropropagated seedlings at spacing of 3.0 x 2.5 m and, along with cultural practices, followed the recommendations for the crop according to Rodrigues et al. (2008). Irrigation was applied by a microsprinkler system, with Netafim® pressure-compensating emitters, with flow rate of 120 L h^{-1}, wetted diameter of 7.4 m, red nozzle of 1.57 mm, and spacing of 6 m between lateral lines and 5 m between emitters. In addition to irrigation, plants received 1,364.6 mm of water by precipitation during the entire experimental period (Figure 1A).

Irrigation was based on crop evapotranspiration (ETc), which considers reference evapotranspiration (ETo) and the crop coefficients defined according to the phenological stages of the crop (COELHO et al., 2015). ETo was determined daily by the Penman-Monteith method, using data collected from a Vantage

Table 1 - Means of the chemical attributes of two composite samples of soil from the experimental area, before planting, Guanambi, BA.

Characteristics	Unit	0.0-0.20 m	Standard Deviation	0.20-0.40 m	Standard Deviation
pH (H_2O)		7.60	0.14	7.60	0.57
P	mg dm^{-3}	318.15	157.47	185.80	21.78
K^+	mg dm^{-3}	567.50	45.96	512.50	154.86
Na^+	$cmol_c$ dm^{-3}	0.20	0.00	0.15	0.07
Ca^{2+}	$cmol_c$ dm^{-3}	3.45	0.49	2.90	0.00
Mg^{2+}	$cmol_c$ dm^{-3}	1.70	0.28	1.30	0.00
Al^{3+}	$cmol_c$ dm^{-3}	0.00	0.00	0.00	0.00
$H^+ + Al^{3+}$	$cmol_c$ dm^{-3}	0.90	0.00	0.95	0.07
S.B.[1]	$cmol_c$ dm^{-3}	6.75	0.92	5.65	0.35
t [2]	$cmol_c$ dm^{-3}	6.75	0.92	5.65	0.35
T [3]	$cmol_c$ dm^{-3}	7.65	0.92	6.65	0.21
V[4]	%	88.00	1.41	85.00	1.41
m[5]	%	0.00	0.00	0.00	0.00
OM[6]	g dm^{-3}	13.50	21.0	10.00	14.00
B	mg dm^{-3}	0.85	0.07	0.75	0.07
Cu^{++}	mg dm^{-3}	1.05	0.21	0.85	0.21
Fe^{++}	mg dm^{-3}	11.85	2.33	11.35	3.46
Mn^{++}	mg dm^{-3}	48.95	3.75	40.70	11.60
Zn^{++}	mg dm^{-3}	24.25	4.31	13.30	2.40
Prem[7]	mg L^{-1}	42.15	0.92	41.40	3.68
EC[8]	dS m^{-1}	1.70	0.00	1.95	0.21

[1]sum of bases; [2]effective cation exchange capacity (effective CEC); [3]CEC at pH 7.0; [4]base saturation; [5]aluminum saturation; [6]soil organic matter; [7]remaining phosphorus; [8]electrical conductivity. pH in water; OM: colorimetry; P, K, Na, Cu, Fe, Mn, Zn: Mehlich-1 extractant; Ca, Mg and Al: 1 mol L^{-1} KCl extractant; H+Al: pH SMP; B: Hot water.

Pro Integrated Sensor automatic weather station (Davis Instruments, Hayward, CA, USA) installed 100 m from the experiment area.

The experiment was conducted in a randomized block design - RBD, evaluating five banana cultivars of the following types: Cavendish - Grande Naine (triploid AAA) and Gros Michel - Calipso, Bucaneiro, FHIA-17 and FHIA-23 (tetraploid AAAA), with five replicates and four usable plants per plot. The number of treatments depends on the variable. Bucaneiro and Calipso hybrids originated from the Banana Breeding Program of Jamaica, while FHIA-17 and FHIA-23 originated from the Banana Breeding Program of the Honduran Agricultural Research Foundation. The four Gros Michel tetraploids have the 'Highgate' as female parent, while those from FHIA have the diploid SH33-62 as male parent.

Regarding phytotechnical data, twenty characteristics were evaluated: mass of bunch (MB) and mass of hands (MH), expressed in kg; number of hands (NH) and number of fruits (NFR); number of leaves at flowering (NLF) and at harvest (NLH); length (LL3) and width of the third leaf (WL3) (cm); total leaf area (TLA) at flowering and at harvest (m^2) estimated by the "new factor" method (KUMAR et al., 2002) - TLA = W x L x 0.80 x 0.662, where W and L are width and length of the third leaf, respectively; 0.80 - correction factor, a constant obtained by mathematical integration as the leaf tends to assume a rectangular shape; N - number of active leaves of the plant; 0.662 - new factor; leaf area index (LAI), at flowering and at harvest (m^2 m^{-2}); ratio between leaf area at flowering and mass of bunch (LAF/MB) (m^2 kg^{-1}); ratio between leaf area at flowering and mass of hands (LAF/MH) (m^2 kg^{-1}); ratio between leaf area at flowering and number of hands (LAF/NH) (m^2 $hand^{-1}$); ratio between leaf area at harvest and mass of bunch (LAH/

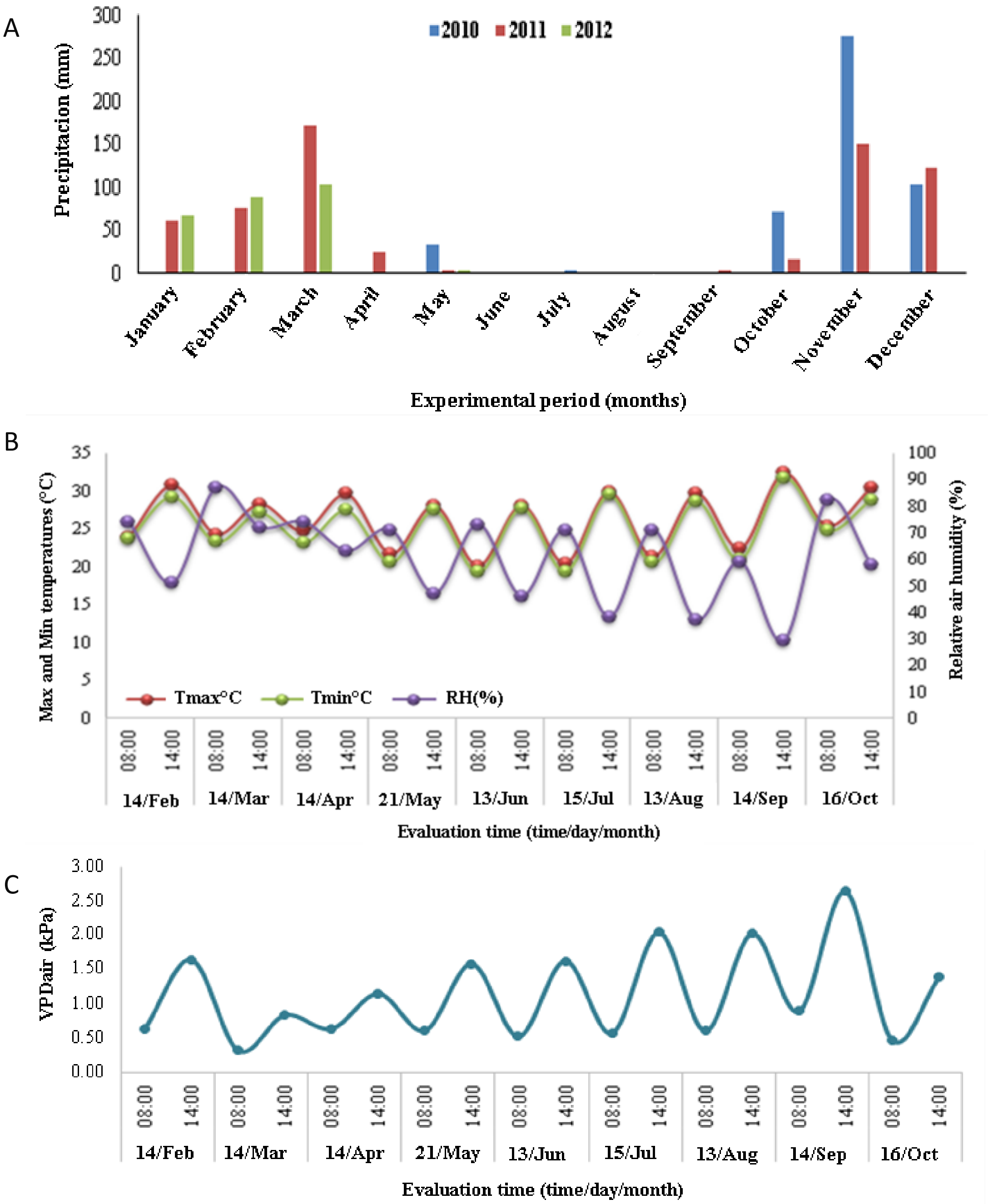

Figure 1 - Data of precipitation during the experimental period (A), from May 2010 to May 2012, minimum and maximum temperatures, relative air humidity (B), and vapor pressure deficit (VPDair) (C) measured at the time of physiological evaluations, from February to October 2011, Guanambi, BA.

Source: data collected at the automatic weather station installed in the experimental area of the Federal Institute of Bahia.

MB)(m^2 kg^{-1}); ratio between leaf area at harvest and mass of hands (LAH/MH) (m^2 kg^{-1}); ratio between leaf area at harvest and number of hands (LAH/NH) (m^2 hand^{-1}); and ratio between leaf area at harvest and number of fruits (LAH/NFR) (m^2 fruit^{-1}).

Ten physiological characteristics were also evaluated: incident radiation on the leaf (Q_{Leaf}) expressed in µmol photons m^{-2} s^{-1}; internal CO_2 concentration (C_i) in µmol CO_2 mol^{-1}; leaf temperature (T_{Leaf}) in °C; stomatal conductance (g_s) in mol H_2O m^{-2} s^{-1}; transpiration (E) in mmol H_2O m^{-2} s^{-1}; net photosynthesis (A) in µmol CO_2 m^{-2} s^{-1}; instantaneous water use efficiency (A/E) in µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}; carboxylation efficiency (A/C_i) in μmol CO_2 m^{-2} s^{-1}/μmol CO_2 mol^{-1}; quantum or photochemical efficiency of photosynthesis (A/Q_{Leaf}) in μmol CO_2 m^{-2} s^{-1}/μmol photons m^{-2} s^{-1} and intrinsic water use efficiency (A/g_s) in μmol CO_2 m^{-2} s^{-1}/mol H_2O m^{-2} s^{-1}.

Gas exchange, incident radiation on the leaves and leaf temperature were always evaluated in the third or fourth leaf, counted from the apex to the base (ARANTES et al., 2016; 2018; RAMOS et al., 2018), using an LCpro+® Portable Photosynthesis System (ADC BioScientific Limited, UK) infrared gas analyzer (IRGA), with ambient temperature and irradiance and airflow of 200 ml min^{-1}, always with the radiation shield facing the sun. Nine monthly evaluations were performed, encompassing the period from February to October 2011, at two reading times, 8:00 h and 14:00 h.

Regarding the statistical analyses of the data of the evaluated characteristics, the following procedure was adopted: a) For phytotechnical characteristics, the treatments, formed by the five cultivars and two production cycles, were arranged in a randomized block design (RBD), in a factorial scheme. The data showed normality by the Lilliefors test and were subjected to analysis of variance (ANOVA) at 5% significance level. In cases of significant interactions between the factors cultivars and cycles, these interactions were decomposed, with the comparison of cultivars within cycles by Tukey test ($p \leq 0.05$) and of cycles within cultivars by F test ($p \leq 0.05$). In the absence of interactions, the effects of the main factors were studied with the comparison of means between cultivars by Tukey test ($p \leq 0.05$) and of means between cycles by F test ($p \leq 0.05$), using the statistical program SISVAR - UFLA, version 5.6; b) For physiological characteristics, the treatments consisted of a 5 x 9 x 2 factorial, which corresponded to five cultivars, nine evaluation periods (months) and two reading times in each period, arranged in a completely randomized design. The data were subjected to the Lilliefors test and did not show normality, that is, they did not follow a normal distribution, so the nonparametric Wilcoxon test (for paired samples) and Kruskal-Wallis test (for independent samples) were used, considering p-value ≤ 0.05 as statistically significant. These analyses were performed using the statistical program SAEG - UFV, version 9.1.

Results and discussion

All phytotechnical characteristics measured in the study showed normal distribution and, therefore, were subjected to analysis of variance (Table 2). Based on the analysis of variance (ANOVA), it was possible to observe that the phytotechnical characteristics mass of bunch (MB), mass of hands (MH), ratio between leaf area at flowering and mass of bunch (LAF/MB), ratio between leaf area at flowering and mass of hands (LAF/MH) and ratio between leaf area at flowering and number of hands (LAF/NH), measured in Cavendish and Gros Michel bananas, were significantly influenced ($p \leq 0.05$) by the interaction between the factors: cultivar and cycle. Of these characteristics, MB, MH, LAF/MB, LAF/MH and LAF/NH also varied independently with cultivars and cycles ($p \leq 0.05$). Number of hands (NH), number of fruits (NFR), ratio between leaf area at harvest and mass of bunch (LAH/MB), ratio between leaf area at harvest and mass of hands (LAH/MH), ratios between leaf area at harvest and number of hands (LAH/NH) and between leaf area at harvest and number of fruits (LAH/NFR) varied independently with cultivars and cycles ($p \leq 0.05$).

Leaf area index at flowering (LAI) varied with the cycles, but the total leaf area at flowering (TLAF) and at harvest (TLAH) and leaf area index at harvest (LAIH) were not influenced by the studied factors ($p \geq 0.05$) (Table 2).

Mass of bunch is one of the main characteristics that express banana yield, but the evaluation of a cultivar must consider other aspects that exert influence on the consumer market, such as fruit size and flavor. Mass of bunch depends on the number of hands per bunch, number of fruits per hand and average fruit mass (BORGES et al., 2011).

Table 2 - Summary of the analysis of variance, with the respective mean squares, means and coefficients of variation, for the phytotechnical characteristics evaluated at flowering and at harvest of two production cycles of banana cultivars of the Cavendish and Gros Michel types, in Guanambi, BA.

	Sources of variation				Units	Means	CV (%)
	Cultivars (A)	Cycles (B)	Interaction (A x B)	Residual			
Degrees of freedom	4	1	4	40			
TLA	4.70 ns	9.53 ns	6.35 ns	4.29	(m^2)	15.01	13.8
LAI	0.23 ns	0.74 *	0.15 ns	0.13	($m^2\ m^{-2}$)	2.57	13.86
TLAH	4.06 ns	1.23 ns	5.05 ns	2.78	(m^2)	11.23	14.85
LAIH	0.11 ns	0.03 ns	0.14 ns	0.08	($m^2\ m^{-2}$)	1.87	14.84
MB	586.57 **	235.84 **	112.84 **	24.02	(kg)	34.33	14.28
MH	436.90 **	191.84 **	97.61 **	20.80	(kg)	30.15	15.13
NH	62.18 **	103.94 **	1.50 ns	0.68	(unit)	10.96	7.54
NFR	23118.97 **	54401.17 **	833.90 ns	421.96	(unit)	204.62	10.04
LAF/MB	0.09 **	0.143 **	0.03 **	0.01	($m^2\ kg^{-1}$)	0.46	15.07
LAH/MB	0.04 **	0.05 **	0.00 ns	0.00	($m^2\ kg^{-1}$)	0.34	15.90
LAF/MH	0.121 **	0.20 **	0.03 **	0.01	($m^2\ kg^{-1}$)	0.53	15.68
LAH/MH	0.05 **	0.07 **	0.01 ns	0.00	($m^2\ kg^{-1}$)	0.39	16.29
LAF/NH	1.02 **	2.94 **	0.15 *	0.05	(m^2 hand^{-1})	1.46	15.4
LAH/NH	0.38 **	1.25 **	0.01 ns	0.03	(m^2 hand^{-1})	1.08	16.77
LAH/NFR	0.001 **	0.006 **	0.0001 ns	0.00	(m^2 fruit^{-1})	0.06	15.48

** and * significant at 1 and 5%, respectively, by the F-test; “ns”, not significant; NLF: number of leaves at flowering; LL3: length of the third leaf; WL3: width of the third leaf; TLA: total leaf area; LAI: leaf area index; NLH: number of leaves at harvest; TLAH: total leaf area at harvest; LAIH: leaf area index at harvest; MB: mass of bunch; MH: mass of hands; MRA: mass of rachis; NH: number of hands; NFR: number of fruits; LAF/MB: ratio between leaf area at flowering and mass of bunch; LAH/MB: ratio between leaf area at harvest and mass of bunch; LAF/MH: ratio between leaf area at flowering and mass of hands; LAH/MH: ratio between leaf area at harvest and mass of hands; LAF/NH: ratio between leaf area at flowering and number of hands; LAH/NH: ratio between leaf area at harvest and number of hands; LAH/NFR: ratio between leaf area at harvest and number of fruits; CV: coefficient of variation

The cultivar that produced the heaviest bunches in the first and second cycles was FHIA-23, with 48.89 kg and 42.21 kg, respectively, according to Table 3. FHIA-17, Grande Naine and Calipso showed intermediate masses, and the lowest mass was observed in Bucaneiro, with 22.83 kg in the first cycle. In the second cycle, the lowest value was obtained by Grande Naine, with 32.88 kg.

FHIA-23 had the highest mass of hands (MH), both in the first (43.10 kg) and in the second (36.63 kg) production cycle. The cultivars FHIA-17, Grande Naine and Calipso showed intermediate values, and the lowest values were observed in Bucaneiro, with 19.88 kg and 28.98 kg in the first and second cycles, respectively (Table 3).

As observed in the present study, in general, Gros Michel hybrids, FHIA-23 and FHIA-17, have higher masses of bunch and hands than Cavendish cultivars, for example, Williams, derived from Grande Naine, in the first and second production cycle, as recorded in Kenya (NJUGUNA et al., 2008), or only in the first cycle, as observed in Australia (SMITH et al., 2014).

Grande Naine and Nanicão were more productive than the Gros Michel hybrids, Bucaneiro and Calipso, in two production cycles in Guanambi, BA (DONATO et al., 2006a). On the other rend, FHIA-23 and FHIA-17 showed the highest production, followed by Grande Naine, and by those of Gros Michel type, Bucaneiro and Calipso, with masses of bunches and hands similar to each other, while in the third cycle, FHIA-17 and Bucaneiro had the highest production, followed by Grande Naine and Calipso (ARANTES et al., 2017).

These results show a wide variation depending on the cycle and site-specific conditions, but in general they indicate higher yield for

Table 3 – Phytotechnical characteristics evaluated at flowering and at harvest in two production cycles in Cavendish and Gros Michel banana cultivars. Guanambi, BA.

Characteristics	Cycles	Cultivars					Mean	CV (%)
		Calipso	Bucaneiro	FHIA-23	FHIA-17	Grande Naine		
MB (kg)	1st	23.88 Cb	22.83 Cb	48.89 Aa	36.66 Ba	28.53 BCa	34.33	14.28
	2nd	33.35 Ba	32.89 Ba	42.21 Ab	41.18 Aa	32.88 Ba		
MH (kg)	1st	20.75 Cb	19.88 Cb	43.10 Aa	31.92 Ba	25.32 BCa	30.15	15.13
	2nd	29.26 Aa	28.98 Aa	36.63 Ab	35.94 Aa	29.76 Aa		
LAF/MB ($m^2\ kg^{-1}$)	1st	0.66 Aa	0.66 Aa	0.35 Ba	0.46 Ba	0.47 Ba	0.46	15.07
	2nd	0.47 Ab	0.45 ABb	0.36 ABa	0.33 Bb	0.45 ABa		
LAF/MH ($m^2\ kg^{-1}$)	1st	0.76 Aa	0.76 Aa	0.39 Ba	0.52 Ba	0.53 Ba	0.53	15.68
	2nd	0.53 Ab	0.52 ABb	0.41 ABa	0.38 Bb	0.49 ABa		
LAF/NH ($m^2\ hand^{-1}$)	1st	2.21 Aa	2.06 Aa	1.26 Ba	1.51 Ba	1.49 Ba	1.46	15.40
	2nd	1.54 Ab	1.35 ABb	0.98 BCa	0.92 Cb	1.32 ABCa		

[1]Means followed by the same uppercase letters in the rows for cultivars do not differ from each other by Tukey test at 5% significance level, and means followed by the same lowercase letters in the columns for cycles do not differ from each other by F test at 5% significance level.

[2]MB: mass of bunch; MH: mass of hands; LAF/MB: ratio between leaf area at flowering and mass of bunch; LAF/MH: ratio between leaf area at flowering and mass of hands; LAF/NH: ratio between leaf area at flowering and number of hands; CV: coefficient of variation.

the Gros Michel cultivars from FHIA; however, FHIA-17 and FHIA-23 are very late, with a longer period from planting to harvest as compared to Grande Naine, Bucaneiro and Calipso (ARANTES et al., 2017), to Williams (SMITH et al., 2014) and to Prata and BRS Tropical cultivars (LUCENA, 2013), and this difference increases with cycles (ARANTES et al., 2017; LUCENA, 2013), which suggests lower yield per unit of time.

The highest values for the ratios between leaf area at flowering and mass of bunch (LAF/MB), mass of hands (LAF/MH) and number of hands (LAF/NH), in the first cycle, were observed in the Gros Michel cultivars originated from Jamaica, Bucaneiro and Calipso. In the second cycle, the LAF/MB and LAF/MH ratios were higher for the Calipso cultivar and lower for FHIA-17, while LAF/NH was higher for Calipso than for FHIA-17 and FHIA-23 (Table 3).

The results show a greater leaf area requirement for fruit production in the cultivars Bucaneiro and Calipso. Banana leaf area varies with the dimensions and number of leaves (KUMAR et al., 2002), so factors such as drought, nutritional and wind stresses, as well as biotic factors, such as the occurrence of Sigatokas, which affect leaf area, also affect production. This suggests that cultivars with greater leaf area requirement for fruit production are less efficient and, therefore, less recommended for environments with predominance of factors that contribute to reducing leaf area. The cultivar Grande Naine requires smaller leaf area at flowering for production (RODRÍGUEZ GONZÁLEZ et al., 2012) as compared to Prata-Anã (RODRIGUES et al., 2009) and, in the present study, it was more efficient than Calipso and Bucaneiro in most cases.

The banana cultivars differed significantly for the phytotechnical characteristics NH, NFR, LAH/MB, LAH/MH, LAH/NH and LAH/NFR, regardless of the production cycle (Table 4).

The highest means for the number of hands (NH) and number of fruits (NFR) were obtained by the cultivar FHIA-23, followed by FHIA-17 (Table 4). These components define the mass of the bunch, as they represent a large part of it and are related to the yield (DONATO et al., 2006b).

The highest means for the ratios between leaf area at harvest and mass of bunch (LAH/MB) and between leaf area at harvest and mass of hands (LAH/MH) were observed in the Bucaneiro cultivar, followed by Calipso.

Table 4 - Phytotechnical characteristics evaluated at flowering and at harvest in banana plants of the Cavendish and Gros Michel types. Guanambi, BA.

Cultivars	Characteristics					
	NH (unit)	NFR (unit)	LAH/MB ($m^2\ kg^{-1}$)	LAH/MH ($m^2\ kg^{-1}$)	LAH/NH ($m^2\ hand^{-1}$)	LAH/NFR ($m^2\ fruit^{-1}$)
Calipso	8.57 d	163.70 c	0.38 ab	0.44 ab	1.29 a	0.07 a
Bucaneiro	9.03 cd	167.65 c	0.42 a	0.48 a	1.28 a	0.07 a
FHIA-23	14.24 a	273.03 a	0.27 d	0.31 d	0.86 b	0.04 c
FHIA-17	12.91 b	236.57 b	0.30 cd	0.35 cd	0.93 b	0.05 bc
Grande Naine	10.02 c	182.15 c	0.35 bc	0.39 bc	1.07 ab	0.06 b
Mean	10.95	204.62	0.34	0.39	1.09	0.06
CV (%)	7.54	10.04	15.90	16.29	16.77	15.48

[1]Means followed by the same letter in the columns do not differ from each other by Tukey test at 5% significance level.
[2]NH: number of hands; NFR: number of fruits; LAH/MB: ratio between leaf area at harvest and mass of bunch; LAH/MH: ratio between leaf area at harvest and mass of hands; LAH/NH: ratio between leaf area at harvest and number of hands; LAH/NFR: ratio between leaf area at harvest and number of fruits; CV: coefficient of variation.

On the other hand, the lowest values were found in FHIA-23. The cultivars Calipso, Grande Naine and FHIA-17 showed intermediate values (Table 4).

The cultivars that had the highest ratios between leaf area at harvest and number of hands (LAH/NH) were Calipso and Bucaneiro, without differing from Grande Naine, while the lowest mean was found in FHIA-23 (Table 4). The cultivars that had the highest ratios between leaf area at harvest and number of fruits (LAH/NFR) were Bucaneiro and Calipso. The lowest means were observed in FHIA-23 and FHIA-17.

As discussed for the flowering period, the ratios between leaf area and production expressed by mass of bunch, mass of hands, number of hands and number of fruits were higher for the Gros Michel cultivars originated from Jamaica, Bucaneiro and Calipso, as compared to the Gros Michel cultivars from FHIA and to Grande Naine, a Cavendish cultivar. These results illustrate the greater leaf area requirement per unit produced for Bucaneiro and Calipso, which suggests lower photosynthetic efficiency per leaf unit, making it possible to infer that these cultivars are less adapted to the conditions that tend to contribute to the reduction of leaf area, such as intense action of winds, insect attacks and leaf diseases (DONATO et al., 2006a; 2021; FARIA et al., 2010). On the other hand, cultivars with lower values for these ratios, which indicate lower leaf area requirement for production, such as FHIA-23 in most cases, had higher mass of bunches and mass of hands (Table 3) and greater number of hands and fruits (Table 4).

The leaf area index (LAI) of the banana plants varied with the cycle, regardless of the cultivar, showing the highest values in the first cycle (Table 5). It is worth mentioning that the greater the LAI, the lower the cost for controlling invasive plants, because the shading reduces the emergence of weeds (LANZA et al., 2017) and maintains a more favorable microclimate under the canopy of the commercial crop. LAI expresses the ratio between leaf area and the soil area occupied by the crop. LAI represents the photosynthetic efficiency of plants as a conditioning factor for yield and also for growth analysis, because it can be used to define the canopy capacity to intercept solar radiation and convert it into dry matter through photosynthesis, besides determining the production potential of the crop (ZANON et al., 2016). Banana plants usually increase the size, vigor, mass of the bunch, number of hands and number of fruits between the cycles (DONATO et al., 2006b, 2009); however, the LAI often does not differ between cycles or may show a small increment from the first to the second cycle, as observed by Arantes et al. (2017), who studied 24 cultivars of different subgroups and observed

LAI increments in only six cultivars, three of Prata type (BRS-FHIA-18, Maravilha and Prata-Anã) and three of Maçã type (BRS Princesa, BRS Tropical and Maçã).

Table 5 – Leaf area index evaluated in two production cycles, in banana plants of Cavendish and Gros Michel types. Guanambi, BA.

Leaf area index ($m^2 m^{-2}$)	Cycles	
	1st	2nd
	2.69 a	2.45 b
Mean	**2.57**	
CV (%)	**13.86**	

[1]Means followed by the same letter in the column do not differ from each other by F test at 5% significance level. [2]CV: coefficient of variation.

Regarding the physiological characteristics, the data did not show normal distribution and thus were subjected to nonparametric analyses (Tables 6, 7 and 8). Significant variations were observed by the Kruskal-Wallis test at 5% significance level among the banana cultivars of the Cavendish and Gros Michel types for transpiration (*E*), stomatal conductance (g_s), net photosynthesis (*A)* and intrinsic water use efficiency (A/g_s) (Table 6), and between evaluation periods (months) for incident radiation on the leaf (Q_{Leaf}), leaf temperature (T_{Leaf}), internal CO_2 concentration (C_i), *E*, g_s, *A*, A/g_s, instantaneous water use efficiency (*A/E*), carboxylation efficiency (A/C_i) and quantum or photochemical efficiency of photosynthesis (A/Q_{Leaf}) (Table 7); for these same variables, except for Q_{Leaf}, there was variation between reading times by the Wilcoxon test at 5% significance level (Table 8).

As in the present study, Arantes et al. (2016) and Ramos et al. (2018) observed variation in photosynthesis and transpiration rates, independently, with Prata and Maçã cultivars, respectively.

Net photosynthesis rate (*A*) was higher in the cultivar FHIA-17 when compared to Grande Naine, transpiration (*E*) was higher for Calipso than for Grande Naine, and stomatal conductance (g_s) was higher for Calipso and FHIA-17 than for Grande Naine. On the other hand, the cultivar Grande Naine proved to be more efficient in terms of intrinsic water use (A/g_s) when compared to Calipso, Bucaneiro and FHIA-17.

High values of instantaneous water use efficiency recorded for a cultivar may indicate greater tolerance to possible water stresses, or longer irrigation intervals, in addition to higher dry mass production per gram of transpired water (BAPTISTA et al., 2001), when under ideal management conditions. According to Zhengbin et al. (2011), plants with higher water use efficiency are those that show better osmotic adjustments, because they maintain the stability of the plasma membrane and of active antioxidant enzymes, that is, they improve physiological functions, using smaller amounts of water, leading to photosynthetic efficiency and greater dry matter accumulation.

Table 6 - Physiological characteristics evaluated in the third leaf in banana plants of Cavendish and Gros Michel types. Guanambi, BA.

Cultivars	Characteristics			
	E	g_s	*A*	A/g_s
Calipso	6.24 A	0.44 A	18.40 AB	45.20 C
Bucaneiro	5.68 AB	0.39 AB	17.39 AB	48.32 BC
FHIA-23	5.61 AB	0.36 AB	16.42 AB	49.23 ABC
FHIA-17	5.53 AB	0.42 A	18.50 A	47.66 BC
Grande Naine	4.94 B	0.32 B	15.99 B	54.45 A
Mean	5.60	0.39	17.34	48.97
CV (%)	43.39	50.78	34.26	24.83

[1] Means followed by uppercase letters in the columns for cultivars do not differ significantly by Kruskal-Wallis test at 5% significance level.

[2] E- transpiration (mmol H_2O m^{-2} s^{-1}); g_s - stomatal conductance (mol H_2O m^{-2} s^{-1}); A - net photosynthesis (μmol CO_2 m^{-2} s^{-1}); A/g_s - intrinsic water use efficiency ((μmol CO_2 m^{-2} s^{-1})(mol H_2O m^{-2} s^{-1})$^{-1}$); CV: coefficient of variation.

Table 7 - Physiological characteristics evaluated in the third leaf of banana plants of Cavendish and Gros Michel types, at different times. Guanambi, BA.

Months	Characteristics									
	Q_{Leaf}	T_{Leaf}	C_i	E	g_s	A	A/E	A/C_i	A/Q_{Leaf}	A/g_s
Feb.	794.87 C	35.28 BCD	227.44 ABC	4.51 CDE	0.28 D	13.72 D	3.07 CD	0.06 D	0.02 CDE	50.57 A
Mar.	1,223.59 AB	36.28 ABCD	229.55 ABC	5.37 BC	0.45 A	17.39 BCD	3.82 BC	0.07 BCD	0.01 DE	40.33 B
Apr.	1,004.10 BC	34.99 CD	226.27 ABC	3.60 E	0.35 BCD	16.20 CD	5.34 A	0.07 CD	0.02 CDE	51.09 A
May.	1,212.23 AB	35.00 CD	222.01 BCD	5.74 BC	0.39 ABCD	17.44 BCD	3.22 BCD	0.07 BCD	0.01 DE	50.75 A
Jun.	1,503.6 A	34.55 CD	214.23 D	6.87 AB	0.45 A	21.91 A	3.33 BC	0.10 A	0.01 E	50.67 A
Jul.	433.19 D	38.25 A	219.57 CD	7.96 A	0.44 AB	18.33 BC	2.57 D	0.08 BCD	0.12 A	47.67 AB
Aug.	888.97 C	36.09 ABCD	218.18 CD	7.21 AB	0.42 AB	19.86 AB	3.06 CD	0.09 AB	0.09 BC	50.47 A
Sep.	650.50 CD	34.38 D	232.81 A	3.89 DE	0.32 CD	15.27 CD	4.19 ABC	0.06 CD	0.03 C	52.06 A
Oct.	828.70 C	37.83 A	232.90 A	5.25 C	0.39 ABCD	15.93 CD	3.03 CD	0.07 CD	0.02 CD	47.14 AB
Mean	**948.86**	**35.85**	**224.77**	**5.60**	**0.39**	**17.34**	**3.51**	**0.078**	**0.042**	**48.97**
CV(%)	**63.69**	**10.24**	**8.10**	**43.32**	**50.49**	**34.26**	**46.66**	**36.82**	**141.56**	**24.83**

[1]Means followed by uppercase letters, in the rows for months, do not differ significantly by Kruskal-Wallis test at 5% significance level.

[2]Q_{Leaf} - incident radiation on the leaf (µmol photons m^{-2} s^{-1}); T_{Leaf} - leaf temperature (°C); C_i - internal CO_2 concentration (µmol CO_2 mol^{-1}); *E* - transpiration (mmol H_2O m^{-2} s^{-1}); g_s - stomatal conductance (mol H_2O m^{-2} s^{-1}); *A* - net photosynthesis (µmol CO_2 m^{-2} s^{-1}); *A/E* - instantaneous water use efficiency ((µmol CO_2 m^{-2} s^{-1})(mmol H_2O m^{-2} s^{-1})$^{-1}$); A/C_i - carboxylation efficiency ((µmol CO_2 m^{-2} s^{-1})(µmol CO_2 mol^{-1})$^{-1}$); A/Q_{Leaf} - quantum or photochemical efficiency of photosynthesis ((µmol CO_2 m^{-2} s^{-1})(µmol photons m^{-2} s^{-1})$^{-1}$); A/g_s - intrinsic water use efficiency ((µmol CO_2 m^{-2} s^{-1})(mol H_2O m^{-2} s^{-1})$^{-1}$); CV: coefficient of variation.

Table 8 - Physiological characteristics evaluated in the third leaf of banana plants of Cavendish and Gros Michel types, at different times. Guanambi, BA.

Characteristics	Times		Mean	CV (%)	∆(08:00-14:00) (%)
	08:00 h	14:00 h			
T_{Leaf} (°C)	33.60 B	38.10 A	35.85	10.24	13.39
C_i (µmol CO_2 mol^{-1})	222.42 B	227.12 A	224.77	8.10	2.11
E (mmol H_2O m^{-2} s^{-1})	5.15 B	6.05 A	5.60	43.39	17.48
g_s (mol H_2O m^{-2} s^{-1})	0.46 A	0.31 B	0.39	50.26	-32.61
A (µmol CO_2 m^{-2} s^{-1})	20.39 A	14.29 B	17.34	34.26	-29.92
A/E ((µmol CO_2 m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1})$^{-1}$)	4.25 A	2.78 B	3.52	46.59	-34.59
A/C_i ((µmol CO_2 m^{-2} s^{-1}) (µmol CO_2 mol^{-1})$^{-1}$)	0.09 A	0.06 B	0.07	36.92	-30.43
A/Q_{Leaf} (µmol CO_2 $m^{-2}s^{-1}$) (µmol photons m^{-2} s^{-1})$^{-1}$)	0.05 A	0.03 B	0.04	140.48	-40.38
A/g_s ((µmol CO_2 m^{-2} s^{-1}) (mol H_2O m^{-2} s^{-1})$^{-1}$)	47.82 B	50.12 A	48.97	24.83	4.81

[1] Means followed by the letter A are higher and means followed by the letter B are lower and differ significantly at 1% and 5% probability levels by Wilcoxon test; Δ (08:00-14:00), represents the percentage variation of the physiological variable, when comparing the measurements performed at 8:00 h and 14:00 h; (-) represents decreases and (+) represents increases.

[2] T_{Leaf} - leaf temperature; C_i - internal CO_2 concentration; *E* - transpiration; g_s - stomatal conductance; *A* - net photosynthesis; *A/E* – instantaneous water use efficiency; A/C_i – carboxylation efficiency; A/Q_{Leaf} - quantum or photochemical efficiency of photosynthesis; A/g_s - intrinsic water use efficiency; CV: coefficient of variation.

The higher rates of photosynthesis and transpiration may be associated with higher yield, as found by Ramos et al. (2018) for Maçã-type cultivars, or show low correlation (BARRERA-VIOLETH et al., 2020). These variations in the responses are justified because the evaluation of gas exchange is based on the efflux of water and influx of CO_2, which are instantaneous and time-point measurements (ARANTES et al., 2016; 2018; RAMOS et al., 2018).

However, in the present study, the higher transpiration rate of the cultivar Calipso (Table 6), less productive (Table 3), compared to Grande Naine, may result from the larger size of the leaf (Table 3), with a larger area, since Gros Michel banana plants have longer leaves than Grande Naine banana plants (SOTO BALLESTERO, 2008), although this is also dependent on stomatal density (ROBINSON; GALÁN SAÚCO, 2012), because the gas exchange process carried out by the stomata depends on leaf surface and leaf density (SILVERE et al., 2017) and can be affected by environmental factors such as: temperature, CO_2, light intensity, and water availability (MCAINSH; TAYLOR, 2017).

FHIA-17, the cultivar with the second highest yield, had a higher photosynthesis rate, which corroborates the results reported by Ramos et al. (2018). Despite the lower photosynthesis rate recorded for the cultivar Grande Naine, 15.99 µmol CO_2 m^{-2} s^{-1}, the values are compatible with those observed by Barrera-Violeth et al. (2020) for the Williams cultivar, Cavendish type, ranging from 12.07 µmol CO_2 m^{-2} s^{-1} to 23.94 µmol CO_2 m^{-2} s^{-1}, when planting density changed from 3.500 plants ha^{-1} to 2.000 plants ha^{-1} under humid tropical conditions in Colombia.

The highest values of stomatal conductance (g_s) were recorded for the banana cultivars in March, May, June, July, August and October, and the lowest value in February, which did not differ from the values observed in April, May, September and October (Table 7). When comparing the evaluation periods, the g_s measured in banana plants was higher in the morning than in the afternoon (Table 8), a consequence of the higher vapor pressure deficit in the afternoon period (Figure 1C), with values frequently higher than 1.5 kPa. The reduction of g_s between the evaluation periods was 32.61%, from 0.46 mol H_2O m^{-2} s^{-1} to 0.31 mol H_2O m^{-2} s^{-1}; however, transpiration increased 17.47%, which shows a better defense mechanism of the cultivar, because T_{Leaf} increased 13.39%. However, severe reductions of g_s, indicating stomatal closure in banana, are recorded when there is association between water deficit and high VPD, as observed for BRS Princesa banana irrigated with a depth corresponding to 50% of crop evapotranspiration under VPD greater than 1.60 kPa (COELHO et al., 2019), when the reduction of g_s was 89.23%, from 0.52 mol H_2O m^{-2} s^{-1} to 0.056 mol H_2O m^{-2} s^{-1}.

Stomatal conductance is related to water use and net photosynthesis, because with the increments in temperature and vapor pressure deficit (VPDair), in the afternoon, its values decrease, as shown in Figures 1B and 1C, respectively. Cultivars that have stomata with sensitivity to vapor pressure deficit may restrict stomatal opening in the afternoon and, thus, can be considered economical in terms of water and possibly more drought tolerant (TURNER, 2013).

For net photosynthesis rate (*A*), the highest value was recorded in June and did not differ from those recorded in August, while the lowest value was recorded in February, similar to those of March, April, May, September and October (Table 7). Regarding the times, the highest rate was recorded in the morning, with a reduction of 29.91% in the afternoon period (Table 8). This decrease in photosynthesis is more associated with increased leaf temperature, a consequence of air temperature, as proven for Prata-type cultivars (ARANTES et al., 2016), Maçã-type cultivars (RAMOS et al., 2018) and for BRS Princesa (COELHO et al., 2019), which compromises the functioning of the membrane and limits the carboxylase activity of RuBisCO (DONATO et al., 2021), because physiological processes are directly influenced by temperature, and heat stress inhibits photosynthesis due to reduction in RuBisCO activation. Additionally, the photosynthetic process can be favored in the morning, because the predominant radiation at 8:00 h has wavelength within the red and far-red range, thus with better effect on photosynthesis, while the predominant radiation from 10:00 h can cause photoinhibition, because it has a greater amount of energy (DONATO et al., 2016).

According to Table 8, the increase in leaf temperature (T_{Leaf}) from 33.60 °C at 8:00 h to 38.10 °C at 14:00 h, resulting from the increase in air temperature, caused an increase in transpiration (*E*), from 5.15 to 6.05 mmol H_2O m^{-2} s^{-1}, and a decrease in instantaneous water use efficiency (*A/E*), from 4.25 to 2.78 µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}. This mechanism is performed by the banana plant favored by moisture in the soil from irrigation and aims at cooling the plant to reduce thermal stress, even under lower stomatal conductance (g_s). Regarding evaluation periods, transpiration (*E*) was higher in July, with a value of 7.96 mmol H_2O m^{-2} s^{-1}, similar to June and August, and lower in April, 3.60 mmol H_2O m^{-2} s^{-1}, which did not differ from the rates measured in February and September.

The highest leaf temperature (T_{Leaf}) in the banana plants was recorded in July (38.25 °C), which indicates conditions for stomatal closure (ROBINSON; GALÁN SAÚCO, 2012), similar to March, August and October, while the lowest value was observed in September (34.38 °C), similar to February, March, April, May and August (Table 7).

Low leaf temperature in September is unusual for the period, which historically has high temperatures for this month in the study region (DONATO et al., 2016, 2021), and contradicts the air temperature data presented here (Figure 1B). However, it should be noted that IRGA measurements are time-point and vary with the reading time, due to the water and thermal conditions of the soil and atmosphere (ARANTES et al., 2018; RAMOS et al., 2018). The gas exchange values recorded in these months corroborate the arguments of researchers such as Lucena (2013), Santos et al. (2013) and Arantes et al. (2016), who stated that the influence of atmospheric conditions and soil moisture, on the day and time of measurement, may not reflect the history of management to which banana plants are subjected, thus influencing the values of the rates.

Temperature increase accompanied by a decrease in relative humidity characterizes a condition of high atmospheric vapor pressure deficit (VPD = 2.65 kPa), as can be seen in Figures 1B and 1C, respectively, in September, which had the highest average temperature (32 °C) and a major decrease in relative air humidity (RH = 29%), resulting in increased evapotranspiration demand and directly influencing all metabolic and physiological processes of the plant. In this context, it is worth mentioning that in C_3 plants, such as banana, the quantum yield of photosynthesis is high up to close to 30 °C and decreases considerably in places with temperature above 34 °C (ROBINSON; GALÁN SAÚCO, 2012). Increase in temperature combined with low relative humidity is common in the local semi-arid region, conditions of high atmospheric vapor pressure deficit, especially in the months of September, October and February (DONATO et al., 2015; 2021). These conditions illustrated in Figure 1B cause increased evapotranspiration demand and affect all metabolic and physiological processes of the plant, which is confirmed by variations in the physiological characteristics of the banana plants influenced by evaluation periods (Table 7) and reading time (Table 8).

The banana plants had the highest values of internal CO_2 concentration (C_i) in October, with 232.88 µmol CO_2 mol^{-1}, similar to the months of March, April, September and October, while the lowest values were observed in June, with 214.23 µmol CO_2 mol^{-1}, similar to May, July and August (Table 7). According to Arantes et al. (2016), the carbon dioxide (CO_2) concentration in the environment determines the internal CO_2 concentration in the plant, since this gas moves from the most to the least concentrated medium, by diffusion, regulated by stomatal opening and closure, and is also a factor that influences stomatal closure. Higher internal CO_2 concentration (C_i) favors photosynthesis, while lower C_i may change the activity of the RuBisCO enzyme from carboxylase to oxygenase, that is, increasing photorespiration and decreasing net photosynthesis. This is due to the elevated K_m (Michaelis-Menten constant) for the carboxylase activity of RuBisCO, which indicates the need for high concentration of CO_2. However, higher C_i in the afternoon may indicate lower RuBisCO activity, which can be confirmed with the reduction in carboxylation efficiency (Table 8).

The cultivars showed, in June, the highest carboxylation efficiency (*A*/C_i), 1.03 µmol CO_2 m^{-2} s^{-1}/µmol CO_2 mol^{-1}, a value similar to that recorded in August, while the lowest value was observed in February, 0.62 µmol CO_2 m^{-2} s^{-1}/µmol CO_2 mol^{-1}, similar to those of March, April, May, July, September and October (Table 7).

In the afternoon evaluation, there was a 30.43% reduction in *A*/C_i, possibly due to the increase in leaf temperature (T_{Leaf}) of the banana plants (Table 8), which can cause an increase in photorespiration rates and in the oxygenase activity of RuBisCO, consequently reducing ATP synthesis. Under ambient CO_2 concentration, the increase in temperature modifies RuBisCO kinetic constants, increases the rate of oxygenation, to the detriment of carboxylation, and increases photorespiration, reducing the net photosynthesis rate (TAIZ et al., 2017).

The banana plants showed significant variation in instantaneous water use efficiency (*A/E*) between the months (Table 7) and the times (Table 8) evaluated. The highest value for *A/E* was obtained in April, 5.34 µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}, similar to that recorded in September, while the lowest value was observed in July, 2.57 µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}, similar to those recorded in February, March, August and October (Table 7). Regarding the reading times, *A/E* decreased 34.58% from 8:00 h to 14:00 h, indicating a sharp reduction in the photosynthesis rate, since transpiration increased (Table 8), corroborating the results found by Arantes et al. (2016), Ramos et al (2018) and Coelho et al. (2019).

The highest intrinsic water use efficiency (*A*/g_s), 52.06 µmol CO_2 m^{-2} s^{-1}/mol H_2O m^{-2} s^{-1}, was found in September, which differed only from March, with the lowest value, 40.33 µmol CO_2 m^{-2} s^{-1}/mol H_2O m^{-2} s^{-1}, similar to July and October (Table 7). On the other hand, *A*/g_s showed a slight increase, 4.80%, from 8:00 h to 14:00 h, illustrating a gain in photosynthetic efficiency with the reduction of g_s and being little affected by temperature, corroborating the results found by Lucena (2013).

Regarding the quantum or photochemical efficiency of photosynthesis (*A*/Q_{Leaf}), the banana plants had the highest means in July, 1.24 µmol CO_2 m^{-2} s^{-1}/µmol photons m^{-2} s^{-1}, and the lowest values in June, 0.15 µmol CO_2 m^{-2} s^{-1}/µmol photons m^{-2} s^{-1}, which did not differ from the values recorded in February, March, April and May (Table 7). Regarding reading times, there was a 40.38% reduction in *A*/Q_{Leaf} (Table 8), probably due to radiation quality, which results in a greater amount of unusable energy, favoring non-photochemical dissipation (TAIZ et al., 2017).

According to Turner et al. (2007), the incident radiation on the leaf (Q_{Leaf}) recommended for the highest photosynthetic efficiency of banana is between 1,500 and 2,000 µmol photons m^{-2} s^{-1}. However, a mean within this range was recorded in the leaves of the cultivars only in one period in the present experiment, in June, with 1,503.6 µmol photons m^{-2} s^{-1}, an atypical value for the period, which is characterized by milder temperatures, and this Q_{Leaf} value did not differ from those measured in March and May (Table 7). On the other hand, the lowest Q_{Leaf} value was observed in July, only 433.19 µmol photons m^{-2} s^{-1}, not differing from the value recorded in September, which may be a consequence of the moment of the measurement, because IRGA measurements are time-point (SANTOS et al., 2013).

Conclusions

The cultivars Bucaneiro and Calipso require larger leaf area per unit produced and FHIA-23, smaller, which suggests higher photosynthetic efficiency per leaf unit for FHIA-23, confirmed by the higher masses of bunches and hands and greater numbers of hands and fruits.

Gas exchange varies with cultivars, evaluation periods and reading times.

The cultivars FHIA-17 and Calipso, Gros Michel type, respectively showed higher photosynthesis and transpiration rates than Grande Naine, Cavendish type.

Net photosynthesis, stomatal conductance, quantum efficiency of photosynthesis, instantaneous water use efficiency and carboxylation efficiency are higher at 8:00 h than at 14:00 h.

The month of June allowed the cultivars to express the highest values of photosynthesis rate, carboxylation efficiency and stomatal conductance.

Acknowledgments

To the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001 and to the National Council for Scientific and Technological Development – CNPq.

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