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Gas exchange in yellow passion fruit hybrids in the Semiarid region

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Abstract
Agronomic characterization and exploitation of the genetic variability in plants of the *Passiflora* can reveal important genetic resources because the *Passiflora* species grown under semiarid conditions make important contributions to breeding. The aim of this work was to evaluate the vegetative and physiological characteristics of fifteen yellow passion fruit hybrids in semiarid conditions. The experiment was conducted at IF Baiano – campus Guanambi, Bahia, Brazil. The 15 treatments were 10 genotypes: H09-10; GP09-02; H09-02; H09-14; H09-07; H09-09; FOP09; GP09-03; H09-30; FOP08 from the Active Germplasm Bank of the Genetic Breeding Program of Embrapa Cassava and Fruits, and five commercial hybrids: FB200; FB300; BRS SC; BRGA; BRS Rubi. The treatments were arranged in a randomized block design, with three replications and five observational units per plot. Vegetative characteristics (main branch length, number of functional leaves, number of nodes, and number of flower buds) were measured at full vegetative development, 90 days after transplanting (DAT). Hybrid H09-10 is the earliest in flowering, physiologically more efficient in the morning, closes stomata in the afternoon, regulates transpiration, and has lower leaf temperature, higher photosynthesis rate, and more efficient water use. Gas exchanges and photosynthesis rates, at 300 DAT, vary between hybrids and reading times: photosynthesis is higher in the morning while transpiration is greater in the afternoon. The reduction in carboxylation efficiency is related to non-stomatal factors. Gas exchange variables of the genotypes tend to be directly correlated with the photosynthetically active radiation incident on the leaf.
Keywords: genotypes, *Passiflora edulis.*, photosynthesis, stomatal conductance

Introduction

Yellow passion fruit (*Passiflora edulis* Sims) is the most cultivated species of the Passifloraceae family in the world, comprising more than 95% of Brazilian passion fruit growing areas, especially in tropical and subtropical regions, due to high fruit quality, vigor, productivity, and juice yield (Diniz et al., 2022). The Brazilian Northeast accounts for 70% of the national passion fruit production, creating jobs and income, mainly for smallholders and family farms (IBGE, 2022). However, the productive yield can be affected by climatic conditions of the semiarid region.

The characterization and exploitation of the genetic variability of the genus *Passiflora* can reveal important genetic resources because uncommercial species make important contributions to breeding. Improved genotypes offer, among other unexplored qualities, resistance to pests, productive longevity, greater adaptation to environmental conditions, extended flowering and greater concentration of chemical components that are attractive to the cosmetics and pharmaceutical industries (Santos-Jiménez et al., 2022).

Vegetative characteristics, cycle duration and productivity of cultivars in highly technological systems, either outdoor or indoor, draw the interest of farmers about effective management techniques and development of suitable cultivars (Souza et al., 2022). To meet this demand, the genetic breeding programs for the passion fruit crop at the Brazilian Agricultural Research Corporation (EMBRAPA) – Cassava and Fruits, aims to obtain more productive and disease-resistant hybrids. However, evaluating hybrids can be time-consuming and expensive. Reducing the evaluation period without compromising the reliability of the information is imperative for growers (Zhao et al., 2022).

Exploring the physiological behavior, depending

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on the genetic identity of the yellow passion fruit cultivated in the Semiarid region, furthers the understanding to guide and optimize breeding programs and crop management in the Brazilian Northeast, aiming at technological and scientific advances in commercial fruit growing, which reflects in productivity and fruit quality. This work aimed to evaluate the vegetative and physiological characteristics of 15 yellow passion fruit hybrids in semiarid conditions.

Material and Methods

The experiment was carried out in the field, in the Agriculture Sector of the Federal Institute of Education, Science and Technology Baiano - campus Guanambi, located in the Ceraíma district, Guanambi, Bahia state, Brazil (14°17'32" S, 42°41'34" W). Samples of the Red-Yellow Latosol, with medium texture, were analyzed at a depth of 0-0.20 m and 0.20-0.40 m, by the Soil Laboratory of Epamig North (**Table 1**). The soil shows base saturation that characterizes it as eutrophic in the depth of 0-0.20 m and dystrophic in the layer of 0.20-0.40 m.

Seedlings of yellow passion fruit were planted in December at spacing of 2.5 m x 2.0 m, under cultural practices for semiarid conditions (Figueiredo et al., 2020; Paiva et al., 2021; Vaz et al., 2022). Drip irrigation was scheduled based on the reference evapotranspiration (ETo) of the crop, determined by the Penman-Monteith method (Pinheiro et al., 2022).

The 15 treatments, 10 hybrids: H09-10; GP09-02; H09-02; H09-14; H09-07; H09-09; FOP09; GP09-03; H09-30; FOP08 from the Active Germplasm Bank of the Genetic Breeding Program of Embrapa Cassava and Fruits, and the five commercial hybrids: FB200; FB300; BRS SC; BRS GA; BRS Rubi, were arranged in a randomized block design, with three replications and five observational plants per plot.

The vegetative characteristics, main branch length, number of functional leaves (with 50% of the blade open and intact), number of nodes, and number of flower buds were measured at full vegetative development, 90 days after transplanting (DAT).

When evaluating gas exchanges, at 90 DAT, a completely randomized design was used, with treatments arranged in a factorial scheme (15x2), with 15 treatments, referring to the hybrids, and two evaluation times, at 08:00 and 14:00, three replications, and one observational plant per plot. At 300 DAT, the evaluations were at 08:00, 10:00, 12:00, 14:00, and 16:00. The gas exchange analyses were carried out using an 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} and always with

Table 1. Analytical result of soil sampling in the area prepared for the cultivation of yellow passion fruit, from collection at depths of 0-0.20 m and 0.20-0.40 m

Depth (m)	pH	P	Cu	Fe	Zn	Mn	K	Na	Ca	Mg	Al
	H_2O			mg dm^{-3}					cmolc dm^{-3}		
0-0.20	6.7	125	-	12.26	4.23	78.89	0.51	0.15	3.45	1,54	0.0
0.20-0.40	7.22	22	3.83	15.52	0.66	38.17	0.38	0.15	2.38	0,97	0.0

Depth (m)	Ca+Mg	H+Al	SB	BS	O.M.
		cmolc dm^{-3}		%	g kg^{-1}
0-0.20	4.99	0.22	5.65	78.89	9.0
0.20-0.40	3.35	0.0	3.89	38.17	4.0

Source: Epamig North Soil Laboratory.

the radiation shield facing the sun. Either the 3rd or 5th leaf was evaluated, as long as they were fully expanded, resulting in the following measurements: incident radiation on the leaf (Q_{leaf}) expressed in μmol photons m^{-2} s^{-1}; leaf temperature (T_{leaf}), °C; internal CO_2 concentration (C_i), μmol CO_2 mol^{-1}; transpiration (E), mmol H_2O m^{-2} s^{-1}; stomatal conductance (g_s), mol 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}; quantum or photochemical efficiency of photosynthesis (A/Q_{leaf}), μmol CO_2 m^{-2} s^{-1}/μmol photons m^{-2} s^{-1}; carboxylation efficiency (A/C_i), μmol CO_2 m^{-2} s^{-1}/μmol CO_2 mol^{-1}.

The data were submitted to analysis of variance and the interactions were further studied according to the significance. The means of the two reading times were compared by the F test (p≤0.05) and the means of the hybrids grouped by the Scott-Knott method (p≤0.05). Therefore, regressions between Q_{leaf} and other physiological variables are presented.

At the time of conducting the experiment, the automatic meteorological station Vantage Pro Integradet Sensor® (Davis Instruments, Wayward, CA, USA) recorded relative humidity at 63.08%, mean daily reference evapotranspiration (ET_o) of 6.50 mm day^{-1}, mean daily insolation of 8.09 h day^{-1}, and mean wind speed of 2.60 m s^{-1} (**Figure 1**).

Results and Discussion

The morpho-vegetative characteristics of the 15 hybrids of yellow passion fruit: main branch length (MBL), number of leaves (NL), number of nodes (NN) and number of flower buds (NFB), at 90 DAT, according to the Scott-Knott criterion (p<0.05), demonstrate that the hybrids varied among themselves as to MBL by 41.75%, forming three groups. The hybrids that showed the greatest branch length were H09-09, FOP09, GP09-03, FB200, H09-30, and FOP08; and the smallest length was observed in GP09-02, BRS Rubi and BRS SC (**Table 2**).

No direct relationship was found between NFL, MBL, and NL. For the number of functional leaves, which directly influences the photosynthetic capacity of the plant, the hybrids showed a small percentage variation of 29.60%, with the formation of only two groups. The first group, with the highest number of leaves, were composed of the hybrids H09-02, H09-07, BRS G.A, H09-09, BRS Rubi, GP09-03, FB200, H09-30 and FB300. Meanwhile, the smallest group was formed by hybrids H09-10, GP09-02, H09-14, FOP-09, BRS SC and FOP-08.

Plant morphology determines leaf gas exchange and water status of yellow passion fruit, and can be altered depending on environmental conditions, influencing hormonal balance. A reduction in stomatal conductance, for example, can affect the initial growth of passion fruit, causing a negative effect on development and biomass accumulation. Changes in leaf morphology, such as increased leaf blade thickness with palisade parenchyma, are related to increased photosynthetic capacity of the crop, due to the optimization of stomatal closure mechanisms under water restriction (Silva et al., 2022; Wang et al., 2022).

There was a small percentage variation (33%) in the number of nodes registered in the yellow passion fruit hybrids, with the formation of two groups. Hybrids H09-10, H09-02, H09-14, H09-07, BRS GA, H09-09, GP09-03, FB200, H09-30, FOP-08 and FB300 exhibited a greater number of nodes, and the opposite occurred in the group composed of the hybrids BRS SC, FOP-09, BRS Rubi, and GP09-02. Then, the highest percentage variation was observed in the number of flower buds, in which the H09-10 genotype was the most precocious by showing the highest number

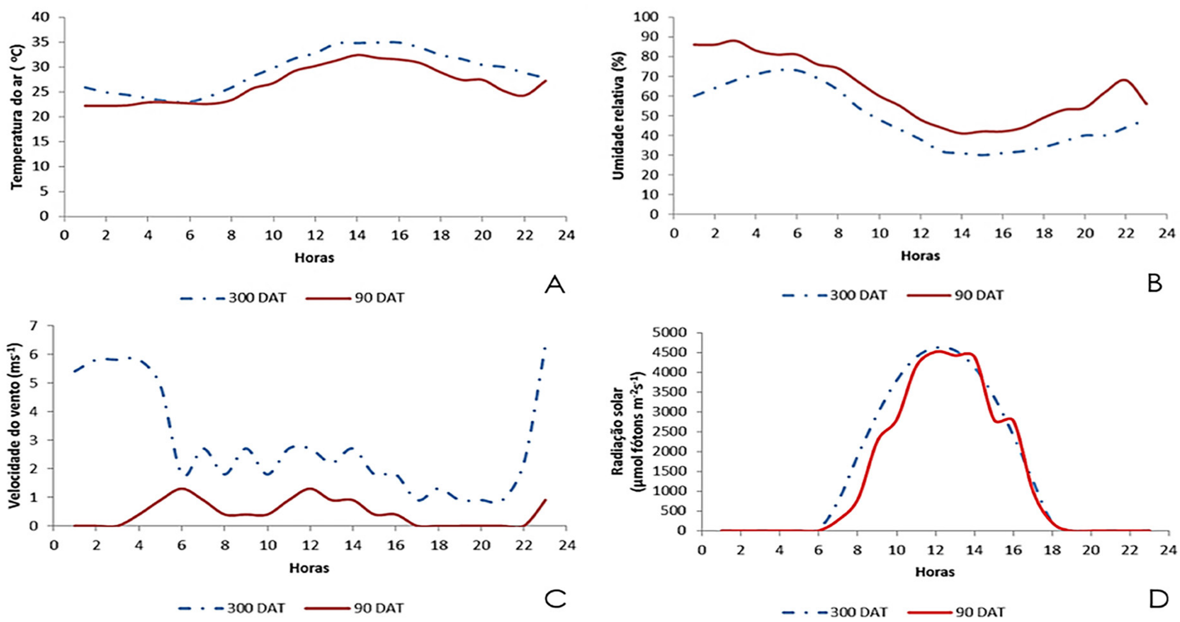

Figure 1. Hourly course of meteorological data, recorded by the Vantage Pro Integrated Sensor® automatic station installed in the experimental area of yellow passion fruit cultivation, at the time of physiological measurements, at 90 and 300 days after transplanting (DAT). Guanambi, Bahia, Brazil. Note: Air temperature (°C) – A; Relative humidity (%) – B; Wind speed (m s-1) – C; Solar radiation (µmol photons m-2 s-1) – D.
Source: Elaborated by the author, with original research results

Table 2. Main branch length (MBL) (cm); number of leaves (NL); number of nodes (NN); number of flower buds (NFB) at 90 days after transplanting, in yellow passion fruit hybrids cultivated in the semiarid region. Guanambi, Bahia, Brazil

Hybrids	Variables			
	MBL (cm)	NL	NN	NFB
H09-10	160.73 B	20.20 B	31.44 A	7.93 A
GP09-02	131.22 C	17.84 B	26.40 B	2.82 C
H09-02	153.00 B	22.91 A	30.22 A	3.67 C
H09-14	160.15 B	20.15 B	29.86 A	5.87 B
H09-07	158.36 B	21.96 A	32.03 A	3.10 C
BRS GA	160.23 B	21.07 A	30.23 A	1.60 D
H09-09	170.35 A	22.62 A	30.07 A	3.25 C
BRS Rubi	146.57 C	20.88 A	26.89 B	0.73 D
FOP-09	173.41 A	19.19 B	27.48 B	2.38 D
GP09-03	182.16 A	22.17 A	32. 87 A	1.98 D
FB200	173.41 A	23.12 A	33.48 A	3.96 C
BRS SC	139.52 C	18.18 B	25.17 B	1.30 D
H09-30	186.00 A	21.22 A	30.75 A	5.40 B
FOP-08	176.80 A	20.37 B	33.34 A	3.80 C
FB300	162.20 B	20.81 A	30.32 A	1.83 D
CV (%)	14.87	15.42	12.34	64.62

Means followed by the same letters in the column belong to the same groupings by the Scott-Knott criterion ($p \leq 0.05$).

of flower buds at 90 DAT; while BRS GA, BRS Rubi, GP09-03, FOP-09, FB300 and BRS SC were flowered later, with less occurrence of flower buds.

The phenological cycle can vary in different periods, in the same time interval, given that solar radiation, temperature, rainfall and relative humidity are limiting factors for the phenological development of the species. Variations in the phenological cycle and flowering peaks can occur for the same genotype in different environments or between genotypes within the same environment, as shown in this study. This result suggests a potential for cultivation of different species of the genus *Passiflora*, so that the grower has regularity of production throughout the year, even in regions where there is an off-season, such as in the semiarid region (Silva et al., 2022; Muñoz-Ordoñez et al., 2023).

Air temperature (°C) and wind speed (m s^{-1}) were higher at 300 DAT, and relative air humidity (%) was lower, when compared to the readings made at 90 DAT (Figure 1). The combination of climatic stress inducers in October, with high temperatures and low relative humidity, characterizes the period (300 DAT) as a critical period, immediately preceding the rains in the semiarid region. Solar radiation at 90 DAT was oscillating throughout the day, with interference from cloudiness at the end of the rainy season. The frequency of climate and meteorological changes in the semiarid region, such as atmospheric dryness, impacts the development and productivity of plants, especially those with C3 metabolism (Silva et al., 2021; Sonmez et al., 2022; Pinheiro et al., 2023).

In the region, solar radiation and air temperature are higher in the afternoon. With the increase in vapor pressure deficit, plants close the stomata to prevent the loss of water to the environment, but it reduces the entry of CO_2 into the substomatal chamber, compromising the carboxylation efficiency, resulting in higher transpiration rate, lower photosynthetic rate, and higher water use efficiency in the afternoon (Pinheiro et al., 2022; França et al., 2023). The behavior was observed in banana plants grown in the same location and may be related to the typical climate of the semiarid region: high temperatures combined with low relative humidity, a combination favorable to the high deficit of atmospheric vapor pressure (Arantes et al., 2018; Lage et al., 2020; Souto et al., 2022; Donato et al., 2023).

Although the measurement of gas exchange is an instantaneous, non-destructive and high-precision procedure to characterize the physiological behavior (Arantes et al., 2018), essential for breeding programs, measurements can vary depending on soil moisture and atmospheric characteristics (Donato et al., 2023). Gas exchange measurements may not reflect the management history because passion fruit leaf gas exchange is susceptible to factors such as salinity, drought, soil and air humidity, nutrition, and interaction with microorganisms (Paiva et al., 2021; Teixeira et al., 2021).

Transpiration (*E*), photosynthesis (*A*) and stomatal conductance (g_s), measured in yellow passion fruit at 90 DAT exhibited variation resulting from a significant interaction ($p<0.05$) between passion fruit hybrids and evaluation times (**Table 3**). Similar behavior was observed for photosynthetically active radiation (Q_{leaf}), leaf temperature (T_{leaf}), internal CO_2 concentration (C_i) and instantaneous water use efficiency – iWUE (A/E). These variables showed differences between the hybrids with the formation of at least three groups.

Transpiration was higher in the afternoon and lower in the morning, except for the hybrid H09-10, which recorded the lowest value, and H09-07, which did not differ (Table 3). The variation between the hybrids was greater in the afternoon, with the formation of eight groups, and smaller at 8 am, with four groups. The increase in transpiration in the afternoon, for most hybrids, reflects the plant's strategy for leaf cooling through the loss of latent heat and consequent reduction in Rubisco oxygenase activity and maintenance of photosynthetic rates, despite the higher Q_{leaf} (Taiz et al., 2017).

The hybrids showed greater variation in stomatal conductance in the afternoon, forming six groups, and

Table 3. Physiological characteristics evaluated in yellow passion fruit hybrids cultivated in the semiarid region, 90 days after transplanting, at two evaluation times. Guanambi, Bahia, Brazil

Hybrids	E		g_s		A		Q_{leaf}		T_{leaf}		C_i		A/E	
	8 am	2 pm	8 am	2 pm	8 am	2 pm	8 am	2 pm	8 am	2 pm	8 am	2 pm	8 am	2 pm
H09-10	3.82Da	2.20Hb	0.44Ca	0.12Fb	24.68Aa	9.00Hb	873.66Db	1749.00Ba	29.93Kb	31.90Ma	231.66Cb	254.66Ba	6.45Aa	4.09Ab
H09-07	3.64Da	3.98Ha	0.37Da	0.28Eb	16.02Gb	16.77Ba	743.33Db	1821.00Ba	30.30Jb	33.16La	275.00Aa	243.33Bb	4.39Da	4.23Ab
H09-14	4.30Cb	5.76Fa	0.44Ca	0.43Ca	23.62Ba	16.75Bb	1237.33Bb	1755.33Ba	31.23Ib	35.13Ka	232.00Cb	270.33Aa	5.49Ba	2.90Bb
BRS GA	4.50Cb	7.05Ea	0.43Cb	0.50Ba	18.44Fa	15.43Cb	1207.33Bb	1480.00Ca	31.96Hb	36.20Ja	262.00Bb	282.66Aa	4.10Ea	2.18Cb
H09-09	4.67Cb	8.53Ca	0.40Cb	0.64Aa	19.47Ea	16.86Bb	1567.00Ab	1842.66Ba	32.60Gb	37.56Ia	247.00Bb	279.33Aa	4.16Ea	1.97Cb
FOP-09	5.20Ba	5.23Ga	0.50Ba	0.18Fb	25.01Aa	9.32Hb	1585.00Ab	1990.66Aa	32.90Fb	38.50Ga	225.33Db	255.66Ba	4.81Ca	1.78Db
GP09-03	5.38Bb	5.87Fa	0.48Ba	0.23Eb	22.00Ca	11.27Gb	1609.66Aa	711.33Db	33.23Db	38.13Ha	241.00Cb	252.33Ba	4.09Ea	1.92Cb
BRS SC	5.95Ab	6.65Ea	0.66Aa	0.25Eb	23.38Ba	14.74Db	1241.33Bb	1923.33Aa	33.03Eb	39.10Fa	251.66Ba	224.33Cb	3.92Ea	2.21Cb
FB200	5.41Bb	10.19Ba	0.53Bb	0.60Aa	25.15Aa	20.12Ab	1073.00Cb	1766.00Ba	32.93Fb	39.56Ea	226.00Db	248.00Ba	4.65Ca	1.97Cb
BRS Rubi	5.12Bb	7.70Da	0.47Ba	0.28Eb	24.80Aa	12.86Fb	1230.66Bb	1982.66Aa	33.26Db	40.16Da	216.66Db	246.00Ba	4.85Ca	1.67Db
FB300	5.14Bb	8.34Ca	0.32Da	0.30Ea	14.71Ha	13.62Eb	1433.33Ab	1773.00Ba	34.46Cb	40.56Ca	256.33Ba	242.67Bb	2.86Ga	1.63Db
H09-02	5.54Bb	10.90Aa	0.43Ca	0.45Ca	21.98Ca	16.88Bb	1194.33Bb	2006.00Aa	34.36Cb	41.90Aa	222.00Db	243.00Ba	3.97Ea	1.55Eb
FOP-08	5.79Ab	11.10Aa	0.41Cb	0.50Ba	20.78Da	16.60Bb	1313.00Bb	1573.00Ca	34.63Db	41.46Ba	227.00Db	252.33Ba	3.58Fa	1.49Eb
H09-30	5.22Bb	8.34Ca	0.35Da	0.27Eb	17.95Fa	10.90Gb	1375.33Ba	1398.00Ca	34.86Ab	41.33Ba	233.00Cb	255.00Ba	3.44Fa	1.30Eb
GP09-02	6.01Ab	9.89Ba	0.39Ca	0.38Da	18.33Fa	17.00Bb	1389.00Ba	1582.33Ca	34.96Ab	41.53Ba	240.00Ca	230.00Ca	3.04Ga	1.72Db
CV (%)	6.74		14.66		2.20		17.21		0.79		4.96		8.51	

Means followed by the same letter, uppercase in the column, belong to the same grouping by the Scott-Knott criterion ($p<0.05$) and lowercase in the rows, do not differ significantly by the F test ($p<0.05$).

four in the morning. Most plants, in the afternoon, reduced or maintained the stomatal conductance observed at 8:00 pm, except for the hybrids BRS GA, H09-09, FB200, H09-02 and FOP-08 (Table 3).

Plants with C3 metabolism, such as yellow passion fruit, have photosynthetic rates between 10 and 30 μmol of CO_2 m^{-2} s^{-1}. With the exception of the values obtained in hybrids H09-10 (9.0 μmol of CO_2 m^{-2} s^{-1}) and FOP-09 (9.32 μmol of CO_2 m^{-2} s^{-1}) at 2 pm, all other values related to photosynthetic rates for the passion fruit plant fit this reference (Pinheiro et al., 2023).

For photosynthetically active radiation, therefore, four groups were formed for the two evaluation times, with a percentage difference of 116.54% for the morning and 182% for the afternoon. The variable, when less than 1,000 μmol photons m^{-2} s^{-1}, did not influence negatively photosynthesis rate of the hybrid H09-10 in the morning, showing the greater photochemical efficiency of the genotype. Conversely, the higher Q_{leaf}, observed in the hybrid H09-02 at the second evaluation time, did not promote an increase in net photosynthesis rates, at 90 DAT, showing a saturation of photosynthesis by light (Pinheiro et al., 2022).

High radiation and temperature may have favored the increase in gas exchange, while the increase in stomatal conductance contributed to higher values of net photosynthesis of the hybrids at both times. The predominant radiation at 8 am has a wavelength in the red and far-red band and tends to favor the photosynthetic process. In contrast, radiation after 10 am has a higher amount of energy, potentially causing photoinhibition (Arantes et al., 2018; Araújo et al., 2022; Kabir et al., 2023).

Leaf temperature was the physiological characteristic with the greatest variation among hybrids, forming 11 groups at 8 am and 13 groups at 2 pm. The highest T_{leaf} measured on the first time can be attributed to the rise in air temperature and the predominance of higher energy radiation, typical of mornings in the semiarid region, compromising the functioning of the enzymatic system to a greater extent than stomatal closure. The transpiration rate increased at 2 pm, except for the hybrid H09-10, with lower T_{leaf} at both times, indicating greater leaf cooling capacity (Wang et al., 2022; Münchinger et al., 2023). In any case, there was stomatal restriction proven by the drop in stomatal conductance.

Temperature influences all metabolic activity: rates close to the optimum for the species favor the enzymatic processing of CO_2 carboxylation, increase net photosynthesis rates, and consequently decrease the internal CO_2 concentration. High temperatures can trigger oxidative stress in plants by increasing the production of reactive oxygen species, as a form of protection, the plant can increase the production of enzymes, non-enzymatic compounds, antioxidants and hormones to act in the oxidant balance, to minimize the effects of stress (Pinheiro et al., 2022).

In the semiarid region, passion fruit trees subjected to high temperatures can experience stress characterized by sudden triggering of the denaturation of enzymes that process CO_2. On the other hand, protein instability is detected, severely reducing photosynthetic performance, unbalancing respiratory rates, causing damage to molecular structures and changes in the activity of the Rubisco enzyme, which can activate photorespiration, with conversion of carboxylase to oxygenase, and reduce net photosynthesis. Consequently, this leads to scorching of the leaf blade and a drastic drop in production, due to the abortion of flower buds (Araújo et al., 2022; Lima et al., 2023).

The hybrids showed small variations in internal CO_2 concentration (C_i), forming four groups at 8 am and three groups at 2 pm. Higher concentration is inherent to the greater or lesser degree of stomatal opening in plants and to the efficiency of carbon use, as CO_2 moves by diffusion, from the most concentrated to the least concentrated medium, regulated by stomatal opening/closing. In the semiarid region, stomatal conductance, root dry mass and photosynthetic rate of yellow passion fruit plants tend to decrease, without detecting a reduction in leaf water potential, when subjected to suboptimal water conditions (Figueiredo et al., 2020; Araújo et al., 2022; Pinheiro et al., 2022).

There is a direct relationship between CO_2 in the environment and the photosynthetic rate of C3-type plants; that is, when the CO_2 existing in the environment is taken up by the plants, there is a significant increase in the photosynthetic rate, due to the activity of the carbon-fixing enzyme, Rubisco, which is capable of concentrating most of this gas in the active site. However, high concentrations of CO_2 induce stomatal closure, reducing gas exchange, water use efficiency and, therefore, the photosynthetic rate (Araújo et al., 2022).

The relationships between the physiological variables are of great importance when elucidating the behavior of the plant subjected to the biotic and abiotic stresses caused by semiarid climate. In this case, for the *A*/*E* ratio, all hybrids showed higher values at 8 am, compared with 2 pm, proving that the best environmental conditions, in this season of the year, occur in the morning. The *A*/*E* ratio can be used to select more drought tolerant hybrids. In this case, the evaluations at both times revealed a percentage variation of 396.15%. Hybrid H09-10, together with H09-07, was the most efficient in the morning and afternoon. The instantaneous water use efficiency, as well as photosynthesis, decreased with increasing temperature, while transpiration increased.

At 300 DAT, the physiological characteristics showed variation resulting from the interaction between the hybrids and the evaluation times (**Table 4**). It is indicated that transpiration rates (*E*) were high for most hybrids in the afternoon. There is a direct linear relationship between leaf temperature and transpiration (Arantes et al., 2018; Lage et al., 2020). There was greater variation between the hybrids at noon and in the afternoon, with the formation of a greater number of clusters, whereas the smallest variation was observed at 8 am, forming four groups. Transpiration rates ranged from the lowest value, 0.83 mmol H_2O m^{-2} s^{-1}, recorded on the FB200 at 4 pm, to the highest value, 8.99 mmol H_2O m^{-2} s^{-1}, for the GP09-03 genotype at 12 pm, with variation percentage of 983%, considering all hybrids and all reading times.

The increase in air temperature during the morning is the result from increased transpiration, decreasing water use efficiency. It should be noted that, under natural conditions, as the temperature rises, the relative humidity of the air decreases and the responses of the various metabolic processes of plants reflect on the interaction between these factors.

For most hybrids, the lowest transpiration rates (*E*) were observed at 4 pm, where the reduced conductance values (g_s) explain the result of stomatal closure, due to the greater vapor pressure deficit (Souto et al., 2022). This variation allowed the formation of four groups in the morning and eight groups in the afternoon, according to the Scott-Knott criterion, which determined that the H09-10 genotype was the only one that reduced transpiration in the morning, due to the stomatal closure evidenced by the reduction of conductance (g_s). Such variations reflect the high evaporative demand of the atmosphere. Water loss by plants is regulated by the activity of guard cells. The increase in transpiration during the day is mainly due to the inability of some plants to absorb enough water to replace that consumed in the transpiration process (Pinheiro et al., 2022).

Stomatal conductance is related to water use and net photosynthesis: the higher the stomatal conductance, the higher the photosynthetic rates. The reduction, in most hybrids, in the afternoon period compared to the morning period, does not seem to be enough to reduce transpiration, except in the hybrid H09-10, whose photosynthetic and transpiration rates were lower at 2 pm. The hybrids showed a percentage variation in the photosynthesis values of 179%, at both times.

Table 4. Physiological characteristics evaluated in yellow passion fruit hybrids cultivated in the semiarid region, 300 days after transplanting, in four evaluation times. Guanambi, Bahia, Brazil

Hybrids	*E*					g_s					*A*				
	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm
H09-10	4.00 Da	3.92 Ea	2.31 Gb	1.10 Gc	1.72 Gbc	0.21 Ea	0.22 Ca	0.08 Eb	0.03 Dc	0.06 Cbc	16.94 Da	15.35 Ab	6.23 Fc	2.43 Hd	5.53 Fc
H09-07	4.55 Cab	4.26 Dab	4.79 Da	4.09 Dab	4.03 Cb	0.27 Ca	0.22 Cb	0.17 Bc	0.14 Ac	0.02 Ac	22.06 Aa	14.16 Bb	11.39 Bc	9.53 Bd	9.06 Ad
H09-14	4.17 Da	2.56 Fbc	2.96 Fb	1.18 Gd	2.09 Fc	0.20 Ea	0.08 Fb	0.08 Eb	0.03 Dc	0.06 Cb	16.50 Da	5.45 Ib	5.19 Gb	1.98 Hc	4.78 Gb
BRS GA	5.43 Ba	5.35 Ca	4.42 Eb	1.44 Gc	3.51 Dd	0.30 Ca	0.23 Cb	0.11 Dc	0.03 Dd	0.11 Bc	20.91 Ba	14.29 Bb	7.22 Ec	2.27 Hd	7.02 Dc
H09-09	6.14 Ab	6.54 Bb	8.54 Aa	4.86 Cc	3.95 Cd	0.38 Aa	0.31 Ab	0.28 Ab	0.13 Ac	0.11 Bc	22.45 Aa	13.48 Cb	13.34 Ab	7.86 Cc	7.57 Cc
FOP-09	3.70 Dab	4.40 Da	3.90 Eab	3.33 Eb	1.49 Gc	0.14 Fa	0.13 Ea	0.08 Eb	0.07 Cbc	0.03 Dc	12.88 Ga	8.37 Gb	6.03 Fc	4.69 Gd	3.06 He
GP09-03	5.78 Bb	5.01 Cc	8.99 Aa	6.35 Ab	4.81 Bc	0.28 Ca	0.16 Eb	0.27 Aa	0.16 Ab	0.13 Bb	18.10 Ca	10.43 Fc	13.21 Ab	10.39 Ac	6.80 Dd
BRS SC	3.75 Db	3.06 Fb	2.07 Gc	6.26 Aa	1.16 Hd	0.13 Fa	0.08 Fb	0.03 Fbc	0.15 Aa	0.02 Dc	10.63 Ia	5.34 Ic	3.50 Id	8.21 Cb	1.76 Ie
FB200	4.10 Da	3.73 Ea	2.12 Gb	1.87 Fb	0.83 Hc	0.15 Fa	0.10 Fb	0.04 Fc	0.03 Dc	0.02 Dc	12.20 Ha	7.63 Hb	2.90 Jc	2.16 Hcd	1.49 Id
BRS Rubi	4.43 Cb	6.83 Ba	3.45 Fc	4.63 Cb	3.48 Dc	0.16 Fb	0.25 Ba	0.06 Fc	0.09 Bc	0.08 Cc	10.31 Ib	11.46 Ea	4.38 Hd	5.74 Ec	5.62 Fc
FB300	6.10 Ab	7.87 Aa	5.11 Dc	3.47 Ed	5.98 Ab	0.31 Ca	0.32 Aa	0.10 Dc	0.06 Cd	0.02 Ab	16.19 Ea	14.45 Bb	7.28 Ed	5.16 Fe	8.98 Ac
H09-02	5.66 Bb	6.83 Ba	6.79 Ba	5.50 Bb	2.88 Ec	0.24 Da	0.26 Ba	0.16 Bb	0.10 Bc	0.06 Cd	15.94 Ea	12.83 Db	8.94 Cc	7.48 Dd	4.74 Ge
FOP-08	4.97 Cbc	5.70 Cab	4.39 Ec	5.87 Ba	2.84 Ed	0.21 Ea	0.19 Da	0.09 Ebc	0.12 Bb	0.06 Cc	14.45 Fa	10.91 Fb	6.22 Fd	7.23 Dc	5.01 Ge
H09-30	6.62 Aa	5.51 Cc	6.26 Cab	3.32 Ed	5.72 Abc	0.34 Ba	0.18 Db	0.14 Cc	0.06 Cd	0.15 Abc	18.61 Ca	10.87 Fb	8.210 Dc	4.60 Gd	8.07 Bc
GP09-02	5.26 Bb	5.67 Cb	7.01 Ba	5.60 Bb	4.23 Cc	0.25 Da	0.17 Db	0.16 Bb	0.11 Bc	0.10 Bc	18.19 Ca	10.57 Fb	8.89 Cc	7.66 Dd	6.15 Ee
CV (%)			41.17					61.90					54.406		
Hybrids	Q_{leaf}					T_{leaf}					C_i				
	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm
H09-10	1573.00 Bb	1709.80 Aa	1720.80 Aa	1528.00 Bb	1060.80 Ac	32.12 Ad	32.84 Hc	35.06 Ia	34.56 Lb	32.80 Ic	304.60 Aa	255.20 Ab	249.00 Ab	261.20 Ab	243.40 Ab
H09-07	1544.00 Bc	1638.80 Bb	1791.60 Aa	1582.80 Bbc	1098.00 Ad	33.04 Bd	34.20 Gc	36.88 Ha	36.36 Kb	34.34 Hc	263.00 Bab	261.60 Aab	228.80 Ab	245.80 Ab	282.20 Aa
H09-14	1666.20 Ab	1764.60 Aa	1774.80 Aa	1587.00 Bb	1005.80 Bc	33.98 Be	35.78 Fc	38.46 Ga	37.58 Jb	35.40 Gd	264.60 Ba	254.40 Aa	216.00 Ba	252.00 Aa	245.20 Aa
BRS GA	1586.80 Bb	1648.80 Bab	1727.20 Aa	1492.80 Cc	514.80 Gd	34.40 Bd	36.48 Ec	40.08 Fa	38.60 Ib	36.56 Fc	262.40 Ca	247.80 Ba	235.80 Aa	242.00 Aa	246.80 Aa
H09-09	1566.20 Bbc	1640.00 Bb	1741.20 Aa	1545.20 Bc	814.60 Dd	34.54 Bd	37.48 Dc	40.86 Ea	39.66 Hb	37.64 Ec	267.20 Cab	238.80 Ba	209.00 Bab	248.00 Aab	243.00 Ab
FOP-09	1616.80 Bb	1699.00 Aab	1772.40 Aa	1650.80 Ab	922.60 Cc	35.30 Bd	38.34 Cc	41.42 Da	40.74 Gb	38.26 Dc	224.60 Cab	233.00 Ba	231.20 Ab	236.40 Aab	207.60 Bb
GP09-03	1673.20 Abc	1770.60 Aa	1757.80 Aab	1655.20 Ac	877.00 Dd	35.90 Ce	38.50 Cd	41.72 Ca	41.30 Fb	38.88 Cc	246.60 Cab	230.40 Bab	237.80 Aab	220.20 Bb	261.20 Aa
BRS SC	1645.20 Ab	1696.40 Aab	1747.00 Aa	1647.20 Ab	927.20 Cc	36.08 Cd	38.62 Bc	41.48 Da	41.62 Ea	39.06 Bc	238.40 Ba	257.60 Aa	246.80 Ab	242.60 Aa	228.20 Ba
FB200	1676.60 Ab	1714.40 Aab	1774.00 Aa	1542.00 Bb	860.20 Dc	36.44 Dd	38.74 Bc	41.74 Ca	41.92 Da	39.08 Bb	224.80 Bab	270.60 Aab	252.60 Aab	232.60 Aa	202.00 Bb
BRS Rubi	1670.80 Aab	1702.20 Aa	1681.80 Ba	1581.00 Bb	754.20 Ec	36.26 Ee	38.78 Bd	41.94 Bb	42.38 Ba	39.30 Ac	256.40 Bab	244.80 Ba	239.40 Ab	229.80 Ab	227.60 Bb
FB300	1722.00 Aa	1741.00 Aa	1796.40 Aa	1443.00 Cb	778.20 Ec	36.24 Fe	38.62 Bd	42.18 Ab	42.46 Ba	39.48 Ac	254.60 Ba	274.60 Aa	252.00 Aa	194.00 Bb	247.00 Ab
H09-02	1566.60 Ba	1658.60 Ba	1621.20 Ba	1583.20 Ba	824.40 Db	35.90 Fe	38.30 Cd	42.04 Bb	42.64 Aa	39.48 Ac	230.80 Cab	253.00 Aa	222.00 Bab	212.60 Bb	219.80 Bab
FOP-08	1646.60 Ab	1566.80 Cb	1763.60 Aa	1382.60 Dc	739.60 Ed	36.26 Ge	38.38 Cd	42.18 Ab	42.62 Aa	39.46 Ac	226.80 Ca	233.20 Ba	246.00 Aa	228.20 Aa	209.80 Ba
H09-30	1685.00 Aa	1712.80 Aa	1752.00 Aa	1560.00 Bb	542.80 Gc	36.22 Hd	38.64 Bc	42.30 Aa	42.48 Ba	39.44 Ab	237.40 Ca	241.20 Ba	173.60 Cab	201.80 Bb	251.60 Aa
GP09-02	1669.80 Aa	1660.00 Bab	1734.40 Aa	1572.80 Bb	666.00 Fc	35.66 Id	38.96 Ac	42.20 Aa	42.10 Ca	39.36 Ab	202.00 Cb	221.60 Bab	217.00 Ba	218.80 Bab	242.20 Aa
CV (%)			23.68					7.44					12.45		

Means followed by the same letter, uppercase in the column, belong to the same grouping by the Scott-Knott criterion (p<0.05) and lowercase in the rows do not differ significantly by the F test (p<0.05).

Hybrids H09-10, BRS Rubi, FOP-09 and FB200 showed the highest rates in the morning as a result of better climate conditions (Figure 1), with mild temperatures, lower vapor pressure deficit, better radiation quality and greater irrigation water supply. This was observed in a test that evaluated the use of plastic film mulch on the productivity and gas exchange of yellow passion fruit irrigated with saline water (Souto et al., 2022). The authors assumed that the highest *gs* values in mulched plants, even under saline stress, are due to increased levels of moisture and water infiltration into the soil, favored by daily irrigation.

Stomatal regulation is an important water stress tolerance mechanism in passion fruit plants, by reducing the transpiration rate and, therefore, the loss of water to the atmosphere. When evaluating passion fruit trees in the semiarid region, it was observed that there is a direct relationship between transpiration and stomatal movement. The flow of water vapor into the atmosphere is reduced as the stomata close, in order to maintain the potential water in the leaves and prevent dehydration of the plants. As a result, stomatal conductance is reduced and, consequently, transpiration (Pinheiro et al., 2022).

The decrease in the photosynthetic rate in the afternoon seems to be more related to enzymatic impairment arising from the change in enzymatic kinetics due to the increase in temperature and the deficit of vapor pressure, rather than to stomatal closure, which proves insufficient to reduce transpiration and interrupt CO_2 supply. In contrast, stomatal closure restricts the entry of CO_2 into the leaf mesophyll cells, which may increase the susceptibility of the crop to photochemical damage (Araújo et al., 2022). Passion fruit leaves have high stomatal density (106 stomata per mm^2) and low capacity for stomatal control (Lima et al., 2023).

The reduction of gaseous exchanges between the hybrids, always in the afternoon, may be associated with the larger leaf area and the greater water demand, mainly in this period, allied to the abiotic stresses in the semiarid region in the month of October. Furthermore, it can be related to the effect of the decrease in water and nutrient uptake, which induces photosynthetic reduction and stomatal closure as a negative effect. The increase in the rate of CO_2 assimilation in leaves is related to the higher inner concentration of carbon dioxide, which can result in stomatal closure in response to environmental stressors.

The maximum vapor pressure deficit, resulting from the higher air temperature and low atmospheric humidity, associated with the greater water demand in the afternoon, promoted stomatal closure, as evidenced by the reduction in g_s, responsible for the reduction in gas exchanges in the afternoon; different from what happened at 90 DAT. The response to water stress includes triggering abscisic acid (ABA) coordinated by the secondary messenger of Ca^{2+} activation existing in the cytosol, whose main function is the transduction of a variety of hormonal and environmental signals (Teixeira et al., 2021).

Meanwhile, the reduction in photosynthetic rates in the afternoon seems to be more related to negative change in enzyme kinetics as a result of increased temperature and vapor pressure deficit, rather than to stomatal closure, which does not seem to be enough to reduce transpiration and not even to interrupt the supply of CO_2.

The rate of photosynthesis and water use efficiency is significantly higher in the morning. The reduction between the reading times is due more to the increase in leaf temperature caused by heat in the afternoon, which raises water deficit and transpiration rates. Then, the plants activate a cooling mechanism to reduce thermal stress, even with low stomatal conductance (Arantes et al., 2018). Genotypes that have stomata sensitive to vapor pressure deficit can restrict stomatal opening in the evening and, therefore, are considered water-use efficient and drought tolerant (Souto et al., 2022; Wang et al., 2022).

The A/E, A/C_i and A/Q_{leaf} interactions varied depending on the interaction between hybrids and the five evaluation times at 300 DAT (**Table 5**). These variables elucidate the behavior of the plant under biotic and abiotic stresses. The high values for the instantaneous water use efficiency (A/E), for example, obtained during the morning, compared with the afternoon, prove that the best environmental conditions in this season of the year, in the semiarid, in this shift.

Plants with C3 metabolism, such as passion fruit, when subjected to drought associated with high temperatures, respond instantly with a reduction in conductance, with stomatal closure, withholding the uptake of atmospheric CO_2 and transpiration, altering the direct relationship between photosynthesis and environmental CO_2, and contain vegetative metabolism (Paiva et al., 2021; Lima et al., 2023).

When comparing the five evaluation times for instantaneous water use efficiency (A/E), higher values were observed at 8 am. Evaluating this parameter can support the selection of more drought-tolerant hybrids. In this case, as there was a percentage variation in the

Table 5. Physiological characteristics evaluated in yellow passion fruit hybrids cultivated in the semiarid region, 300 days after transplanting, at five evaluation times. Guanambi, Bahia, Brazil

Hybrids	(*A/E*)					(*A/C_i*)					(*A/Q_{leaf}*)				
	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm	8 am	10 am	12 pm	2 pm	4 pm
H09-10	4.24 Ba	3.94 Aa	2.73 Ac	2.25 Ad	3.23 Ae	0.055 Fa	0.060 Aa	0.025 Cb	0.095 Ec	0.023 Bb	0.010 Ba	0.0089 Aa	0.0036 Cbc	0.0062 Ac	0.0052 Fb
H09-07	4.89 Aa	2.14 Db	2.39 Ac	2.34 Ac	2.26 Bc	0.084 Ba	0.055 Ab	0.046 Abc	0.039 Bcd	0.032 Ad	0.014 Aa	0.0086 Ab	0.0063 Bbc	0.0060 Ac	0.0082 Ebc
H09-14	4.01 Ca	3.34 Bbc	1.93 Bcd	1.73 Bd	2.29 Bb	0.062 Ea	0.020 Db	0.021 Cb	0.083 Eb	0.019 Cc	0.009 Ba	0.0031 Cbc	0.0029 Dbc	0.0052 Ac	0.0047 Fb
BRS GA	3.87 Ca	2.71 Cb	1.76 Bd	1.66 Bd	2.10 Bc	0.080 Ca	0.059 Ab	0.030 Bc	0.099 Ed	0.029 Ac	0.013 Ab	0.0087 Ac	0.0041 Cd	0.0050 Ae	0.0181 Aa
H09-09	3.68 Da	2.08 Db	1.65 Bc	1.62 Bc	1.91 Cbc	0.084 Ba	0.049 Bb	0.053 Ab	0.032 Cc	0.031 Ac	0.014 Aa	0.0082 Ab	0.0076 Ab	0.0049 Ac	0.0092 Db
FOP-09	3.52 Da	1.90 Dbc	1.57 Bcd	1.41 Cd	2.07 Bb	0.058 Fa	0.033 Cb	0.027 Bbc	0.019 Dcd	0.015 Cd	0.007 Ca	0.0049 Cb	0.0034 Cb	0.0048 Ab	0.0033 Gb
GP09-03	3.15 Ea	2.13 Db	1.56 Bc	1.66 Bc	1.41 Cc	0.074 Da	0.045 Bb	0.054 Ab	0.048 Ab	0.026 Bc	0.010 Ba	0.0059 Bb	0.0075 Ab	0.0047 Ab	0.0078 Eb
BRS SC	2.83 Ea	1.79 Db	1.47 Bb	1.31 Cc	1.55 Cbc	0.044 Ga	0.022 Dc	0.033 Bb	0.034 Bb	0.009 Dd	0.006 Da	0.0031 Cbc	0.0020 Dc	0.0036 Bab	0.0023 Gc
FB200	3.01 Ea	2.07 Db	1.46 Bc	1.17 Cc	1.87 Cb	0.054 Fa	0.035 Cb	0.014 Cc	0.094 Ec	0.008 Dc	0.007 Da	0.0044 Cb	0.0016 Dc	0.0036 Bc	0.0017 Gc
BRS Rubi	2.34 Fa	1.69 Db	1.46 Bc	1.25 Cc	1.64 Cbc	0.040 Ga	0.044 Ba	0.019 Cb	0.025 Cb	0.025 Bb	0.006 Da	0.0067 Ba	0.0026 Db	0.0029 Bb	0.0074 Ea
FB300	2.67 Fa	1.84 Db	1.41 Bb	1.52 Bb	1.50 Cb	0.063 Ea	0.057 Aa	0.034 Bbc	0.027 Cc	0.036 Ab	0.009 Cab	0.0083 Ab	0.0040 Cc	0.0028 Bc	0.0116 Ca
H09-02	2.85 Ea	1.89 Db	1.32 Bc	1.39 Cc	1.65 Cbc	0.069 Da	0.052 Ab	0.038 Bc	0.036 Bc	0.022 Bd	0.010 Ba	0.0077 Aab	0.0055 Bbc	0.0015 Cc	0.0057 Fbc
FOP-08	2.91 Ea	1.92 Db	1.31 Bcd	1.23 Cd	1.76 Cbc	0.063 Ea	0.046 Bb	0.031 Bc	0.032 Cc	0.024 Bc	0.008 Ca	0.6962 Bab	0.0035 Cc	0.0015 Cbc	0.0068 Eab
H09-30	2.82 Ea	1.98 Db	1.28 Bc	1.41 Cc	1.41 Cc	0.078 Ca	0.047 Bb	0.036 Bc	0.023 Ccd	0.032 Ad	0.011 Bb	0.0063 Bc	0.0047 Ccd	0.0014 Cd	0.0149 Ba
GP09-02	3.50 Da	1.87 Db	1.27 Bc	1.37 Cc	1.46 Cc	0.092 Aa	0.046 Bb	0.037 Bbc	0.035 Bc	0.025 Bd	0.010 Ba	0.0063 Bb	0.0051 Bb	0.0012 Cb	0.0092 Da
CV (%)			41.39					52.,86					57.69		

Means followed by the same uppercase letter in the column belong to the same grouping by the Scott-Knott criterion ($p<0.05$).

A/E values of 396.15% between the reading times, it is possible to state that the hybrid H09-10 was the most efficient in the morning. There was a decrease, as well as in photosynthesis, due to the increase in temperature, while transpiration increased. Water use efficiency in C3 plants may increase more due to the increase in the photosynthetic rate than to the decrease in the transpiration rate (Wang et al., 2022).

For instantaneous carboxylation efficiency (*A/C_i*), three groups were formed, regardless of the evaluated time. The highest values expressed were during the morning, with a variation of 0.092 to 0.054 μmol CO_2 m^{-2} s^{-1}/μmol CO_2 mol^{-1}, resulting from the environmental conditions of the first time. Instantaneous carboxylation efficiency of yellow passion fruit plants is significantly influenced by water use strategies, in quantity and quality, and is a variable used to identify the action of non-stomatal factors that interfere in the CO_2 assimilation rate. An increase verified in the *A/C_i* among some hybrids, at 2 pm, is due, above all, to the increments recorded for the internal CO^2 concentration and to the gains in the CO_2 assimilation rate, in addition to the variations that occurred in the climatic variables registered on the day in which the evaluations were carried out (Pinheiro et al., 2022).

When evaluating irrigation strategies with saline water and potassium fertilization on the physiology and fruit production of yellow passion fruit in the semiarid region (Lima et al., 2023), it was found that the decrease in carboxylation efficiency may be related to increased photorespiration and the restriction of Rubisco activity, due to the low availability of substrate (ATP and NADPH) for enzymatic activation and regeneration, resulting from the accumulation of salts in leaf tissues. The environment favors the oxygenation of Rubisco and the increase of the photorespiratory pathway, significantly reducing carbon compounds (Lima et al., 2023).

When evaluating the increase in CO_2 in C3 plants, an increase in productivity of 30% was observed, while in plants with C4 metabolism, the increase was limited to 10%. For stomatal conductance, this variable would decrease 40% of the potential, and water use would decrease by at least 10%. Thus, water use efficiency in C3 plants would increase more due to the increase in the photosynthetic rate in comparison with the decrease in transpiration rate. Passion fruit can respond to environmental conditions with a drop in photosynthetic gain under circumstances of high temperature due to photorespiration (Silva et al., 2021; Sonmez et al., 2022; Souto et al., 2022).

The regression studies present the gas exchange variables of the hybrids in a trend of direct relation with the photosynthetically active radiation incident on the leaf (Q_{leaf}), the independent variable (**Figure 2**). Therefore, the higher the Q_{leaf}, the higher the stomatal conductance (g_s), the transpiration (*E*) and photosynthesis (*A*) rates and the instantaneous water use efficiency (*A/E*). The latter indicates the greater efficiency of the hybrids in terms of water resource use, one of the main barriers to passion fruit production in the semiarid region, especially when considering that one of the striking characteristics of this region is the poor spatial and temporal distribution of rainfall, which can lead to disturbances. morphophysiological features to cultures.

It should be added that the high rate of solar radiation incident on the plants can influence the physical characteristics of the vegetables, reflecting on the growth and production of the passion fruit. Plants can be exposed to high light intensity and absorb more energy than necessary for photosynthesis. This excess of light energy, above the utilization capacity, can result in a condition of photoinhibition, generating reactive oxygen species, highly harmful to cell integrity and functionality. High radiation may be associated with increased ambient temperature. However, in this case, it seems not to have been so exorbitant as to cause a significant reduction in photosynthesis rates, which remained linear with the increase in Q_{leaf}. Furthermore, with the slight reduction in stomatal conductance, a consequent suppression of photosynthesis could be observed, which did not happen.

Gas exchange is influenced by climatic conditions. Thus, the decreases registered for the variables follow a quadratic behavior and are intrinsic to the increases verified in the accumulated solar radiation. This can be related to the increase in temperature and the reduction in the relative humidity of the air. The increase in photosynthetically active radiation can stimulate stomatal conductance rates, for example, to a certain extent, but if in excess, it can have the opposite effect (Machado et al., 2022; Souto et al., 2022).

In this experiment, the yellow passion fruit reached the maximum conductance with values close to 1522.5 μmol photons m^{-2} s^{-1}. From this value, Q_{leaf} was considered limiting to the conductance, which responded in a decrease to the environmental conditions, concomitant to the high values of radiation and the possible lower amount of water vapor in the atmosphere, which promote a greater expenditure of energy to protect against photoinhibition and for the maintenance of hydraulic conductivity throughout the plant tissues. There is a relationship between the daytime values of *A* and g_s inherent to stomatal regulation and the supply of CO_2 to the site of carboxylation (Lima et al., 2023).

The highest leaf transpiration rate was also verified for the frequency of 1522.5 μmol photons m^{-2} s^{-1} of Q_{leaf}, presumably due to the fact that the internal concentration of carbon dioxide in the leaf was also

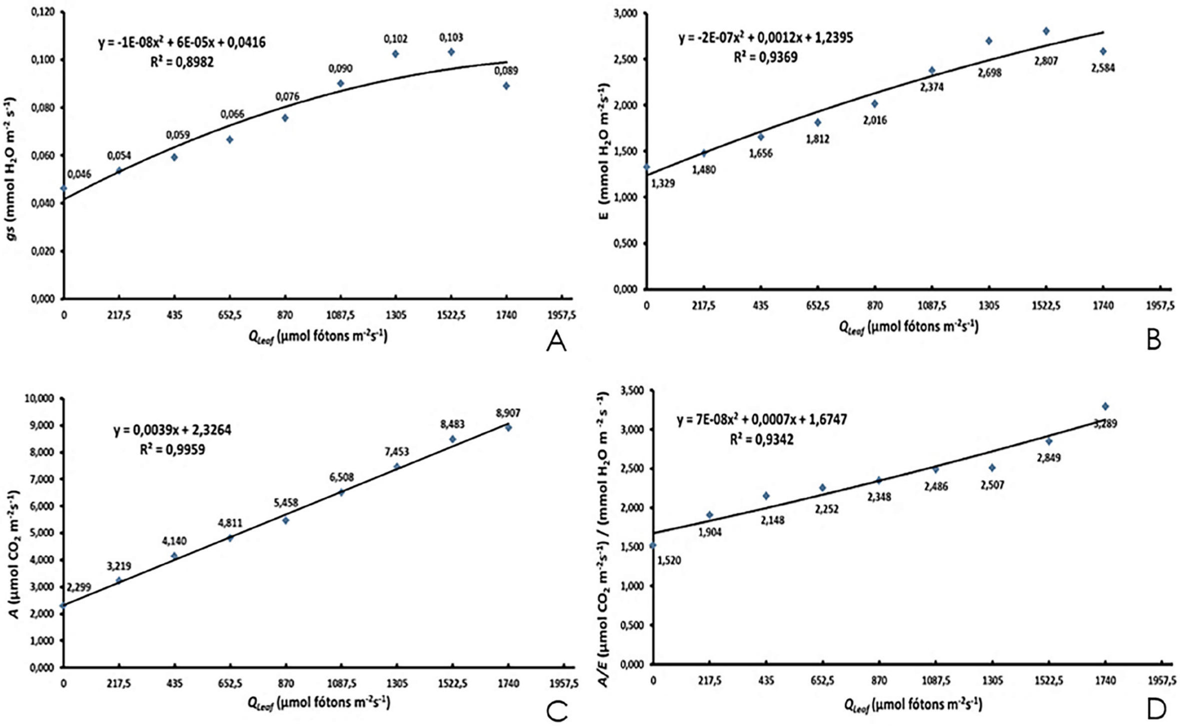

Figure 2. Gas exchanges of yellow passion fruit hybrids, grown in the Semiarid Region, as a function of photosynthetically active radiation incident on the leaf (Q_{leaf}): A) Stomatal conductance (g_s); B) Transpiration Rate (*E*); C) Rate of photosynthesis (*A*); D) Instantaneous water use efficiency (*A/E*). Guanambi, BA.

higher at that time because for the plant to absorb CO_2 from the external environment, it inevitably loses water, due to the greater stomatal opening. With the reduction in stomatal conductance, there is a consequent decrease in transpiration, which may restrict the entry of CO_2, indicating the interdependence between CO_2 assimilation and water consumption (Sonmez et al., 2022; França et al., 2023).

The selection must consider vegetative, reproductive and physiological aspects, related to vigor and precocity in the production of plants cultivated in certain environments (Souza et al., 2022). Evaluating physiological traits in response to the growing environment and management for the breeding of promising hybrids makes it possible to observe components that are difficult to measure, even if they have complex inheritance. Thus, the breeding process is shortened, and costs are reduced, which is particularly interesting for breeding yellow passion fruit as its crop cycle has been shortened due to the high climatic instability of the semiarid region, especially water stress, responsible for at least 40% of crop losses and threatening food security (Lima et al., 2023).

In this growing region, there is a negative relationship between water evaporation and rainfall, causing depletion in photosynthetic efficiency, due to atypical changes in gas exchange by plants and water deficit (Paiva et al., 2021; Araújo et al. al., 2022; Donato et al., 2023). It is assumed, therefore, that yellow passion fruit cultivated under water restriction and high temperatures may respond with low fruit productivity due to reduced photosynthetic activity. This makes the yellow passion fruit dependent, under these conditions, on irrigation and proper management at different phenological stages.

Conclusions

Hybrid H09-10 is the most precocious, closes stomata in the afternoon, restricts transpiration, has lower leaf temperature, higher photosynthesis rate and efficient water use in semiarid conditions.

Gas exchanges, at 300 DAT, vary between hybrids and evaluation times, and are higher in the morning, as well as photosynthesis rates, whereas transpiration is greater in the afternoon.

The reduction in the efficiency of instantaneous carboxylation is more related to non-stomatal factors.

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