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Climatic Variation on Gas Exchange and Chlorophyll *a* Fluorescence in *Tabebuia roseoalba* and *Handroanthus heptaphyllus* (Bignoniaceae)

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HIGHLIGHTS

- Climatic conditions influence the physiological mechanisms of species.
- High irradiance and air temperature reduce photosynthetic performance of species.
- The highest physiological performance of the species is between 8 am and 9 am.

Abstract: Climatic variation throughout the day influences the ecophysiological performance of plants at different growth stages and phases. Therefore, this work aimed to evaluate the effect of climatic variation on ecophysiological aspects of *T. roseoalba* and *H. heptaphyllus* at different hours of the day and indicate the ideal time for measuring ecophysiological variables in these species. The research was carried out in a greenhouse at the forest nursery of the Federal University of Paraíba, Campus II, in the municipality of Areia, Paraíba state, Northeastern Brazil. The experimental design was completely randomized, consisting of 10 evaluation times throughout the day (from 8 am to 5 pm), with 1 h hour interval between each evaluation. Temperature and air relative humidity inside and outside the greenhouse were evaluated to understand the effect on gas exchange (net assimilation rate of CO_2, stomatal conductance, transpiration rate, internal concentration of CO_2, and vapor-pressure deficit) and chlorophyll *a* fluorescence (initial, maximum, and variable fluorescence, photochemical quenching, and electron transport rate). Data were submitted to canonical correlation analysis and principal component analysis to verify the relationship between climatic and ecophysiological variables. For both species, higher correlation was found between internal and external relative humidity with all the ecophysiological variables analyzed, except for initial fluorescence. Thus, climatic factors influenced the photosynthetic performance of *T. roseoalba* and *H. heptaphyllus* plants, and 8 am to 9 am is indicated for carrying out ecophysiological evaluations in both species.

Keywords: abiotic factors; daily course; ipê-branco; ipê-rosa; photosynthesis; physiological responses.

INTRODUCTION

Tabebuia roseoalba (Ridl.) Sandwith is a tropical tree species that grows 7 to 3 m in height and has a stem of 40 to 50 cm in diameter [1]. Popularly known as "ipê-branco", "pau-d'arco", and "ipê-do-cerrado", the species is widely distributed in South America, occurring in several regions of Brazil, predominantly in the semi-deciduous seasonal forests of Atlantic Forest and Cerrado, and seasonal deciduous forests of Caatinga [2,3]. Also, this species is of high economic and ecological importance, being used for landscaping due to its size and flowering over different seasons of the year, and reforestation of degraded areas due to the rapid adaptation to dry and stony soils [4].

Handroanthus heptaphyllus (Vell.) Mattos, popularly known as “ipê-rosa”, “ipê-roxo”, and “pau-d’arco”, is a native arboreal species that grows 10 to 20 m [5]. Widely distributed in Brazil, mainly in the seasonal semi-deciduous forests [6], this species is of high economic and ecological importance, being used in the timber industry for civil construction, due to desirable properties of its wood, such as high density and durability [7]. It is also used in urban afforestation and restoration of forest remnants in disturbed areas, and as antitumor, antioxidant, and antidepressant agents due to is biological activity [8,9].

Given the ecological importance of *T. roseoalba* and *H. heptaphyllus*, studies on their ecophysiological responses to adverse climatic factors (abiotic factors) are crucial. Climatic variation throughout the day influences the ecophysiological performance of plants in the different growth stages and phases, mainly air temperature, relative humidity, and irradiance (luminosity), the main abiotic factors that affect plant metabolism [10]. Arboreal forest species, obtained from natural regeneration or seedlings, are more sensitive to climatic variations due to their intrinsic characteristics [11]. Climatic variation can affect the physiological processes of the plants, changing photosynthesis rate and chlorophyll *a* fluorescence [12].

High irradiance is one of the main factors that interfere in the physiological and morphological processes of plants, decreasing their primary metabolism, altering photosynthetic processes, reducing energy transfer and absorption in the reaction centers, CO_2 fixation, net assimilation rate of CO_2, transpiration rate, and stomatal conductance [13]. Irradiance is not associated exclusively with the availability of energy for photosynthesis. It can also induce signals responsible for regulating physiological mechanisms through light receptors sensitive to light intensity, spectrum quality, and polarization [14]. Also, high temperatures can negatively affect the ecophysiological processes of plants, with photosynthesis being the most sensitive process to heat stress [15]. If severe throughout the day, heat stress can inhibit photosynthesis in minutes, reducing photosynthetic activities, affecting the intracellular concentration of CO_2, stomatal opening, and transpiration rate, in addition to inhibiting electron transport and suppressing Rubisco's activation state [16].

In this context, ecophysiological studies of forest species, such as *T. roseoalba* and *H. heptaphyllus*, are essential to understand the physiological behavior, adaptation, and stabilization of these species in adverse climatic conditions. There is no information on how climatic variation affects the ecophysiological aspects of such species. This information can help to understand the dynamics of *T. roseoalba* and *H. heptaphyllus* in vegetation fragments and may contribute to the propagation and conservation of these species in disturbed areas. In this study, we hypothesize that: (1) *T. roseoalba* and *H. heptaphyllus* respond differently throughout the day; and (2) heat stress (high temperature) associated with high irradiance (photosynthetically active radiation) throughout the day reduces the plant photosynthetic performance, negatively affecting gas exchange and chlorophyll *a* fluorescence parameters.

Thus, this study aimed to evaluate the effect of climatic variation on ecophysiological aspects of *T. roseoalba* and *H. heptaphyllus* at different hours of the day and indicate the ideal time for measuring these ecophysiological variables.

MATERIAL AND METHODS

The research was carried out in a greenhouse at the forest nursery of the Federal University of Paraíba, Campus II, in the municipality of Areia, Paraíba state, Northeastern Brazil (6°57'59'' S, 35°42'57'' W). The region is located in the Brejo microregion and Agreste Paraibano mesoregion, where altitudes reach 400 to 600 m, temperature of 22 °C, and average annual rainfall of 1,400 mm [17]. The climate is tropical with dry summer and autumn-winter rains, classified as As [18]. During the experiment, air temperature and relative humidity were monitored daily using a digital Thermo hygrometer (MT-241A, Minipa), whose average values were 24.2 °C and 53.5%, respectively.

T. roseoalba and *H. heptaphyllus* seeds were obtained from the seed bank from the Center for Agricultural Sciences, Federal University of Paraíba, Areia, Paraíba, Northeastern Brazil. The selected seeds were dehiscence at the initial stage, that is, at the maturation phase. After screening manually, the seeds were exposed to shade for 24 h. Before sowing, the seeds were disinfected by immersion in a 2% sodium hypochlorite solution for 5 min.

Then the seeds were sown in 8 dm^3 plastic pots filled with a substrate composed of vegetal soil and Bioplant® at a 3:1 ratio. The substrate had the following chemical attributes: 5.42 pH (H_2O); 118.7 and 217.2 mg dm^{-3} of P and K^+, respectively; 0.43, 4.62, 0.00, 3.50, 3.10, 7.58, and 12.2 $cmol_c$ dm^{-3} of Na^+, H^++Al^{+3}, Al^{3+}, Ca^{2+}, Mg^{2+}, sum of bases, and cation exchange capacity, respectively; 62.1% base saturation; and 29.86% organic matter. Five seeds were sown per pot and 30 days after emergence, a thinning was carried out leaving the most uniform seedlings. Irrigation was performed daily using the gravimetric method, by weighing the pots and maintaining the substrate at 80% field capacity [19].

The experimental design was completely randomized, consisting of ten evaluation times throughout the day (from 8 am to 5 pm), with 1 h intervals between each evaluation. For each species, 12 replicates were used, two plants per plot, totaling 24 individuals of each species.

Internal (InT) and external (ExT) temperature (°C), and internal (InRH) and external (ExRH) relative humidity of the greenhouse were monitored using a portable digital thermo-hygrometer (MT-241A, Minipa). Photosynthetically active radiation (*PAR*) (µmol m^{-2} s^{-1}) was measured using the natural light sensor of the portable infrared gas analyzer (IRGA, LI-6400XT, LI-COR). Also, net assimilation rate of CO_2 (*A*, µmol m^{-2} s^{-1}), stomatal conductance (*gs*, mol m^{-2} s^{-1}), transpiration rate (*E*, mmol of H_2O m^{-2} s^{-1}), internal concentration of CO_2 (*Ci*, µmol of CO_2 m^{-2} s^{-1}), and vapor-pressure deficit (*VPD*) were analyzed using IRGA following the protocol: relative air humidity between 50 and 60%, air flow of 300 µmol s^{-1}, CO_2 concentration of 400 µmol mol^{-1}, and natural light sensor coupled to a 6 cm^2 leaf chamber.

Subsequently, chlorophyll *a* fluorescence parameters were measured using a fluorimeter (LI-6400-40 LCF, LI-COR) coupled to IRGA. Leaves were subjected to a saturating flash of actinic irradiation (approximately 2,500 µmol photons m^{-2} s^{-1}) and a pulse of far-red light to determine initial fluorescence (F_0'), maximum fluorescence (F_m'), variable fluorescence (F_v'), photochemical quenching (*qP*), and electron transport rate (*ETR*).

Ecophysiological evaluations were carried out 365 days after sowing, on days under favorable climatic conditions, with full brightness, to assess the real effect of climatic factors on plants. The measurements were performed on three healthy and fully expanded leaves located in the middle third of the plants.

Canonical Correlation Analysis (CCA) and Principal Component Analysis (PCA) were performed to evaluate correlations between the climatic (*PAR*, InT, ExT, InRH, and ExRH) and ecophysiological variables (*A*, *gs*, *E*, *Ci*, *VPD*, F_0', F_m', F_v', *qP*, and *ETR*). Wilks' lambda test was performed to analyze the significance of canonical roots. Also, Pearson's correlation analysis was performed, then values were classified according to the degree of dependence of Stell and Torrie (1980). All statistical analyzes were performed in R *v.4.0.3* [20].

RESULTS

Wilks' Lambda test revealed significant correlations between the climatic and ecophysiological variables ($p < 0.05$). The first three canonical pairs in *T. roseoalba* (R^2 from 0.69 to 0.97) and the first four canonical pairs in *H. heptaphyllus* (R^2 from 0.60 to 0.96) significantly correlated (Table 1).

Table 1. Wilks's Lambda test. R^2: Canonical correlation; F: Approximate F value; DF_N: numerator degrees of freedom; DF_D: denominator degrees of freedom.

Tabebuia roseoalba					
Canonical Function	R^2	F	DF_N	DF_D	Pr > F
1	0.97	10.14	40	120.48	< 0.0001
2	0.95	6.06	28	102.38	< 0.0001
3	0.69	2.27	18	82.51	0.0065
4	0.55	1.64	10	60.00	0.1184
5	0.34	1.03	4	31.00	0.4059
Handroanthus heptaphyllus					
Canonical Function	R^2	F	DF_N	DF_D	Pr > F
1	0.96	10.25	40	120.48	< 0.0001
2	0.94	7.01	28	102.38	< 0.0001
3	0.79	3.50	18	82.51	< 0.0001
4	0.60	2.18	10	60.00	0.0312
5	0.38	1.37	4	31.00	0. 2683

According to the first canonical pair, the most important climatic variables for both species were air relative humidity inside (cc = 0.68 and 0.54) and outside (cc = 0.41 and 0.45) the greenhouse, which positively correlated with internal concentration of CO_2 (cc = 0.89 and 0.82), stomatal conductance (cc = 0.88 and 0.80), photochemical quenching (cc = 0.80 and 0.81), net assimilation rate of CO_2 (cc = 0.79 and 0.68), vapor-pressure deficit (cc = 0.79 and 0.78), variable fluorescence (cc = 0.78 and 0.79), electron transport rate (cc = 0.73 and 0.55), maximum fluorescence (cc = 0.69 and 0.66), and transpiration rate (cc = 0.68 and 0.73) (Table 2). Otherwise, internal temperature (cc = -0.58 and -0.50) did not correlate with the ecophysiological variables, except by initial fluorescence (Table 2).

Table 2. Canonical correlations and canonical pairs between climatic and ecophysiological variables for *Tabebuia roseoalba* and *Handroanthus heptaphyllus*.

Variable	**Canonical Pair**	
Group I: *Climatic*	**S1**	**S2**
Photosynthetically active radiation (PAR)	0.1249	0.3335
Internal temperature (InT)	-0.5813	-0.5071
External temperature (ExT)	0.0723	0.3191
Internal relative humidity (InRH)	0.6815	0.5478
External relative humidity (ExRH)	0.4153	0.4588
Group II: *Ecophysiological*		
Net assimilation rate of CO_2 (A)	0.7960	0.6891
Stomatal conductance (g_s)	0.8887	0.8019
Transpiration rate (E)	0.6883	0.7323
Internal concentration of CO_2 (Ci)	0.8944	0.8264
Vapor-pressure deficit (VPD)	0.7956	0.7854
Initial fluorescence (F_0')	- 0.3982	- 0.3833
Maximum fluorescence (F_m')	0.6992	0.6632
Variable fluorescence (F_v')	0.7877	0.7949
Photochemical quenching (qP)	0.8093	0.8167
Electron transport rate (ETR)	0.7362	0.5518
Wilk's Lambda	0.0016200	0.00156137
Cumulative variance (%)	0.6428	0.6333
R^2	0.97	0.96
Significance	**	**

**Significant at 1% probability by the Chi-Square test; S1: *Tabebuia roseoalba*; S2: *Handroanthus heptaphyllus*; R^2: canonical correlation.

According to Principal Component Analysis (PCA) for *T. roseoalba*, the principal components 1 and 2 (PC1 and PC2) explained respectively 62.25 and 33.25% of the total inertia, which corresponded to 95.50% of data variability (Figure 1A). Air relative humidity (internal and external) positively correlated with stomatal conductance, maximum fluorescence, vapor-pressure deficit, transpiration rate, net assimilation rate of CO_2, variable fluorescence, photochemical quenching, electron transport rate, and internal concentration of CO_2 (Figure 1A).

For *H. heptaphyllus*, the main components (62.89% in PC1 and 32.15% in PC2) explained 95.04% of data variability, with positive correlations between air relative humidity (internal) and vapor-pressure deficit, stomatal conductance, maximum fluorescence, transpiration rate, net assimilation rate of CO_2, variable fluorescence, photochemical quenching, and internal concentration of CO_2 (Figure 1B).

In both species, the internal temperature eigenvector was positioned left side, presenting negative values, indicating this parameter distinguished from the ecophysiological variables analyzed, except for initial fluorescence (Figure 1A and B).

The ecophysiological variables in both species strong correlated ($r \geq 0.72$), according to Pearson's correlation analysis, except by initial fluorescence (Figure 2A and B). In *T. roseoalba*, photosynthetically active radiation and air temperature (external) moderately correlated with internal concentration of CO_2 (0.60 and 0.62) and electron transport rate (0.61 and 0.65) (Figure 2A). Similarly, air relative humidity (internal) moderately correlated with stomatal conductance (0.57), transpiration rate (0.56), net assimilation rate of CO_2 (0.52), vapor-pressure deficit (0.52), and maximum fluorescence (0.51) (Figure 2A). In *H. heptaphyllus*, electron transport rate positively correlated with air temperature (external) (0.74) and photosynthetically active radiation (0.66), while internal concentration of CO_2 positively correlated with photosynthetically active radiation (0.54) (Figure 2B).

The climatic variables varied throughout the day, in which photosynthetically active radiation (PAR) ranged from 49.00 µmol s^{-1} m^{-2} (5 pm) to 1486.14 µmol s^{-1} m^{-2} (12 pm) (Figure 3). Maximum temperatures of 40.8 °C (InT) and 38.6 °C (ExT) (Figure 3) were recorded in the same period as for photosynthetically active radiation, at 1 pm and 12 pm. In contrast, internal and external relative humidity drastically reduced during the highest irradiance (PAR) and air temperature (InT and ExT) periods, with minimum at 2 pm (InRH = 30%; ExRH = 32%) and maximum at 8 am and 5 pm (Figure 3).

Net assimilation rate of CO_2 (*A*) of the species decreased significantly throughout the day, due to the increase in photosynthetically active radiation (*PAR*) and air temperature (InT and ExT) (Figure 4A). In *T. roseoalba* and *H. heptaphyllus*, the highest net assimilation rate of CO_2 was recorded earlier in the day, at 8 am and 9 am (10.42 and 8.48 µmol m^{-2} s^{-1} in *T. roseoalba*, and 6.54 and 5.78 µmol m^{-2} s^{-1} in *H. heptaphyllus*), decreasing thereafter (Figure 4A). In both species, the lowest values were observed at 5 pm (Figure 4A). Stomatal conductance (*gs*) varied similarly as net assimilation rate of CO_2, with maximum at 8 am in both species (0.1871 mol m^{-2} s^{-1} in *T. roseoalba* and 0.1128 mol m^{-2} s^{-1} in *H. heptaphyllus*), decreasing significantly during the day, with the lowest values recorded at 5 pm (Figure 4B).

Transpiration rate also varied similarly as net assimilation rate of CO_2 and stomatal conductance in both species, with maximum earlier in the day at 8 am and 9 am, registering 3.81 and 3.11 mmol of H_2O m^{-2} s^{-1} in *T. roseoalba* and 2.80 and 2.49 mmol of H_2O m^{-2} s^{-1} in *H. heptaphyllus*, respectively (Figure 4C).

Internal concentration of CO_2 despite behaving similarly as the other gas exchange variables, registered maximum at 9 am in both species, 317.23 µmol CO_2 mol^{-1} in *T. roseoalba* and 291.05 µmol CO_2 mol^{-1} in *H. heptaphyllus* (Figure 4D).

Vapor-pressure deficit (*VPD*) decreased with increasing irradiance and air temperature, ranging from 3.16 kPa (8 am) to 1.49 kPa (5 pm) in *T. roseoalba*, and from 2.77 kPa (8 am) to 1.29 kPa (5 pm) in *H. heptaphyllus* (Figure 4E).

Initial fluorescence (F_0') increased significantly along the day in both species, with maximum at 3 pm to 5 pm, which corresponded to a decrease of 25.9% in *T. roseoalba* and 25.3% in *H. heptaphyllus* between the highest and lowest values recorded during the day (Figure 5A). Maximum was recorded at 5 pm, 564.27 electrons $quantum^{-1}$ in *T. roseoalba* and 491.73 electrons $quantum^{-1}$ in *H. heptaphyllus* (Figure 5A).

In contrast, maximum fluorescence (F_m') decreased throughout the day, with maximum at 8 am and 9 am and minimum at 4 pm and 5 pm in both species (Figure 5B). Values ranged from 608.44 to 1268.31 electrons $quantum^{-1}$ in *T. roseoalba* and from 498.59 to 876.23 electrons $quantum^{-1}$ in *H. heptaphyllus* (Figure 5B).

Variable fluorescence (F_v') behave similarly as maximum fluorescence, increasing considerably at the beginning of the day in both species, with maximum at 8 am (<InT and ExT; <PAR), 850.08 electrons $quantum^{-1}$ in *T. roseoalba* and 508.85 electrons $quantum^{-1}$ in *H. heptaphyllus* (Figure 5C).

Photochemical quenching (*qP*) decreased drastically throughout the day in both species, similarly as maximum and initial fluorescence. The highest values were recorded at 8 am (0.7067 electrons $quantum^{-1}$ in *T. roseoalba* and 0.5793 electrons $quantum^{-1}$ in *H. heptaphyllus*), and lowest values at 5 pm (Figure 5D). From the highest and lowest values observed, *qP* dropped 78.5% in *T. roseoalba* and 81.4% in *H. heptaphyllus* (Figure 5D).

Electron transport rate (*ETR*) decreased significantly with increasing photosynthetically active radiation and temperature, registering the lowest values at 5 pm in both species (Figure 5E). On the other hand, maximum values were recorded earlier in the day (8 am) (89.28 electrons $quantum^{-1}$ in *T. roseoalba* and 60.70 electrons $quantum^{-1}$ in *H. heptaphyllus*). Thus, *ETR* increased approximately 73% in *T. roseoalba* and *H. heptaphyllus* compared to the lowest values observed (Figure 5E).

DISCUSSION

Wilk's Lambda and Canonical Correlation Analysis (CCA) evidenced the relationship between the groups of variables, indicating that the climatic variables (group I) correlated with the ecophysiological variables (group II) in *T. roseoalba* and *H. heptaphyllus* along the day. The importance of these groups of variables is revealed by the higher coefficients of the first canonical pair, that is, the higher the canonical coefficient the greater the importance of the variable for the group [21, 22].

Regarding the internal and external environmental variables during the day, previous works found similar results to the present study, observing maximum photosynthetically active radiation from 11 am to 1 pm, and maximum air temperature from 1 pm to 3 pm [23,24,25]. Such an increase in *PAR* and air temperature possibly decreased air relative humidity throughout the day, in the hottest hours (11 am to 1 pm) [26].

Photosynthetically active radiation together with other climatic factors, such as high temperature, can regulate and alter the mechanisms for the photosynthetic process of plants [27].

During the day, due to increasing air temperature (external and internal) and photosynthetically active radiation (*PAR*), both species reduced the assimilation rate of CO_2 (*A*), stomatal conductance (*gs*), transpiration (*E*), internal concentration of CO_2 (*Ci*), and vapor-pressure deficit (*VPD*). Decreased gas exchange throughout the day indicates the negative effect of high temperature and irradiance on plants, decreasing ATP and NADPH concentration due to a reduction in the photosynthesis photochemical stage [28,29].

Results showed that *A*, *gs*, and *E* in both species were strongly correlated, and acting as mechanisms and strategies responsible for regulating temperature and water content in the leaves, depending directly on stomatal opening and closure [30]. Decreased *E* under high temperature and irradiance possibly occurred due to the lower efficiency of leaves to assimilate and store CO_2, since the competition between CO_2 and H_2O molecules probably reduced water loss by the stomata during this period [31].

A high internal concentration of CO_2 (*Ci*) earlier in the day possibly occurred due to higher assimilation of CO_2 during this period, indicating that CO_2 was being fixed by the enzyme ribulose 1,5-bisphosphate carboxylase/oxygenase (Rubisco) [32]. Therefore, stomatal closure during the hottest hours of the day reduced *Ci*, thus causing a diffusive resistance of CO_2 in the leaves throughout the day [33]. Also, the decrease in vapor-pressure deficit (*VPD*) throughout the day may be associated with a lower stomatal opening during the warmer period, to reduce the gas exchange flow in the leaves [34].

Chlorophyll *a* fluorescence variables showed similar behavior to gas exchange variables in both species, except for initial fluorescence (F_0'), which behaved oppositely. Higher F_0' throughout the day under high temperature and radiation possibly indicate limitations in the transfer of energy to the reaction centers of photosystem II [35]. Under unfavorable climatic conditions, as we observed during the hottest hours of the day in the present study, F_0' increased thereby influencing the structure of PSII photosynthetic pigments [36]. On the other hand, the reduction in maximum fluorescence (F_m') during this period may have altered the photochemical activity of the plant, since high F_m' directly influence on energy transfer, which is used to reduce NADPH, ATP, and ferredoxin and thus increase the assimilation of CO_2 by the leaves [37]. In contrast, higher variable fluorescence (F_v') earlier in the day possibly improved the capacity to transfer electrons captured by the photosynthetic pigment molecules [38].

Photochemical quenching (*qP*) decreased proportionally with increasing temperature. The number of open reaction centers was thus reduced preventing greater light capture during this period along the day [39]. This trend indicates the lower photochemical quenching efficiency of the studied species, with similar behavior to net assimilation rate of CO_2 (*A*). Stresses caused by climatic variation provide deleterious effects on the photosynthetic mechanisms of plants. In addition, it reduces the plant photochemical efficiency and other ecophysiological parameters, such as photochemical dissipation and electron transport rate (*ETR*) in the photosynthetic apparatus [40,41]. High electron transport rate (*ETR*) indicates greater use of light energy for photochemical processes, in addition to improving photosynthesis [42], as we observed in the present study for both species.

Here we observed that the climatic variables evaluated throughout the day influenced the ecophysiological performance of *T. roseoalba* and *H. heptaphyllus*. The ecophysiological variables were affected because they were evaluated in a greenhouse (protected environment). In this environment, the air evaporative demand was satisfactory, and evapotranspiration was reduced due to decreased wind speed and solar radiation provided by the greenhouse covering, providing favorable conditions for carrying out climatic and ecophysiological assessments.

CONCLUSION

T. roseoalba and *H. heptaphyllus* changed their physiological mechanisms due to environmental conditions throughout the day; The ecophysiological behavior of the species is highly dependent on climatic conditions; High irradiance and air temperature negatively influenced the physiological behavior of *T. roseoalba* and *H. heptaphyllus*, drastically reducing their photosynthetic performance; The appropriate time to carry out gas exchange and chlorophyll *a* fluorescence evaluations in *T. roseoalba* and *H. heptaphyllus* is from 8 am to 9 am.

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ERRATUM

In the Article “Climatic Variation on Gas Exchange and Chlorophyll a Fluorescence in Tabebuia roseoalba and Handroanthus heptaphyllus (Bignoniaceae)” DOI number: https://doi.org/10.1590/1678-4324-2022210338, published in the journal Brazilian Archives of Biology and Technology, vol. 65, page 1.

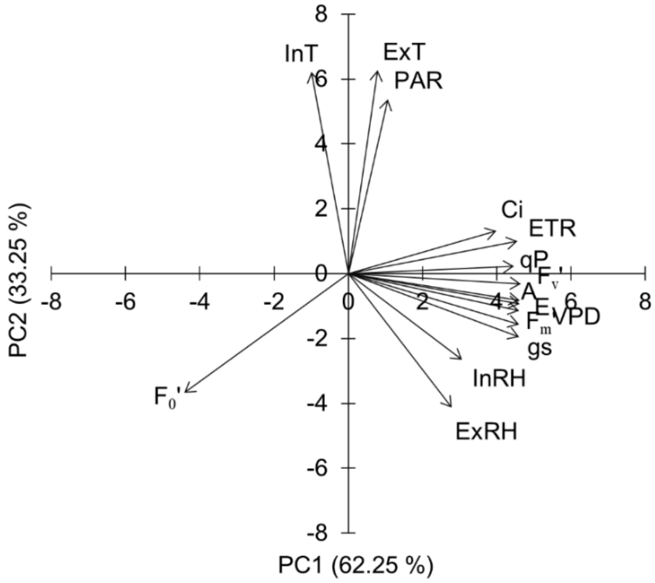
That read:

“(…) Air relative humidity (internal and external) positively correlated with stomatal conductance, maximum fluorescence, vapor-pressure deficit, transpiration rate, net assimilation rate of CO2, variable fluorescence, photochemical quenching, electron transport rate, and internal concentration of CO2 (Figure 1A).

Read:

"(…) Air relative humidity (internal and external) positively correlated with stomatal conductance, maximum fluorescence, vapor-pressure deficit, transpiration rate, net assimilation rate of CO2, variable fluorescence, photochemical quenching, electron transport rate, and internal concentration of CO2 (Figure 1A).

(a) *Tabebuia roseoalba*



(b) *Handroanthus heptaphyllus*

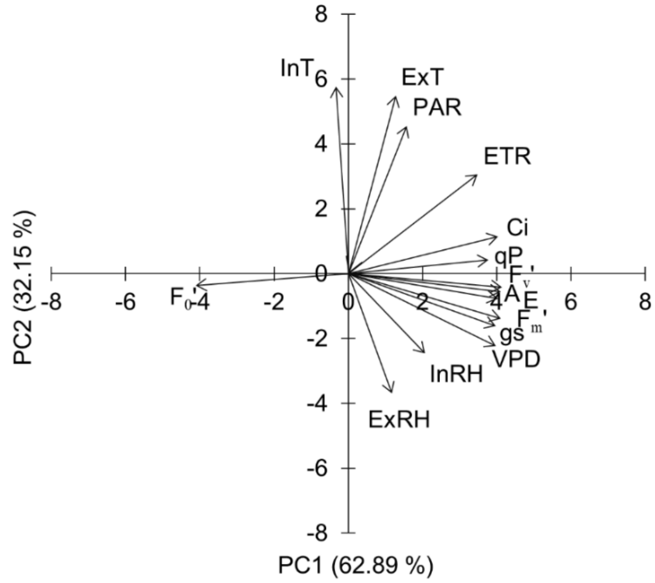


Figure 1. Principal Component Analysis (PCA) for climatic and ecophysiological variables in Tabebuia roseoalba (a) and Handroanthus heptaphyllus (b)."

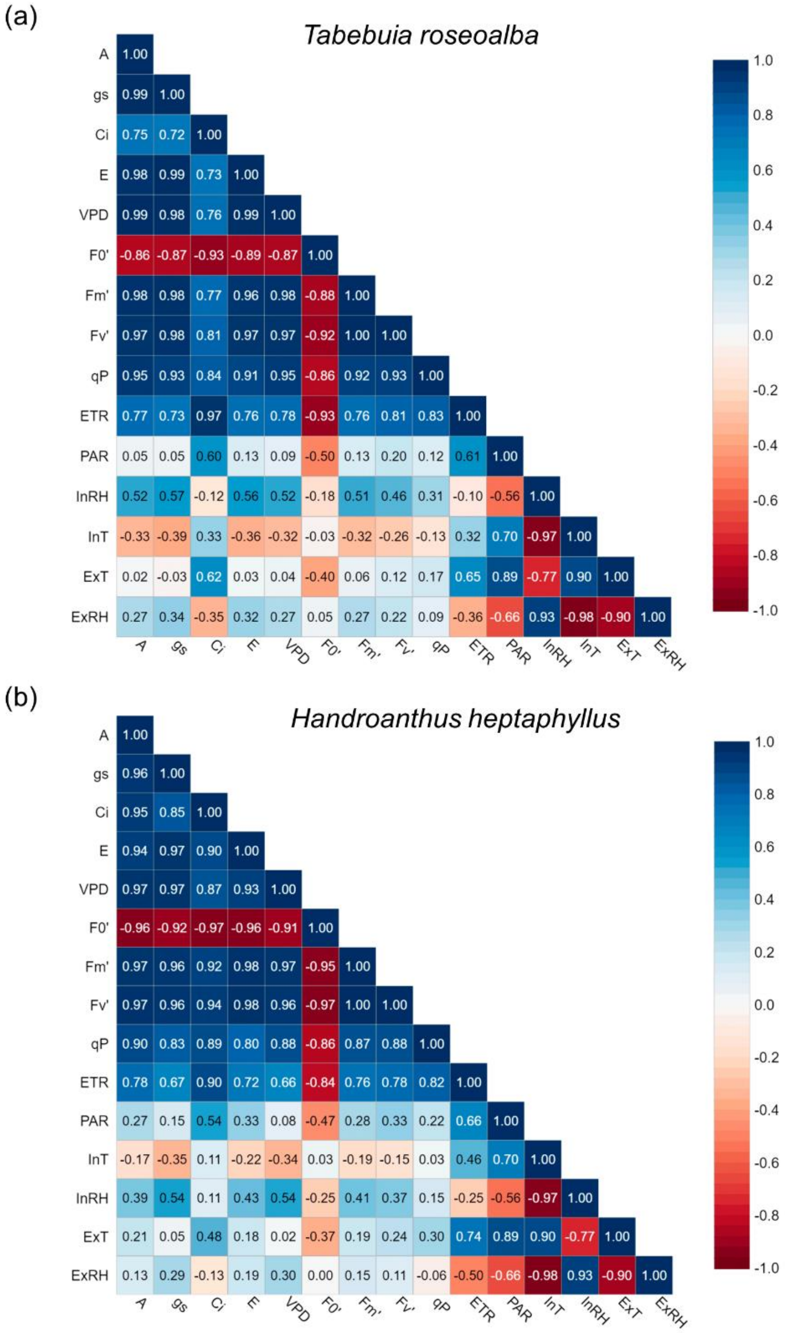
and

That read:

“(…) In H. heptaphyllus, electron transport rate positively correlated with air temperature (external) (0.74) and photosynthetically active radiation (0.66), while internal concentration of CO2 positively correlated with photosynthetically active radiation (0.54) (Figure 2B).

Read:

“(…) In H. heptaphyllus, electron transport rate positively correlated with air temperature (external) (0.74) and photosynthetically active radiation (0.66), while internal concentration of CO2 positively correlated with photosynthetically active radiation (0.54) (Figure 2B).



	A	gs	Ci	E	VPD	F0'	Fm'	Fv'	qP	ETR	PAR	InRH	InT	ExT	ExRH
A	1.00														
gs	0.99	1.00													
Ci	0.75	0.72	1.00												
E	0.98	0.99	0.73	1.00											
VPD	0.99	0.98	0.76	0.99	1.00										
F0'	-0.86	-0.87	-0.93	-0.89	-0.87	1.00									
Fm'	0.98	0.98	0.77	0.96	0.98	-0.88	1.00								
Fv'	0.97	0.98	0.81	0.97	0.97	-0.92	1.00	1.00							
qP	0.95	0.93	0.84	0.91	0.95	-0.86	0.92	0.93	1.00						
ETR	0.77	0.73	0.97	0.76	0.78	-0.93	0.76	0.81	0.83	1.00					
PAR	0.05	0.05	0.60	0.13	0.09	-0.50	0.13	0.20	0.12	0.61	1.00				
InRH	0.52	0.57	-0.12	0.56	0.52	-0.18	0.51	0.46	0.31	-0.10	-0.56	1.00			
InT	-0.33	-0.39	0.33	-0.36	-0.32	-0.03	-0.32	-0.26	-0.13	0.32	0.70	-0.97	1.00		
ExT	0.02	-0.03	0.62	0.03	0.04	-0.40	0.06	0.12	0.17	0.65	0.89	-0.77	0.90	1.00	
ExRH	0.27	0.34	-0.35	0.32	0.27	0.05	0.27	0.22	0.09	-0.36	-0.66	0.93	-0.98	-0.90	1.00

	A	gs	Ci	E	VPD	F0'	Fm'	Fv'	qP	ETR	PAR	InT	InRH	ExT	ExRH
A	1.00														
gs	0.96	1.00													
Ci	0.95	0.85	1.00												
E	0.94	0.97	0.90	1.00											
VPD	0.97	0.97	0.87	0.93	1.00										
F0'	-0.96	-0.92	-0.97	-0.96	-0.91	1.00									
Fm'	0.97	0.96	0.92	0.98	0.97	-0.95	1.00								
Fv'	0.97	0.96	0.94	0.98	0.96	-0.97	1.00	1.00							
qP	0.90	0.83	0.89	0.80	0.88	-0.86	0.87	0.88	1.00						
ETR	0.78	0.67	0.90	0.72	0.66	-0.84	0.76	0.78	0.82	1.00					
PAR	0.27	0.15	0.54	0.33	0.08	-0.47	0.28	0.33	0.22	0.66	1.00				
InT	-0.17	-0.35	0.11	-0.22	-0.34	0.03	-0.19	-0.15	0.03	0.46	0.70	1.00			
InRH	0.39	0.54	0.11	0.43	0.54	-0.25	0.41	0.37	0.15	-0.25	-0.56	-0.97	1.00		
ExT	0.21	0.05	0.48	0.18	0.02	-0.37	0.19	0.24	0.30	0.74	0.89	0.90	-0.77	1.00	
ExRH	0.13	0.29	-0.13	0.19	0.30	0.00	0.15	0.11	-0.06	-0.50	-0.66	-0.98	0.93	-0.90	1.00

Figure 2. Pearson's correlation coefficients between climatic and ecophysiological variables in *Tabebuia roseoalba* (a) and *Handroanthus heptaphyllus* (b) plants.”

and

That read:

"(…) Maximum temperatures of 40.8 °C (InT) and 38.6 °C (ExT) (Figure 3) were recorded in the same period as for photosynthetically active radiation, at 1 pm and 12 pm. In contrast, internal and external relative humidity drastically reduced during the highest irradiance (PAR) and air temperature (InT and ExT) periods, with minimum at 2 pm (InRH = 30%; ExRH = 32%) and maximum at 8 am and 5 pm (Figure 3).

Read:

"(…) Maximum temperatures of 40.8 °C (InT) and 38.6 °C (ExT) (Figure 3) were recorded in the same period as for photosynthetically active radiation, at 1 pm and 12 pm. In contrast, internal and external relative humidity drastically reduced during the highest irradiance (PAR) and air temperature (InT and ExT) periods, with minimum at 2 pm (InRH = 30%; ExRH = 32%) and maximum at 8 am and 5 pm (Figure 3).

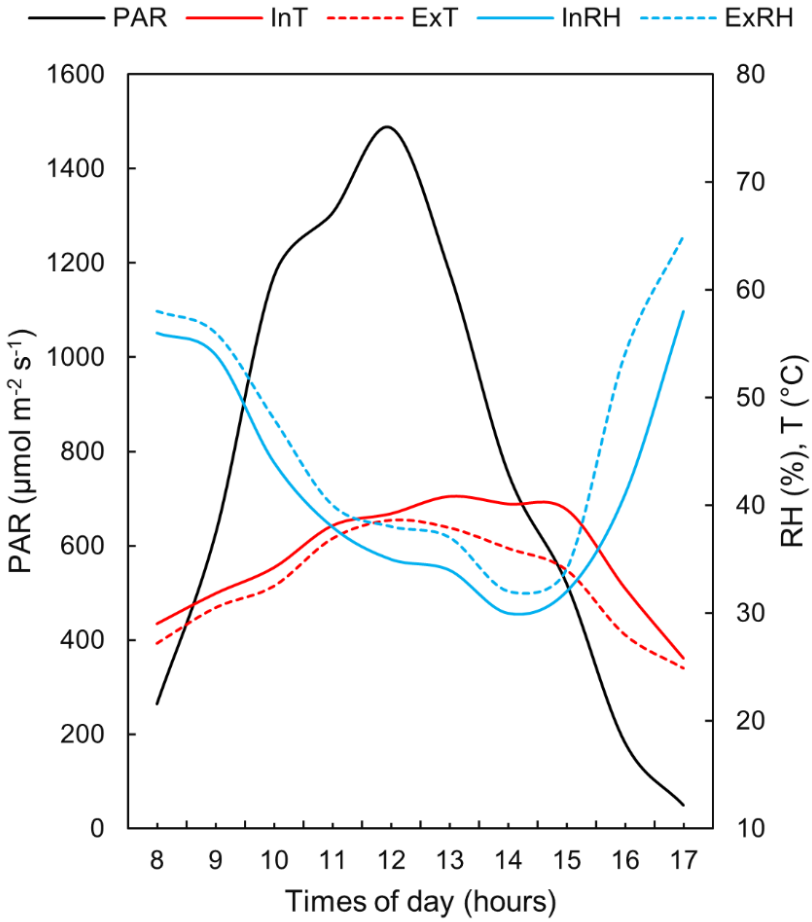


Figure 3. Photosynthetically active radiation (PAR), internal (InT) and external (ExT) temperature, and internal (InRH) and external (ExRH) relative humidity of the environment (greenhouse) during the experiment."

and

That read:

"(…) Vapor-pressure deficit (VPD) decreased with increasing irradiance and air temperature, ranging from 3.16 kPa (8 am) to 1.49 kPa (5 pm) in T. roseoalba, and from 2.77 kPa (8 am) to 1.29 kPa (5 pm) in H. heptaphyllus (Figure 4E).

Read:

"(…) Vapor-pressure deficit (VPD) decreased with increasing irradiance and air temperature, ranging from 3.16 kPa (8 am) to 1.49 kPa (5 pm) in T. roseoalba, and from 2.77 kPa (8 am) to 1.29 kPa (5 pm) in H. heptaphyllus (Figure 4E).

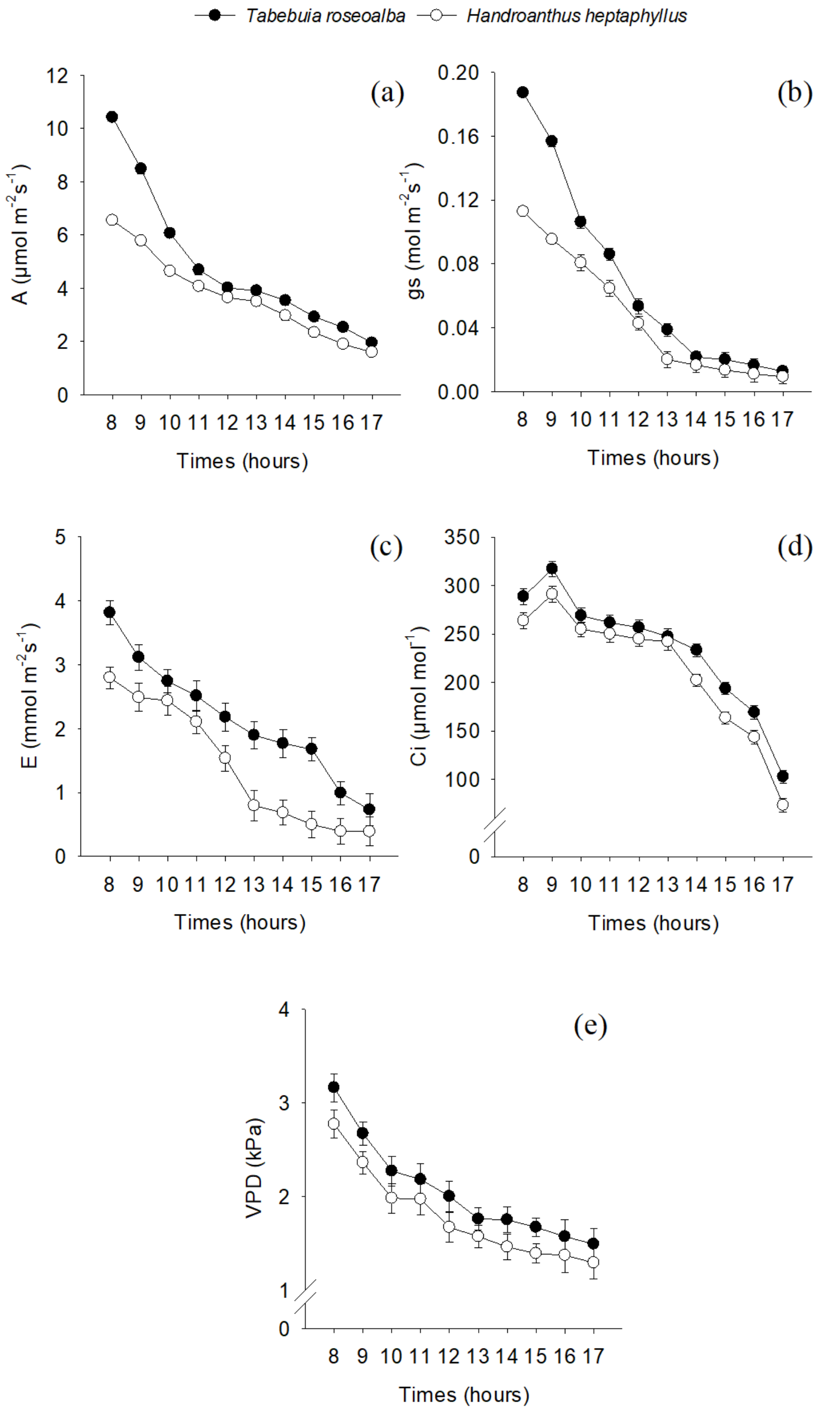


Figure 4. Net assimilation rate of CO_2 (*A*) (a), stomatal conductance (*gs*) (b), transpiration rate € (c), internal concentration of CO_2 (*Ci*) (d), and vapor-pressure deficit (*VPD*) (e) in *Tabebuia roseoalba* (●) and *Handroanthus heptaphyllus* (○) plants along the day. "

and

That read:

"(…) On the other hand, maximum values were recorded earlier in the day (8 am) (89.28 electrons quantum-1 in T. roseoalba and 60.70 electrons quantum-1 in H. heptaphyllus). Thus, ETR increased approximately 73% in T. roseoalba and H. heptaphyllus compared to the lowest values observed (Figure 5E).

Read:

"(…) On the other hand, maximum values were recorded earlier in the day (8 am) (89.28 electrons quantum-1 in T. roseoalba and 60.70 electrons quantum-1 in H. heptaphyllus). Thus, ETR increased approximately 73% in T. roseoalba and H. heptaphyllus compared to the lowest values observed (Figure 5E).

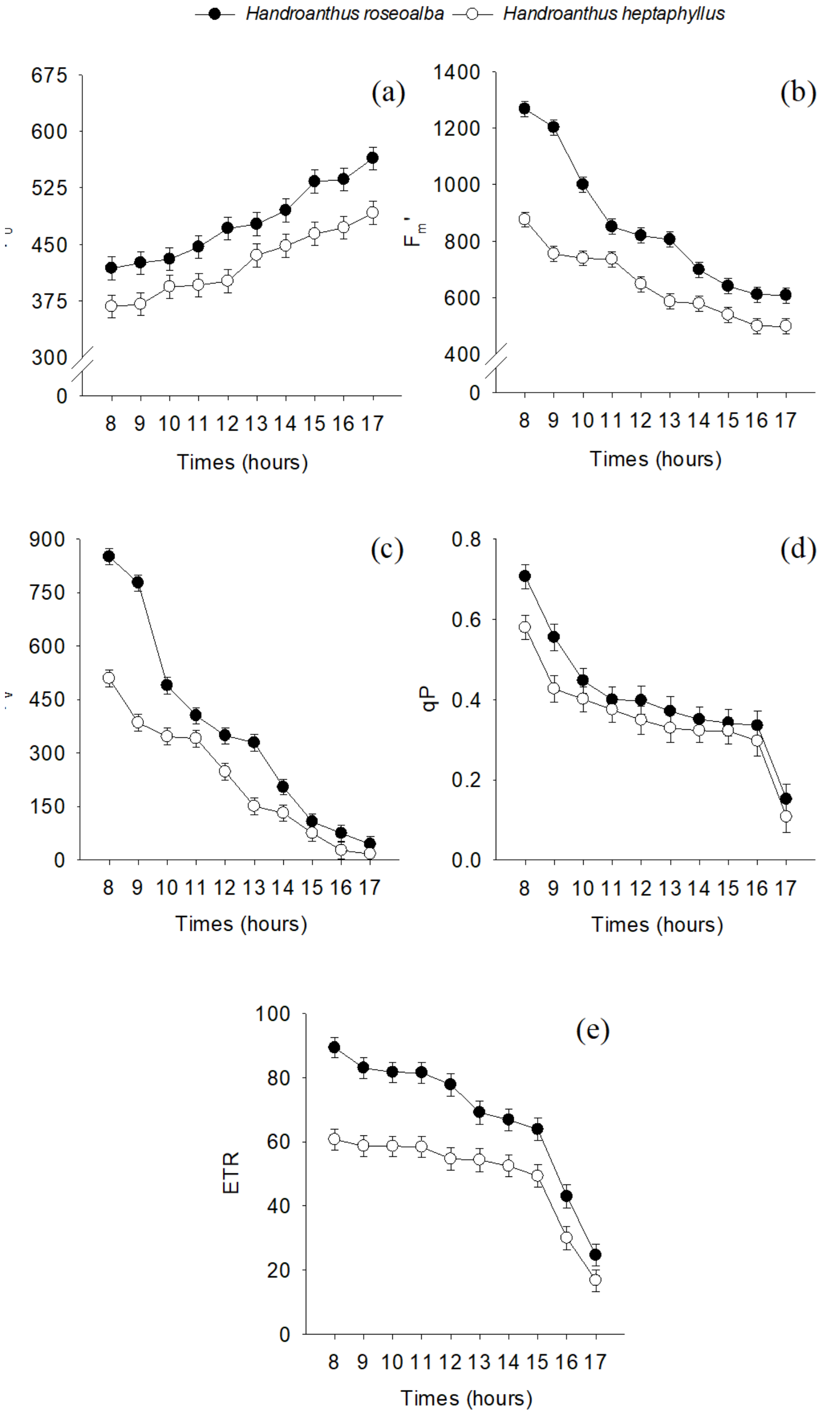


Figure 5. Initial fluorescence (F_0') (a), maximum fluorescence (F_m') (b), variable fluorescence (F_v') (c), photochemical dissipation (qP) (d), and electron transport rate (*ETR*) (e) in *Tabebuia roseoalba* (●) and *Handroanthus heptaphyllus* (○) plants along the day."