

Ecophysiology of *Ceiba glaziovii* (Kuntze) K. Schum. Submitted to Shading

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Abstract

The *Ceiba glaziovii* is a forest species used for pharmacological purposes and in the recovery of degraded areas. Nevertheless, the availability of light may be somewhat limiting to its development and may directly influence its physiological and biochemical processes. Thus, the objective of this work was to evaluate the ecophysiological behavior of *C. glaziovii* plants under different shading levels. The design used was completely randomized, with 5 treatments and 8 repetitions. The treatments used were composed of different shading levels: 0% (full sun), 30%, 50%, 70% and 90% shade. For the analyzes, growth characteristics, gas exchange, chlorophyll indices and chlorophyll a fluorescence were evaluated. Data were subjected to analysis of variance by the F test, and in cases of significance a polynomial regression analysis was performed. The highest values for gas exchange, chlorophyll indexes and fluorescence were 90% shading. Shading is beneficial to *C. glaziovii* plants, providing positive effects on growth, gas exchange, chlorophyll indexes and chlorophyll a fluorescence.

Keywords: barriguda, irradiance, light intensity, photochemical efficiency, plant adaptation

1. Introduction

The *Ceiba glaziovii* (Kuntze) K. Schum. is a species belonging to the family Malvaceae, popularly known as barriguda or paineira, occurring in northeastern Brazil in hyperxerophilous caatingas in rugged environments and in arboreal caatinga (Araújo et al., 2019). It has fast growth, ornamental characteristics, and its bark and leaves are used in folk medicine to treat inflammation, heart problems and hypertension, and can be used in mixed plantations, especially for the recovery of degraded areas (Nascimento et al., 2012; Pereira Júnior et al., 2014).

Several abiotic factors can interfere with the growth and development of forest species, especially in the seedling phase, such as water availability, salinity and luminosity. In this context, light is one of the most important environmental factors and may interfere with physiological processes, and these responses may vary by species (Dutra et al., 2012).

The amount of light energy intercepted by leaves directly influences plant development, where the satisfactory growth of some species under higher or lower light intensity may be associated with the ability to quickly adjust their physiological behavior (Dapont et al., 2016). In addition to acting as the driving force of photosynthesis, light interferes with the structure and operation of the photosynthetic apparatus and consequently on plant yield (Li et al., 2014).

Given this, some studies show that under shading conditions forest species can behave in different ways, such as Caron et al. (2014) in *Ilex paraguariensis* A. St. Hil., where shading provides lower shoot biomass production, Queiroz and Firmino (2014) confirm that shading up to 30% has a positive influence on the initial development of *Dipteryx alata* Vog., and Reis et al. (2016) in plants of *Copaifera langsdorffii* Desf conclude that 50% shading provides better seedling quality and therefore better field survival. In this sense, studies that seek to know the physiological behavior of forest species under shading conditions is of great importance.

Therefore, the objective of the present work was to evaluate the ecophysiological behavior of *C. glaziovii* plants under different shading levels.

2. Material and Methods

The experiment was conducted in a greenhouse belonging to the Laboratory of Plant Ecology, Department of Plant Science and Environmental Sciences, Center for Agricultural Sciences, Federal University of Para ía, Campus II, Areia, Para ía, Brazil. During the experiment, the environment presented an average temperature of 27.9 °C and a relative humidity of 63.4%, whose measurements were made using a portable digital thermo-hygrometer (Minipa, model MT-241A).

The seeds of *C. glaziovii* were collected in matrices located in Campina Grande, Para ía State, Northeast Brazil. The seeds were planting in plastic pots with a capacity of 5 dm³ and in substrate formulated of vegetal soil and sand (3:1). In Table 1 are the chemical attributes of the substrate used.

Table 1. Chemical attributes of the substrate used in the experiment, Areia – PB, 2019

pH in H ₂ O	P	K	Na	H+Al	Al	Ca	Mg	BS	CEC	O.M
	mg dm ³		cmolc dm ³						g kg ⁻¹	
6.19	118.69	217.18	0.33	2.81	0.00	4.50	1.40	6.78	9.59	31.77

BS: base sum; CEC: cation exchange capacity; O.M: organic matter.

Two seeds/pot were used and at 10 days after emergence (DAE) thinning occurred, selecting uniform individuals, with an average of 6 cm height. Then the plants were transferred to the different shading levels (treatments) and the evaluations started at 30 days after emergence (DAE). Each shading level within the greenhouse was determined from a digital luxmeter (Minipa, model MLM-1011), and the irradiance within the shaded screens was calculated in proportion to the full sun condition (0% shade) (Figueiredo et al., 2019). Shading screens were purchased from local businesses.

The site of the experiment has high coverage and specific areas, so that the light was not influenced during the day. Daily, during the experimental period, the pots were weighed and rotated, maintaining the field capacity around 80%, according to the methodology proposed by Casaroli and Jong van Lier (2008).

The experimental design was completely randomized, consisting of 5 treatments: 0%, 30%, 50%, 70% and 90% shading and 8 repetitions, each repetition consisting of one plant, totaling 40 plants.

For growth analyzes, plant height (PH) (cm), stem diameter (SD) (mm) and leaf number (NL) were measured at 30 and 60 DAE. At 60 DAE, the plants were collected from the pots and subjected to root separation. The roots were then rinsed under running water for cleaning and debris removal and thus the length of the main root (RL) (cm) was determined by a millimeter ruler and the diameter of the main root (RD) (mm) using a digital caliper. Subsequently, the volume of the root system (RV) (mL) was determined from the

displacement of the water column in a graduated beaker, inserting the roots after washing, in a beaker with a known volume of water (50 mL) (Ribeiro et al., 2019). From the difference, the direct response of the root system volume was obtained through the equivalence of units ($1 \text{ mL} = 1 \text{ cm}^3$).

For gas exchange analysis, it was measured at 60 DAE, the CO_2 assimilation rate (A) ($\mu\text{mol m}^{-2} \text{ s}^{-1}$), stomatal conductance (g_s) ($\text{mol m}^{-2} \text{ s}^{-1}$), transpiration rate (E) ($\text{mmol m}^{-2} \text{ s}^{-1}$), internal CO_2 concentration (C_i) ($\mu\text{mol mol}^{-1}$) and leaf temperature (T_{leaf}) ($^{\circ}\text{C}$). Subsequently, from these data the instantaneous water use efficiency ($WUE: A/E$) [$(\mu\text{mol m}^{-2} \text{ s}^{-1})/(\text{mmol m}^{-2} \text{ s}^{-1})$] and instantaneous carboxylation efficiency ($ICE: A/C_i$) [$(\mu\text{mol m}^{-2} \text{ s}^{-1})/(\mu\text{mol m}^{-2} \text{ s}^{-1})$] were calculated. For the measurements, a 6 cm^2 leaf chamber with natural light sensor coupled, air humidity between 50-60%, air flow of $400 \mu\text{mol s}^{-1}$ and $400 \mu\text{mol mol}^{-1}$ of atmospheric CO_2 were used. The analyzes were performed on undetected leaves, healthy and completely expanded in the middle third of the plants during the day with total sunlight conditions, in the period between 11:00 am and 12:00 am. The acclimatization time of the leaves inside the equipment was approximately 5 minutes for each leaf. Measurements were performed using a portable infrared gas analyzer (IRGA) (LICOR, model LI-6400XT).

For quantification of indexes chlorophyll a , b , total and a/b ratio at 60 DAE, a portable chlorophyllometer (ClorfiLOG®, model CFL 1030) was used in four leaves of the middle third of the plants.

For chlorophyll a fluorescence, initial fluorescence (F_0), maximum fluorescence (F_m), variable fluorescence ($F_m - F_0$), maximum quantum yield of PSII (F_v/F_m) and F_v/F_0 ratio were evaluated at 60 DAE. For the measurements, healthy leaves were used in the middle third of the plants, being adapted to the dark by tweezers for a period of 30 minutes. For the analysis was used a portable modulated fluorometer (Sciences Inc.- model OS-30p, Hudson, USA).

Data were subjected to analysis of variance by the F test, and in cases of significance, a polynomial regression analysis was performed, with the adjustment of representative curves. To perform the statistical analyzes was using SAS® (Cody, 2015).

3. Results and Discussion

Shading levels positively influenced *C. glaziovii* growth (Figure 1A, B and C). Plant height (PH) increased linearly at 60 DAE (Figure 1A), the number of leaves (NL) followed the same trend, with the highest values obtained in shading of 90% (Figure 1B). Stem diameter (SD) data best fitted a quadratic effect, with the largest increases observed in shading of 53.4% at 60 DAE when compared to the treatments with higher light intensity (Figure 1C).

The better vegetative growth evidenced by these PH, NL and SD results can be attributed to the increase in the plants capacity to absorb water as the lowest evaporation under shading conditions, which consequently accelerates the vegetative growth rate (El-Bassiony et al., 2014). This growth pattern in *C. glaziovii* may promote its use in restoration of degraded areas, especially in advanced stages of succession, for under this condition to greater competition for light (Valadão et al., 2014).

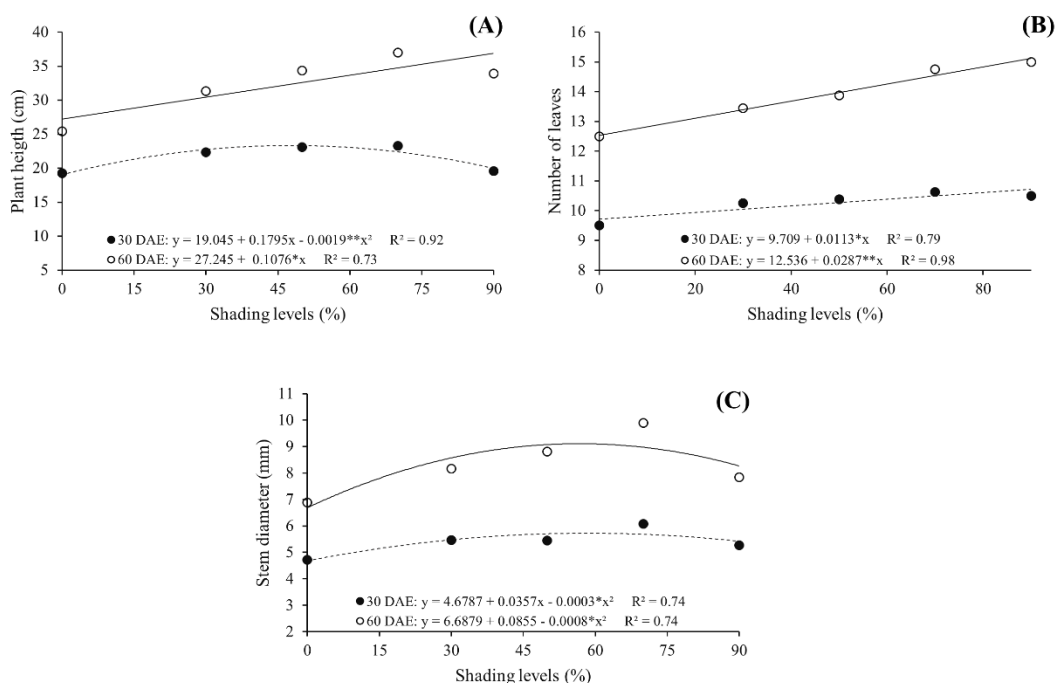


Fig 1. Plant height (A), number of leaves (B) and stem diameter (C) in plants of *Ceiba glaziovii* at 30 and 60 days after emergence, as a function of shading levels

The length (RL) and root diameter (RD) increased linearly as a function of shading levels, with increases of 33.7 and 25.3%, respectively, compared to plants conducted under full sun (Figure 2A and B). However, root volume (RV) was higher in shading of 70% (Figure 2C).

These increases in RL, RD and RV indicate that *C. glaziovii*, when subjected to shading conditions, invests most of the growth in the shoots, a fact that can be observed in Figure 1, as well as in the root system, providing a larger biomass allocation. Thus, the deep root system improves the absorption of water and nutrients, increasing its survivability, especially during the dry season (Castro et al., 2014).

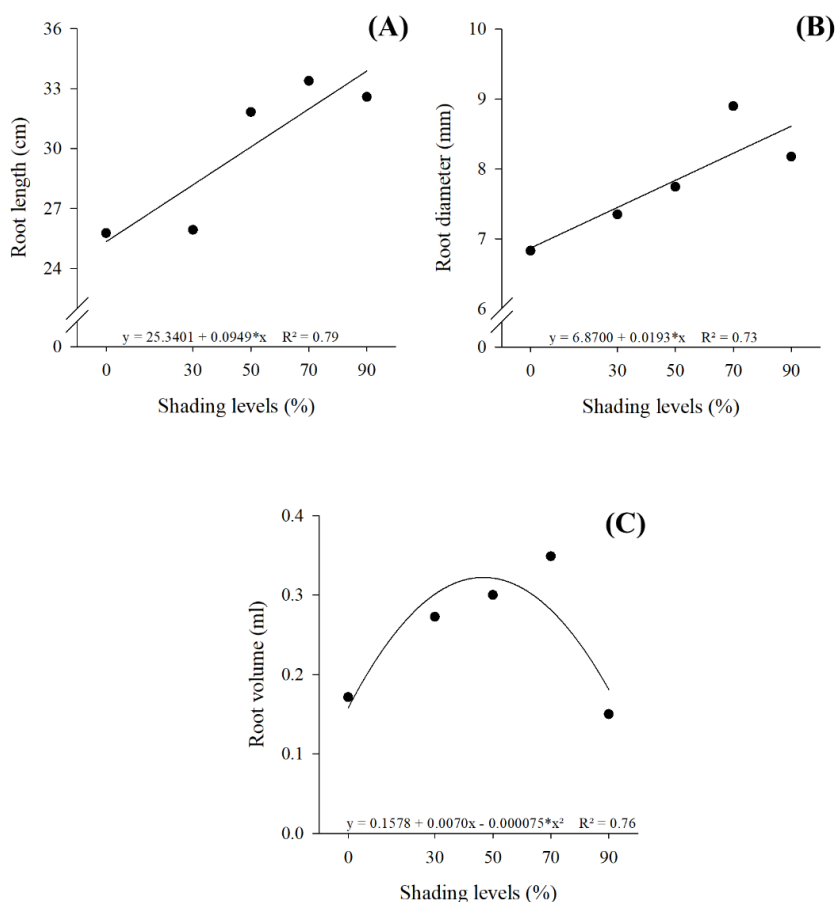


Fig 2. Root length (A), root diameter (B) and root volume (C) in plants of *Ceiba glaziovii*, as a function of shading levels

Shading positively influenced *C. glaziovii* gas exchange (Figure 3A, B, C and D). The CO_2 assimilation rate (A) increased linearly, reaching a rate of $8.7 \mu\text{mol m}^{-2} \text{s}^{-1}$ in 90% shading (Figure 3A). The values for stomatal conductance (g_s) and transpiration (E) fit a quadratic effect, with the highest efficiencies in shading levels of 69.1 and 75.5%, respectively (Figure 3B and C). The internal concentration of CO_2 (C_i) was reduced with increasing shading levels, 10.4% reduction in 90% shading (Figure 3D).

The increase in A is a strong indication that *C. glaziovii* is a species adapted to shaded environments, thus requiring a lower light intensity to reach the photosynthetic peak, and this behavior is also associated with increases in chlorophyll indices. In this sense, large amounts of light can cause physiological disturbances and may induce the photoinhibition process (Tang et al., 2015). Increases in g_s may be associated with increases in A, due to the reduction in the amount of CO_2 in intercellular spaces, which may induce stomata opening. However, high shading levels provide decreases for this variable, probably due to the vapor pressure deficit along with a higher temperature (Saraiva et al., 2014).

The transpiration rate is directly influenced by g_s , where the stomatal opening and closing mechanism controls the exchange of leaf gases with the environment (Sousa et al., 2016).

Reductions in C_i can be attributed to higher photosynthetic rates, which is an indication that CO_2 is being fixed by Rubisco (Sun et al., 2014).

Shading provided increases in instantaneous water use efficiency (WUE) and carboxylation efficiency (ICE), with the highest values recorded in shading of 90% (Figure 3E and F). Leaf temperature (T_{leaf}) was reduced with increasing shading levels (Figure 3G).

Increases in WUE and ICE may be associated with gains in A , showing a close correlation between these variables, because a higher CO_2 assimilation induces a higher Rubisco activity, providing greater CO_2 availability compared to O_2 (Nazar et al., 2015). Reductions in T_{leaf} can be explained by gains in g_s and E causing leaf cooling, which is positive, since overheating of the photosynthetic apparatus can affect physiological and biochemical processes (Morais et al., 2017).

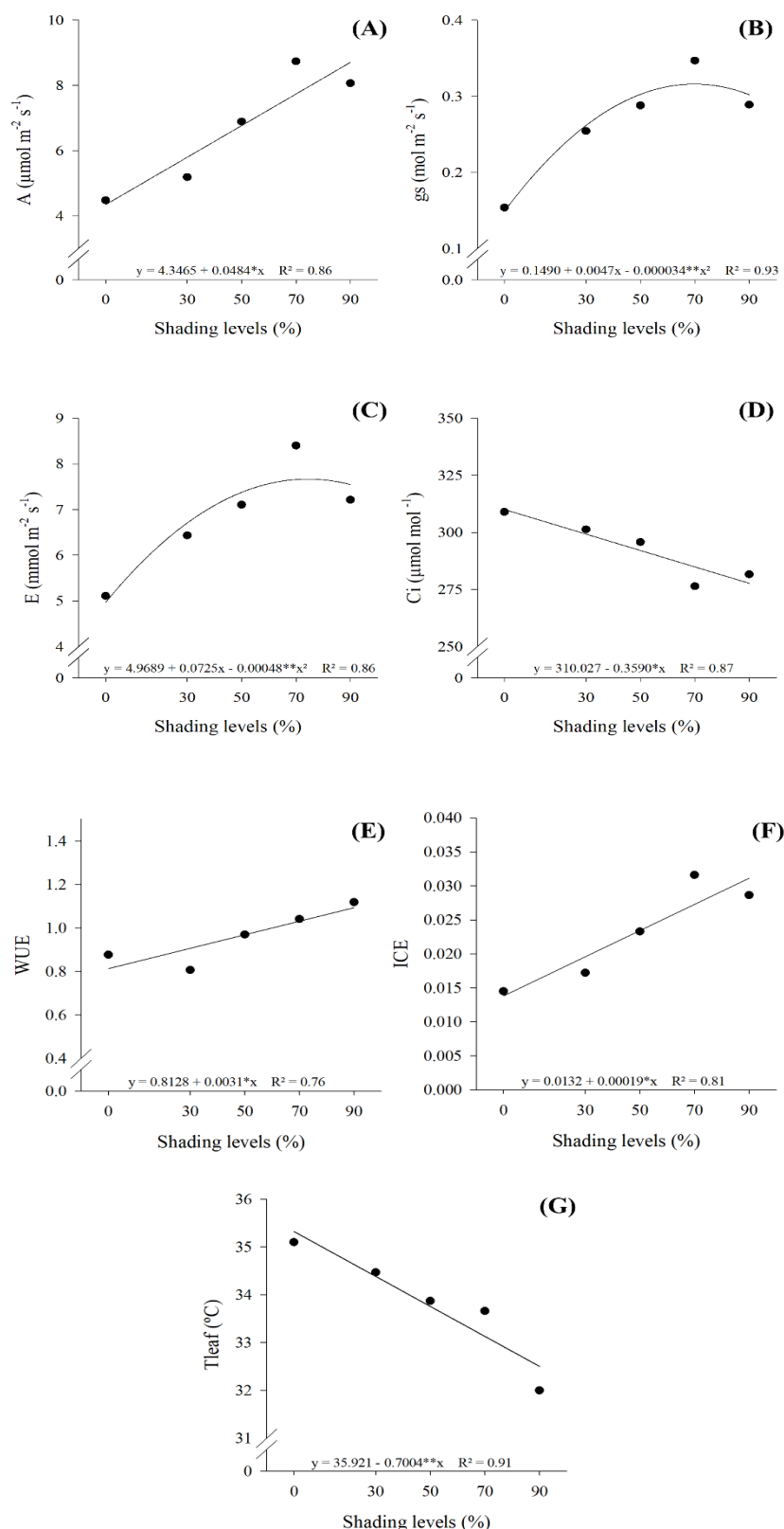


Fig 3. CO_2 assimilation rate (A), stomatal conductance (B), transpiration rate (C), internal CO_2 concentration (D), instantaneous water use efficiency (E), instantaneous carboxylation efficiency (F) and leaf temperature (G) in plants of *Ceiba glaziovii*, as a function of shading levels

Chlorophyll indices were higher in the shade treatments (Figure 4A, B and C). Up to the 72.3% level, shading was positive for chlorophyll *a* (Figure 4A). Chlorophyll *b* and total indices increased linearly as a function of shading levels, with values in the order of 12.1 and 51.2 ICF, respectively, at 90% shading (Figure 4B and C).

These additions can be explained by the fact that plants grown in shaded environments tend to synthesize a greater amount of chlorophyll per reaction center, thicker leaves and larger areas, possibly as an adaptation mechanism, favoring the capture of light (Taiz et al., 2017). The linear increase in chlorophyll *b* can be attributed to the fact that this pigment is degraded more slowly than chlorophyll *a* (Nery et al., 2016), contributing to a higher total chlorophyll index.

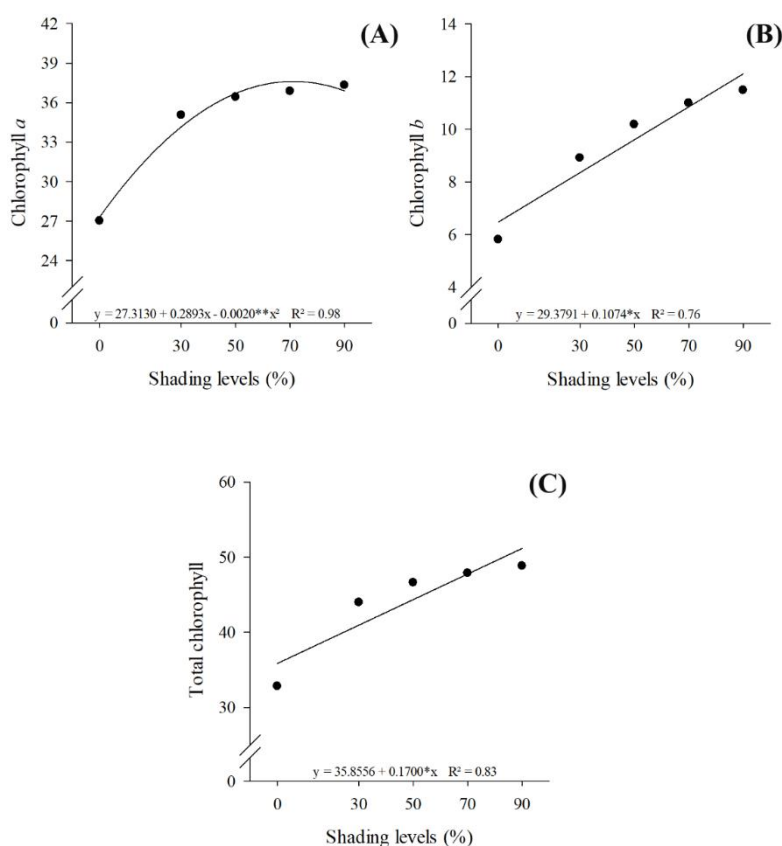


Fig 4. Chlorophyll *a* (A), chlorophyll *b* (B) and total chlorophyll (C) in plants of *Ceiba glaziovii*, as a function of shading levels

Chlorophyll *a* fluorescence parameter was positively influenced by shading levels. The initial fluorescence (F_0) was reduced as the shading levels increased (Figure 5A). Maximum fluorescence (F_m), variable fluorescence (F_v), maximum quantum yield of PSII (PQE) and F_v/F_0 ratio increased in shaded environment (Figure 5B, C, D and E).

F_0 is measured when all reaction centers are open, and reductions in this variable are a good indication that less energy is being lost in the form of heat, favoring the photochemical phase of photosynthesis (Fu et al., 2012). Increases in F_m and F_v suggest that photo-acclimation of

plants occurred under shading as a way to maximize light uptake (Reed et al., 2012). The fact that these variables are indicative of the state in which the PSII reaction centers reached their maximum capacity, associated with the active potential energy in the PSII reinforces this statement (S áet al., 2018).

The positive results found in F_v/F_m indicate that in a shaded environment *C. glaziovii* plants tend to have a higher photochemical activity than PSII. This shows that under full sun conditions the plants are subjected to the photoinhibition process (Dąbrowski et al., 2015). The F_v/F_0 ratio followed the same trend, which is a way of measuring the efficiency of PSII photochemical reactions (Zivcak et al., 2014).

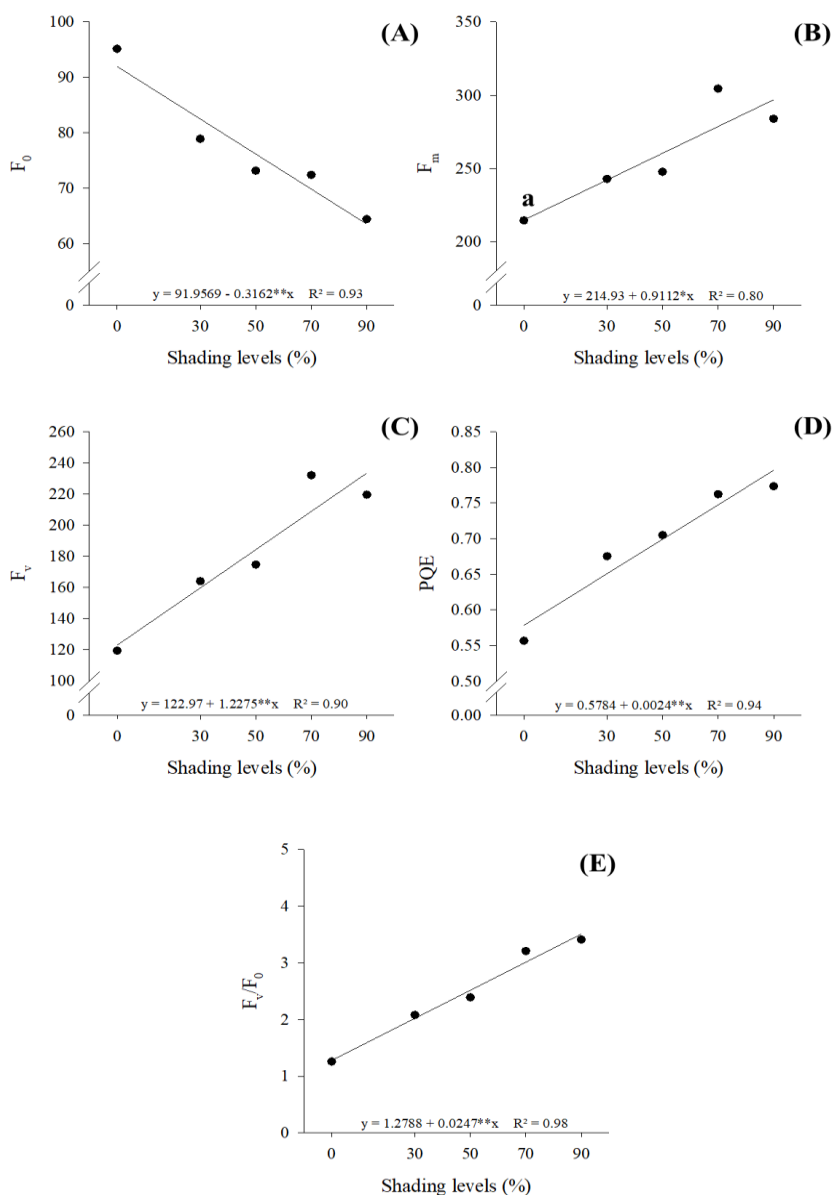


Fig 5. Initial fluorescence – F_0 (A), maximum fluorescence – F_m (B), variable fluorescence – F_v (C), maximum quantum yield of PSII – PQE (D) and F_v/F_0 ratio (E) in plants of *Ceiba glaziovii*, as a function of shading levels

4. Conclusions

Higher shading levels provide better growth, photosynthetic rate, chlorophyll indices and chlorophyll *a* fluorescence in *C. glaziovii* plants;

Shading is beneficial for *C. glaziovii* plants and can provide higher quality seedlings.

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