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Morphophysiological comparison of *Schizolobium parahyba* varieties seedlings cultivated under different shading levels

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Abstract

Schizolobium parahyba varieties are found in both Atlantic and Amazon Forests, being considered suitable raw material for pulp, paper, pharmaceutical, and bioenergy industries. Hence, seeking to exploit the production of native seedlings adapted to adverse environments, this work aimed to evaluate seedlings growth of two *S. parahyba* varieties under three different shading conditions (full sunlight, 30%-shading screen, and 70%-shading screen). We carried out the experiment in full sunlight, 30% shading screen and 70% shading screen and used a commercial substrate Tropstrato Florestal ® in a factorial scheme 2x3, for 90 days. Growth and physiological (gas exchange and pigments content) parameters were assessed at the end of the experiment. In contrast to the results found for this analysis, verified by means of the IRGA measuring device, most of the growth traits differed among treatments while the photosynthetic pigments were strongly influenced by shading levels regardless of varieties. *S. parahyba* var. amazonicum 'Paricá' presented better fitting and growth under 70%-shading screen, since it displays a close physiognomy of 'terra firma' regions, thus being suitable for reforestation in closed-canopy forests. On the other hand, *S. parahyba* var. parahyba 'Guapuruvu' presented better responses on growth parameters under the 30%-shading screen, with potential for open forests. *S. parahyba* varieties present some phenotypic variation to shading levels wherein this information can be useful for this species management.

Keywords: Luminosity, Forest species, Ecological succession, Shading, Photosynthetic pigments.
Abbreviations: IRGA_Infrared Gas Analyzer.

Introduction

The reforestation of large areas in Brazil is a crucial practice to control extinction of species, even by recovering degraded areas as well as by keeping going forest product outputs. Since plants depend on light as a primary energy source for their growth and development, the level of light (or shading) is a fundamental factor for reforestation projects. Among tree species with a potential use for reforestation, the varieties of *Schizolobium parahyba*, Fabaceae (or Leguminosae) family has been pointed out as suitable due to fast growth and height (Gondin et al. 2015; Narita et al. 2018).

Schizolobium parahyba var. *amazonicum* (Huber ex Ducke) Barneby, commonly known as 'Paricá' or 'cuiabano pine', occurs in primary and secondary vegetation - both lowland and highland forest in the Amazon (Cordeiro et al. 2019). This plant presents high survival rates and fast development, both in height and diameter, with trunks of 1 m diameter and ~30 m height, reaching a yield of 13 to 35 m^3 ha^{-1} $year^{-1}$ (Gomes *et al.* 2010; Terezo et al. 2010; Cordeiro et al. 2015). According to Carvalho (2007), *S. parahyba* var. *amazonicum* 'Paricá' has been used for forest regeneration in Pará State since 1976, where it has been stood out due to its potential to agroforestry composition coupled to socioeconomic benefits. Cordeiro et al. (2019) claimed that this species may be an alternative of employment and income for cocoa and cupuaçu producers in the Amazon, with the tree canopy being used as a natural shading in agroforestry consortium (Marques et al. 2004; Ohashi et al. 2010).

In degraded areas, this species can be cultivated in open-top places due to its ability in adapting to high light intensities (Gomes et al. 2010; Butzke et al. 2018). The wood of *S. parahyba* var. *amazonicum* 'Paricá' is light and moderately dense so that the trunks are used to manufacture medium blades or door kernels (Carvalho 2007; Cordeiro et al. 2015), and to produce glued laminated wood (Glulam) from standing forests (Terezo et al. 2019). Recently, this species has been pointed out as an alternative to producing cellulosic film demanded by the cellulose industry coupled to a reduced waste of raw material and pollution (Scatolino et al*.* 2018). Moreover, the mix of Paricá pulp with *Eucalyptus grandis* (eucalyptus) has been used by industries of pulp and paper (Vidaurre et al. 2018).

Schizolobium parahyba var. *parahyba* (Vell) Blake 'Guapuruvu' covers an area between Bahia and Rio Grande do Sul, around the Atlantic Pluvial Forest (Caron et al. 2010). It is a pioneer deciduous heliophyte tree that presents characteristics closely related to the Atlantic Forest. It is known as 'pataqueira', 'pau-de-tambor', 'pau-de-canoa', 'pau-de-vintém', and holds a fast growth, suitable for silvicultural production, and important for forest cultivation in both South and Southeast (Lorenzi 1998; Caron et al. 2010). This species is also indicated for ecological restoration projects in the Atlantic Forest due to its canopy shape, which shadows secondary and later successional species (Calonego 2017). *S. parahyba* var. *parahyba* 'Guapuruvu' presents a light and softwood, with a coarse texture, thereby displaying low durability under natural conditions. The height, reached by adulthood (40 m high and 120 cm DAP), makes it commercially important for the manufacture of ships, plates, furniture, door materials, linings, and tables, as well as toys and heels for shoes (Lorenzi 1998).

Although these species are widely exploited by the timber industry, they can also be applied to several purposes such as energy sources (Narita et al*.* 2018), regeneration of degraded areas, and commercial forests. However, the technical knowledge of its potential for commercial production is still limited (Barroso et al. 2018). Furthermore, little is known about the initial development of such species (Butzke et al. 2018).

The photosynthetic ability in maintaining positive carbon balances is a physiological mechanism that leads to plant resilience against environmental stressors. In this context, given the importance of clearings for shading composition in forests (Marimon et al. 2008), it is necessary to establish strategies to better understanding the developmental behavior of seedlings under different degrees of luminosity, pot sizes, fertilization inputs, seed origin, growth habits, and morphological variations to base forest recovery programs and regular growth of natural ecosystems (Ohashi et al. 2010; Roweder et al. 2015; Butzke et al. 2018).

Based on the premise that regardless of varieties this species may have similar morphophysiological characteristics under different environments, this study aimed to evaluate seedlings production, and the variation of the phenotypes, of two *S. parahyba* varieties at different shading levels, seeking to establish the most suitable light level to grow healthy and strong plants to forest regeneration projects.

Results

In total 24 variables were analyzed here and of these, at the end of the experiment, six variables displayed significant differences ($p < 0.05$) for the shading x varieties interaction, such as stem, leaves, shoot and total dry weight, height-to-shoot weight ratio, and seedling quality index. Regarding shading factor, five variables presented significant differences, namely total leaf area, chlorophyll a content, total chlorophyll content, chlorophyll a/b ratio, and carotenoids content. On the other hand, five variables showed differences for varieties as a factor, especifically stem diameter, specific leaf area, shoot dry weight, height-to-shoot weight, and shoot-to-root ratio (Tab. 1).

Result morphological analysis

The growth-related parameters of *S. parahyba*, as plant height, number of leaves, height-to-diameter ratio, and root dry weight were similar for both varieties under different shading levels (Tab. 2). On the other hand, stem diameter differed between varieties, but no significant difference was observed when shading levels were compared (Fig. 1A). A remarkable variation in the initial growth of *S. parahyba* var. *amazonicum* 'Paricá' was observed as a function of the different levels of shading, in which higher values were observed in stem, leaves, shoot, and total dry weight (Fig. 1B-E) at 70%-shading screen. At 30%-shading screen, stem, leaves, shoot and total dry weight showed higher values (Fig. 1B-E) in *S. parahyba* var. *parahyba* 'Guapuruvu'. Height-to-shoot weight presented interesting and opposite changes as a function of varieties, while at 70%-shading screen, the *S. parahyba* var. *parahyba* 'Guapuruvu' displayed values higher than observed in *S. parahyba* var. *amazonicum* 'Paricá'. Finally, at 30%-shading screen, the *S. parahyba* var. *amazonicum* 'Paricá' showed higher values as compared to *S. parahyba* var. *parahyba* 'Guapuruvu' (Fig. 1F).

The total leaf area was higher at 70%-shading screen regardless of varieties (Fig. 2A). Concerning specific leaf area, the *S. parahyba* var. *parahyba* 'Guapuruvu' presented higher values at both 70%-shading screen and full sunlight (0%) (Fig. 2B), which means that, at these treatments, *S. parahyba* var. *parahyba* 'Guapuruvu' showed leaves thinner than *S. parahyba* var. *amazonicum* 'Paricá'. Furthermore, *S. parahyba* var. *amazonicum* 'Paricá' allocated more biomass to shoots than *S. parahyba* var. *parahyba* 'Guapuruvu', as evidenced by values of shoot-to-root ratio (Fig. 2C). Regarding seedling quality index, *S. parahyba* var. *parahyba* 'Guapuruvu' displayed higher values at 30%-shading screen, while at 70%-shading screen, the *S. parahyba* var. *amazonicum* 'Paricá' showed higher values (Fig. 2D).

Result physiological analysis

Concerning photosynthetic pigments, four parameters showed differences for shading as a factor, namely chlorophyll a content, total chlorophyll content, chlorophyll a/b ratio, and carotenoids content (Tab. 1). All these pigment parameters displayed a similar pattern and were found in lower concentrations at 70%-shading screen, without or with few changes for both varieties (Fig. 3A-C). The changes in carotenoid content are quite impressive, with a large reduction in the *S. parahyba* var. *amazonicum* 'Paricá' at 70%-shading screen (Fig. 3D). It should be noted that, for photosynthetic pigments, *S. parahyba* var. *amazonicum* 'Paricá' shows better responses to shading levels treatments as compared to *S. parahyba* var. *parahyba* 'Guapuruvu' (Fig. 3). For gas exchange parameters, internal CO_2 concentration (C_i), stomatal conductance (g_s), net assimilation rate (A), transpiration rate (E), and water use efficiency (WUE) did not differ among treatments by considering the interaction of factors; neither for isolated (varieties nor shading levels) (Tab. 3).

Discussion

At 90 days, the analysis of gas exchange parameters was carried out by using a portable Infrared Gas Analyzer - IRGA, LCiSD ADC system®, most of the growth characteristics

Table 1. Summary of the analysis of variance related to morphophysiological parameters evaluated on *Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá' seedlings growing under full sunlight, 30% or 70%-shading screens treatments.

Variables	Source of variation				Average	CV (%)
	Shading (S)	Varieties (V)	S x V	Residuals		
	Degrees of freedom					
	2	1	2	18		
Plant height	8.75ns	182.05ns	60.22ns	100.98	51.67	18.66
Stem diameter	0.32ns	7.47*	0.51ns	1.19	5.88	19.63
Height-to-diameter ratio	1.77ns	4.20ns	0.25ns	1.41	8.87	13.62
Number of leaves	0.66ns	2.04ns	0.16ns	1.73	2.85	32.37
Stem dry weight	0.06ns	0.34ns	0.85*	0.07	1.43	27.26
Root dry weight	0.16ns	0.03ns	0.03ns	0.31	1.28	27.67
Leaves dry weight	0.47ns	0.23ns	0.66*	0.1	1.02	42.84
Shoot dry weight	0.52ns	1.15282*	3.01*	0.15	2.45	28.22
Total dry weight	0.81ns	0.8103ns	5.28*	0.45	3.73	25.66
Height-to-shoot weight	18.77ns	197.973*	149.13*	30.73	3.87	28.67
Shoot-to-root ratio	0.64ns	1.35375*	0.44ns	0.17	1.97	27.28
Specific leaf area	2017.4ns	30180.7*	5768.3ns	5661.7	204.70	24.09
Total leaf area	27292.6*	7618.4ns	3098.0ns	4968.4	196.96	25.67
Seedling quality index	0.002ns	0.000ns	0.033*	0.007	0.35	27.46
Carotenoids	16800.4*	5744.3ns	746.7ns	2978.6	0.17	28.52
Chlorophyll a	27270.9*	10558.0ns	1634.5ns	5840.7	1.82	32.67
Chlorophyll b	2746.71ns	2366.91ns	704.59ns	1604.4	0.76	36.13
Chlorophyll ratio	262.93*	75.33ns	3.26ns	49.63	2.59	35.23
Total chlorophyll	47313.2*	22920.3ns	4470.3ns	12831.4	2.58	29.64
Transpiration rate (E)	16.60ns	53.55ns	11.66ns	15.42	4.71	41.56
Stomatal conductance (*gs*)	0.00ns	0.00ns	0.00ns	0	0.04	55.31
Net assimilation rate (*A*)	15.67ns	0.37ns	4.51ns	5.47	3.64	47.82
Internal CO_2 concentration (*Ci*)	22715.3ns	5075.9ns	8623.9ns	8217.3	330.04	29.34
Water use efficiency (WUE)	0.30ns	0.87ns	0.04ns	0.1	0.93	66.61

CV: Coefficient of Variation; *: significant at the 5% probability level ($0.01 \leq p < 0.05$); ns: not significant ($p \geq 0.05$) by F test.

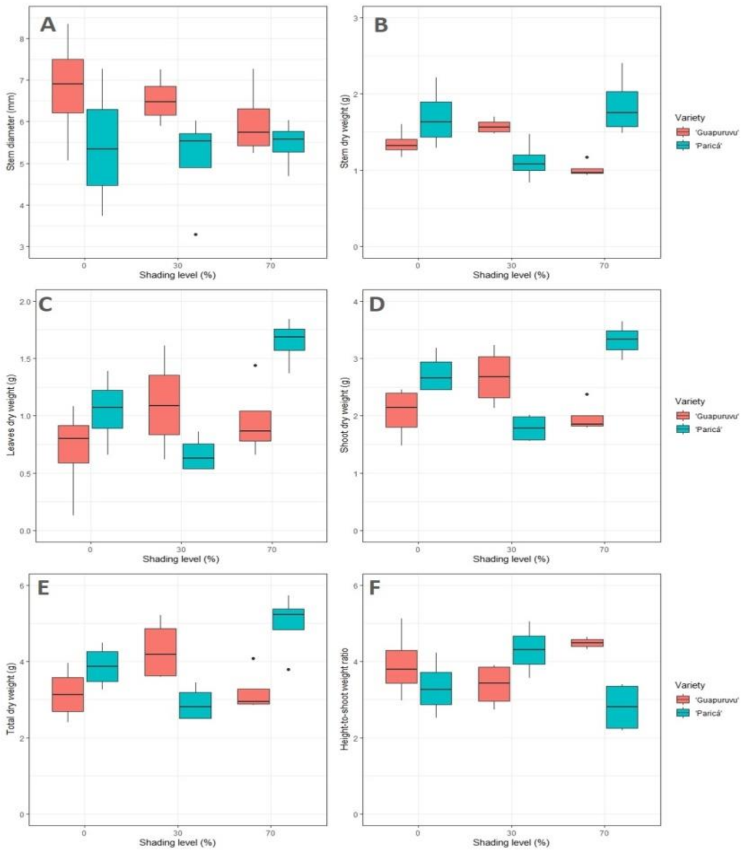

Figure 1. Interaction between shading levels (full sunlight, 30%-shading screen, and 70%-shading screen) and varieties (*Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá') of growth-related parameters in 90-day-old seedlings. Stem diameter (**A**), stem dry weight (**B**), leaves dry weight (**C**), shoot dry weight (**D**), total dry weight (**E**), and height-to-shoot weight ratio (**F**).

Table 2. Interaction between shading levels (full sunlight, 30%-shading screen, and 70%-shading screen) and varieties (*Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá') of growth-related parameters (plant height, height-to-diameter ratio, number of leaves, and root dry weight) in 90-day-old seedlings.

Parameters	full sunlight		30%-shading		70%-shading	
	Guapuruvu	Paricá	Guapuruvu	Paricá	Guapuruvu	Paricá
Plant height (cm)	53.3 ± 3.50	47.8 ± 2.73	57.5 ± 1.39	46.5 ± 2.67	52.5 ± 1.99	52.5 ± 2.28
Height-to-diameter ratio	7.76 ± 0.13	8.92 ± 0.25	8.81 ± 0.09	9.27 ± 0.35	8.80 ± 0.26	9.68 ± 0.50
Number of leaves	3.25 ± 0.24	2.83 ± 0.14	2.50 ± 0.14	2.50 ± 0.25	3.25 ± 0.38	2.75 ± 0.24
Root dry weight (g)	1.09 ± 0.07	1.14 ± 0.06	1.62 ± 0.08	1.11 ± 0.06	1.24 ± 0.09	1.49 ± 0.12

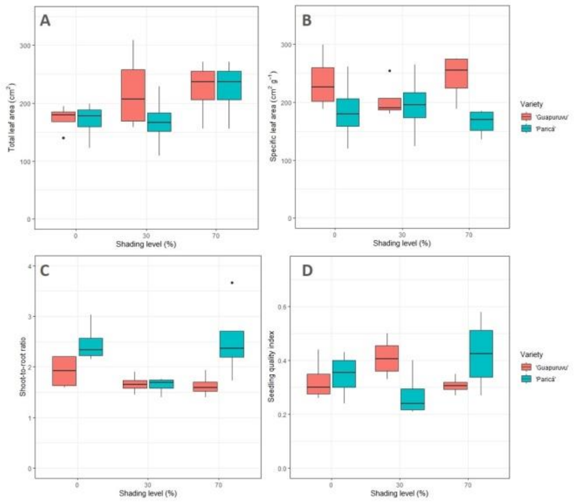

Figure 2. Interaction between shading levels (full sunlight, 30%-shading screen, and 70%-shading screen) and varieties (*Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá') of growth-related parameters in 90-day-old seedlings. Total leaf area (A), specific leaf area (B), shoot-to-root ratio (C), and seedling quality index (D).

Table 3. Interaction between shading levels (full sunlight, 30%-shading screen, and 70%-shading screen) and varieties (*Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá') of physiological-related parameters (chlorophyll b content, transpiration rate, stomatal conductance, net assimilation rate, internal CO_2 concentration, and water use efficiency) in 90-day-old seedlings

Parameters	full sunlight		30%-shading		70%-shading	
	Guapuruvu	Paricá	Guapuruvu	Paricá	Guapuruvu	Paricá
Chlorophyll b content (mg g^{-1})	0.61 ± 0.07	0.59 ± 0.02	0.90 ± 0.11	0.77 ± 0.06	0.83 ± 0.08	0.83 ± 0.04
Transpiration rate (*E* - mmol H_2O m^{-2} s^{-1})	4.17 ± 0.28	4.38 ± 0.69	5.10 ± 0.55	4.69 ± 0.46	4.14 ± 0.48	5.79 ± 0.60
Stomatal conductance (*gs* - mol H_2O m^{-2} s^{-1})	0.05 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.05 ± 0.01
Net assimilation rate (*A* - µmol CO_2 m^{-2} s^{-1})	3.04 ± 0.35	2.39 ± 0.11	2.91 ± 0.17	3.64 ± 0.46	5.53 ± 0.55	4.34 ± 0.48
Internal CO_2 concentration (*Ci* -mmol m^{-2} s^{-1})	342.8 ± 31.3	424.9 ± 23.9	252.5 ± 20.2	302.0 ± 5.9	351.3 ± 30.4	306.9 ± 12.9
Water use efficiency (WUE)	0.81 ± 0.13	0.75 ± 0.05	0.63 ± 0.05	1.05 ± 0.28	1.37 ± 0.04	0.99 ± 0.21

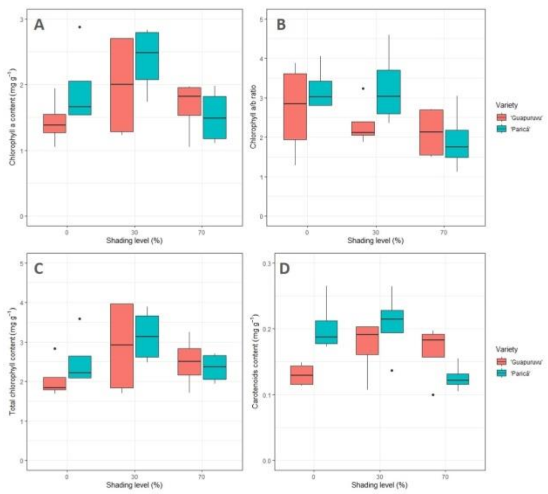

Figure 3. Interaction between shading levels (full sunlight, 30%-shading screen, and 70%-shading screen) and varieties (*Schizolobium parahyba* var *parahyba* 'Guapuruvu' and *S. parahyba* var *amazonicum* 'Paricá') of physiological-related parameters in 90-day-old seedlings. Chlorophyll a content (**A**), chlorophyll a/b ratio (**B**), total chlorophyll content (**C**), and carotenoids content (**D**).

differed among treatments; while photosynthetic pigments were strongly influenced by shading levels regardless of varieties. In this context, *S. parahyba* var. *amazonicum* 'Paricá' showed better results at 70%-shading screen, and *S. parahyba* var. *parahyba* 'Guapuruvu' at 30%-shading screen. The initial growth behavior of *S. parahyba* var. *parahyba* 'Guapuruvu' at different levels of shading is in close agreement with the results previously reported by Campos & Uchida (2002), which evaluated the production of Pau-de-balsa (*Ochroma lagopus* (Cav. Ex. Lam.) Urban) and Caroba-do-mato (*Jacaranda copaia* Aubl. D. Don.) seedlings, Amazonian species that also demand some high light level.

The behavior in leaf dry weight of *S. parahyba* var. *parahyba* 'Guapuruvu' were not observed in *S. parahyba* var. *amazonicum* 'Paricá', which showed enhanced leaf dry weight at the highest level of shading (Fig. 1C). According to Silva et al. (2007), increased photosynthetic surface area is a common trait of shaded leaves, which demonstrates the ability in adapting to shading. In the present study, an increase in total leaf area was observed (Fig. 2A), corroborating with the hypothesis of plasticity behavior. A similar pattern for total dry weight (Fig. 1E) in *S. parahyba* var. *parahyba* 'Guapuruvu' was also demonstrated by Silva et al. (2007), in which the treatments did not differ at full sunlight, 50%- and 70%-shading screens regarding the development of the Amazonian species Jutaí-mirim (*Hymenaea parvifolia* Huber), which suggests that there may be a balance in biomass production and allocation as a plasticity response to the environment. Moreover, Matos et al. (2009) observed that *S. parahyba* var. *amazonicum* 'Paricá' seedlings displayed better results for shoot dry weight when produced at 75%-shading screen, as similarly showed in this study.

The biomass accumulation and partitioning are considered a good way to evaluate photosynthesis efficiency and consequently plant growth. Otherwise, plant height, number of leaves and stem diameter, the total dry biomass demonstrates how the seedlings react to different light levels (Felfili & Abreu 1999). For instance, Rosa et al. (2009) demonstrated that *S. parahyba* var. *amazonicum* 'Paricá' presents a high plasticity under nursery conditions, also with low levels of shading screens (30%), thereby presenting a proper tolerance to high incidence of solar radiation.

Regarding height-to-shoot weight ratio (Fig. 1F), an important relationship that indicates seedling lignification ability (Silva et al., 2007), it was observed that *S. parahyba* var. *parahyba* 'Guapuruvu' holds a better lignification capacity as compared to *S. parahyba* var. *amazonicum* 'Paricá', in a manner that the lowest level of shading provided better results. However, for Butzke et al. (2018), a linear increase in the seedling height as a function of shading levels is expected. Furthermore, as reported by Caron et al. (2010), the better development of roots can be assessed by the growth of stem and leaves, which demonstrates the ability in allocating energy during its development.

When the emergence, growth, and quality standard of *S. parahyba* var. *amazonicum* 'Paricá' seedlings were assessed under different levels of shading and sowing depths, Rosa et al. (2009) observed that seedlings of such varieties obtained a linear response as a function of shading intensities, with a better result at 30%-shading screen. Considering the values proposed by Hunt (1990), who considers the seedling quality index value of 0.2 as minimum for seedlings quality, it is reasonable to suggest that seedlings evaluated in this study showed values above the expected (Fig. 2D). Different results were observed by Aguiar et al. (2020) regarding the production of *S. parahyba* var. *amazonicum* 'Paricá' seedlings by using rock phosphate powder as a substrate.

The results obtained in the present study are, at least partially, expected because *S. parahyba* is a pioneer species, essentially a heliophyte adapted to environments exposed to direct light, which holds fast growth and development (Lorenzi 1998; Cordeiro et al. 2015). As a result of the evaluation of photosynthetic pigments (Fig. 3), it was found non-significant differences for varieties as a factor; while significant for shading levels (Tab. 1). This evidences that both varieties present similar physiological responses - as observed in tropical forest species - despite being non-native to the Amazon rainforest. It is important to highlight that the responses in chlorophyll a and b, the photosynthetic pigments that absorb light and boost photosynthesis in green plants, corroborate with the result previously found for this species, leastwise at 30%-shading screen, since it is well-known as adapted to open environments (Lorenzi 1998; Cordeiro et al. 2015). Despite the several evidences that lower light levels enhance pigments content, the decreased level observed at 70%-shading screen may be affected by the increase in the total leaf area (Fig. 2A). However, we cannot define in this study the details of the cause-consequence relationship between these parameters.

According to Caron et al. (2010), for 80 days, it was noticed that growth-related variables of *S. parahyba* var. *parahyba* 'Guapuruvu' in 45-day-old seedlings were not influenced by different levels of shading (0, 30, 50, and 70%), mainly related to non-reversive damages in the tissues. Similar to Conduru-de-sangue (*Brosimum rubescens* Taub.), a monodominant species found in the Cerrado - Amazon ecotone, *S. parahyba* var. *amazonicum* 'Paricá' is pointed out by Moura et al. (2017) as a species of fast growth and suitable ability to fit to different edaphoclimatic conditions, also extreme shading conditions. For instance, it shows acclimation responses. On the other hand, it also behaves as tolerant under full sunlight (Marimon et al. 2008). In several studies, the relationship between luminosity and shading is considered a key event to improve growth in forest species (Elli et al. 2017). The importance of understanding these conditions lay on the seedling's ability to survive in environments like those simulated by forest nurseries, thus determining the conditions of tolerance and plant succession of each species.

Materials and methods

Plant materials

Site description, plant growth, and experiment conduction

The present work was carried out in the Forest Nursery at the Universidade Federal do Tocantins (UFT), 11°43'45"S and 49°04'07"W, 280 m asl, from June to September 2019, at the municipality of Gurupi, Tocantins State, part of the Legal Amazon based on Complementary Law N^{o}. 124/2007. The predominant climate in the region is Aw (tropical climate with summer rains) or tropical savanna, with an annual mean temperature of 29.5 °C and mean rainfall of 1,804 mm, characterized by rainy summers and dry winters, according to Köppen classification (Alvares et al. 2013). The photosynthetically active radiation (full sunlight) at the middle of the day was superior to 1500 µmol photons m^{-2} s^{-1}. The seeds used in the experiment were previously purchased from Arbocenter Seeds Trade LTDA. The seed dormancy breaking of *S. parahyba* var. *parahyba* 'Guapuruvu' was carried out by dipping it in boiling water at 96 °C, followed by incubation at 28 ºC for 48 h (Fowler & Bianchetti 2000). Otherwise, *S. parahyba* var. *amazonicum* 'Paricá' seeds were immersed in water at 95 ºC, then kept out of heating for 24 h (Carvalho 2007; Lorenzi 1998). Two seeds of each species were manually sown in each 25x30 cm polyethylene bag, containing commercial substrate (Bioflora®). Subsequently, they were placed in a greenhouse covered with 50%-shading screen. Two daily irrigations were performed. At 30 days after sowing (), normal seedlings were transferred to three different environments containing three distinct shading levels (full sunlight, 30%-shading screen, and 70%-shading screen). Finally, thinning procedure was carried out, leaving one healthy and strong seedling per polyethylene bag.

Environment temperature and humidity were accomplished by a digital thermo-hygrometer (MaxiTrack model 20.6600) at the middle of the day for each treatment during the experiment. Full sunlight: 41.6 °C and 22% humidity; in 30%-shading screen: 39.9 °C and 29% humidity; and in 70%-shading screen: 38.8 °C and 31% humidity. Therefore, the experiment was arranged in a completely randomized design, 2x3 factorial scheme, with two varieties ('Paricá' and 'Guapuruvu') and three levels of shading (full sunlight, 30%-shading screen, and 70%-shading screen), containing 4 repetitions (4 plants per repetition; totaling 16 plants per treatment).

Morphological analysis

Quantitative growth analysis was performed at 90 days. For this, plant height, stem diameter, and number of leaves of all plants were measured in each environment. To determine biomass gain, plants were collected and washed on sieves. Then, they were packed in paper bags and placed in a forced ventilation oven at 70 ºC, for 72 h, aiming at assessing the dry weight of leaves, stem, roots, shoot, as well as total dry weight. Leaf area was measured by a digital imaging method by using scanners (Hewlett-Packard Scanjet G2410), with the images being processed by the ImageJ software (Schneider et al. 2012). Based on these data, specific and total leaf area were evaluated. Finally, seedling quality index, height-to-diameter ratio, height-to-shoot weight ratio, and shoot-to-root ratio were calculated. The seedling quality index was calculated according to the methodology of Dickson et al. (1960).

Physiological analysis

At 90 days, the analysis of gas exchange parameters was carried out by using a portable Infrared Gas Analyzer - IRGA, LCiSD ADC system®. Measurements were made on expanded leaves at the first insertion of the primary branch, being measured on the third leaf, from 9 to 12 am, on a sunny day. One plant from each repetition was used for randomized measurements of internal CO_2 concentration (C_i - mmol m^{-2} s^{-1}), net assimilation rate (A - µmol CO_2 m^{-2} s^{-1}), stomatal conductance (g_S - mol H_2O m^{-2} s^{-1}) transpiration rate (E - mmol H_2O m^{-2} s^{-1}), and water use efficiency (WUE), the ratio between *A* and *E*.

Photosynthetic pigments, carotenoids and chlorophylls, contents were assessed in two seedlings per replicate (Siebeneichler et al. 2019). After weighing 0.200 g of leaflets from each seedling, they were kept in a 15 mL tube covered with aluminum foil. Then, 10 mL of 80% acetone was added to each tube, where the leaves were macerated and then placed in a thermal box with ice under green light for 48h. The quantification was performed by assessing the absorbances of the samples in a spectrophotometer at 663, 646, and 470 nm. A white sample containing only 80% was used as control.

Statistical analysis

The obtained data were submitted to analysis of variance (ANOVA). When significant, the means were compared by Tukey's test at the level of 5% probability, using the *ExpDes.pt* package (Ferreira et al. 2013). All figures were plotted by using the *ggplot2* package (Wickham 2016), on the R software (R Core Team 2021).

Conclusion

By comparing the initial growth of both *Schizolobium parahyba* varieties for 90 days at full sunlight, 30%- and 70%-shading screens treatments, it is evidenced that the evaluated varieties present some level of phenotypic plasticity to shading, with similar initial growth and remarkable morphophysiological responses under such conditions. When both varieties were compared, a higher growth was observed in *S. parahyba* var. *parahyba* 'Guapuruvu' at 30%-shading screen, while *S. parahyba* var. *amazonicum* 'Paricá' showed better results at 70%-shading screen. It is closely related to its natural occurrence, as Amazon Basin, and its distribution, which is similar to primary upland forest, high floodplain, secondary forests with great monospecific dominance. The conditions of temperature and humidity provided by artificial environments (shading) favored increased growth in both varieties, which is higher than those indicated for the field. Therefore, new studies on the species are extremely important since its conventional uses can replace different (even exotic) genus in our biomes.

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