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Influence of luminosity on the initial growth of *Carapa guianensis*, *Clitoria fairchildiana*, and *Inga edulis* tree seedlings

Influência da luminosidade no crescimento inicial de mudas de espécies arbóreas: *Carapa guianensis*, *Clitoria fairchildiana* e *Inga edulis*

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Abstract

The success of forest plantations can be improved by understanding the response of plants to different environmental conditions. The objective of this study is to evaluate the growth and leaf characteristics of tree seedlings subjected to different levels of luminosity. The experiment was conducted in nursery conditions, where seedlings of *Carapa guianensis*, *Clitoria fairchildiana* and *Inga edulis* were subjected to the following treatments: T50 = 50% shading, T75 = 75% shading, and SL = sunlight. During 90 days, height, stem diameter (SD), specific leaf area (SLA), chlorophyll content index (CCI) and F_v/F_m ratio were determined. *C. fairchildiana* showed a greater growth in height and better responses of F_v/F_m in the T75 treatment. *I. edulis* showed higher values for SLA in all treatments compared to the other species. Both *C. fairchildiana* and *I. edulis* presented increases in CCI values in function of time when compared with *C. guianensis*, which reduced CCI values. Under the evaluated conditions, *C. fairchildiana* showed a better development, while *C. guianensis* did not develop well.

Additional keywords: Andiroba; ingá; shading; sombreiro.

Resumo

O sucesso de plantios florestais pode ser potencializado a partir do entendimento sobre a resposta das plantas a diferentes condições ambientais impostas. Objetivou-se, com este estudo, avaliar o crescimento e as características foliares de mudas de espécies arbóreas submetidas a diferentes níveis de luminosidade. O experimento foi conduzido em condições de viveiro, onde mudas de *Carapa guianensis*, *Clitoria fairchildiana* e *Inga edulis* foram submetidas aos tratamentos: T50 = 50% de sombreamento; T75 = 75% de sombreamentos; e SL = pleno sol. Durante 90 dias, foram determinados: altura, diâmetro à altura do coleto (DAC), área foliar específica (AFE), índice de conteúdo de clorofila (ICC) e razão F_v/F_m. *C. fairchildiana* exibiu maior crescimento em altura e melhores respostas de F_v/F_m no tratamento T75. *I. edulis* exibiu maiores valores de AFE em todos os tratamentos, comparada às demais espécies. Tanto *C. fairchildiana* quanto *I. edulis* apresentaram aumentos nos valores de ICC em função do tempo, quando comparadas com *C. guianensis*, que se reduziu. Nas condições avaliadas, *C. fairchildiana* apresentou melhor desenvolvimento, enquanto *C. guianensis* não se desenvolveu bem.

Palavras-chave adicionais: Andiroba; ingá; sombreamento; sombreiro.

Introduction

Impacts caused by vegetation removal can be attenuated and even corrected by re-vegetation using species appropriate for each situation. However, it is necessary to seek an understanding of the behavior of forest species which are suitable for reforestation because, depending on the species and the ecological group, plants may react differently when subjected to stress conditions (Gonçalves et al., 2010). This is because plant growth and adaptation to different environments are related to efficiency in the use of available resources, such as water, CO_2, nutrients and irradiance (Almeida et al., 2004; Gonçalves et al., 2012; Marenco et al., 2014).

With regard to light, it is observed that changes in light intensity caused by natural or anthropogenic actions may exceed or limit the energy flow necessary for the photosynthetic process of plants. In this sense, early, intermediate or late stage plants in ecological succession may present different natural requirements regarding an efficient use of light energy. Abrupt changes in the supply of light in the environment may lead to harmful consequences for plants, and may even lead to plant death (Dias & Marenco, 2007; Gonçalves et al., 2010).

Among the diverse species that comprise the Amazon flower diversity and are configured in specific ecological groups, it is possible to emphasize:

1) *Carapa guianensis* Aubl. ("Andiroba") – a climax plant (opportunist) important to the Amazon region, this species belongs to the Meliaceae family. It has an arboreal canopy that may reach more than 30 m of height; it occurs in all the Amazon basin. The species blooms in August-September and January-February, and the fruits ripen in June-July and February-March. This species has an important use in the timber industry and presents ecological value and medicinal properties, such as oil extracted from its seeds (Lorenzi, 1992; Angelo et al., 2001); 2) *Clitoria fairchildiana* RA Howard ("Sombreiro") – a secondary plant belonging to the Fabaceae family (Papilionoideae subfamily). It is distributed throughout the Amazon. Also known as "Faveira" or "Palheteira", it has an arboreal habit from medium to large with a wide canopy. The fruit is a dehiscent vegetable. This species has a fast growth and is useful in reforestation for restoration of riparian forests (Lorenzi, 1992; Portela et al., 2001; Silva & Môro, 2008); 3) *Inga edulis* Mart. ("Ingá-de-metro") - a late secondary species belonging to the Fabaceae family (Mimosoideae subfamily). This plant is an arboreal legume tolerant to acidic soils, and may reach 5-10 m in height. It has a wide distribution in South America, blooms mainly between November and February and fruits between July and November. Its fruit is well appreciated by the Amazon population. In some northern states, it is commonly used in family farms and agroforestry systems. It occurs naturally in secondary succession areas in the Amazon (Lorenzi, 1992; Possette & Rodrigues, 2010).

Knowing the need to increase the knowledge about Amazonian forest species in relation to their ecophysiological behavior, we verified that studies involving luminosity and its relation with the growth and development of arboreal species are necessary, mainly studies regarding the use of such plants in reforestation programs or for the recovery of degraded areas since the amount of light available to plants at the juvenile phase is one of the essential factors for success in their establishment in the natural environment. The objective of this study is to evaluate the growth and leaf characteristics of three tropical tree species at the juvenile phase subjected to different light conditions.

Material and methods

The experiment was conducted at the State University of Roraima, *campus* of São João da Baliza (00º57'65" N and 59º55'63" W) between February and May 2014. The climate of the region is Af, according to the Köppen classification, with average annual temperatures around 27 ºC and an average annual rainfall of 1,800-2,300 mm (Alvares et al., 2013; Brasil, 2010). The species selected for the study were *Carapa guianensis*, *Clitoria fairchildiana* and *Inga edulis.* The seeds for the production of seedlings were obtained in a region of the municipality of São João da Baliza. Seedlings were produced in nursery conditions by sowing in black plastic bags measuring 15 cm in width and 25 cm in height. A black soil (soil of the 20 cm layer) from an old sawing area near the experiment area was used as substrate. The seedlings were irrigated daily at 8:00 a.m. and 5:00 p.m. for 90 days. Then, plants were separated according to height and diameter uniformity, and randomly distributed into the following treatments: T75 = partial shading exposure of 75% (shade), T50 = partial shading exposure of 50% (shade) and SL = exposure to sunlight. Five replicates per treatment were used in the experiment (n=5), kept 40 cm apart from each other.

Measurements of total height (h) and stem diameter (SD) were performed every 30 days during the 90 days of the experiment using a graduated ruler and a digital caliper, respectively. The absolute growth rates of height (AGR-h) and stem diameter (AGR-SD) were calculated by the ratio between the difference of two successive measurements (V_2 and V_1) and the time interval (t_2 and t_1) between the two measurements: $AGR = (V_2 - V_1)/(t_2 - t_1)$ (Benincasa, 2003). To evaluate efficiency in the use of light by plants, the measurement of the maximum quantum efficiency of photosystem II (F_v/F_m) was performed using a portable fluorometer (Pocket PEA, Hansatech Instruments, Norfolk, UK). The measurements were made in three mature and healthy leaves per plant between 8:00 a.m. and 12:00 a.m. every 10 days during the 90 days of experiment (Gonçalves et al., 2010). In order to evaluate the chlorophyll content index (CCI), five measurements were made on mature and healthy leaves of each plant using a portable chlorophyll meter (Clorofilog, CFL 1030, Falker), also between 8:00 a.m. and 12:00 a.m. every 10 days (Barbieri Junior et al., 2012). The specific leaf area (SLA) was determined using 10 leaf discs with a known area (three leaves per plant), which were placed in an oven (70ºC) until constant weight. It is calculated by the ratio between area of leaf discs and dry weight of leaf discs (Gonçalves et al., 2012).

The experimental design was completely randomized in a 3 x 3 factorial design consisting of three treatments (T50, T75 and SL) and three species (*Carapa guianensis, Clitoria fairchildiana* and *Inga edulis*). Data were subjected to analysis of variance (ANOVA) and means were compared by Student *t* and Tukey tests ($p<0.05$). When necessary, regression curves were designed to verify the dependence relation between variables. The statistical software used for the analyses was BioEstat 5.3 (Mamirauá Institute, Brazil).

Results

In the evaluation of absolute growth values in plant height, greater increases were observed in the T75 treatment for the species *C. fairchildiana* and *I. edulis* after 90 days of experiment (Figure 1A, Table 1). *C. fairchildiana* showed values of 0.32, 0.25 and

0.16 cm day^{-1} in T75, T50 and SL treatments, respectively. *C. guianensis*, which is considered a low growth plant, showed increases of 0.07, 0.05 and 0.02 cm day^{-1} in T75, T50 and SL treatments, respectively (Figure 1A, Table 1). In relation to stem diameter, *C. fairchildiana* presented the highest growth rate among all treatments compared to the other species after 90 days of experiment (Figure 1B). *C. fairchildiana* showed absolute growth in stem diameter (0.06, 0.05 and 0.05 mm day^{-1}) in treatments T50, SL and T75, respectively (Figure 1B, Table 1).

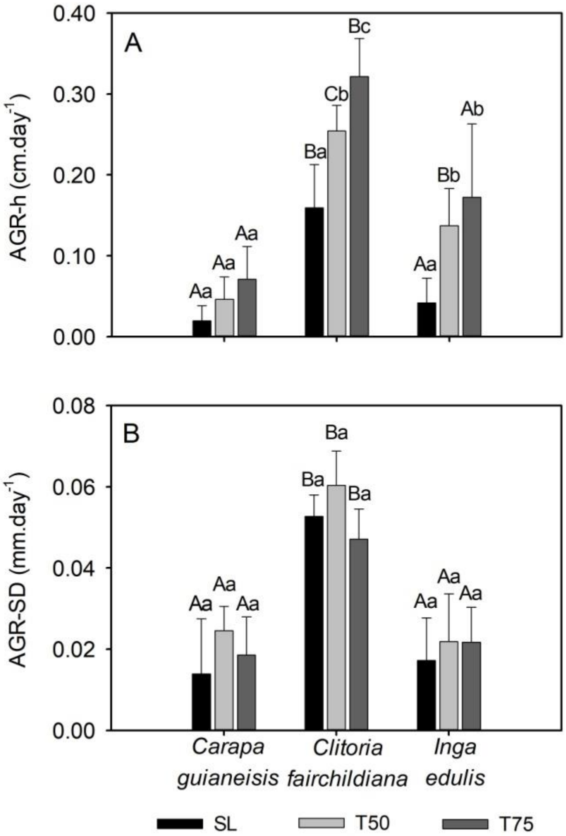

Figure 1 - Absolute growth rate in height (AGR-h) and stem diameter (AGR-SD) of three tree species submitted to different luminosity intensity after 90 days of experiment. Means followed by the same capital letter, species comparison, and lower case, treatments comparison, do not differ significantly by the Tukey test ($p<0.05$). The vertical bars represent the standard deviations.

Table 1 - Height and stem diameter of three tree species submitted to different light intensity.

Specie	Treatment	Height (cm)		Stem diameter (mm)	
		Initial	Final	Initial	Final
	SL	41.2 ± 1.92a	44.0 ± 2.65^{a}	6.88 ± 1.55^{a}	9.75 ± 0.75b
Carapa guianensis	T50	40.2 ± 2.14a	44.4 ± 2.41b	8.30 ± 1.02^{a}	10.5 ± 0.71b
	T75	40.4 ± 5.03a	46.8 ± 5.59b	8.84 ± 1.62a	10.5 ± 1.47a
	SL	39.9 ± 4.06a	54.2 ± 8.76b	7.01 ± 0.42a	11.8 ± 0.49b
Clitoria fairchildiana	T50	32.7 ± 7.73a	55.6 ± 6.35b	6.33 ± 0.89a	11.8 ± 1.01b
	T75	36.8 ± 5.04a	65.8 ± 8.35b	7.08 ± 0.73a	11.3 ± 0.62b
	SL	27.3 ± 6.77a	30.1 ± 3.73^{a}	5.42 ± 0.67a	6.96 ± 0.47b
Inga edulis	T50	25.3 ± 1.48a	37.6 ± 5.03b	5.05 ± 1.26a	7.02 ± 1.16b
	T75	26.7 ± 2.97a	42.2 ± 10.10b	5.56 ± 0.59a	7.51 ± 1.04b

Means followed by the same letter, initial and final comparison, do not differ by t Student test ($p<0.05$). T50 - 50% partial shading; T75 - 75% partial shading; SL - sunlight.

SLA values decreased with the increase in luminosity for all species studied (Figure 2). In addition, we found that the lowest SLA values were observed for *C. guianensis* and *C. fairchildiana* in the SL treatment after 90 days of experiment (106 and 105 cm^{2} g^{-1}, respectively). On the other hand, the highest values were observed in the T75 treatment for the species *I. edulis* (213 cm^{2} g^{-1}).

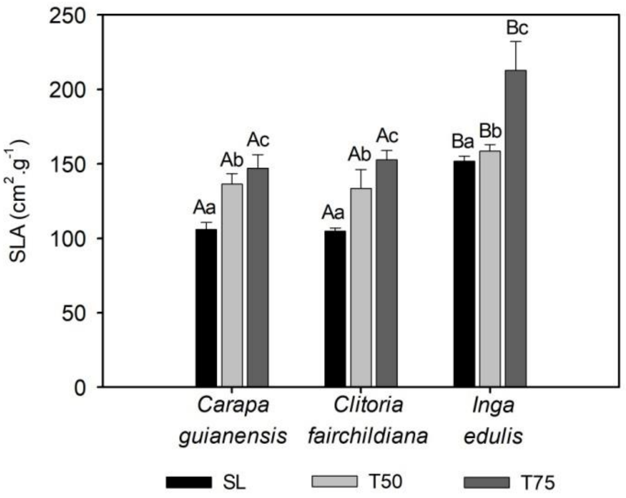

Figure 2 - Specific leaf area (SLA) of three tree species subjected to different light intensity after 90 days of experiment. Means followed by the same upper-case letter in the comparison between species and lower-case letter in the comparison between treatments did not represent significant differences by the Tukey test (p <0.05). Vertical bars represent standard deviations.

By the comparison of F_v/F_m values among treatments, we found that only *C. guianensis* showed a statistical difference after 90 days of experiment. There were lower responses of maximum quantum efficiency of photosystem II when plants were exposed to sunlight (Figure 3).

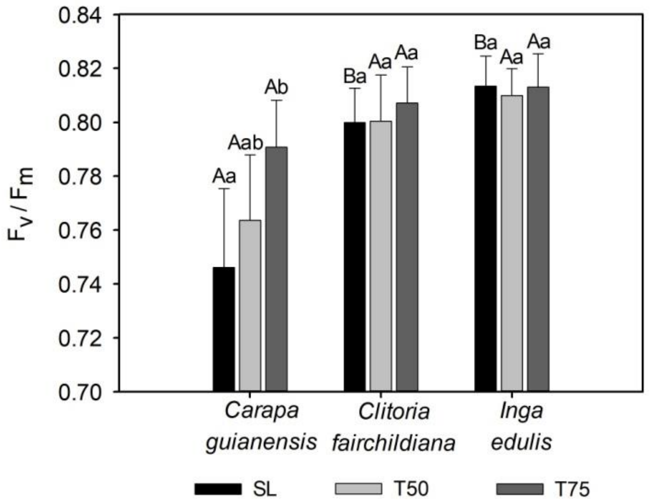

Figure 3 - Maximum quantum efficiency of photosystem II (F_v/F_m) of three tree species submitted to different light intensity after 90 days of experiment. Means followed by the same capital letter, species comparison, and lower case, treatments comparison, do not differ significantly the Tukey test (p<0.05). The vertical bars represent the standard deviations.

In the analysis of CCI of the species in the different treatments, we verified that *C. guianensis* and *I. edulis* showed lower values in the SL treatment at the end of the experiment compared to shaded treatments, except for *C. fairchildiana*. In addition, *C. guianensis* showed reductions of 24.5, 15.6 and 23.3% for the treatments SL, T50 and T75, respectively, after 90 days of experiment, presenting a linear negative relation of CCI values in function of the period analyzed in all treatments (Figure 4A, Table 2). *C. fairchildiana* showed a marked increase in CCI value in all treatments (Figure 4B, Table 2). For the species *I. edulis*, CCI values decreased in the SL treatment (25.6%). However, values increased by 16.1 and 15.2% in the treatments T50 and T75, respectively, after 90 days of experiment (Figure 4C, Table 2).

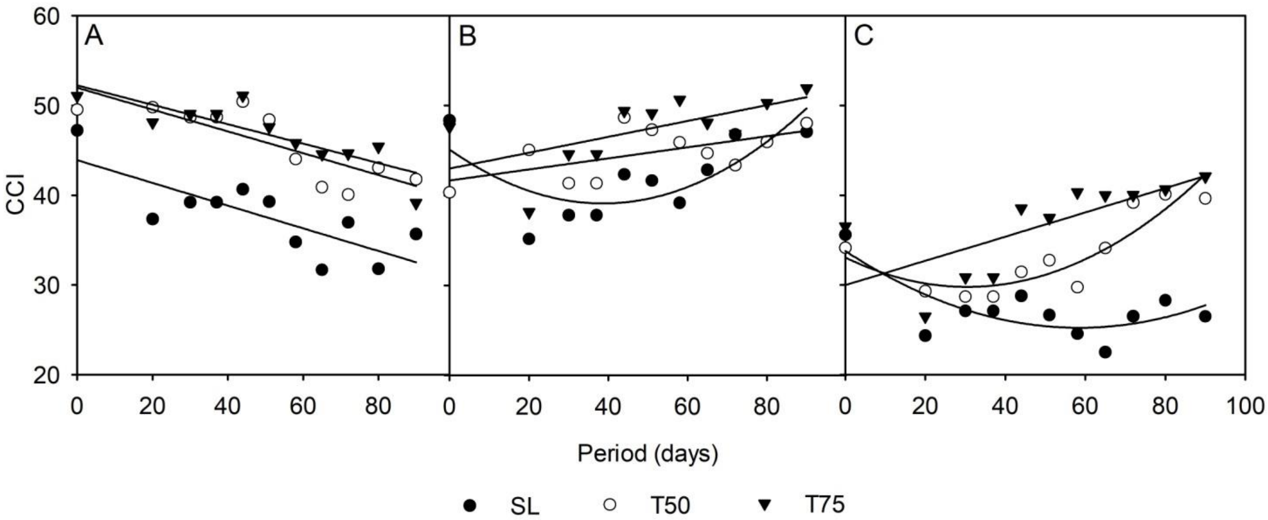

Figure 4 - Relation between chlorophyll content index (CCI) and experiment time for *Carapa guianensis* (A), *Clitoria fairchildiana* (B) and *Inga edulis* (C) subjected to different light intensity. SL - exposure to sunlight, T50 - partial shading exposure of 50% (shade) and T75 - partial shading exposure of 75% (shade).

Table 2 - Relationship between chlorophyll content index (CCI) and time of three tree species submitted to different light intensity.

Specie	Treatment	Regression	R^2	p
	SL	y = 43.9 - (0.127*x)	0.609	<0.01
Carapa guianensis	T50	y = 52.0 - (0.121*x)	0.677	<0.01
	T75	y = 52.2 - (0.108*x)	0.710	<0.01
	SL	y = 45.1 - (0.310*x) + (0.0040*x^2)	0.606	<0.05
Clitoria fairchildiana	T50	y = 41.7 + (0.062*x)	0.345	<0.05
	T75	y = 43.0 + (0.088*x)	0.381	<0.05
	SL	y = 33.8 - (0.293*x) + (0.0025*x^2)	0.557	<0.05
Inga edulis	T50	y = 33.0 - (0.215*x) + (0.0035*x^2)	0.817	<0.01
	T75	y = 30.0 + (0.135*x)	0.517	<0.05

Relationship between chlorophyll content index (CCI) and time of three tree species submitted to different light intensity. T50 - 50% partial shading; T75 - 75% partial shading; SL - sunlight. r^2 - determination coefficient; p - probability.

Discussion

C. fairchildiana, because it is a species considered secondary in the process of succession, may explain the fact that it presented a greater growth in height in environments less illuminated, since one of the characteristics of this group of plants is investing in the growth in height in search of a greater luminosity. Some species are considered intolerant to shading and are able to invest in height in an attempt to achieve a more illuminated environment. This trait is also explored in more densely planted forest plantations in the expectation of reaching greater heights in a shorter time. This may have a direct correlation with *C. fairchildiana* in the T75 treatment. Engel & Poggiani (1990), in a study on the influence of shading on the growth of native tree species, found that *Zeyhera tuberculosa* and *Tabebuia avellanedar*, under experimental conditions, confirmed the ability of the species to adapt to a great diversity of habitats due to their ability to acclimate to a range of light intensities from sunlight to 82% shade without suffering damages to their growth. According to the same authors, such characteristics show that species have a strategy of fast allocation of assimilates to shoots when shaded, which allows them to overcome the competing vegetation and expose their photosynthetic surface to light in a more favorable way. Under natural conditions, these species would benefit from small clearings in the canopy. In addition, if the growth in height of *C. fairchildiana* was lower in the sunlight treatment, that is, a more illuminated environment compared to the T75 treatment, it may also be related to the control of the transpiratory process and thermal equilibrium strategies favored in a milder environment (Rego & Possamai, 2006). *C. guianensis* and *I. edulis* showed a lower growth in height in the sunlight treatment. This may be related to an intolerance by these species to an excess of luminosity at the juvenile phase, reducing the photosynthetic use of light and increasing light dissipation. Rego & Possamai (2006) stated that, for some species, the reduction of height growth under natural light is associated with an increased light availability, increases in leaf temperature, intensification of respiratory rate and induction of stomata closure, leading to a reduction of carbon sequestration. This behavior, a lower growth in height when exposed to sunlight, was also reported for several tree species during the juvenile phase (Scalon et al., 2006; Silva et al., 2007; Dutra et al., 2012; Ferreira et al., 2012). In contrast, Portela et al. (2001), in a study on responses of tree of two tree species under different shading conditions, verified that *C. fairchildiana* was higher in the sunlight treatment after 150 days of experiment. The same result was found by Gonçalves et al. (2012), studying the behavior of *Swietenia macrophylla* in different light environments. Often, plants with a greater height growth show a higher transpiratory flow, requiring larger and more efficient root systems which, in turn, may require preponderant vascular systems, a fact that may favor growth in diameter (Gonçalves et al., 2012). When stem diameter was analyzed in *C. fairchildiana*, we observed that our data corroborate the values observed by Scalon et al. (2006) for the same species. The authors did not find differences for this variable among the different treatments of luminosity applied.

The SLA values were lower in more illuminated environments, a fact also observed by Lima et al. (2008) and Gonçalves et al. (2012) studying the effects of luminosity on the growth of seedlings of *Caesalpinia ferrea* and *Swietenia macrophylla*, respectively. It is reported that SLA indicates anatomical or morphological changes in leaves mainly by expressing differences in leaf thickness when plants are submitted to different light conditions (Gobbi et al., 2011; Krupek; Lima, 2012). Thus, SLA results usually show a greater leaf blade expansion without a corresponding increase in leaf dry matter. In addition, we observed that the higher the SLA, the higher the concentration of chlorophyll per leaf area unit. This may promote a more efficient absorption of light in low light environments, and balance the photo-destructive effects under high light intensities (Evans & Poorter, 2001; Gonçalves et al., 2012).

F_v/F_m values lower than 0.80 mean that plants were at some stress state (Björkman & Demmig-Adams, 1987; Thach et al., 2007). Therefore, a significant decrease in the values of F_v/F_m found for the species *C. guianensis* may indicate a photoinhibition effect, representing loss of photochemical efficiency by plants in the SL treatment. These results corroborate with those observed by Gonçalves et al. (2010), who found a decrease in the values of F_v/F_m also for seedlings of *C. guianensis* after 45 days of experiment. The species *C. fairchildiana* and *I. edulis* showed values of maximum quantum efficiency of photosystem II within appropriate patterns of plant responses, indicating that they present better strategies for the use of light energy with a reduced energy dissipation in the form of fluorescence, which, to a certain extent, confirms the better photosynthetic performance with reflections in higher heights of these plants.

It is important to note that the CCI variable was collected using a portable chlorophyll meter (non-destructive optical method) which expresses chlorophyll index and not an absolute value per unit area or mass, although this type of result is proportional to the concentrations of chlorophyll in leaves (Barbieri Junior et al., 2012). In this sense, Rego & Possamai (2006) observed decreases in the chlorophyll content of *Cariniana legalis* when exposed to sunlight, as well as Engel & Poggini (1991), studying chlorophyll contents in four tree species submitted to different light treatments. This was observed for *C. guianensis* in this study, however for CCI values, which agrees with Gonçalves et al. (2012), who verified a decrease in CCI values for *Swietenia macrophylla* exposed to sunlight. Some species of plants exposed to high luminosity undergo physiological adjustments, and this includes chlorophyll contents in an attempt to acclimatize to environmental conditions. In this sense, *C. fairchildiana* initially showed a decrease in CCI values until about 30 days of exposure to sunlight, with a subsequent recovery of value at the end of the experiment, indicating a good physiological plasticity.

Conclusions

The species *Clitoria fairchildiana* was the most efficient in the use of light when exposed to different light conditions, probably because it has more efficient mechanisms for the photosynthetic use of light. It may even be indicated for crops in a wide range of luminosity, which is consistent with its secondary successional ecological condition.

The species *Carapa guianensis* has the least plasticity in the use of light energy, suggesting that it is not suitable for use in crops under sunlight.

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