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SHADING PERIODS IN THE PRODUCTION OF SEEDLINGS OF FOREST SPECIES

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ABSTRACT: Shading is a technique used in the production of forest seedlings to increase seedling growth and quality. However, few works have quantified the ideal shading duration. In this context, this work aimed to quantify the effect of different shading periods on the production of species of different successional classifications. Seedlings of three species (*Guazuma ulmifolia*, *Cordia trichotoma* and *Hymenaea courbaril*) were produced in five shading periods at 50% intensity in a completely randomized design. At the end of 90 production days, height, diameter, robustness index, shoot (leaves and stems) and root dry mass, shoot and root mass ratio and the Dickson quality index were evaluated. Prolonged shading periods, over 45 days, are interesting in the production of *G. ulmifolia* and *C. trichotoma* seedlings. *H. courbaril* seedlings can be produced in full sun.

KEYWORDS: Successional groups, Seedling quality, *Guazuma ulmifolia, Cordia trichotoma, Hymenaea courbaril*

PERÍODO DE SOMBREAMENTO NA PRODUÇÃO DE MUDAS DE ESPÉCIES FLORESTAIS

RESUMO: O sombreamento é uma técnica usada na produção de mudas florestais para o aumento do crescimento e qualidade de mudas. Contudo poucos trabalhos quantificam a duração ideal para o sombreamento. Nesse contexto este trabalho teve por objetivo quantificar o efeito de diferentes períodos de sombreamento na produção de espécies de diferentes classificações sucessionais. Foram produzidas mudas de três espécies (*Guazuma ulmifolia*, *Cordia trichotoma* e *Hymenaea courbaril*) em cinco períodos de sombreamento a 50% de intensidade, em delineamento inteiramente casualizado. Ao final de 90 dias de produção foram avaliados a altura, o diâmetro, o índice de esbeltez, a massa seca da parte aérea (folhas e caules) e raiz, a relação de massas da parte aérea e raiz e o índice de qualidade de Dickson. Períodos prolongados de sombreamento, acima de 45 dias, são interessantes na produção de mudas de *G. ulmifolia* e *C. trichotoma*. Mudas de *H. courbaril* podem ser produzidas a pleno sol.

PALAVRAS CHAVE: Grupos sucessionais, Qualidade de mudas, *Guazuma ulmifolia*, *Cordia trichotoma*, *Hymenaea courbaril*

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INTRODUCTION

Shading is present in the growth and development of regenerating seedlings under forest fragments; therefore, the ability to tolerate this factor is an important indicator used in the successional classification of species (Rodrigues et al., 2015). In general, species considered as pioneers have little tolerance to shading, while species classified as climax have greater tolerance to it.

For the production of quality seedlings, it is necessary to know the species classification according to its successional characteristics, aiming to adjust production procedures and the initial needs of the species (Gonçalves et al., 2005). The hypothesis that the use of shading is correlated with the successional group is suggested. Therefore, species with pioneer behavior do not need shading and species with secondary or climax behavior need shading for the production of seedlings.

For the use of shading in the production of seedlings, there are two fundamental variables: shading intensity and period. Intensity is linked to the amount of available light, through the use of shading screens that block a certain percentage of light, and also the quality of light, making it possible to filter out certain spectrums of radiation by the color of screens used. The focus of research in this field has been on shading intensity (Gomes and Freire, 2019) and radiation quality (Sabino et al., 2016), with great diversity of responses in forest species.

The shading period has the ability to change the morphological characteristics and quality of seedlings. Seedlings produced under long shading periods tend to increase the production of shoots to the detriment of roots, compromising their final quality (Fonseca et al., 2002). The shading period also has a management characteristic within nursery operations, since knowing the ideal shading period, producers can better dimension the physical structures for the desired production volume.

Although important, there are few works dedicated to this variable. In this context, the aim of this work was to verify which is the necessary shading period for the production of seedlings of forest species of different successional classifications.

MATERIAL AND METHODS

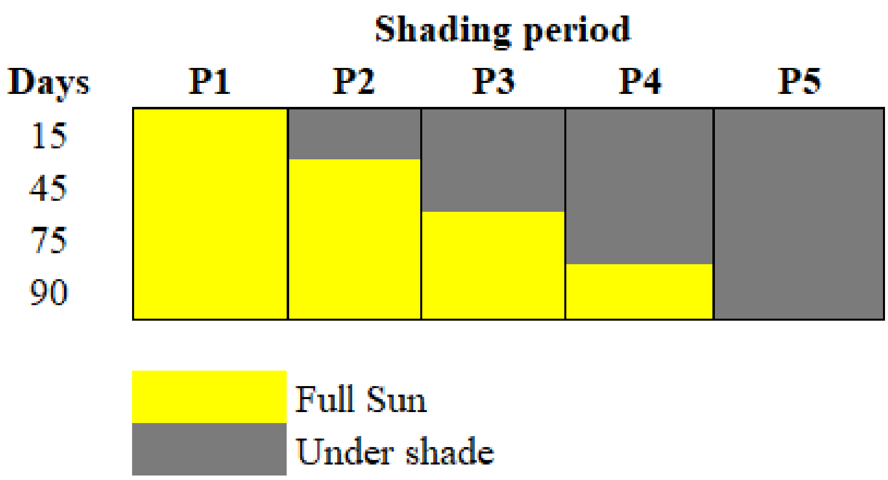
The experiment was carried out in nursery located in the municipality of Lavras, state of Minas Gerais (21° 13' 14.033" S and 44° 58' 0.232" W). The climate in the region is Cwb type according to the Köppen climate classification, with average annual temperature of 19.3°C and annual precipitation of 1530 mm, with months from October to March showing the highest precipitation and months from April to September showing low rainfall and temperatures (Alvares et al., 2013).

Three forest species of different successional stages were used: *Guazuma ulmifolia* (Mutamba, common name in Portuguese), pioneer, *Cordia trichotoma* (Louro-pardo, common name in Portuguese), with initial secondary characteristics, and *Hymenaea courbaril* (Jatobá, common name in Portuguese), with climax species characteristics. Seeds were collected from native stands in the region of Lavras, MG, and subsequently processed. Seed coat dormancy of *Hymenaea courbaril* seeds was overcome by sanding with emery.

The production of seedlings was carried out in 115 cm³ tubes manually filled with substrate composed of 10% vermiculite, 20% tanned bovine manure, 20% carbonized rice husk and 50% coconut fiber. Nutritional management was carried out with the application of controlled-release Basocote®mini fertilizer (three months) composed of 13% nitrogen, 6% phosphorus, 16% potassium (13-6-16 NPK) added with 1.4% magnesium and micronutrients, and controlled-release Osmocote®plus (8 to 9 months), composed of 15% nitrogen, 9% phosphorus, 12% potassium (15-9-12 NPK), both at concentration of 4kg/m³ of substrate. Irrigation was performed with automatic system four times a day and lasting 5 minutes.

Treatments consisted of different shading periods, as follows: P1 (90 days in full sun), P2 (15 days in the shade and 75 days in full sun), P3 (45 days in the shade and 45 days in full sun), P4 (75 days in the shade and 15 days in full sun) and P5 (90 days in the shade), as shown in Figure 1. Shading was provided by a synthetic black blanket with 50% light interception.

Figure 1. Shading period in days in shade house for the production of *Guazuma ulmifolia, Cordia trichotoma* and *Hymenaea courbaril* seedlings.



The experiment followed a completely randomized design in a 3 (species) x 5 (shading periods) factorial scheme with plots of 48 seedlings and useful area of 12 central seedlings and four replicates.

At 90 days, height (H) was measured using graduated ruler, and the stem diameter (Dc) was measured using digital caliper. To measure dry matter, 4 seedlings representing the average of each plot were selected. Seedlings had their root system washed in running water, divided into shoots and roots and placed in paper bags in forced air circulation oven at 70°C for 72 hours. The leaf (LDM) and stem (StDM) dry matter was weighed on a precision analytical scale, which together made up the shoot dry matter (SDM) and root dry matter (RDM). The sum of SDM and RDM resulted in the total dry matter (TDM)

To compare the quality of seedlings, the Dickson quality index was calculated, according to the following formula:

$$DQI = \frac{TDM(g)}{\frac{H(cm)}{Dc(mm)} + \frac{SDM(g)}{RDM(g)}}$$

Measurements were submitted to analysis of variance by the F test at 5% error probability, and when significant, the Tukey test was applied at 5% error probability. All statistical analyses were performed using the SISVAR software (Ferreira, 2019).

RESULTS AND DISCUSSION

The interaction between species and shading periods was significant for H, H/D, RDM and DQI. The effect of different species resulted in significant differences for Dc, SDM, LDM, StDM TDM and SDM/RDM, while the effect of different shading periods was significant for SDM, LDM, TDM and SDM/RDM (Table 1). Coefficients of variation remained moderate, ranging from 8.76% for H to 21.69% for DQI, indicating high experimental precision.

Table 1. Summary of the analysis of variance of the effect of species and shading periods on the growth and quality of forest seedlings.

SV	DF	Mean Square									
		H	Dc	H/D	SDM	LDM	StDM	RDM	TDM	SDM/RDM	DQI
Species	2	1605*	24.27*	51.88*	6016*	879*	2391*	936*	9991*	11.48*	116*
Shade	4	1.32	0.14	1.31*	25.73*	7.27*	6.18	16.84*	61.71*	0.14*	4.63*
Species*Shade	8	7.06*	0.12	1.24*	11.13	2.5	4.08	20.31*	32.26	0.05	2.54*
Residue	48	1.47	0.10	0.39	7.44	1.56	3.3	7.41	19.04	0.03	1.37
CV%		8.76	12.63	12.31	16.73	16.77	20.54	17.23	13.59	17.2	21.69
Mean		13.85 cm	2.55 mm	5.08	16.31 g	7.46 g	8.85 g	15.79 g	32.11 g	1.01	5.39

*Significant effect (p<0.05) by the F test. SV: Source of Variation; DF: Degrees of freedom; Shade: Shading periods; CV%: Coefficient of variation; H: Height; Dc: Stem diameter; H/D: robustness index; SDM: Shoot dry matter; LDM: Leaf dry matter; StDM: Stem dry matter; RDM: Root dry matter; TDM: Total dry matter; DQI: Dickson Quality Index.

According to the interaction between species and the shading period used in the production of seedlings (table 2), it is possible to notice that for height, species presented distinct growth characteristics, regardless of shading period, and *Hymenaea courbaril* stood out with the highest averages, followed by *Guazuma ulmifola*. The height of *Cordia trichotoma* in all periods was well below average value (13.85 cm).

There were three different height behaviors in the different shading periods. Linear growth was observed with prolonged shading in *Guazuma ulmifolia*, which corroborates observations of Fonseca et al. (2002) for *Trema micranta* and of Marana et al. (2015) for *Jacaratia spinos*a. For *Hymenaea courbaril*, it was possible to observe higher mean height values in full sun (P1) and for *Cordia trichotoma*, there was no difference between shading periods in the height of seedlings at 90 days.

No significant difference was observed for the robustness index (H/D) between shading periods for *Cordia trichotoma* and *Hymenaea courbaril*; however, for *Guazuma ulmifolia*, production in full sun (P1) resulted in the lowest indexes. Comparing species, the lowest robustness indexes were observed for *Cordia trichotoma* for all shading periods. The H/D ratio expresses the seedling proportionality, and high H/D values can cause seedlings to bend in the field (Viana et al., 2008). H/D ratios must be between 5.4 and 8.1 in any phase of the seedling production period (Carneiro, 1995); however, this parameter must be analyzed together with other characteristics (Fonseca et al., 2002). *Cordia trichotoma* seedlings did not reach the minimum limit of 5.4 in any treatment, as well as *Guazuma ulmifolia* seedlings produced entirely in full sun (P1).

Table 2. Mean height, robustness index (H/D), root dry matter (RDM) and Dickson quality index (DQI) values of *Cordia trichotoma, Guazuma ulmifola* and *Hymenaea courbaril* seedlings in different shading periods at 90 days.

Species	P1	P2	P3	P4	P5
			Height (cm)		
Cordia trichotoma	4.85 Ac	5.37 Ac	4.90 Ac	4.76 Ac	4.65 Ac
Guazuma ulmifolia	11.13 Bb	15.03 Ab	14.98 Ab	15.25 Ab	14.90 Ab
Hymenaea courbaril	23.83 Aa	21.88 Ba	22.23 Ba	21.85 Ba	22.10 Ba
			H/D		
Cordia trichotoma	3.01 Ac	3.75 Ab	3.27 Ab	3.22 Ab	3.15 Ab
Guazuma ulmifolia	4.30 Cb	6.36 Aa	6.50 Aa	5.57 Ba	6.20 Aa
Hymenaea courbaril	6.37 Aa	6.07 Aa	5.99 Aa	6.03 Aa	6.3 Aa
			RDM (g)		
Cordia trichotoma	17.11 Ab	13.40 Bb	14.79 Bb	19.52 Aa	19.41 Aa
Guazuma ulmifolia	9.00 Ac	8.25 Ac	9.10 Ac	9.10 Ab	7.81 Ab
Hymenaea courbaril	25.81 Aa	20.68 Ba	22.63 Ba	20.60 Ba	19.82 Ba
			DQI		
Cordia trichotoma	6.34 Ab	4.11 Bb	5.19 Bb	7.12 Aa	7.14 Aa
Guazuma ulmifolia	3.58 Ac	2.21 Ac	2.55 Ac	3.25 Ab	2.42 Ab
Hymenaea courbaril	7.87 Aa	6.83 Aa	8.01 Aa	7.15 Aa	7.04 Aa

Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically by the Tukey's test at 5% error probability.

Species show different behavior regarding the shading period and the dry matter accumulation in the root system. *Hymenaea courbaril* obtained greater RDM accumulation when produced entirely in full sun (P1), while for *Cordia trichotoma*, the longer shading periods (P4 and P5) provided greater RDM values. *Guazuma ulmifolia* showed no differences in RDM in the different shading periods. Fonseca et al. (2002) and Marana et al. (2015) observed reduction in RDM values with prolonged shading periods, as occurred with *Hymenaea courbaril*, justifying the fact by the reduction in the translocation of assimilates to roots.

The Dickson quality index is a good indicator of seedling quality, as its calculation considers robustness and balance of biomass distribution in the seedling, considering the results of several important parameters used to assess seedling quality (Fonseca et al., 2002).

DQI values did not vary between shading periods for species *Guazuma ulmifolia* and *Hymenaea courbaril*; however, for *Cordia trichotoma*, longer shading periods resulted in higher DQI values. *Hymenaea courbaril* showed higher DQI values when produced in full sun (P1, P2 and P3), while DQI values for *Cordia trichotoma* seedlings were similar to those of *Hymenaea courbaril* when produced in longer shading periods (P4 and P5). *Guazuma ulmifolia* presented the lowest values for this index in all analyzed periods.

All species showed reduction in DQI values in P2, which is possibly linked to the fact that they are in a condition of low light intensity, followed by high light intensity in full sun in a short period of time and in a non-gradual way. Environments of full sun or complete shade can inhibit photosynthetic processes, either by excess or lack of input energy (Zhang et al., 2003). Variation in luminosity can directly affect the various photoreceptors present in plants (Folta and Maruhnich, 2007), causing metabolic alterations and, consequently, influencing plant growth and development (Oren-Shamir et al., 2001). Therefore, the lower development of species in P2 is associated with the adaptation of the photosynthetic apparatus of plants under the conditions of light energy, directly reflecting on the development and quality of plants.

There was differential growth between species for Dc, SDM, LDM StDM, TDM and SDM/RDM (Table 3). *Hymenaea courbaril* stood out in all analyzed parameters, and *Cordia trichotoma* presented smaller development, and *Guazuma ulmifolia* remained with intermediate values (Table 3).

Table 3. Mean growth values of stem diameter (Dc), shoot dry matter (SDM), leaf dry matter (LDM), stem dry matter (StDM), total dry matter (TDM) and SDM/RDM ratio in seedlings of different species at 90 days.

Species	Dc (cm)	SDM (g)	LDM (g)	StDM (g)	TDM (g)	SDM/RDM
Cordia trichotoma	1.50 c	3.39 c	1.48 c	1.91 c	18.70 c	0.20 c
Guazuma ulmifolia	2.52 b	10.09 b	6.57 b	3.52 b	20.36 b	1.19 b
Hymenaea courbaril	3.65 a	35.47 a	14.33 a	21.14 a	57.28 a	1.65 a

Means followed by equal letters in the column do not differ statistically by the Tukey's test at 5% error probability.

As for biomass accumulation and distribution, the highest SDM, LDM, StDM and TDM values were observed for *Hymenaea courbaril*, with 61.92% of biomass destined for shoots; however, only 38.24% of this value is destined for leaf dry mass. *Guazuma ulmifolia* allocates 65.11% of SDM to LDM and *Cordia trichotoma* allocates 43.65% of SDM to LDM (Table 3). Taiz and Zeiger (2004) reported that there is greater accumulation of photosynthetic compounds in the stem of plants of some species exposed to higher luminosity due to the higher photosynthetic rate.

C. trichotoma was the species that most invested in roots, with about 82% in relation to shoots, thus presenting low SDM/RDM ratio (Table 3). The lower shoot/root ratio in plants under high light intensity indicates greater allocation of assimilates in the root system (Taiz and Zeiger, 2004). The species had shown potential for phenotypic plasticity and great adaptive capacity in the initial phase (Kelling et al., 2017). Intermediate species may undergo morphophysiological modifications that allow them to survive in different light gradients (Lima et al., 2010).

Shading periods affected SDM, LDM, TDM and SDM/RDM parameters (Table 4). The P2 shading period was less effective in SDM, LDM and TDM accumulation. For the SDM/RDM ratio, the longer shading period (P5) promoted greater ratio, indicating greater biomass accumulation in the shoots of seedlings. This phenomenon corroborates the hypothesis that plants grown with greater availability of water and nutrients, or both, in a shaded location, have higher shoot/root ratio compared to plants grown with relative deficit of water and nutrients in full sun (Duryea and Landis, 2012).

Table 4. Effect of shading period on the average shoot dry matter (SDM), leaf dry matter (LDM), total dry matter (TDM) accumulation and SDM/RDM ratio in seedlings at 90 days.

Shading	SDM (g)	LDM (g)	TDM (g)	SDM/RDM
P1	16.23 a	7.41 a	33.54 a	0.92 b
P2	13.97 b	6.27 b	28.08 b	0.91 b
P3	17.62 a	7.98 a	33.13 a	1.04 b
P4	16.15 a	7.25 a	32.56 a	1.01 b
P5	17.36 a	8.21 a	33.04 a	1.16 a

Means followed by the same letter, in the column, do not differ statistically by the Tukey's test at 5% error probability.

Finally, there is significant difference between shading period and the successional group in the production of forest seedlings. Species showed different growth rate in nursery, with emphasis on *Hymenaea courbaril*, which, although classified as a climax species (Portes et al., 2010), showed superior growth in all analyzed parameters (Tables 2 and 3), and obtained better seedling quality when produced in full sun. Under the effect of shading, there is no consensus on its use for the species, with some studies highlighting shading at intensity of 30% to 50% (Pagliarini et al. 2017), and for full sun production (Campos and Uchida, 2002). Possibly, there is a genetic component in the different populations of the species that can be explored.

The same phenomenon occurred for *Guazuma ulmifolia*, classified as a pioneer species (Portes et al., 2010), which presented the best parameters when produced under longer shading periods. *Cordia* *trichotoma*, considered an initial secondary species, presented an expected behavior, with better quality parameters when produced in longer shading periods.

In conclusion, *Hymenaea courbaril* seedlings obtained better development and quality when produced entirely in full sun, while *Guazuma ulmifolia* and *Cordia trichotoma* seedlings required longer shading periods.

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