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PROTECTED ENVIRONMENTS AND REFLECTIVE MATERIAL IN THE PRODUCTION OF *Hymenaea courbaril* SEEDLINGS

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Resumo

Ambientes protegidos e material refletor na produção de mudas de Hymenaea courbaril. A produção de mudas, em sua maioria, é realizada em ambientes protegidos que influencia o crescimento e desenvolvimento vegetal. O presente trabalho teve por objetivo avaliar tipos de cobertura de ambientes protegidos e material refletor na produção de mudas de Hymenaea courbaril. Os experimentos foram desenvolvidos em quatro ambientes protegidos: (A1) estufa agrícola coberta com filme de polietileno de baixa densidade (PEBD) com tela de 42% - 50% de sombreamento sob o filme; (A2) telado agrícola com tela aluminizada de 35% de sombreamento; (A3) telado agrícola com tela preta de 30% de sombreamento e (A4) telado agrícola com tela preta de 18% de sombreamento. Em cada ambiente protegido foram testados sistemas de produção com e sem material refletor sobre a bancada de cultivo. O material refletor de radiação fotossinteticamente ativa utilizado foi a tela aluminizada (Aluminet®). Por não haver repetições dos ambientes protegidos, cada ambiente foi considerado um experimento. Em cada ambiente, o delineamento experimental utilizado foi o inteiramente casualizado com quatro repetições e cinco plantas por parcela. Dentre as variáveis analisadas, observou-se que telado agrícola com tela preta (18% de sombreamento) apresentou mudas de melhor qualidade, o sistema com material refletor apresentou maiores valores para número de folhas e diâmetro do colo.
Palavras-chave: Jatobazeiro*;* telas pretas; tela aluminizada; filme de PEBD.

Abstract

Most seedling production is carried out in protected environments influencing plant growth and development. The present study aimed to evaluate types of the cover of protected environments and reflective material in the production of seedlings of *Hymenaea courbaril*. The experiments were carried out in four protected environments: (A1) agricultural greenhouse covered with low-density polyethylene (LDPE) film with 42% - 50% shading screen under the film; (A2) agricultural screen with an aluminized screen with 35% shading; (A3) agricultural screen with a black screen of 30% of shading, and (A4) agricultural screen with a black screen of 18% of shading. Production systems were tested with and without reflective material on the cultivation bench in each protected environment. The photosynthetically active radiation reflecting material used was the aluminized screen (Aluminet®). As there were no repetitions of the protected environments, each environment was considered an experiment. In each environment, the experimental design used was completely randomized, with four replications and five plants per plot. Among the variables analyzed, it was observed that the agricultural screen with a black screen (18% of shading) presented better quality seedlings. The system with reflective material presented higher values of the number of leaves and stem diameter.
Keywords: Jatobazeiro; black screens; aluminum screen; LDPE film.

INTRODUCTION

The species *Hymenaea courbaril* L. (Fabaceae), known as Jatobazeiro, plays essential ecological roles such as carbon sequestration and structuring of degraded areas (SALOMÃO *et al.*, 2019). In addition to these ecological functions, this species is of economic interest because it provides a large volume of wood used in various production chains (COSTA *et al.*, 2011; SILVA *et al.*, 2016). The extraction of wood from *H. courbaril* causes forest fragmentation that results in a decrease in the genetic variability of populations. The distance from plant individuals interferes with cross-pollination, favors inbreeding, and reduces gene flow and the frequency of vigorous individuals in the population (ROCHA *et al.* 2019). Thus, conservation measures must be adopted so that the exploitation of wood from natural populations is replaced by the exploitation of wood produced from trees formed by commercial seedlings that, with proper management, can be exploited early.

The seedlings of *H. courbaril* are formed from seeds from the fruits of parent plants; however, this species presents seeds with dormancy mechanisms, resulting in the slow and uneven emergence of seedlings, and thus, this process can last up to 180 days (CARVALHO FILHO *et al.*, 2003). Scarification of the thick seed coat summarizes the emergence event for about ten days (COSTA *et al.*, 2019; CARVALHO *et al.*, 2020). The species is frequently found in Gallery Forests of the Cerrado biome, characterized by the formation of closed corridors over watercourses with high canopy overlap, resulting in 70 to 95% canopy coverage (SANO *et al.*, 2008). Thus, the beginning development of this tree species is tolerant to a low light regime for its initial development. According to Oliveira *et al.* (2011), direct solar radiation, which occurs in areas where trees are removed, harms the initial growth of *Hymenaea courbaril* in the fragments.

Managing the micrometeorological conditions of the protected environment is a technique for producing commercial seedlings. In this way, this environment is used to favor suitable conditions for the species in cultivation, and its different configurations influence plant growth and development (COSTA *et al.*, 2020, SILVA *et al.*, 2020) and with the high technology of sensors and controllers, greater precision and more favorable conditions for intensive plant production is achieved (COSTA *et al.*, 2020). These environmental characteristics can result in vigorous and high-quality seedlings for the producer (SILVA *et al.*, 2020).

Another way to improve the production of forest seedlings is the use of cultivation benches covered with reflective material. This technique recently studied in plant production is based on the greater availability of light energy with materials that reflect photosynthetically active radiation, contributing to the photosynthetic process. In the scientific literature, reports of the benefits of using benches with reflective material were found, such as the increase in the plant growth rate of *Passiflora edulis* seedlings (SANTOS *et al.*, 2017) and fruits (COSTA *et al.*, 2021). In the production of *Syzygium cumini* seedlings on benches with reflective material, they showed higher quality, according to the Dickson quality index, in environments of 30% and 50% of shading compared to those without the reflective material (SALLES *et al.*, 2017). Other species, such as *Dipteryx alata* (COSTA *et al.*, 2020a; COSTA *et al.*, 2020b), *Carica papaya* (CABRAL *et al.*, 2020), and *Schizolobium amazonicum* (MORTATE *et al.*, 2019) have benefited from the use of reflective material on the cultivation benches, and high-quality seedlings were produced.

Considering that the production of high-quality seedlings of *Hymenaea courbaril* is essential, this study aimed to evaluate different types of protected environments and the influence of the reflective material on the bench for the production of *H. courbaril* seedlings.

MATERIAL AND METHODS

The experiments were carried out from September to November 2019 at the State University of Mato Grosso do Sul (UEMS), in Cassilândia-MS, at 19º07'21" S, 51º43'15" W, and an altitude of 516 m (CASSILANDIA-A742 automatic station). The climate of the region is Aw-type, rainy in summer and dry in winter. The *H. courbaril* seedlings were developed under protected environments and reflective material on the cultivation bench. The protected environments used were: (A1) agricultural greenhouse covered with low-density polyethylene film (plastic screen) (LDPE) with a screen of 42%-50% shading under the film; (A2) agricultural screen with an aluminized screen with 35% shading; (A3) agricultural screen with a black screen of 30% of shading and (A4) agricultural screen with a black screen of 18% of shading. All environments had dimensions of 8.0 m wide by 18.0 m long. The A1 environment had a zenith opening, side, and front closing at 90º, a black screen with 30% shading, and a ceiling height of 3.5m. The A2, A3, and A4 environments had a ceiling height of 4.0 m, and the side and front screen closed by 45%. Inside the protected environments, production systems were tested with (WRM) and without (WTRM) reflective material on the cultivation benches using the aluminized thermo-reflective screen (Aluminet®).

Data on air temperature (T, in °C), relative humidity (RH, in %), global solar radiation (GSR, Wm-2), and photosynthetically active radiation (PAR, in µmol m^{-2} s^{-1}) were collected and obtained. The variables T, RH, and GSR in the cultivation environments were collected through meteorological stations model E4000 (Irriplus Scientific Equipment) and in the external environment through station A742 - Cassilândia (INMET). Global solar radiation was considered from 9 am to 4 pm, Brasília time. The PAR was obtained through the manual collection with a portable digital pyranometer (Apogee) on sunny days and with slight cloudiness at 11:00 am Brasília time (BR). To compare the micrometeorological variables of air temperature, relative air humidity, global solar radiation, and photosynthetically active radiation in different cultivation and outdoor environments, each collection month was considered a block, totaling three blocks. These data were submitted to ANOVA, and the means were compared by the Tukey test at a 5% probability.

Seeds were collected in plants close to the university, where fruits from five plant parents were collected. The fruits were pulped, and the seeds were scarified in the region opposite the hilum and placed in immersion with water for 24 h. Then, two seeds were placed at a depth of 3.0 cm per polyethylene bag (15.0 x 25.0 cm) on September 14, 2019, with a capacity of 1.8 L, filled with Carolina Soil® substrate. After emergence stabilization, thinning was performed, leaving one seedling per container. Irrigation was performed daily, using a watering can, according to the needs of the crop, without soaking the substrate.

The data on the seedling height (HS), stem diameter (SD), and number of leaves (NL) were collected, and the relationship between seedling height and stem diameter (RHD) at 60 and 90 days after sowing (DAS) was determined. The shoot dry mass (SDM) and root dry mass (RDM) were collected. The total dry mass (TDM) was obtained using SDM and RDM. The relationship between shoot and root dry mass (RSR), root dry mass and total dry mass (RRT), seedling height and shoot dry mass (RHD), and the Dickson quality index (DQI) at 90 DAS were estimated. The absolute growth rate (AGR) was determined between the collections of seedling height at 60 and 90 DAS.

The seedling height was collected with a ruler graduated in millimeters and the stem diameter with a digital caliper in millimeters. The seedlings were kept in an air circulation oven at a temperature of 65 ºC for 72 h and measured on an analytical balance to obtain the dry mass.

As there were no repetitions of the protected environments (Figure 1), each environment was considered an experiment. In each environment, initially, the data were submitted to the individual analysis of variances of the benches, then evaluating the mean squares of the residues and, when possible, to the joint analysis of the experiments in 4 x 2 factorial (4 protected environments x 2 types of benches: with and without reflective material). A completely randomized design with four replications and five plants per plot was used in each cultivation environment. Data were submitted to ANOVA, and the means were compared by the Tukey test at a 5% probability.

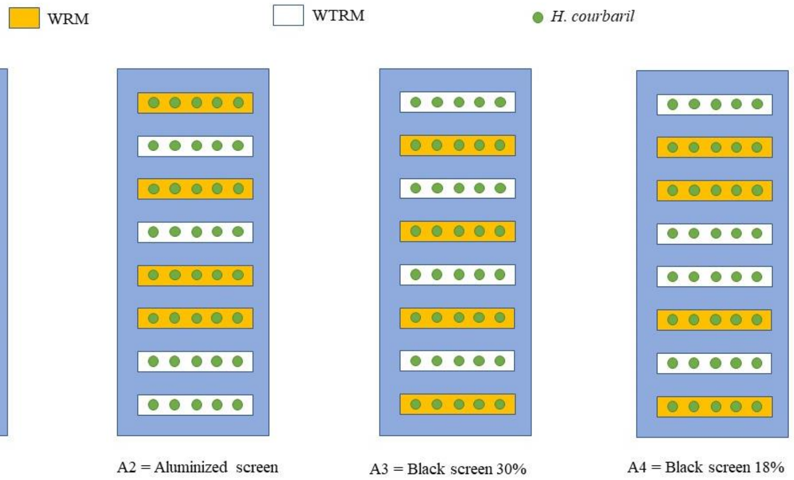

Figure 1. Illustrative sketch of the experiment. WRM = with reflective material; WTRM = without reflective material.
Figura 1. Croqui ilustrativo do experimento. WRM = com material refletor; WTRM = sem material refletor.

RESULTS

It was found that the temperature of the environment with the aluminized screen (25.1 ºC) and with the black screen of 18% (25.0 ºC) were lower than the environment covered with the black screen of 30% (26.9%). The relative humidity of the air in the environment with the black screen of 18% (73.4%) was higher than in the full sun (60.5%). When comparing the environments, it is noted that the temperature variation was 1.9 ºC, and the relative humidity ranged by 12.9% (Figure 2).

As for the total global solar radiation (full sun), only 25.4% reached the interior of the agricultural greenhouse covered with LDPE (plastic greenhouse) associated with 42-50% shading screen under the film, 34.5% reached the interior of the aluminized screen with 35% shading, 45.5% reached the interior of the black screen with 30% shading, and 55.1% reached the interior of the black screen with 18% shading (Figure 3).

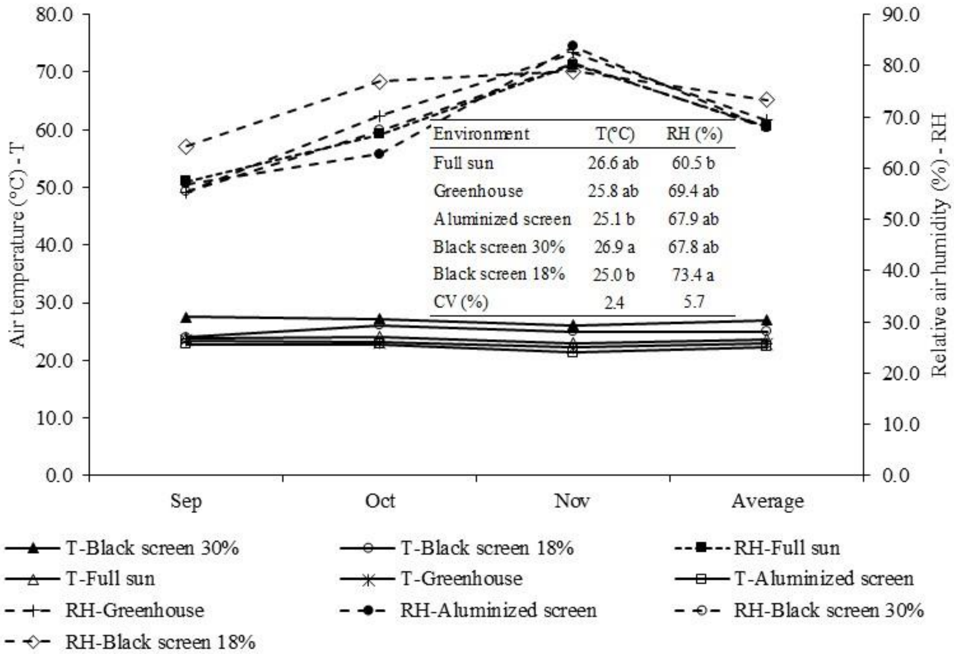

Figure 2. Air temperature (T, ºC) and relative humidity (RH, %) in the cultivation and outdoor environments. Means followed by the same lowercase letter in the column do not differ by the Tukey test at a 5% probability. CV = coefficient of variation.

Figura 2. Temperatura do ar (T, ºC) e umidade relativa do ar (RH, %) nos ambientes de cultivo e externo. Médias seguidas de mesma letra minúscula na coluna não diferem entre si pelo teste de Tukey a 5% de probabilidade. CV = coeficiente de variação.

The incident photosynthetically active radiation (PAR) in the cultivation environments decreased according to the type of environment and its constituent materials. According to the covering material, it was verified that the greenhouse covered with a low-density polyethylene film associated with a 42-50% shading screen under the film presented the lowest PAR (542 µmol $m^{-2}s^{-1}$), followed by the aluminized screen of 35% shading (876 µmol $m^{-2}s^{-1}$) and 30% black screen (1100 µmol $m^{-2}s^{-1}$) that did not differ from each other, just as the 30% shading black screen did not differ from the 18% shading (1380 µmol $m^{-2}s^{-1}$) (Figure 4).

For all variables, the ratio between the largest and smallest mean square of the residue (RMSR) was less than 7, allowing for the joint analysis and comparison of the protected environments in the 4 x 2 factorial scheme (four protected environments x two production systems, with and without reflective material on the grow bench).

Among the variables studied, it is possible to notice that most of them were not influenced by the interaction between the factors (A x B). Only NL90 and SD90 were influenced by the factorial scheme. The influence of the protected environment was significant for seedling height at 60 and 90 DAS (HS60 and HS90), the number of leaves (NL60 and NL90), the relationship between seedling height and stem diameter (RHD60 and RHD90), root dry mass (RDM), the relationship between shoot and root dry mass (RSR), and the relationship between root dry mass and total dry mass (RRT) (Table 1).

The WRM system showed higher reflected PAR than the WTRM in all protected environments (Figure 5) and only influenced the number of leaves and stem diameter (Tables 3 and 5). Among the environments used, the Greenhouse with plastic cover, with 42%-50% of shading, presented larger seedlings, according to the height of the shoot (HS60 and HS90) and with a greater number of leaves at 60 DAS (NL 60) (Table 2). In the Greenhouse environment, the seedlings of *H. courbaril* had a greater number of leaves and a greater stem diameter at 90 DAS when conducted on the system with a reflective material (Table 3).

It is observed that the distribution of shoot and root phytomass follows a proportion, on average, from 69% to 31%, that is, of the total phytomass of *H. courbaril* seedlings, 69% is shoot and 31% is from the root system, regardless the cultivation environment and the use or not of reflective material on the bench (Figure 6).

This phytomass distribution found for *H. courbaril* seedlings (69% shoot and 31% root system) is similar to the distribution observed for papaya seedlings (*Carica papaya*) by Cabral *et al.* (2020), who found, on average, 67% for the shoot and 33% for the root system, as well as for achachairu (*Garcinia humilis*) seedlings, in which Silva *et al.* (2021) found 68% for the shoot and 32% for the root system.

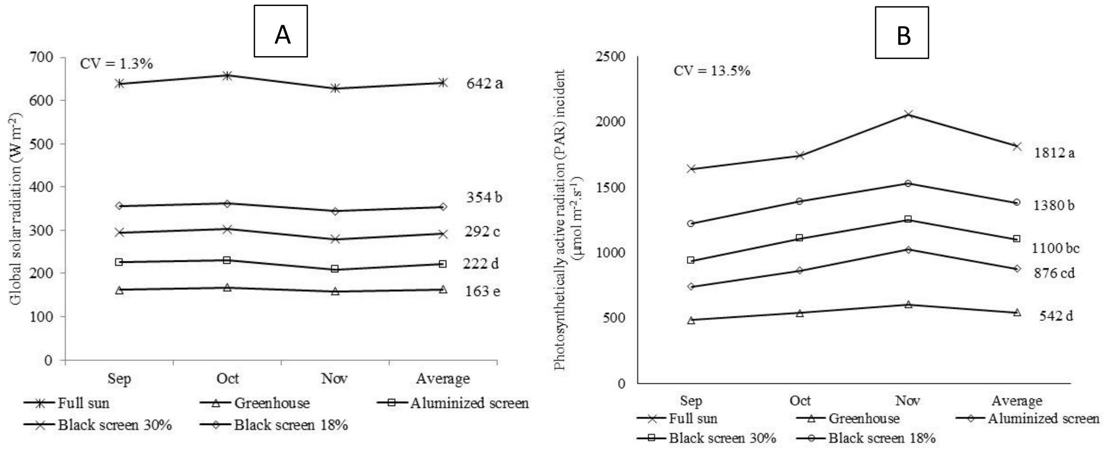

Figure 3. A - Global solar radiation (W m^{-2}) incident in protected environments and under the full sun. Equal lowercase letters do not differ from each other by the Tukey test at a 5% probability. CV= coefficient of variation. B - Incident photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}) in protected environments and under the full sun. Equal lowercase letters do not differ from each other by the Tukey test at a 5% probability. CV= coefficient of variation

Figura 3. A - Radiação solar global (W m^{-2}) incidente nos ambientes protegidos e a pleno sol. Letras minúsculas iguais não diferem entre si pelo teste Tukey a 5% de probabilidade. CV= coeficiente de variação. B - Radiação fotossinteticamente ativa (PAR, µmol m^{-2} s^{-1}) incidente nos ambientes protegidos e a pleno sol. Letras minúsculas iguais não diferem entre si pelo teste Tukey a 5% de probabilidade. CV= coeficiente de variação.

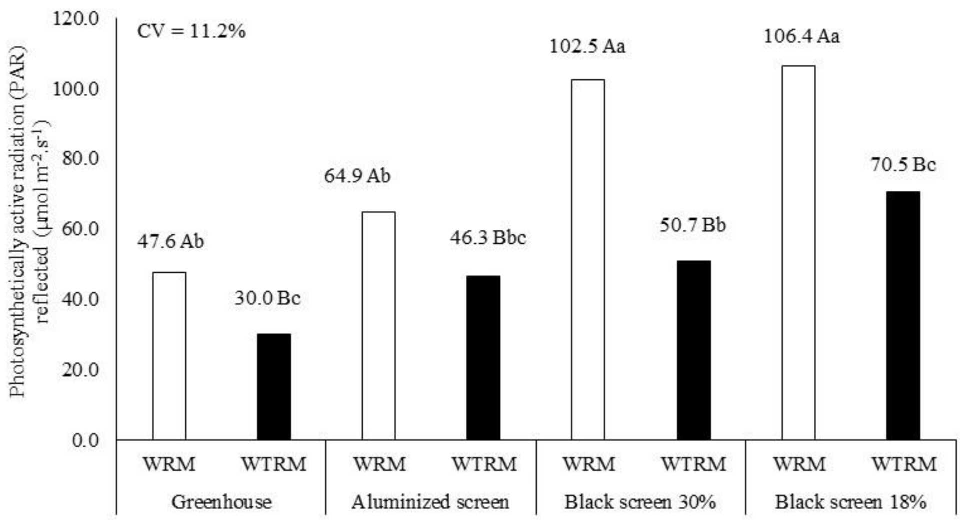

Figure 4. Reflected photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}) in the production systems with (WRM) and without (WTRM) reflective material on the cultivation bench inside the protected environments. Means followed by the same lowercase letter in the comparison of environments within each production system and by the same capital letter in the comparison of production systems within each environment do not differ by the Tukey test and F test, respectively, both at a 5% probability. CV = coefficient of variation.

Figura 4. Interação entre os fatores para a radiação fotossinteticamente ativa (PAR, µmol m^{-2} s^{-1}) refletida nos sistemas de produção com (WRM) e sem (WTRM) material refletor na bancada de cultivo dentro dos ambientes protegidos. Médias seguidas de mesma letra minúscula na comparação dos ambientes dentro de cada sistema de produção e de mesma letra maiúscula na comparação dos sistemas de produção dentro de cada ambiente, não diferem entre si pelo teste F a 5% para os sistemas de produção e teste de Tukey para os ambientes a 5% de probabilidade. CV = coeficiente de variação.

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Table 1. Analysis of variance for seedling height (HS), stem diameter (SD), number of leaves (NL) at 60 and 90 days after sowing (DAS), shoot dry mass (SDM), root system dry mass (RDM), total dry mass (TDM), relationship between seedling height and stem diameter (RHD) at 60 and 90 DAS, relationship between shoot and root dry mass (RSR), relationship between root system dry mass and total dry mass (RRT), relationship between seedling height and shoot dry mass (RHS), Dickson quality index (DQI), and absolute growth rate (AGR) between 60 and 90 DAS.

Tabela 1. Análise de variância para as variáveis altura das mudas (HS), diâmetro do colo (SD) e número de folhas (NL) aos 60 e 90 dias após a semeadura (DAS), massa seca da parte aérea (SDM), massa seca do sistema radicular (RDM), massa seca total (TDM), relação entre a altura da muda e diâmetro (RHD) do colo aos 60 e 90 DAS, relação entre a massa seca da parte aérea e do sistema radicular (RSR), relação entre a massa seca do sistema radicular e massa seca total (RRT), relação entre a altura da muda e massa seca da parte aérea (RHS), índice de qualidade de Dickson (DQI) e taxa de crescimento absoluto (AGR) entre 60 e 90 DAS.

	HS60	NL60	SD60	HS90	NL90	SD90	SDM	RDM
Environment (A)	**	*	ns	**	**	ns	ns	*
Benches (B)	ns	ns	ns	ns	ns	ns	ns	ns
A X B	ns	ns	ns	ns	*	*	ns	ns
CV	6.9	11.2	5.6	7.0	6.2	6.1	16.5	18.4
	TDM	**RHD60**	**RHD90**	**RSR**	**RRT**	**RHS**	**DQI**	**AGR**
Environment (A)	ns	**	*	**	**	ns	ns	ns
Benches (B)	ns	ns	ns	ns	ns	ns	ns	ns
A X B	ns	ns	ns	ns	ns	ns	ns	ns
CV	15.2	8.49	8.4	17.0	11.5	18.7	18.9	28.3

ns = not significant; * significant at 5%; ** significant at 1%

Table 2. Seedling height (HS, cm) at 60 and 90 DAS, number of leaves (NL) and stem diameter (SD, mm) at 60 days after sowing (DAS), relationship between seedling height and stem diameter (RHD) at 60 and 90 DAS, shoot dry mass (SDM, g), root dry mass (RDM, g), total dry mass (TDM, g), relationship between shoot and root dry mass (RSR), relationship between root dry mass and total dry mass (RRT), relationship between seedling height and shoot dry mass (RHS), Dickson quality index (DQI), and absolute growth rate (AGR, cm day^{-1}) between 60 and 90 DAS.

Tabela 2. Altura de plantas (HS, cm) aos 60 e 90, número de folhas (NL) e diâmetro do colo (SD, mm) aos 60 dias após semeadura (DAS), relação entre a altura da muda e diâmetro (RHD) do colo aos 60 e 90 DAS, massa seca da parte aérea (SDM, g), massa seca do sistema radicular (RDM, g), massa seca total (TDM, g), relação entre a massa seca da parte aérea e do sistema radicular (RSR), relação entre a massa seca do sistema radicular e massa seca total (RRT), relação entre a altura da muda e massa seca da parte aérea (RHS), índice de qualidade de Dickson (DQI) e taxa de crescimento absoluto (AGR, cm dia^{-1}) entre 60 e 90 DAS.

Environments/Benches	HS60	NL60	SD60	HS90	RHD60	RHD90	SDM
Plastic greenhouse	31.07 a	7.51 a	3.60 a	41.52 a	8.67 a	8.99 a	4.75 a
Aluminized screen	30.23 a	6.79 ab	3.59 a	37.63 b	8.43 ab	8.17 ab	4.11 a
Screen 30%	28.95 ab	6.95 ab	3.85 a	38.81 ab	7.55 bc	8.62 ab	4.38 a
Screen 18%	26.80 b	6.38 b	3.62 a	35.83 b	7.41 c	7.90 b	4.03 a
WTRM	29.78 a	7.06 a	3.68 a	38.51 a	8.14 a	8.53 a	4.17 a
WRM	28.73 a	6.76 a	3.65 a	38.38 a	7.89 a	8.31 a	4.46 a
CV (%)	6.9	11.2	5.6	7.01	8.5	8.4	16.5
Environments/Benches	**RDM**	**TDM**	**RSR**	**RRT**	**RHS**	**DQI**	**AGR**
Plastic greenhouse	1.75 ab	6.49 a	2.71 a	0.27 c	8.92 a	0.56 a	0.43 a
Aluminized screen	1.62 b	5.73 a	2.55 a	0.29 bc	9.55 a	0.53 a	0.31 a
Black screen 30%	2.06 ab	6.44 a	2.20 ab	0.32 ab	9.04 a	0.60 a	0.41 a
Black screen 18%	2.19 a	6.22 a	1.88 b	0.35 a	9.09 a	0.65 a	0.38 a
WTRM	1.85 a	6.02 a	2.33 a	0.31 a	9.47 a	0.56 a	0.36 a
WRM	1.96 a	6.42 a	2.34 a	0.31 a	8.83 a	0.60 a	0.40 a
CV (%)	18.4	15.2	17.0	11.5	18.7	18.9	28.3

Equal lowercase letters in the column do not differ from each other by the Tukey test at 5% probability for the cultivation environments and F test for the cultivation benches, CV= coefficient of variation.

Table 3. Interaction between environment and reflective material for leaf number (NL90) and stem diameter (SD90) at 90 days after sowing of *H. courbaril* seedlings in greenhouses with different shading and the reflective material or not on the cultivation bench.

Tabela 3. Interação entre ambiente e material refletor para número de folhar (NL90) e diâmetro do colo (SD90) aos 90 dias após semeadura de mudas de *H. courbaril* em estufas com diferentes sombreamentos e material refletor ou não em bancada.

	------------ NL90 ------------		-------------------- SD90 --------------------	
Environments	WRM	WTRM	WRM	WTRM
Plastic greenhouse	13.83 Aa	12.65 Ab	4.98 Aa	4.32 Ab
Aluminized screen	11.05 Ba	12.15 Aa	4.63 Ba	4.59 Aa
Black screen 30%	13.22 Aa	12.25 Aa	4.48 Ba	4.55 Aa
Black screen 18%	11.55 Ba	11.45 Aa	4.42 Ba	4.69 Aa
CV (%)	7.0		6.1	

Equal capital letters in the column and lowercase letters in the line for each variable do not differ by the Tukey test at 5% probability for cultivation environments and F test for cultivation benches, CV= coefficient of variation.

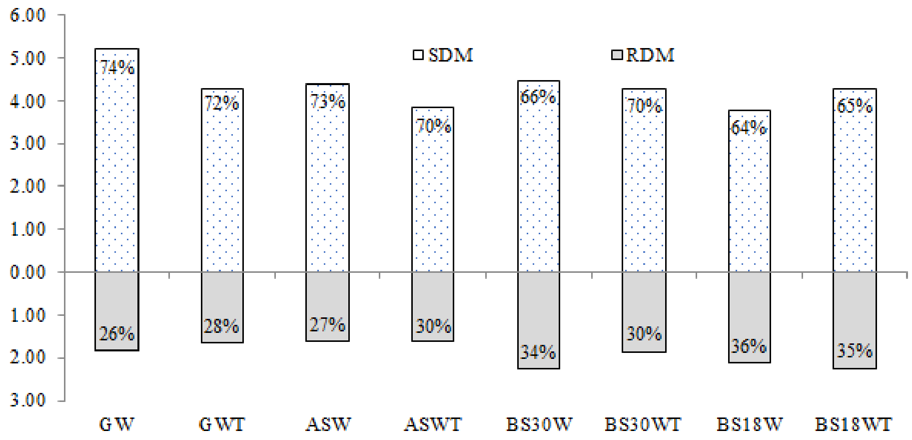

Figure 5**.** Distribution of shoot (SDM) and root (RDM) phytomass in the environment of plastic greenhouse and cultivation bench with (GW) and without (GWT) reflective material, in the environment of aluminized screen and cultivation bench with (ASW) and without (ASWT) reflective material, 30% shading black screen environment and cultivation bench with (BS30W) and without (BS30WT) reflective material, and 18% shading black screen environment and cultivation bench with (BS18W) and without (BS18WT) reflective material.

Figura 5. Distribuição de fitomassas áreas (SDM) e radiculares (RDM) no ambiente de estufa plástica e bancada com material refletor (GW) e sem material refletor (GWT), no ambiente de tela aluminizada e bancada com material refletor (ASW) e sem material refletor (ASWT), ambiente de tela preta de 30% de sombreamento e bancada com material refletor (BS30W) e sem material refletor (BS30WT), ambiente de tela preta de 18% e bancada com material refletor (BS18W) e sem material refletor (BS18WT).

DISCUSSION

Cultivation environments

The cultivation environments used showed significant differences, such as variations in temperature, humidity, and incident PAR. The seedlings in an environment with higher temperatures showed greater growth, which is in line with what was observed by Corrêa *et al.* (2013), who observed that clones of the hybrid *Eucalyptus urophylla* x *grandis* showed greater growth in an environment with a temperature of 32 ºC when compared to an environment with a temperature of 25 ºC.

The incident PAR in full sun was 1812 µmol $m^{-2}s^{-1}$ and of this total, in the period studied, on average, 30% reached the interior of the greenhouse, 48% the aluminized screen, 61% the 30%-black screen, and 76% the 18%-black screen (Figure 4). These results show that the shading value does not correspond to the percentage of PAR inside the environment, as the black screen of 30% of shading lets through only 61% and the aluminized screen of 35% lets through 46% of the external PAR. It is vital to characterize each cultivation environment in terms of solar radiation and luminosity; for example, the 18% shading screen that has 82% luminosity was reached by 55.1% of the total external radiation. This difference in luminosity and solar radiation in the environments is associated with the sun's path throughout the day (slope) as a function of the type of coverage and the material of the meshes of the screens (Figure 3).

The plastic greenhouse, as well as the 30%-black screen, produced tall seedlings and, in the same way, other authors studied the influence of shading provided by protected environments on shoot growth in forest seedlings, as described by Silva *et al.* (2018) who obtained seedlings of *Garcinia humilis* with averages of 11.97 cm produced in environments with 50% of shading and 10.47 cm in height for seedlings produced under screens of 18% of shading, both environments being covered by black screens of the shade type. For the production of *H. brasiliensis* seedlings, Silva *et al.* (2020) compared two environments with 50% shading, one being an agricultural greenhouse with aluminet mesh and the other an agricultural screen environment with mesh type of Sombrite® and found that the screened environment produced seedlings of *H. brasiliensis* with more than 3 cm of height when compared to the seedlings produced under the screen. The same authors emphasized that the height measurement, when analyzed in isolation, is not enough to characterize a quality seedling, and it is necessary to verify other variables together or more complex variables, such as quality indexes. Etiolated seedlings have greater heights; however, they are physiologically more fragile than those that grew without light deprivation; that is, physiologically healthy seedlings are smaller than seedlings that suffered abiotic stress due to light deprivation (TAIZ *et al.*, 2017).

The DQI is traditionally used to determine the quality of seedlings of tree species (SILVA *et al.*, 2020). In the present study, the BHEI was not influenced by the treatments and presented an average of 0.58, which is similar to the averages found by Gonzaga *et al.* (2016) in most of their treatments, but Rocha *et al.* (2017) found a DQI with a mean of 0.3. Among the biometric indexes used in this experiment, the RSR and the RRT were influenced by the cultivation environment. Seedlings with larger RSR indicate an imbalance between the shoot and root; that is, the shoot is much more developed than the root. Seedlings with this type of architecture are undesirable because they are less efficient in fixing and exploiting the soil and are susceptible to tipping over (SILVA *et al.*, 2020). The RSR of seedlings produced under the plastic greenhouse was higher than those produced under the 18% shading screen (Table 2). According to this index, the greenhouse covered with an 18% shading screen is more suitable for the production of seedlings of *H. courbaril*. However, the seedlings under the 18% shading screen showed a greater relationship between root dry mass and total dry mass (RRT) when compared to seedlings produced under the greenhouse, in addition to greater root dry mass when compared to the aluminized screen, with 35% shading (Table 3). In other words, the agricultural greenhouse covered with the greenhouse environment with 18% shading produced better-quality seedlings using RRT or RSR as a reference.

H. courbaril is a natural species of gallery forests with 70 to 95% canopy coverage (SANO *et al.*, 2008). According to Oliveira *et al.* (2011), direct solar radiation impairs the growth and initial development of this species. In this study, the shading of 18% of the cultivation environment was sufficient to promote quality seedlings, according to RSR and RRT biometric indexes. Depending on its structure, the cultivation environment minimizes plant exposure to external environmental factors that can interfere with plant integrity and protect against abiotic factors, such as excessive exposure to solar radiation, wind, or precipitation. The ambient treatments in the present study applied to the formation of *H. courbaril* seedlings did not modify the proportion of photoassimilates distribution between the shoot and root, maintaining a distribution of 31% for the root system and 69% for the shoot. In this way, the proportion of 1 to 2 was maintained in the distribution of photoassimilates between the shoot and root parts of the seedlings; that is, the phytomass of the shoot is twice as large as the root.

Reflective material on the bench

WMR demonstrated efficiency in reflecting the PAR (Figure 5). This extra PAR may have increased the stem diameter and the number of leaves in seedlings produced under a plastic greenhouse. Thus, this study, associated with the others using WRM, demonstrates that each species responds to this treatment differently. In comparison, Costa *et al.* (2020) did not observe the effect of the reflective material on these variables in an experiment with *Dipteryx alata* seedlings using different materials to reflect the PAR. Santos *et al.* (2017) reported the increase in the number of leaves in *Passiflora edulis* seedlings with 50 DAS caused by the PAR reflected by a mirror on the bench. In an assay using *Schizolobium amazonicum* with 55 DAS, Mortate *et al.* (2019) observed an increase in stem diameter when seedlings were formed on benches with reflective material when produced in environments with a lower incidence of GR, that is, the agricultural greenhouse covered with plastic screen and with screen under the film. According to Salles *et al.* (2017), *Syzygium cumini* seedlings under 30% and 50% shading environments showed higher SD when cultivated with reflective material, which in the assay used aluminum foil.

There is little literature on the study of seedling production with reflective material in seedling cultivation benches. The reports noted that several materials can direct the PAR to the plant, with the mirror, aluminum foil, and aluminet-type screen being examples of usable materials. According to the species studied, there are also different responses to the reflected PAR. The use of the reflective material causes the PAR to reach the leaves in the lower third of the plant, which the leaves may shade at the plant apex. In this way, the once-shaded leaves can participate more actively in converting light energy into chemical energy and collaborate with plant growth and/or development. In the present study, despite not influencing many of the variables analyzed, the bench with reflective material provided greater availability of PAR and resulted in *H. courbaril* seedlings with a greater number of leaves and stems with a more developed diameter when produced under an agricultural greenhouse with the shading of 42-50%. The present study and those mentioned that address the use of PAR reflection can be seen as a prototype to develop products that improve plant production.

CONCLUSIONS

- The agricultural screen with a black screen of 18% shading was the most suitable environment for producing *H. courbaril* seedlings according to the biometric indexes RSR and RRT.
- Under the plastic greenhouse, an environment with a lower incidence of global radiation, using reflective material to take advantage of the PAR, resulted in seedlings with larger stem diameters and a greater number of leaves.

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