Shading level, reflective material, and seeding depth on the growth of baru seedlings

Geany Giovana Silva da Costa[1*], Edilson Costa, Eliamara Marques da Silva[1], Renato Silva Borges[1], Flávio Ferreira da Silva Binotti[1], Gustavo Haralampidou Costa Vieira[1], Andréia Fróes Galuci Oliveira de Souza[1]

([1]University of Mato Grosso do Sul, Cassilândia, MS, Brazil, Zipcode 79.540-000, highway MS 306, km 6.4. Phone: +55(67)35967600)

Abstract: The baru (*Dipteryx alata* Vog.) is a native species of Brazilian cerrado, and has been widely used in reforestation, medicine, and food industry. In the formation of baru seedlings, the use of protected environments aims to provide adequate environmental conditions for plants and the reflective material on the growing benches aims to expand the supply of photosynthetically active radiation to abaxial leaves and, consequently, increase the photosynthetic rate. This study aimed to evaluate the effects of shading levels, reflective material, and seeding depth on the growth of baru seedlings. The seedlings were grown in full sunlight, and in three production nurseries constructed with 18%, 30%, and 50% shading screens on growing benches coated or not coated with a reflective material (Aluminet®). The seeds were sown at depths of 2.0 or 4.0 cm in black polyethylene bags of 15.0 × 25.0 cm (1.8 L), filled with substrate formulated from the mixture of sandy soil: bovine manure: vermiculite (5: 3: 2). At 53, 86 and 120 days after sowing, the substrate temperature, plant height, stem diameter, shoot dry matter, root dry matter, total dry matter, absolute growth rate, and Dickson quality index (DQI) was measured. The increase of the light intensity did not favor the increase of the growth of baru seedlings because the best level of shading for the formation of baru seedlings was 50%. The environment with 50% shading promoted higher plants, larger stem diameter and, a greater accumulation of shoot dry mass and total dry mass. The use of the reflective material on growing benches increased the temperature of the substrate at all shading levels, and it did not improve the growth and quality of baru seedlings, because of the growth parameters were similar. The seeding depth of 2.0 and 4.0 cm did not interfere in the quality of the baru seedlings because the plants showed DQI, plant height, stem diameter and, biomass similar.

Keywords: *Dipteryx alata*, seedling production, plant growing environment, light restriction.

Citation: Costa, G. G. S. da, E. Costa, E. M. da Silva, R. S. Borges, F. F. da Silva Binotti, G. H. C. Vieira, A. F. G de O. de Souza. 2020. Shading level, reflective material, and seeding depth on the growth of baru seedlings. Agricultural Engineering International: CIGR Journal, 22(4): 83-92.

1 Introduction

The Brazilian Cerrado is one of the most important biomes in the country due to its wide diversity, where its natural resources constitute the means of survival for many communities, such as indigenous people, fishermen, among others. These communities obtain their livelihood by collecting some native fruits or other species of fruit trees that occur in the region. However, the native fruit trees of the cerrado are losing their space, due to the fires and deforestation of areas for the implantation of other activities for commercial purposes. A better understanding of the biodiversity of native cerrado species, from seed treatment to post-harvest processing, can help all producers interested in the implementation of orchards and/or reforestation areas. This may also help

Received date: 2019-08-22 **Accepted date:** 2020-09-04

***Corresponding author: Geany Giovana Silva da Costa, MSc.**, State University of Mato Grosso do Sul, Cassilândia, MS, Zipcode 79540-000, Brazil. Email: geanys.costa@hotmail.com. Tel: +55(67)35967600.

future entrepreneurs who are interested in investing in the cultivation of these Cerrado species, which have characteristics for medicinal and nutritional use, for the protection and survival of animals, recovery of degraded areas, as well as for the use of wood, or *in natura* consumption of the fruits.

The baru (*Dipteryx alata* Vog.) is a species that has a wide distribution in the Brazilian Cerrado region, and its chestnut can be exploited by the sustainable use, enjoying its nutritive characteristics (proteins and lipids). The adult plant has a medium size, with trunk diameter reaching 0.8 to 1.0 m, and its wood has high resistance to rotting and xylophagous organisms, excellent quality, durability and high density (0.90 to 1.10 m m^{-3}), and can be used for stakes and fences, naval and civil construction, and external structures (Lorenzi, 2009). For the production of high-quality seedlings, various requirements and technologies are needed, such as seed selection, the use of suitable substrates and containers, as well as the type of protected environment and proper management of irrigation and mineral nutrition.

The use of the appropriate protected environment allows the production of high-quality seedlings, with better development and initial growth. Thus, these seedlings can remain shorter in seedling nurseries, reducing crop management, seedling mortality rate, and cost of production (Rudek et al., 2013). In the formation of baru seedlings it has been observed that the shading of 50% does not influence the seedling emergence (Oliveira et al., 2014) and the emergence speed (Costa et al., 2015), however it has been obtained plants with an adequate diameter for planting (Costa et al., 2015; Mota et al., 2012).

Protected environments can be constructed with different cover materials, formats, and structures, and due to these differences, there are several physiological and adaptation responses of plants according to each species (Mota et al., 2012). The amount and quality of solar radiation incident on plants can interfere with their growth and development (Dutra et al., 2012), therefore, the choice of the protected environment as well as the distribution of solar radiation inside this environment, with the use of growing benches coated with reflective material can promote better vigor and quality of baru seedlings.

The technique of the use of reflective material on the growing banks in nurseries constructed with different levels of shading has the purpose of reflecting the photosynthetically active radiation (PAR), which reaches the reflective materials for the leaves. This allows better use of light energy, which increases the amount of energy absorbed and the photosynthetic rate. However, the efficiency of light-absorption by plants depends on the photosynthetic apparatus of each species (Souza et al., 2011). Passion fruit seedlings on growing benches with mirror-type reflective material showed a high growth rate (Santos et al., 2017), as well as produced high quality baru seedlings (Costa et al., 2020). High quality jambolan seedlings (*Syzygium cumini*) were obtained on growing bench with reflective aluminum foil material in an environment with 30% shading (Salles et al., 2017) and *Schizolobium amazonicum* seedlings in a plastic greenhouse with a 42%-50% shading screen under polyethylene film (Mortate et al., 2019).

Some species require a specific seeding depth, in order to obtain adequate germination and uniformity in the seedling's emergence. When the sowing is performed in greater depth, the seedling emergence is impaired, resulting in the lack of stand uniformity, which increases the costs with longer permanence of the plants in the nurseries. On the other hand, when sowing is performed very superficially, it can lead to the formation of abnormal plants (Sousa et al., 2007). Therefore, there is a need to carry out studies to determine the appropriate seeding depth for the production of baru seedlings.

Given the above, this study aimed to evaluate the effects of shading levels, reflective material, and seeding depth on the growth and production of high-quality baru seedlings.

2 Material and methods

The experiments were conducted at the State University of Mato Grosso do Sul (UEMS), in Cassilândia, MS, Brazil (19°07'21" S, 51°43"15" W, and 516 m altitude). The regional climate, according to the Köppen classification, is rainy tropical (Aw).

Seeds of baru (*Dipteryx alata* Vog.) were extracted from mature fruits collected from trees established in a Cerrado area of the municipality of União de Minas, Minas Gerais, Brazil (19°31'47" S, 50°20'02" W, and altitude of 500 m), in July 28th, 2017. The seeds were stored under laboratory conditions for 60 days.

The experiments were carried out in four production environments with different levels of shading: a) 0% shading (full sunlight) (E_1); b) agricultural shading screenhouse with galvanized steel structure, measuring 8.00 m width by 18.00 m length and 3.50 m high, closing at 45° inclination, with black shading screen (Sombrite®) on the sides and roof providing 18% (E_2), 30% (E_3), and 50% (E_4) of shade. In these production environments, the seedlings were grown on growing benches (1.40 m width × 3.50 m length × 0.80 m high) coated or not coated with a reflective material (Aluminet®). On October 23rd, 2017, the seeds were sown at 2.0 or 4.0 cm depths in black polyethylene bags of 15.0 × 25.0 cm (1.8 L), filled with substrate formulated from the mixture of sandy soil: bovine manure: vermiculite (5: 3: 2).

The substrate was fertilized with applying 500 mg kg^{-1} of 04-20-20 fertilizer formulation. At 22 days after emergence, 800 mg L^{-1} of a micronutrient mineral fertilizer complex, containing 1.82% B, 1.82% Cu, 7.26% Fe, 1.82% Mn, 0.36% Mo, 0.355% Ni, and - 0.73% Zn were applied. This micronutrient fertilizer complex was applied as a 20-mL solution, previously diluted in pure water, to the side of each plant.

Since there were no replicates for the seedling production environments (i.e., shading levels), each one was considered an individual experiment. At each shading level, a completely randomized experimental design was used, in a 2 × 2 factorial scheme (two growing benches × two seeding depths), with five replications of eight seedlings each.

The data of air temperature (°C) and relative humidity (%) were gathered daily using a GP2 Data Logger (Delta-T Devices Ltd., Burwell, Cambridge, UK) installed within the seedling production environments. The PAR and PAR reflected from the growing benches with and without reflective material were measured daily at 9:30 a.m. with a photosynthetically active radiation meter (APG-MQ-200, Apogee Instruments Ltda., Piracicaba, SP, BRA).

During the growth of baru seedlings, the temperature of the substrate (ºC) was determined at 1:00 p.m. using a digital thermometer. The number of emerged seedlings was recorded daily until the 24th day, and the emergence speed index (ESI) was calculated using Maguire's equation (Maguire, 1962). The plant height (PH) and stem diameter (SD) were measured using a millimeter ruler and digital caliper, respectively, at 53, 86, and 120 days after sowing (DAS). At 120 DAS, the shoot dry matter (SDM) and root dry matter (RDM) were determined after drying in an oven at 65ºC for three days. From the SDM and RDM, the total dry matter (TDM) was calculated.

The absolute growth rate (AGR) was calculated from the PH between 53 and 86 days ($AGR_{53\text{-}86}$), between 86 and 120 days ($AGR_{86\text{-}120}$), and between 53 and 120 days ($AGR_{53\text{-}120}$), and the values expressed per cm day^{-1}. The Dickson quality index (DQI) was determined from the morphological traits using the following equation proposed by Dickson et al. (1960):

$$DOI = \frac{TDM(g)}{\frac{PH(cm)}{SD(mm)} + \frac{SDM(g)}{RDM(g)}} \quad (1)$$

where total dry matter (TDM, g); plant height (PH, cm); stem diameter (SD, mm); shoot dry matter (SDM, g); root dry matter (RDM, g).

The data were submitted to analysis of variances, and then by analysis of grouping experiments, joint analysis to compare the seedling production environments was performed for the variables that presented ratio between the residual mean square of individual analyses smaller than 7.0 (Banzatto and Kronka, 2013). The averages of production environments were grouped by the Scott-Knott test at the 5% probability level, while the average of growing benches and seeding depth were compared by Student's t-test at the 5% probability level.

3 Results and discussion

The light radiation incidence in production environments with 18%, 30%, and 50% shading levels was lower than in full sunlight (Figure 1).

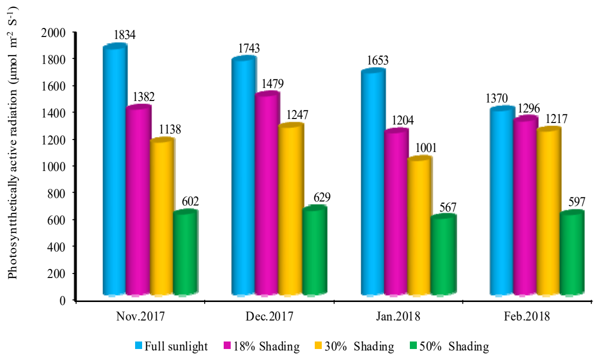

Figure 1 Photosynthetically active radiation (μmol m^{-2} s^{-1}) under different sunlight conditions

The increase of the light intensity does not favor the increase of the photosynthesis rate, because when all the photosynthetic pigments have extra energy, the plants can no longer capture this light energy, reaching the point of light saturation. These pigments with additional energy can transfer this energy to the reaction centers, which are accessory pigments (chlorophyll b, carotenoids, and phycobilins). These pigments can absorb light energy in the 680 and 700 nm bands and interact with electron transfer, being absorbed by chlorophyll a, acting in the photosynthetic process and not reaching the saturation point (Taiz and Zeiger, 2017). Therefore, the low light intensity in the more shaded environments can provide the seedlings better assimilation of energy by chlorophyll and other photosynthetic pigments, to perform photosynthesis with adequate light intensity (Figure 1).

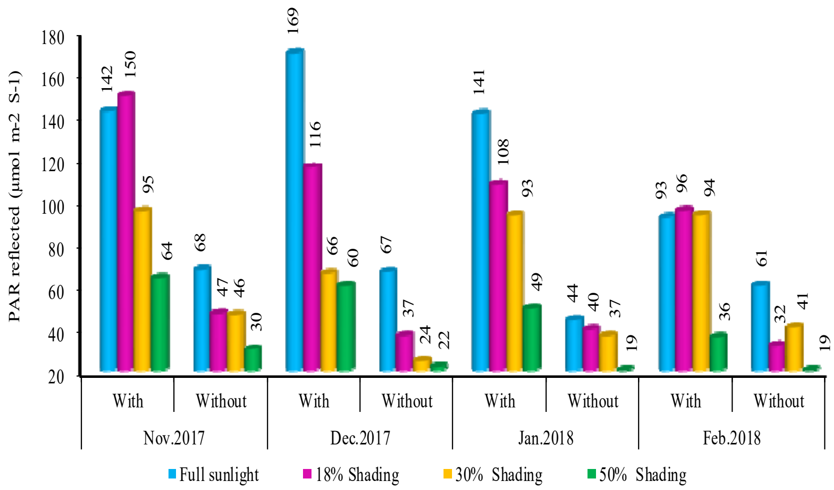

Figure 2 Photosynthetically active radiation (PAR) reflected from the growing benches with and without reflective material under different sunlight conditions

The reflected photosynthetically active radiation (PAR) was higher in the growing benches coated with a reflective material (Aluminet®), in all the environments of seedling production (Figure 2).

The temperature and relative air humidity inside the growing environments did not directly influence the growth of baru seedlings (Figures 3 and 4).

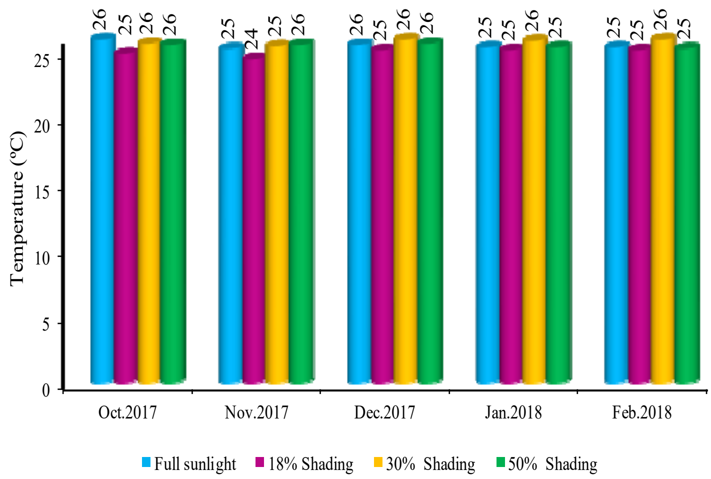

Figure 3 Temperature (°C) under different sunlight conditions

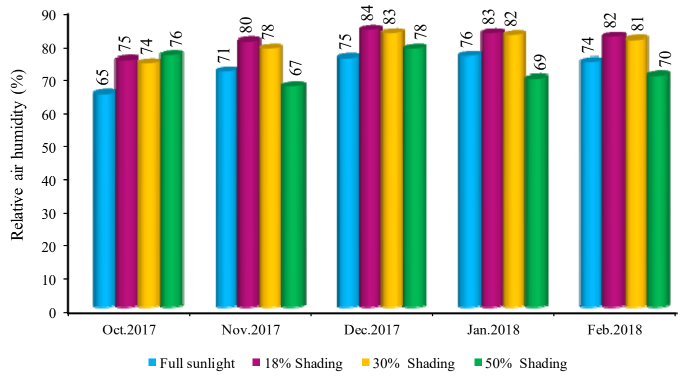

Figure 4 Relative air humidity (%) under different sunlight conditions

The use of the reflective material on the growing benches increased the temperature of the substrate at all shading levels (Figure 5).

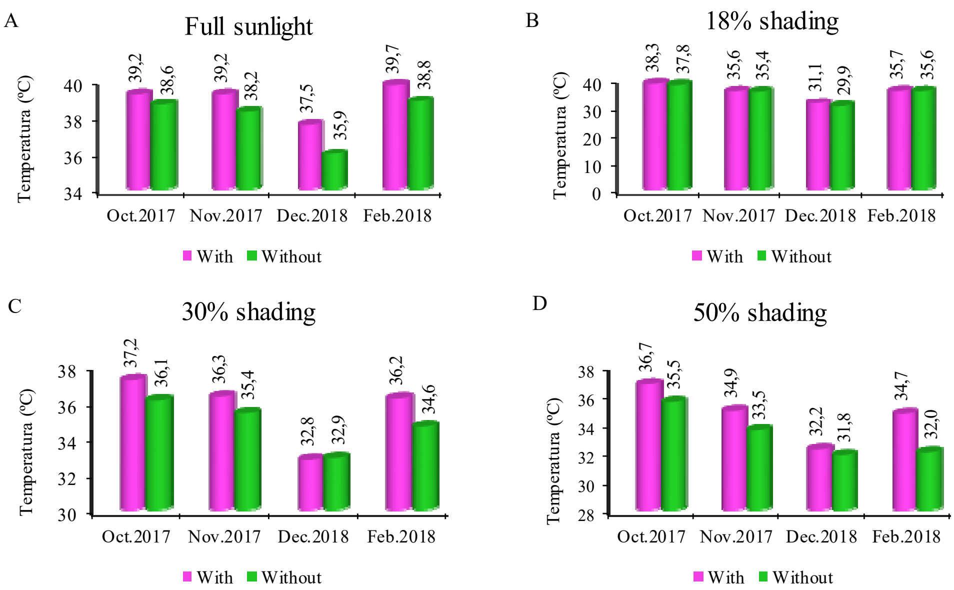

Figure 5 Temperature (ºC) of the substrate in the seedling production environments from the growing benches with and without reflective material

Joint analysis and comparison of production environments were performed for all variables since the ratio between the largest and smallest residue mean square (RMSr) was lower than 7 (Table 1) (Banzato and Kronka, 2013).

Table 1 Residual mean square and residue mean square ratio (RMS$_R$) for the joint analysis of baru seedlings (*Dipteryx alata* Vog.) grown in different production environments

Production environment	ESI	PH_1	PH_2	PH_3	SD_1	SD_3	SD_3
Full sunlight	0.016	0.447	0.553	0.794	0.061	0.046	0.041
18% shading	0.009	0.798	0.727	1.547	0.035	0.085	0.156
30% shading	0.013	0.960	1.676	2.354	0.199	0.103	0.099
50% shading	0.011	1.882	3.798	4.634	0.066	0.226	0.155
RMSr	1.81	4.21	6.87	5.84	5.71	4.96	3.77
Production environment	SDM	RDM	TDM	DQI	AGR_1	AGR_2	AGR_3
Full sunlight	0.621	0.196	1.320	0.086	0.00032	0.00033	0.00014
18% shading	0.736	0.248	1.670	0.102	0.00068	0.00051	0.00020
30% shading	1.931	0.296	3.341	0.110	0.00019	0.00032	0.00014
50% shading	1.610	0.188	2.318	0.063	0.00104	0.00118	0.00053
RMSr	3.11	1.58	2.53	1.75	5,55	3.71	3.84

Note: RMSr: ratio between the residual mean square of individual analyses of the four production environments. ESI: emergence speed index. $PH_{1, 2 \text{ and } 3}$: plant heigh at 53, 86, and 120 days after sowing (DAS), respesctivelly. $SD_{1, 2 \text{ and } 3}$: stem diameter at 53, 86, and 120 DAS, respesctivelly. SDM: shoot dry mass. RDM: root dry mass. TDM: total dry mass. DQI: Dickson quality index. $AGR_{1, 2 \text{ and } 3}$: absolute growth rate between 53 and 86 DAS, 86 and 120 DAS, and between 53 and 120 DAS, respesctivelly .

The results of the analysis of variance indicated that there was a significant interaction between the production environment and use of reflective material (E × R) for the SD at 53 DAS (SD_1), and significant interaction between the production environment and seeding depth (E × D) for PH at 120 DAS (PH_3). There was no triple interaction between production environment × use of reflective material × seeding depth (E × R × D) for any of the variables. For most variables, significant differences were reported only for seedling production environments (Table 2).

Table 2 Significance of variance analysis of baru seedlings (*Dipteryx alata* Vog.) under different shading levels, reflective material and seeding depth

Cause of variation	ESI	PH_1	PH_2	PH_3	SD_1	SD_2	SD_3
Production environment (E)	**	**	**	**	ns	ns	**
Reflective material (R)	ns	ns	ns	ns	ns	ns	ns
Seeding depth (D)	**	ns	ns	ns	ns	ns	ns
Interaction (E × R)	ns	ns	ns	ns	*	ns	ns
Interaction (E × R)	ns	ns	ns	*	ns	ns	ns
Interaction (B × D)	ns	ns	ns	ns	ns	ns	ns
Interaction (E × R × D)	ns	ns	ns	ns	ns	ns	ns
Cause of variation	**SDM**	**RDM**	**TDM**	**DQI**	**AGR_1**	**AGR_2**	**AGR_3**
Production environment (E)	**	**	**	*	ns	**	**
Reflective material (R)	ns	ns	ns	ns	ns	ns	ns
Seeding depth (D)	ns	ns	ns	ns	ns	ns	ns
Interaction (E × R)	ns	ns	ns	ns	ns	ns	ns
Interaction (E × R)	ns	ns	ns	ns	ns	ns	ns
Interaction (B × D)	ns	ns	ns	ns	ns	ns	ns
Interaction (E × R × D)	ns	ns	ns	ns	ns	ns	ns

Note: *: significant at 5%; **: significant at 1%, ns: non-significant. ESI: emergence speed index. $PH_{1,\ 2\ and\ 3}$: plant heigh at 53, 86, and 120 days after sowing (DAS), respesctivelly. $SD_{1,\ 2\ and\ 3}$: stem diameter at 53, 86, and 120 DAS, respesctivelly. SDM: shoot dry mass. RDM: root dry mass. TDM: total dry mass. DQI: Dickson quality index. $AGR_{1,\ 2\ and\ 3}$: absolute growth rate between 53 and 86 DAS, 86 and 120 DAS, and between 53 and 120 DAS, respesctivelly .

Table 3 Average values of emergence speed index (ESI), plant height (PH), and stem diameter (SD) of baru seedlings (Dipteryx alata Vog.) under different shading levels, reflective material and seeding depth

Cause of variation	ESI	PH_1 (cm)	PH_2 (cm)	SD_2 (mm)	SD_3 (mm)
Production environment					
Full sunlight	0.55 A	7.38 D	9.30 D	4.28 A	4.55 B
18% shading	0.45 B	8.16 C	10.30 C	4.35 A	4.87 A
30% shading	0.43 B	9.04 B	11.05 B	4.20 A	4.93 A
50% shading	0.39 B	10.01 A	12.47 A	4.45 A	5.00 A
Growing benches					
Without reflective material	0.46 A	8.62 A	10.69 A	4.31 A	4.87 A
With reflective material	0.45 A	8.67 A	10.86 A	4.34 A	4.79 A
Seeding depth					
2 cm	0.52 A	8.57 A	10.61 A	4.33 A	4.88 A
4 cm	0.39 B	8.72 A	10.95 A	4.31 A	4.78 A
CV (%)	24.07	11.69	12.06	7.84	6.96

Note: Mean followed by distinct letters, in the columns show significant differences by Scott-Knott test for the seedling production environments, and significant differences by Student's t-test for growing benches and seeding depth, both at the 1% probability level. CV: coefficient of variation.

The shading environments did not differ from each other for the ESI of baru seedlings (Table 3). The environment with 50% shading provided higher seedling height at 53 and 86 DAS. At 86 days, there was no significant difference between the growing environments for SD; however, at 120 DAS, the small SD was obtained under full sunlight (0% shading). There was no significant difference in the use of reflective material on the growth benches for the variables measured.

The seeding depth of 2.0 cm resulted in higher emergence rate index of baru seedlings, while 4.0 cm sowing depth prevented the embryo's rapid growth, and the seedlings took longer to reach the soil surface (Table 3). These results indicate that when sowing is performed in greater depth the emergence of the seedlings is difficult due to the physical barrier of the soil that resulted in a higher energetic expenditure of the seeds so that the hypocotyl could break the soil layer. Some studies have reported that shaded environments do not influence the emergence rate of seedlings. Oliveira et al. (2014) showed that the greenhouse and agricultural shading screenhouse did not influence the emergence rate of baru seeds. Costa et al. (2015) also observed that 50% shading level did not influence the emergence speed of baru seedlings, results similar to those reported in this study.

The highest PH was obtained in the environment with

50% shading (Table 3). Similar results were reported by Ajalla et al. (2012) and by Mota et al. (2012), which obtained a higher height of baru seedlings grown in agricultural nurseries with 50% shading screens. These authors highlight the importance of the use of shading screens in the initial growth of the seedlings, with protection against extreme climatic conditions and high solar radiation. The rapid growth in shaded environments shows the mechanism of adaptation of the species, with a higher concentration of photoassimilates resulting in greater growth of the shoots, that is, greater elongation of the cells in the more shaded environments. Lower plant growth when exposed to full sunlight may have been caused by some physiological stress (Taiz and Zeiger, 2017).

For PH at 120 days, there was an interaction between production environments and seeding depth (Table 4). The seedlings produced from sowing at 2 and 4 cm depth had a higher height in the environment with 50% shading.

Table 4 Plant height (cm) of baru seedlings (Dipteryx alata Vog.) at 120 days affected by the interaction between the production environment and seeding depth

Production environment	Seeding depth	
	2 cm	4 cm
Full sunlight	10.09 Ca	11.30 Ca
18% shading	11.32 Ca	12.56 Ba
30% shading	13.23 Ba	12.98 Ba
50% shading	15.63 Aa	14.58 Aa
CV (%)	12.02	

Note: Mean followed by distinct uppercase letters, in the columns for the seedling production environments or distinct lowercase letters, in the rows for Seeding depth show significant differences by Scott-Knott and Student's t-tests, respectively, both at the 5% probability level. CV: coefficient of variation.

During the 120 days of seedling growth, the temperature and the PAR in the 50% shading environment were lower when compared to the other production environments, and this should have favored shoot growth. Therefore, with this lower solar radiation incidence, the seedlings explored the morphological mechanisms in an attempt to obtain more energy for the initial growth of the plants.

For the SD of baru seedlings at 53 DAS, there was an interaction between production environments and the use of reflective material in the growing benches (Table 5). The seedlings produced in the environment with 50% shading screens had greater growth in SD when grown on benches with the use of reflective material, whereas the SD of seedlings grown in other production environments was not influenced by the use of reflective material.

Table 5 Stem diameter (mm) of baru seedlings (Dipteryx alata Vog.) at 53 days affected by the interaction between the production environment and growing benches with or without reflective material

Production environment	Growing benches	
	With reflective material	Without reflective material
Full sunlight	3.89 Ba	4.08 Aa
18% shading	3.77 Ba	3.81 Aa
30% shading	3.83 Ba	3.90 Aa
50% shading	4.11 Aa	3.74 Ab
CV (%)	7.71	

Note: Mean followed by distinct uppercase letters, in the columns for the seedling production environments or distinct lowercase letters, in the rows for seeding depth show significant differences by Scott-Knott and Student's t-tests, respectively, both at the 5% probability level. CV: coefficient of variation.

The use of reflective material on the growing benches increased the efficiency of light energy absorption by the leaves, since the light energy that passes through the upper leaves of the plant can be reflected the lower leaves with the use of reflective materials, and this can increase the photosynthetic rate of the plants. This increased light absorption efficiency increased SD of plants at 53 DAS in the environment with 50% shading screen (Table 5). Up to 120 days, baru seedlings were better adapted to the reflective material and environment with a lower incidence of light radiation, increasing SD thickness and resulting in greater resistance to tipping when the seedlings are planted in the field.

The larger SD in the environment with 50% shading screens corroborated the results obtained by Ajalla et al. (2012), which evaluated baru seedlings at different levels of shading (0%, 30% and 50%), and observed a larger SD (5.4 mm) at 60 days for the seedlings grown in the environment with 50% shading. Costa et al. (2015) obtained larger SD (5.0 mm) in baru seedlings at 75 days in the environment with a 50% shading screen. Similarly, Mota et al. (2012), also obtained larger SD (4.40 mm) from baru seedlings at 125 days in the environment with 50% shading. These authors showed that, regardless of the evaluation period, the environment with a 50% shading screen increased the SD of the baru seedlings.

The seedlings produced in the environment with 50% shading had a greater accumulation of shoot dry mass and total dry mass (Table 6). This indicates that the baru seedlings had a higher energy demand and a higher translocation of photoassimilates to shoot and roots, since this environment provided the lowest intensity of photosynthetically active radiation, at most up to 600 μmol m^{-2} s^{-1}. All shaded environments provided greater root dry mass accumulation. For the growing benches with and without reflective material and seeding depth, there was no significant difference.

Table 6 Average values of shoot dry matter (SDM), root dry matter (RDM), and total dry matter (TDM) of baru seedlings (Dipteryx alata Vog.) at 120 days under different shading levels, reflective material and seeding depth

Cause of variation	SDM ($g\ plant^{-1}$)	RDM ($g\ plant^{-1}$)	TDM ($g\ plant^{-1}$)
Production environment			
Full sunlight	2.50 C	1.27 B	3.77 C
18% shading	2.91 C	1.67 A	4.58 B
30% shading	3.53 B	1.75 A	5.28 B
50% shading	5.81 A	1.74 A	7.54 A
Growing benches			
Without reflective material	3.47 A	1.57 A	5.04 A
With reflective material	3.90 A	1.64 A	5.55 A
Seeding depth			
2 cm	3.83 A	1.60 A	5.43 A
4 cm	3.54 A	1.61 A	5.15 A
CV (%)	30.02	29.98	27.79

Note: Mean followed by distinct letters, in the columns show significant differences by Scott-Knott test for the seedling production environments, and significant differences by Student's t-test for growing benches and seeding depth, both at the 1% probability level. CV: coefficient of variation.

Table 7 Average values of absolute growth rate at 53, 86, and 120 days after sowing, and Dickson quality index (DQI) of baru seedlings (Dipteryx alata Vog.) at 120 days under different shading levels, reflective material and seeding depth

Cause of variation	$AGR_{(53-86)}$ ($cm\ day^{-1}$)	$AGR_{(86-120)}$ ($cm\ day^{-1}$)	$AGR_{(53-120)}$ ($cm\ day^{-1}$)	DQI
Production environment				
Full sunlight	0.058 A	0.041 C	0.049 B	0.87 B
18% shading	0.065 A	0.048 C	0.056 B	1.09 A
30% shading	0.061 A	0.061 B	0.061 B	1.12 A
50% shading	0.075 A	0.078 A	0.076 A	1.17 A
Growing benches				
Without reflective material	0.063 A	0.058 A	0.060 A	1.04 A
With reflective material	0.066 A	0.056 A	0.061 A	1.08 A
Seeding depth				
2 cm	0.062 A	0.058 A	0.060 A	1.08 A
4 cm	0.067 A	0.056 A	0.062 A	1.04 A
CV (%)	36.59	42.46	26,08	28,36

Note: Mean followed by distinct letters, in the columns show significant differences by Scott-Knott test for the seedling production environments, and significant differences by Student's t-test for growing benches and seeding depth, both at the 1% probability level. CV: coefficient of variation.

The highest dry mass accumulation of baru seedlings in the environment with a 50% shading screen was also observed by Mota et al. (2012). In this environment, the seedlings did not reach the point of light saturation, less than 600 μmol m^{-2} s^{-1}. Thus, the energy produced in the photosynthesis was possibly invested in dry mass of the shoots and roots. Also, this environment provided greater initial seedling growth. Therefore, environments that provide luminosity, temperature, water availability, and nutrients necessary for the initial growth of plants can provide more vigorous seedlings.

Gonçalves et al. (2005) studied the growth, rate of photosynthesis and stress indicators in young rosewood plants (*Aniba rosaeodora* Duke) under different light intensities (10 to 250 μmol m^{-2} s^{-1}; 500 to 800 μmol m^{-2} s^{-1}; 700 to 1000 μmol m^{-2} $s^{-1}$and 1300 to 1800 μmol m^{-2} s^{-1}), and reported that the greatest accumulation of dry mass occurred when the seedlings were grown in the 500 m range, similar to the present study. This suggests that each species is best suited to a particular incidence of sunlight.

There was no significant difference in the AGR from 53 to 86 DAS (Table 7). After this period, the environment with 50% shading screen resulted in an increase in the height growth rate of 0.076 cm day^{-1} in the period from 86 to 120 days, whereas in the period from 53 to 120 days this increase was 0.078 cm^{-1}. There was no significant difference in the use of reflective material and seeding depth.

In order to determine the quality standard of the seedlings, the morphological characteristics are the most used and have the preference for the seedling producers, so the DQI is mentioned as a measure for morphological evaluation (Eloy et al., 2013). This pattern calculates the robustness and balance between shoot and root of the seedlings, so the higher the DQI, the better the quality standard (Gomes et al., 2002). This factor allows evaluating the potential of the seedlings when submitted to the field conditions.

The environment with a 50% shading screen provided a higher quality of the seedlings compared to full sunlight but did not differ from the environments with 18 and 30% shading (Table 7). This indicates that the shaded environments resulted in high-quality baru seedlings. Reis et al. (2016) evaluated the growth and quality of *Copaifera langsdorffii* Desf. seedlings under different shading levels (0, 30%, 50%, 70% and 90%), and found that the 50% shading environment provided better quality seedlings.

Exposure of the seedlings to full sunlight for a long period and high luminosity has impaired seedling quality because the seedlings receive an amount of light above their capacity to absorb, causing the loss in the efficiency of the photochemical reactions, reducing the photosynthetic rate and consequently, causing the blockage of physiological processes. The shading was important for the production of high-quality baru seedlings.

4 Conclusions

The increase of the light intensity did not favor the increase of the growth of baru seedlings because the best level of shading for the formation of baru seedlings was 50%.

The environment with 50% shading promoted higher plants, larger SD and, a greater accumulation of shoot dry mass and total dry mass.

The use of the reflective material on growing benches increased the temperature of the substrate at all shading levels, and it did not improve the growth and quality of baru seedlings, because of the growth parameters were similar.

The seeding depth of 2.0 and 4.0 cm did not interfere in the quality of the baru seedlings because the plants showed the DQI, PH, SD and, biomass similar.

References

Ajalla, A. C. A., E. Volpe, M. C. Vieira, and N. A. H. Zárate. 2012. Produção de mudas de baru (*Dipteryx alata* Vog.) sob três níveis de sombreamento e quatro classes texturais do solo. *Revista Brasileira de Fruticultura*, 34(3): 888-896.

Banzatto, D. A., and S. N. Kronka. 2013. *Experimentação Agrícola*. 4th ed. Jaboticabal: Funep.

Costa, E., J. G. Dias, K. G. Lopes, F. F. S. Binotti, and E. D. Cardoso. 2015. Telas de sombreamento e substratos na produção de mudas de *Dipteryx alata* Vog. *Floresta e Ambiente*, 22(3): 416-425.

Costa, E., T. C. Lopes, A. G. Silva, T. Zoz, J. S. Salles, A. H. F. Lima, F. F. S. Binotti, and G. H. C. Vieira. 2020. Reflective material in the formation of Dipteryx alata *seedlings.* Research, Society and Development*, 9(8): e430985428.*

Dickson, A., A. L. Leaf, and J. F. Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *The Forest Chronicle*, 36(1): 10-13.

Dutra, T. R., P. H. Grazziotti, R. C. Santana, and M. D. Massad. 2012. Desenvolvimento inicial de mudas de copaíba sob diferentes níveis de sombreamento e substratos. *Revista Ciência Agronômica*, 43(2): 321-329.

Eloy, E., B. O. Caron, D. Schmidt, A. Behling, L. Schwers, and E. F. Elli. 2013. Avaliação de qualidade de mudas de *Eucalyptus grandis* utilizando parâmetros morfológicos. *Revista Floresta*, 43(3): 373-384.

Gomes, J. M., L. Couto, H. G. Leite, A. Xavier, and S. L. R. Garcia. 2002. Parâmetros morfológicos na avaliação de qualidade de mudas de *Eucalyptus grandis*. *Revista árvore*, 26(6): 655-664.

*Gonçalves, J. F. C., D. C. S. Barreto, U. M. Santos Junior, A. V. Fernandes, P. T. B. Sampaio, and M. S. Buckeridge. 2005. Growth, photosynthesis and stress indicators in Young rosewood plants (*Aniba rosaeodora *Duke) under different light intensities.* Brazillian Journal of Plant Physiology*, 17(3): 325-334.*

Lorenzi, H. 2009. *Árvores brasileiras*: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Vol. 3. Nova Odessa: Instituto Plantarum.

Maguire, J. D. 1962. Speed of germination aid in selection and evaluation for seedling emergence and vigor. *Crop Science*, 2(2): 176-177.

Mortate, R. K., E. Costa, G. H. C. Vieira, H. F. Sousa, R. S. Borges, W. F. S. Barbosa, and G. G. S. Costa, 2019. Levels of shading and reflective material in benches for *Schizolobium amazonicum* seedlings. *Journal of Agricultural Science*, 11(5): 485-495.

Mota, L. H. S., S. P. Q. Scalon, and R. Heinz. 2012. Sombreamento na emergência de plântulas e no crescimento inicial de *Dipteryx alata* Vog. *Ciência Florestal*, 22(3): 423-431.

Oliveira, L. C., E. Costa, A. D. Oliveira, and M. H. A. Jorge. 2014. Emergência do baruzeiro sob ambientes protegidos e substratos. *Revista de Agricultura Neotropical*, 1(1): 10-16.

Reis, S. M., B. H. Marimon-Júnior, P. S. Morandi, C. Oliveira-Santos, B. D. Oliveira, and B. S. Marimon. 2016. Desenvolvimento inicial e qualidade de mudas de *copaifera langsdorffii* desf. sob diferentes níveis de sombreamento. *Ciência Florestal*, 26(1): 11-20.

Rudek, A., F. A. Oliveira Garcia, and F. S. B. Peres. 2013. Avalição da qualidade de mudas de eucalipto pela mensuração da área foliar com o uso de imagens digitais. *Enciclopédia Biosfera*, 9(17): 3775-3787.

Salles, J. S., A. H. F. Lima, and E. Costa. 2017. Mudas de jambolão sob níveis de sombreamento, bancadas refletoras e profundidade de semeadura. *Revista de Agricultura Neotropical*, 4(5): 110-118.

Santos, T. V., T. C. Lopes, A. G. Silva, R. C. M. Paula, E. Costa, and F. F. Silva Binotti. 2017. Produção de mudas de maracujá amarelo com diferentes materiais refletores sobre bancada. *Revista de Agricultura Neotropical*, 4(4): 26-32.

Sousa, A. H., M. C. C. Ribeiro, V. H. Carvalho Mendes, P. B. Maracajá, and D. M. Costa. 2007. Profundidades e posições de semeadura na emergência e no desenvolvimento de plântulas de moringa. *Revista Caatinga*, 20(4): 56-60.

Souza, G. D., E. M. Castro, A. M. Soares, A. D. Santos, and E. Alves. 2011. Teores de pigmentos fotossintéticos, taxa de fotossíntese e estrutura de cloroplastos de plantas jovens de *Mikania laevigata* Schultz Bip. ex Baker cultivadas sob malhas coloridas. *Semina: Ciências Agrárias*, 32(supl 1): 1834-1854.

Taiz, L., and E. Zeiger. 2017. *Fisiologia Vegetal*. 6th. ed. Porto Alegre: Artemed.