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Original Article

How cutting types and shading levels influence the vegetative propagation of *Pereskia aculeata*?

Como o tipo de estaca e níveis de sombreamento influenciam a propagação vegetativa de *Pereskia aculeata*?

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Abstract

Information from *Pereskia aculeata* Miller (Cactaceae) responses regarding the portion of the stem cuttings branch parental plants and the shading level need to be investigated in order to establish techniques for their producing seedlings. We aimed was to evaluate the effect of cutting types and shading levels in the production of *P. aculeata* seedlings. We studied three cutting types, collected from different portions of the stem cuttings branch: herbaceous, semi-hardwood, and hardwood, which were arranged under two shading levels: 0% (full sun) or 50% (shade). The selected parent plants had an adequate and vigorous phytosanitary aspect. After 90 days after the cuttings, the seedlings were evaluated regarding survival, growth indicators, biomass production and partitioning, and allometric indices. Seedlings from hardwood cuttings and produced under 0% shading showed higher survival. The largest number of sprouts occurred in seedlings of semi-hardwood and hardwood cuttings. The highest leaf area values occurred in seedlings of semi-hardwood and hardwood cuttings under 0% shading. Seedlings from hardwood cuttings had higher biomass allocation in the roots under 50% shading. Seedlings of herbaceous and semi-hardwood portion allocated values ≥ 70% of the biomass in the aerial part. Seedlings of species are able to adjust to different shading levels as a plasticity mechanism. For the production of *P. aculeata* seedlings, the hardwood portion of the stem cuttings branch under full sun cultivation is recommended. In addition, semi-hardwood cuttings grown under 50% shading can also be used for seedlings production.

Keywords: "Ora-pro-nóbis", acclimatization, sprouting, hardwood, luminosity, plasticity.

Resumo

Informações das respostas da *Pereskia aculeata* Miller. (Cactaceae) quanto à porção da estaca do ramo da planta matriz e o nível de sombreamento precisam ser investigadas com o intuito de estabelecer protocolos para sua produção de mudas. Objetivamos avaliar o efeito do tipo de estaca e níveis de sombreamento na produção de mudas de *P. aculeata*. Estudamos três tipos de estacas baseados na porção de coleta do ramo: herbácea, semi-lenhosa e lenhosa, acondicionadas sob dois níveis de sombreamento: 0% (pleno sol) ou 50% (sombra). As plantas matrizes selecionadas tiveram aspecto fitossanitário adequado e eram vigorosas. Após 90 dias da estaquia, as mudas foram avaliadas quanto a sobrevivência, indicadores de crescimento, produção e particionamento de biomassa e índices alométricos. Mudas provenientes de estacas lenhosas e produzidas sob 0% de sombreamento tiveram maior sobrevivência. Os maiores números de brotos ocorreram nas mudas de estacas da porção semi-lenhosas e lenhosa. As maiores áreas foliares e radiculares ocorreram nas mudas de estacas semi-lenhosas e lenhosas sob 0% de sombreamento. Mudas provenientes de estacas da porção lenhosa tiveram maior alocação de biomassa nas raízes sob 50% de sombreamento. Mudas de estacas da porção herbáceas e semilenhosas alocaram valores ≥ 70% de biomassa da parte aérea. As mudas da espécie são capazes de se ajustar aos diferentes níveis de sombreamento como mecanismo de plasticidade. Para a produção de mudas *de P. aculeata*, recomenda-se utilizar a porção lenhosa do ramo do caule sob pleno sol. Além disso, estacas semi-lenhosas crescidas sob 50% de sombreamento podem ser utilizadas para a produção de mudas.

Palavras-chave: Ora-pro-nóbis, aclimatização, brotação, lenhosa, luminosidade, plasticidade.

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1. Introduction

"Ora-pro-nóbis" (*Pereskia aculeata* Miller., Cactaceae) is a plant of agromedicinal interest, and due to its high levels of protein in the leaves that varies from 17.40 to 28.59% (Almeida and Corrêa, 2012; Souza et al., 2016). It is a plant rich in fibers, minerals, especially iron, calcium, zinc and magnesium, and compounds with antioxidant functions (Souza et al., 2016). Its leaves makes *P. aculeata* an alternative source of proteins in human food. In cooking, it can be used in soups, stews, omelettes, pies and salads. In the industry, its presence in flour, cookies and pasta stands out (Rocha et al., 2008). Considering that *P. aculeata* has a wide distribution throughout Brazil, there is a need to stimulate consumption in food, it is necessary to establish propagation protocols for the species.

Sexual propagation is difficult in some species, including for *P. aculeata*, and propagation by cuttings becomes a cheap alternative to overcome this difficulty. In addition to being used for commercial purposes, propagation by cuttings contributes to the rescue and genetic conservation of native species, obtaining large volumes of seedlings and ease of transport (Zem et al., 2015). The use of cuttings is one of the most widely used plant propagation techniques in recent times, and consists of using a part of the mother plant to be multiplied (Ferriani et al., 2010).

The production of seedlings can be influenced by several factors, internal and external to the plant. The genetic material, the technique and location of the cut, age, nutritional and water conditions of the mother plant, are some of the intrinsic factors that can influence the propagation. Among the external factors, there is the collection, time of year, substrate and environmental conditions (Guimarães et al., 2019). The vegetative propagation by cuttings allows to obtain plants identical to the mother plant, reduces the period to plant develop and increases the uniformity in species of difficult rooting (Tosta et al., 2012).

The most used types are herbaceous, semi-hardwood and hardwood. Herbaceous cuttings are usually removed from the pointer part or the median portion of branches in a vegetative growth stage and without lignification (Roncatto et al., 2008). The semi-hardwood, on the other hand, are also removed from branches with vegetative growth, however with a lignification process already started. Hardwood cutting are usually removed from branches that no longer have vegetative growth and the lignification process is intense (Oliveira et al., 2003).

The development of seedlings can be directly influenced by the abiotic factors of the environment in which they are inserted, which may have adjustments mechanisms to overcome adversities (Binotti et al., 2019; Raai et al., 2020; Santos et al., 2020). Among these factors, we can highlight the shading, with influence on the morphophysiology of the plants, in addition to photosynthetic regulation. The sunlight plays an important role, as it is directly related to the photosynthetic apparatus and regulation of metabolic processes, mainly in the seedling phase.

The luminosity must be used as efficiently as possible, in order not to cause damage to the integrity of the physiological processes and so that these adaptations are reflected in the synthesis of photoassimilates, which will result in the increase of the plant's biomass (Aimi et al., 2017; Vaz et al., 2020; Santos et al., 2023). However, each plant may present morphophysiological adjustment mechanisms in order to increase its plasticity.

For *P. aculeata* there is difficulty in obtaining seeds, and considering the fact that hardwood cuttings have a higher degree of lignification, a factor that contributes to the maintenance of water in the stem and in the cell turgidity, we hypothesized that the use of hardwood cuttings under shading environment, may favor the vegetative propagation of *P. aculeata* seedlings. Therefore, the aimed was to evaluate the effect of the collection portion of the stem cuttings branch and shading levels in the production of *P. aculeata* seedlings.

2. Material and Methods

2.1. General conditions

The experiment was carried out at Horto de Plantas Medicinais (Garden of Medicinal Plants) (22º 11' 43.7" S and 54º 56' 08.5" W, 452 m), in Faculty of Agricultural Sciences, at the Universidade Federal da Grande Dourados (UFGD), Dourados, Mato Grosso do Sul, Brazil. The region's climate is classified as CWa with hot summers with a rainy season, winters with moderate temperatures, and a dry season (Fietz et al., 2017).

2.2. Cuttings types, shading levels, and experimental design

The experimental design used was randomized blocks, with the treatments arranged in a subplot scheme, with the plots being shading levels, and in the subplots the types of piles, with four replications. Each experimental unit consisted of five black polyethylene bags with a capacity of 500 mL, with a cutting in each.

We studied the production of *P. aculeata* seedlings according to three cutting types, collected from different portions of the stem cuttings branch: herbaceous, semi-hardwood and hardwood, which were arranged under two shading levels: 0% (full sun) and 50% (shade). The shading was simulated, using the use of a black colored canvas with 50% retention of luminosity (Sombrite®) on the top and side cover. During the experimental period, the following mean values were recorded in environments with 0% and 50% shading: temperature (29.6 and 28.5 ºC), relative humidity (72 and 78%) and photosynthetically active radiation (928.33 and 330.20 μmol photons m^{-2} s^{-1}), respectively.

For the development of the experiment, the selected parent plants (maintained for 25 years in the HPM, from UFGD) had an adequate and vigorous phytosanitary aspect. The botanical material was identified and an exsiccate is deposited at the Herbarium, at UFGD, under registration No. 5226. Then, branches were collected using pruning shears, from 8 am to 10 am, which bases were placed in a container with water until the time of burial in the substrate, in order to avoid dehydration of the tissue (Santos et al., 2019).

The cuttings were prepared according to the branch portion, leaving them with an average length of 20 cm, an average diameter of 2.27; 3.45 and 4.51 mm and 6, 2, and 2 leaves, for herbaceous, semi-hardwood and hardwood cuttings, respectively. As regards the leaves on the cuttings, in the herbaceous ones they were smaller and remained whole, while in the semi-hardwood and hardwood ones they were older and were cut in half, remaining with similar surface areas.

The base substrate was constituted from the homogenization of Dystrophic Red Latosol + Tropstrato® (1:1, v/v) with the following chemical attributes after mixing, according to the methodology proposed by Silva (2009): pH $CaCl_2$ = 5.94; P = 42.65 mg dm^3; K = 1.99 $cmol_c$ dm^3; Ca = 13.28 $cmol_c$ dm^3; Mg = 19.00 $cmol_c$ dm^3; H + Al = 2.37 $cmol_c$ dm^3; V (%) = 62.88, and the physical attributes: total porosity = 61% and real density = 0.94 g cm^3. The containers were filled with the substrate, wetting was carried out afterwards and the burial of $^1/_3$ of the cuttings was carried out. Irrigations were carried out daily, with two irrigation shifts, aiming to maintain 70% of the water retention capacity in the substrate (Souza et al., 2000), and spontaneous plants were also uprooted when necessary.

2.3. Evaluated characteristics

After 90 days after the cuttings, the seedlings were evaluated for the following characteristics:

a) Survival: calculated considering the number of live seedlings with buds and leaves fully expanded.
b) Growth indicators: the number of sprouts and leaves per sprouts was counted. Subsequently, the seedlings were collected, which were washed in running water to remove excess impurities from the substrate, and the rooting percentage (minimum emission of two centimeters) was counted and the length of the largest root was measured, with a ruler graduated in millimeters. Leaf and root surface areas were also determined using an area integrator (LI-COR 3100, Nebraska).
c) Biomass production and partitioning: the dry biomasses of the aerial part and roots were quantified using a thousandsimal precision scale (0.0001 g) after drying in an oven with forced air circulation at 60 ± 5 ºC by 72 hours. It was also calculated the partitioning of photoassimilates in the aerial part and root of the seedlings, and the results expressed as a percentage of biomass.
d) Allometric indices: from the leaf area and dry biomass data, the leaf area ratio, specific leaf mass and specific leaf area (Hunt, 2017) and the root/shoot ratio were calculated.

2.4. Statistical analysis

Survival data were submitted to the Shapiro-Wilk test to verify normal distribution. The data were submitted to ANOVA, and when significant (F test, $P < 0.05$), the averages of the isolated effects and the interactions were compared by Student's t test for shading levels and Tukey for a portion of the stem cuttings branch ± SD (standard deviation) ($P \leq 0.05$), using the SISVAR software. Subsequently, in order to describe the relationship and similarity between the characteristics and the treatments studied, respectively, a complementary analysis of Pearson's linear correlation (r) ($P \leq 0.05$), multivariate of principal components analyze (PCA) and similarity dendrogram using the Euclidean distance was performed, using the PAST 3.21 software.

3. Results and Discussion

P. aculeata seedlings were influenced by the types of cuttings and/or shading levels, proving our initial hypothesis that the production of seedlings of this species depends on the portion of the cuttings branch and the luminosity availability used for its propagation. The survival rate and number of leaves per sprouts of the seedlings were influenced by the factors under study individually ($P \leq 0.05$) (Figure 1). Seedlings from hardwood cuttings and produced in full sun (0%) showed higher survival (95 and 93%, respectively) (Figures 1a and 1b). The same response was found for number of leaves, that is, higher values under the same culture conditions (Figures 1c and 1d). It should also be noted that as for the type of cutting used, the lowest values of these characteristics occurred in seedlings from the portion of the branch of herbaceous cuttings.

The higher values are associated with a greater number of carbohydrate reserves contained in the cuttings of the hardwood portion (Silva et al., 2020), having an energy source to maintenance survival. According to these authors, *Aloysia citriodora* Palau seedlings propagated using the hardwood portion of the stake showed a higher survival. With regard to shading levels, the increase in survival under conditions with high irradiance, here represented by the condition of 0% shading (full sun), indicates that *P. aculeata* has a good adjustments capacity due to its greater adaptability to this condition, which eliminates the use of shade screens, reducing production costs in terms of nursery. Such conditions are favorable for the photosynthetic mechanism of *P. aculeata*, as the species can present CAM or C_3 metabolism (Wang et al., 2012; Venter et al., 2022).

Similarly, Santos et al. (2019) found that *Lippia alba* (Mill.) N.E. Brown seedlings had the highest survival under 0% shading. In addition, seedlings exposed to high irradiance since the seedling phase may present better responses to the field, since they are already rusted (acclimatized), reducing the period of acclimatization of the seedling during and after nursery, in addition to mitigating the mortality rate and replacement of seedlings regarding the luminosity factor. However, at the same time, all other cultivation conditions must be verified in the production of seedlings, such as substrate, humidity, container, among others.

The lower survival value when using cuttings from the herbaceous portion is due to the fact that initially they had a higher number of leaves (6 leaves/cutting) in relation to the other types, possibly promoting greater water loss by leaf transpiration, resulting in a stressful condition for the for-seedling propagation. In addition, vegetative parts from the apical meristematic region have a lower degree of lignification and lose their turgor markedly than from other stem regions (Oliveira et al., 2003; Roncatto et al., 2008). With the reduction of the water potential of the tissue, especially foliar, the plants tend to present morphophysiological adjustments in order to adapt to adverse conditions, such as leaf fall due to the hormonal regulation produced by ethylene and abscisic acid (Salazar et al., 2015; Soares et al., 2019).

In general, all *P. aculeata* seedlings showed well-developed sprouts with several leaves per sprout (Figure 2a), with the largest number of sprouts (2.64 and 2.43 sprouts) occurring in seedlings from semi-hardwood and hardwood cuttings, respectively, regardless of the shading level (Figure 2b). Although we have not quantified it, we suggest that possibly these higher values are possibly due to the greater quantity of reserves and phytohormones contained in these cuttings, since they have a larger diameter of the collection (3.45 and 4.51 mm) compared to herbaceous seedlings (2.27 mm), which contributes to the investment of photoassimilates in new vegetative organs, in addition to the degree of physiological maturity of these cuttings.

The increase in the number of sprouts per seedling is desirable, especially since it is vegetative propagation, that is, the greater the number of shoots, the greater the potential of the species to present more leaf limbs, consequently increasing the metabolic processes and development of the seedlings.

Regarding the leaf (LA) and root area of *P. aculeata* seedlings, the interaction between the factors under study ($P \leq 0.05$) for these characteristics was found (Figure 3).

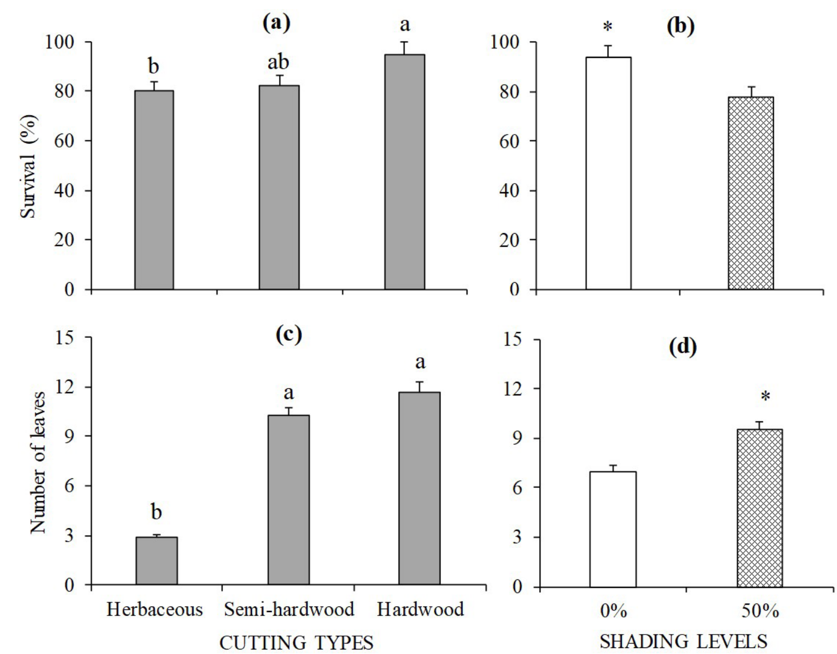

Figure 1. Survival (a–b) and number of leaves (c–d) in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch and shading levels. (a–c) Equal letters do not differ statistically ± SD (Tukey, $P \leq 0.05$); (b–d) * ± SD (Student's t, $P \leq 0.05$).

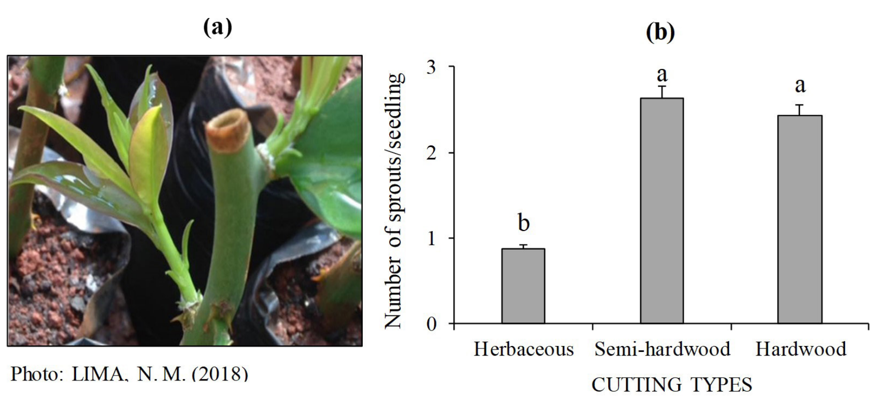

Figure 2. Visual aspect of sprouting (a) and number of sprouts (b) in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch. (b) Equal letters do not differ statistically ± SD (Tukey, $P \leq 0.05$).

For LA, in the unfolding of the interaction, there was no significant difference between the types of cuttings in the seedlings in full sun (0% shading), while shaded seedlings showed a higher value when using the herbaceous portion (Figure 3a), possibly as a light compensation strategy in this condition. As for the shading levels, when using semi-hardwood and hardwood cuttings, the shaded seedlings had lower LA, differing statistically from these same stem portions in full sun (0%). The increase in LA in full sun with semi-hardwood and hardwood cuttings is due to the greater number of leaves (Figure 1c) and sprouts (Figure 2b) in these same conditions, which favored the emission of new leaves by sprouting, maximizing luminous utilization and photosynthetic capacity.

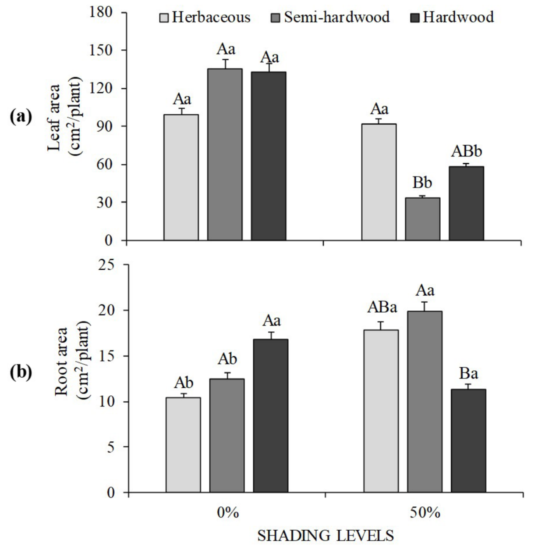

Figure 3. Leaf (a) and root (b) area in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch and shading levels. Uppercase letters compare the stem cuttings branch within each shading level ± SD (Tukey, $P \leq 0.05$). Lowercase letter compare the effect of shading levels in each stem cuttings branch ± SD (Student's t, $P \leq 0.05$).

Under 0% shading, seedlings propagated with hardwood cuttings had a larger root area (16.26 cm^2), differing from the other types of cuttings in this environment (Figure 3b), possibly the greater amount of carbohydrates and physiological maturity these cuttings, which contribute to the use of the rhizospheric area in a way more efficient, especially for being in a condition of greater exposure to intense light. On the other hand, under 50% shading, seedlings from herbaceous and semi-hardwoods had higher values for these materials closer to the meristematic region and with greater expression of auxin, which is preserved in this luminosity condition, which favors root development.

The aerial part dry mass (DMAP) and specific leaf area (SLA) were influenced by the interaction between the factors under study ($P \leq 0.05$) (Figure 4). The highest DMAP value (0.309 g) occurred in seedlings from herbaceous cuttings under 50% shading (Figure 4a) due to the greater leaf area

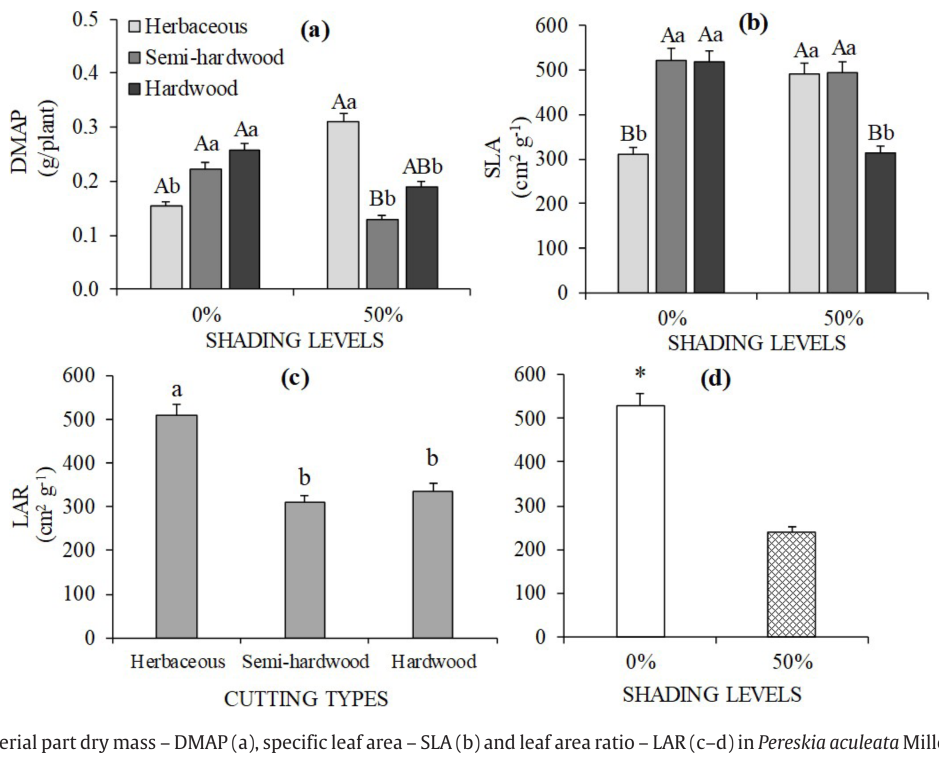

Figure 4. Aerial part dry mass – DMAP (a), specific leaf area – SLA (b) and leaf area ratio – LAR (c–d) in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch and shading levels. (a–b) Uppercase letters compare the stem cuttings branch within each shading level ± SD (Tukey, $P \leq 0.05$). Lowercase letter compare the effect of shading levels in each stem cuttings branch ± SD (Student's t, $P \leq 0.05$). (b) Equal letters do not differ statistically ± SD (Tukey, $P \leq 0.05$). (d) * ± SD (Student's t, $P \leq 0.05$).

and number of initial leaves in the same condition. On the other hand, the lowest SLA values occurred in herbaceous and hardwood seedlings under 0% shading (Figure 4b), respectively, demonstrating that lower lignification cuttings reduce turbidity in a marked manner under high irradiance, whereas in this same luminous availability, the semi-hardwood and hardwood branches favored higher SLA values.

Although seedlings from hardwood cuttings under 0% shading did not present higher biomass production, these had better indicator of sprouting and leaf aspects, suggesting good vegetative development capacity and survival throughout the crop by physiological adjustments. Leaf area ratio was influenced by cuttings types and shading levels individually ($P \leq 0.05$), with higher values (507.82 and 530.26 $cm^2 g^{-1}$) when using herbaceous cuttings and under 0% shading, respectively (Figures 4c and 4d).

In general, the seedlings had a higher allocation of biomass in the aerial part under 50% shading with herbaceous cutting (Figure 5). Seedlings from hardwood cuttings had a higher allocation of biomass in the roots (42%) under 50% shading, compared to the other portions of cuttings in this same light availability. On the other hand, when using the herbaceous and semi-hardwood portion, we observed that the seedlings allocated values ≥ 70% of the biomass in the aerial part, regardless of the shading level, indicating plasticity through physiological adjustments to contrasting light environments, important feature for resilience and potential for cultivation in different light regimes.

The partitioning of photoassimilates is a determining factor in the seedlings, since they need to present sufficient quantities to produce high quality seedlings. There are no reference standards in the literature regarding the ideal percentage between each organ of the plant, which may vary depending on several factors, such as the cultivated species, luminous preference, natural habitat, among other physiological aspects; but generally, most of the photoassimilates produced are directed to the development of the aerial part to regulate the biosynthesis of carbohydrates. *Aloysia citriodora* Palau seedlings in a shaded environment had lower allocation of biomass in the roots when using hardwood cuttings (Silva et al., 2020), different from what was observed for *P. aculeata* seedlings. Pearson's linear correlation analysis (r) showed a significant correlation ($P \leq 0.05$) between number of sprouts and number of leaves (r = 0.94), root dry mass and root area (r = 0.85), total dry mass and aerial part dry mass (r = 0.95) and root/aerial part (R/Pa) and aerial part dry mass (r = 0.95) (Figure 6), these being of high positive

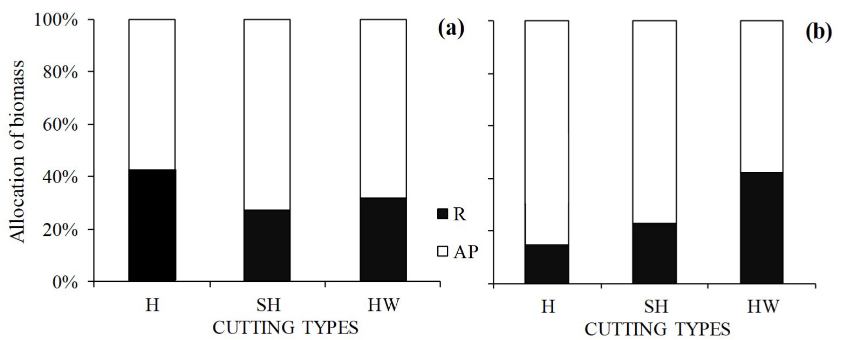

Figure 5. Allocation of biomass of the aerial part (AP) and roots (R) in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch (H= herbaceous; SH= semi-hardwood; HW= hardwood) and shading levels. (a) 0%= full sun; (b) 50%= shade.

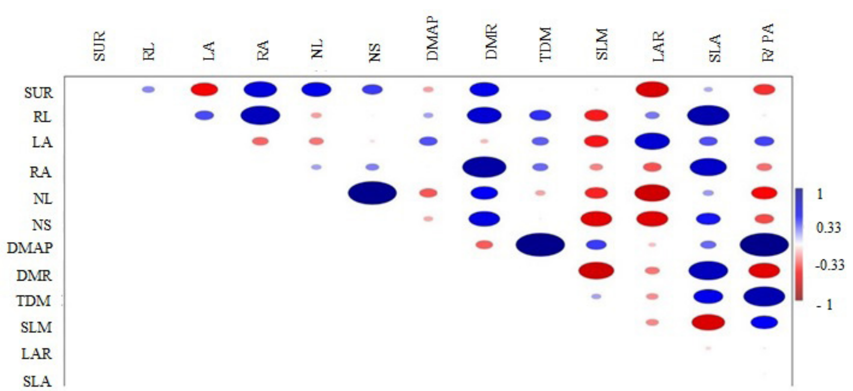

Figure 6. Pearson's linear correlation analysis (r) of characteristics of *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch and shading levels ($P \leq 0.05$). SUR: survival; RL: root length; LA: leaf area; RA: root area; NL: number of leaves; NS: number of sprouts; DMAP: aerial part dry mass; DRM: root dry mass; TDM: total dry mass; SLM: specific leaf mass; LAR: leaf area ratio; SLA: specific leaf area; R/Pa: root/shoot ratio.

magnitude, that is, the increase of a certain characteristic results in the increase of another. In general, most of the characteristics had no significant effect and showed little correlation (r = < 0.60) or even negatively. As the seedlings present a higher number of sprouts, the production of new leaves will increase, consequently favoring the physiological capacity of the species and the production of photoassimilates.

Although the root indicators were not influenced by any of the factors under study ($P > 0.05$), a positive correlation was found between root dry mass and root area, demonstrating that the species has good rooting capacity and root development, regardless of cultivation conditions in our study. According to Zem et al. (2016), the genus *Pereskia* presents good radial induction for presenting direct rhizogenesis.

However, the rooting potential varies between species, some of which are easy and fast, while others depend on the use of phytohormones or specific techniques. In this sense, the rate of growth of seedlings propagated in a vegetative manner is conditioned both by the emission of new shoots and in the induction and radical formation, both in a balanced way, since the absence or low capacity of formation of these organs at the same time can affect the mortality of seedlings in the formation process throughout the seedling production cycle.

As for the factorial loads of the characteristics of the PCA, we found that those with the greatest representativeness in positive decreasing order, that is, with values ≥ 0.30 (Coelho, 2003) in PC 1 were root dry mass, number of sprouts and leaves, root area and survival, while in PC 2 were total dry mass, specific leaf area, aerial part dry mass, root length, leaf area and root/aerial part (Table 1). Only specific leaf mass and leaf area ratio showed low experimental representativeness considering the standards established by Santos et al. (2020) and Wang et al. (2012).

We found that 64.77% of the remaining variance was explained by the PCA, with 37.52% and 27.25% corresponding to components 1 and 2, respectively. Root length, specific leaf area, root area, root dry mass, number of sprouts and leaves, and survival showed better results in seedlings from semi-hardwood and hardwood cuttings, when produced under 50% and 0% shading, respectively (Figure 7).

Regarding the cluster analysis (cophen. corr.: 0.71), we observed formation of three subgroups and a greater similarity between the seedlings produced using semi-hardwood and hardwood cuttings in 50% and 0% shading, respectively, since the Euclidean distance was shorter (3.36) compared to the others (Figure 8), in function

Table 1. Eigenvectors and their scores for characteristics in *Pereskia aculeata* Miller. seedlings propagated by different portions of the stem cuttings branch and shading levels.

	PC 1	**PC 2**	**PC 3**	**PC 4**
SUR	**0.3092**	-0.0698	0.2845	-0.2436
RL	0.1925	**0.3946**	-0.1909	-0.3149
LA	-0.1209	**0.3066**	-0.3565	0.3337
RA	**0.3326**	0.2157	0.1007	-0.3985
NL	**0.3373**	-0.1716	0.1528	0.4025
NS	**0.3440**	-0.0305	0.0963	0.4917
DMAP	-0.1801	**0.4011**	0.3088	0.1291
DMR	**0.4298**	0.1133	-0.0940	-0.1177
TDM	-0.0464	**0.4610**	0.2942	0.0967
SLM	-0.2827	-0.0949	0.4141	-0.2901
LAR	-0.2123	0.0907	-0.5282	-0.1260
SLA	0.2730	**0.4081**	-0.0745	0.0696
R/Pa	-0.3019	**0.3140**	0.2570	0.1509

Legend: SUR: survival; RL: root length; LA: leaf area; RA: root area; NL: number of leaves; NS: number of sprouts; DMAP: aerial part dry mass; DRM: root dry mass; TDM: total dry mass; SLM: specific leaf mass; LAR: leaf area ratio; SLA: specific leaf area; R/Pa: root/shoot ratio.

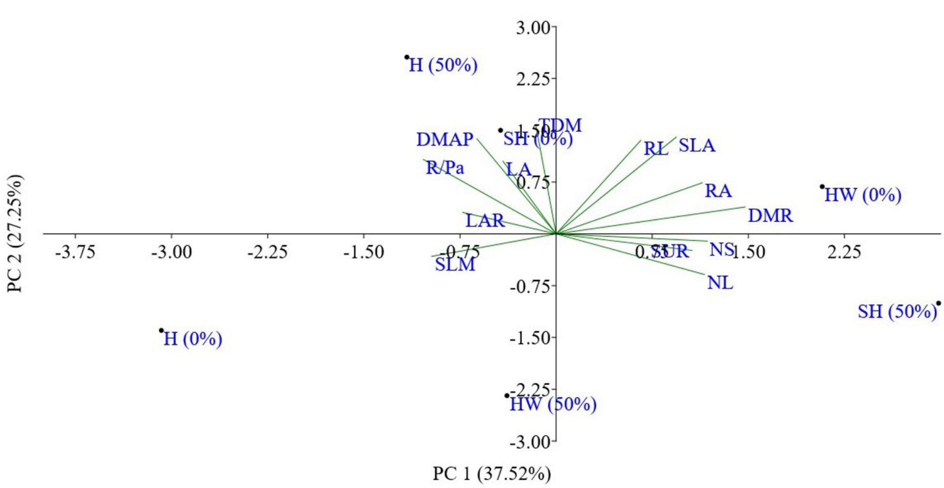

Figure 7. Principal component analysis (PCA) of *Pereskia aculeata* Miller. seedling characteristics propagated by different portions of the stem cuttings branch (H= herbaceous; SH= semi-hardwood; HW= hardwood) and shading levels (0% and 50%). SUR: survival; RL: root length; LA: leaf area; RA: root area; NL: number of leaves; NS: number of sprouts; DMAP: aerial part dry mass; DRM: root dry mass; TDM: total dry mass; SLM: specific leaf mass; LAR: leaf area ratio; SLA: specific leaf area; R/Pa: root/shoot ratio.

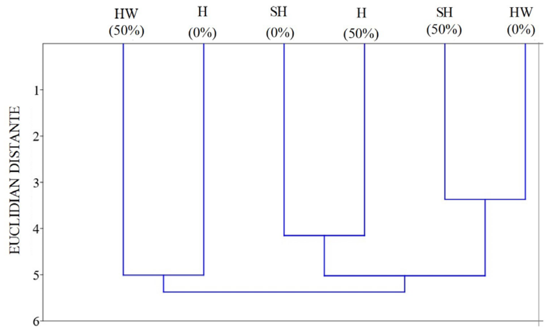

Figure 8. Grouping – similarity dendrogram based on Euclidean distance of *Pereskia aculeata* Miller. seedling characteristics propagated by different portions of the stem cuttings branch (H= herbaceous; SH= semi-hardwood; HW= hardwood) and shading levels (0% and 50%).

on the higher survival values, number of sprouts, leaf and root areas of seedlings under these conditions, reinforcing that these cuttings types are the most ideal for the production of *P. aculeata* seedlings. Through this multivariate analysis it is possible to identify the best treatments, that is, those that promoted better conditions for the growth of seedlings. However, these analyzes in a complementary way in works with seedlings production are still little performed, requiring an increasing statistical application.

Based on the results obtained, the hypothesis is accepted that the use of more lignified portions of stem cuttings, especially hardwood ones, favor the production of *P. aculeata* seedlings, but it is disagreed that the shaded environment is more suitable for biomass production, since most of the evaluated characteristics, especially survival and biomass production of the aerial part, presented better results in seedlings under 0% shading. This information is promising for improving techniques for collecting vegetative material and establishing nursery practices, since the use of shade screens can be dispensed with, favoring costs for the nurseryman and/or producer/farmer.

4. Conclusion

The use of the hardwood portion of the stem cuttings is the most suitable for the production of *Pereskia aculeata* Miller. seedlings under 0% shading for promoting greater indicators of survival, sprouting and leaf aspects. In addition, semi-hardwood cuttings grown under 50% shading can also be used for seedlings production.

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References

AIMI, S.C., ARAUJO, M.M., TONETTO, T.S., TABALDI, L.A., SALDANHA, C.W., FARIAS, J.G. and OLIVEIRA, G.G., 2017. Shading as a conditioning factor to forest species planting: a study with *Apuleia leiocarpa. Bosque (Valdivia)*, vol. 38, no. 2, pp. 371-379. http://dx.doi.org/10.4067/S0717-92002017000200014.

ALMEIDA, M.E.F. and CORRÊA, A.D., 2012. Utilização de cactáceas do gênero *Pereskia* na alimentação humana em um município de Minas Gerais. *Ciência Rural*, vol. 42, no. 4, pp. 751-756. http://dx.doi.org/10.1590/S0103-84782012000400029.

BINOTTI, E.D.C., BINOTTI, F.F.S., LUCHETI, B.Z., COSTA, E. and PINTO, A.H., 2019. Shading levels and plant growth regulator for formation of *Schizolobium amazonicum* compact seedlings. *Engenharia Agrícola*, vol. 39, no. 5, pp. 586-591. http://dx.doi.org/10.1590/1809-4430-eng.agric.v39n5p586-591/2019.

COELHO, A.M., 2003. *Agricultura de precisão: manejo da variabilidade espacial e temporal dos solos e das culturas. Tópicos em Ciência do Solo*. Viçosa: Sociedade Brasileira de Ciência do Solo, vol. 3, pp. 259-290.

FERRIANI, A.P., ZUFFELLATO-RIBAS, K.C. and WENDLING, I., 2010. Miniestaquia aplicada a espécies florestais. *Revista. Agroambiente On-Line*, vol. 4, no. 2, pp. 102-109. http://dx.doi.org/10.18227/1982-8470ragro.v4i2.363.

FIETZ, C.R., FISCH, G.F., COMUNELLO, E. and FLUMIGNAN, D.F., 2017. *Documentos 138: O clima da região de Dourados, MS*. 3. ed. Dourados: Embrapa Agropecuário Oeste.

GUIMARÃES, R.N., SOUZA, E.R.B., NAVES, R.V., MELO, A.P.C. and RUBIO NETO, A., 2019. Vegetative propagation of pequi (souarinut) by cutting. *Ciência Rural*, vol. 49, no. 2, pp. 1-6. http://dx.doi.org/10.1590/0103-8478cr20180579.

HUNT, R., 2017. Growth analysis, individual plants. *Encyclopedia of Applied Plant Sciences*, vol. 8, pp. 421-429.

OLIVEIRA, A.P., NIENOW, A.A. and CALVETE, E.O., 2003. Capacidade de enraizamento de estacas semilenhosas e lenhosas de cultivares de pessegueiro tratadas com AIB. *Revista Brasileira de Fruticultura*, vol. 25, no. 2, pp. 282-285. http://dx.doi.org/10.1590/S0100-29452003000200025.

RAAI, M.N., ZAIN, N.A.M., OSMAN, N., REJAB, N.A., SAHRUZAINI, N.A. and CHENG, A., 2020. Effects of shading on the growth, development and yield of winged bean (*Psophocarpus tetragonolobus*). *Ciência Rural*, vol. 50, no. 2, pp. 1-7. http://dx.doi.org/10.1590/0103-8478cr20190570.

ROCHA, D.R.C., PEREIRA JÚNIOR, G.A., VIEIRA, G., PANTOJA, L., SANTOS, A.S. and PINTO, N.A.V.D., 2008. Macarrão adicionado de ora-pro-nóbis (*Pereskia aculeata* Miller) desidratado. *Alimentos e Nutrição*, vol. 19, no. 4, pp. 459-465.

RONCATTO, G., NOGUEIRA FILHO, G.C., RUGGIERO, C., OLIVEIRA, J.C. and MARTINS, A.B.G., 2008. Enraizamento de estacas herbáceas de diferentes espécies de maracujazeiro. *Revista Brasileira de Fruticultura*, vol. 30, no. 4, pp. 1094-1099. http://dx.doi.org/10.1590/S0100-29452008000400041.

SALAZAR, C., HERNÁNDEZ, C. and PINO, M.T., 2015. Plant water stress: association between ethylene and abscisic acid response. *Chilean Journal of Agricultural Research*, vol. 75, no. 1, pp. 71-79. http://dx.doi.org/10.4067/S0718-58392015000300008.

SANTOS, C.C., BERNARDES, R.S., GOELZER, A., SCALON, S.P.Q. and VIEIRA, M.C., 2020. Chicken manure and luminous availability influence gas exchange and photochemical processes in *Alibertia edulis* (Rich.) A. Rich. seedlings. *Engenharia Agrícola*, vol. 40, no. 4, pp. 420-432. http://dx.doi.org/10.1590/1809-4430-eng.agric.v40n4p420-432/2020.

SANTOS, C.C., FRANCO-RODRIGUES, A., ARAUJO, G.M., SCALON, S.D.P.Q. and VIEIRA, M.D.C., 2019. Impact of phosphorus and luminosity in the propagation, photochemical reactions and quality of *Lippia alba* (Mill.) N.E. Brown. *Revista Colombiana de Ciencias Horticolas*, vol. 13, no. 2, pp. 291-302. http://dx.doi.org/10.17584/rcch.2019v13i2.9023.

SANTOS, C.C., GOELZER, A., SILVA, O.B., SANTOS, F.H.M., SILVERIO, J.M., SCALON, S.P.Q., VIEIRA, M.C. and HEREDIA ZÁRATE, N.A., 2023. Morphophysiology and quality of Alibertia edulis seedlings grown under light contrast and organic residue. *Revista Brasileira de Engenharia Agrícola e Ambiental*, vol. 22, no. 05, pp. 375-382. http://dx.doi.org/10.1590/1807-1929/agriambi.v27n5p375-382.

SILVA, F.C., 2009. *Manual de análises químicas do solo, plantas e fertilizantes*. 2. ed. Brasília, DF. Embrapa Informação Tecnológica, 627 p.

SILVA, O.B., GOELZER, A., SANTOS, C.C., TORALES, E.P., HEREDIA ZÁRATE, N.A. and VIEIRA, M.C., 2020. Propagation of *Aloysia citriodora* Palau using different cutting types under light intensity. *European Journal of Medicinal Plants*, vol. 31, no. 3, pp. 1-9. http://dx.doi.org/10.9734/ejmp/2020/v31i330217.

SOARES, M.M., FREITAS, C.D.M., OLIVEIRA, F.S., MESQUITA, H.C., SILVA, T.S. and SILVA, D.V., 2019. Effects of competition and water deficit on sunflower and weed growth. *Revista Caatinga*, vol. 32, no. 2, pp. 318-328. http://dx.doi.org/10.1590/1983-21252019v32n204rc.

SOUZA, C.C., OLIVEIRA, F.A., SILVA, I.F. and AMORIM NETO, M.S, 2000. Avaliação de métodos de determinação de água disponível e manejo da irrigação em terra roxa sob cultivo de algodoeiro herbáceo. *Revista Brasileira de Engenharia Agrícola e Ambiental*, vol. 4, no. 3, pp. 338-342. http://dx.doi.org/10.1590/S1415-43662000000300006.

SOUZA, M.R.M., PEREIRA, P.R.G., MAGALHÃES, I.P.B., SEDIYAMA, M.A.N., VIDIGAL, S.M., MILAGRES, C.S.F. and BACARAT-PEREIRA, M.C., 2016. Mineral, protein and nitrate contents in leaves of *Pereskia aculeata* subjected to nitrogen fertilization. *Pesquisa Agropecuária Tropical*, vol. 46, no. 1, pp. 43-50. http://dx.doi.org/10.1590/1983-40632016v4637959.

TOSTA, M.S., OLIVEIRA, C.V.F., FREITAS, R.M.O., PORTO, V.C.N., NOGUEIRA, N.W., and TOSTA, P.A.F., 2012. Ácido indolbutírico na propagação vegetativa de cajaraneira (*Spondias sp*.). *Semina: Ciências Agrárias*, vol. 33, no. suppl. 1, pp. 2727-2740. http://dx.doi.org/10.5433/1679-0359.2012v33Supl1p2727.

VAZ, R.S., SALOMÃO, L.C., MORGADO, H.S., SOUSA, C.M. and OLIVEIRA, H.F.E., 2020. Crescimento e produção de manjericão sob diferentes níveis de luminosidade e reposição de água. *Horticultura Brasileira*, vol. 38, no. 3, pp. 324-328.

VENTER, N., COWIE, B.W., PATERSON, I.D., WITKOWSKI, E.T. and BYRNE, M.J., 2022. The interactive effects of CO_2 and water on the growth and physiology of the invasive alien vine *Pereskia aculeata* (Cactaceae): implications for its future invasion and management. *Environmental and Experimental Botany*, vol. 194, no. 1, pp. e104737. http://dx.doi.org/10.1016/j.envexpbot.2021.104737.

WANG, D., HECKATHORN, S.A., WANG, X. and PHILPOTT, S.M., 2012. A meta-analysis of plant physiological and growth responses to temperature and elevated CO_2. *Oecologia*, vol. 169, no. 1, pp. 1-13. http://dx.doi.org/10.1007/s00442-011-2172-0. PMid:22037993.

ZEM, L.M., WEISER, A.H., ZUFFELLATO-RIBAS, K.C. and RADOMSKI, M.I., 2015. Estaquia caulinar herbácea e semilenhosa de *Drimys brasiliensi. Revista Ciência Agronômica*, vol. 46, no. 2, pp. 396-403.

ZEM, L.M., ZUFFELLATO-RIBAS, K.C. and KOEHLER, H.S., 2016. Enraizamento de estacas semilenhosas de *Pereskia aculeata* nas quatro estações do ano em diferentes substratos. *Revista Eletrônica Científica*, vol. 2, no. 3, pp. 227-233. http://dx.doi.org/10.21674/2448-0479.23.227-233.