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Original Article

Foliar application of silicon sources and shading levels in *Peltophorum dubium* (Spreng.) Taub.

Aplicação foliar de fontes de silício e níveis de sombreamento em *Peltophorum dubium* (Spreng.) Taub.

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Abstract

Depending on the intensity and ecological successional classification of plants, light availability can become an unfavorable condition for producing high-quality seedlings. We hypothesized that applying silicon sources might contribute to inducing tolerance to different shading levels for *Peltophorum dubium* (Spreng.) Taub. seedlings. Two independent experiments were developed: I) the application of five doses of silicon oxide (SiO_2: 0.0; 1.0; 2.0; 4.0; and 6.0 g L^{-1}); and II) the application of five doses of potassium silicate (K_2SiO_3: 0.0; 5.0; 10.0; 15.0; and 20.0 mL L^{-1} of water). Both were associated with three shading levels: 0% (direct sunlight), 30%, and 50%. In experiment I, we observed that seedlings were more responsive to shading levels and had little influence from foliar application of SiO_2, with higher growth, biomass, and quality values when grown under direct sunlight (0% shading). In experiment II, the foliar application of 20.0 mL L^{-1} of K_2SiO_3 contributed to greater heights under 0% and 30% shading. Meanwhile, under 50% shading, the dose of 5.0 K_2SiO_3 favored the species' growth. The application of K_2SiO_3 favored the increase in the dry mass of the aerial part (DMAP). The highest biomass production and seedling quality occurred under 0% and 30% shading. The 50% shaded environment was most unfavorable to the growth and quality of *P. dubium* seedlings. Even though the seedlings were not very responsive to silicon sources, K_2SiO_3 provided a greater response than SiO_2. High-quality seedling production is favored when the seedlings are grown under direct sunlight (0% shading).

Keywords: silicon oxide, potassium silicate, light availabilities, physiological adjustments, phenotypic plasticity.

Resumo

A disponibilidade luminosade dependendo da intensidade e a classificação ecológica sucessional das plantas pode se tornar uma condição desfavorável a produção de mudas de alta qualidade. Hipotetizamos que a aplicação de fontes de silício pode contribuir na indução da tolerância a diferentes níveis de sombreamento para mudas de *Peltophorum dubium* (Spreng.) Taub. Foram desenvolvimentos dois experimentos independentes: I) aplicação de cinco doses de óxido de silício (SiO_2): 0,0; 1,0; 2,0; 4,0 e 6,0 g L^{-1}) e II) aplicação de cinco doses de silicato de potássio (K_2SiO_3): 0,0; 5,0; 10,0; 15,0 e 20,0 mL L^{-1} de água, ambos associados a três níveis de sombreamento: 0% (pleno sol), 30% e 50%. No experimento I, observamos que as mudas foram mais responsivas aos níveis de sombreamento e pouco influenciadas pela aplicação foliar de SiO_2, com maiores valores de crescimento, biomassa e qualidade quando produzidas sob pleno sol (0% sombreamento). No experimento II, a aplicação foliar de 20,0 mL L^{-1} de K_2SiO_3 contribuiu em maiores alturas sob 0% e 30%, enquanto que sob 50% de sombreamento a dose de 5,0 K_2SiO_3 favoreceu o crescimento da espécie. A aplicação de K_2SiO_3 favoreceu no incremento de massa seca da parte aérea. As maiores produções de biomassa e qualidade das mudas foram sob 0% e 30% de sombreamento. O ambiente com 50% de sombreamento foi mais desfavorável ao crescimento e qualidade das mudas de *P. dubium*. Embora as mudas sejam pouco responsivas as fontes de silício, o K_2SiO_3 contrubuiu mais do que o SiO_2. A produção de mudas de alta qualidade é favorecida quando cultivadas sob pleno sol (0% de sombreamento).

Palavras-chave: óxido de silício, silicato de potássio, disponibilidades luminosas, ajustes fisiológicos, plasticidade fenotípica.

1. Introduction

The areas destined for growing forest species present low fertility and little soil management practice, which affects the expression of these species' productive potential (Araújo et al., 2020). Thus, these areas become a limiting factor in their production and quality. Furthermore, abiotic factors, such as light, are determinants of plant survival and initial growth (Budiastuti et al., 2020; Garcia et al., 2021).

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Thus, depending on the ecological successional classification and the phenotypic plasticity potential, each species can adjust to the light environment or be more sensitive to stressful conditions that can impair their early establishment (Santos et al., 2020; Lima et al., 2021). Thus, there has been an increase in the use of nursery management practices that can contribute to inducing tolerance to adverse stressful conditions to increase the quality standard of the plants. Among the products used, we can mention silicon (Si), used as fertilizer in agriculture and forestry, which has several sources on the market. The most commonly used sources include silicon oxide (SiO_2) and potassium silicate (K_2SiO_3).

Even though silicon is not an essential element, it is beneficial and acts in the plant metabolism, especially the antioxidant system, alleviating the stressful effects of adverse conditions (Cavalcanti Filho, 2017; Verma et al., 2020; Santos et al., 2022; Santos et al., 2023a). Furthermore, it is involved in hormonal and nutritional regulation (Greger et al., 2018; Bhat et al., 2019) varying according to the source. For example, in K_2SiO_3, there is also the effect of Si and K on plant nutrition and metabolism. In contrast, SiO_2 has the individual effect of Si.

Native to the Brazilian Cerrado, *Peltophorum dubium* (Spreng.) Taub. (Fabaceae) is a tree species popularly known as "canafistula", which presents silvicultural interest (Melotto et al., 2019). The species is classified as early secondary, with a pioneer characteristic (Oliveira et al., 2018). It presents high hardiness and fast growth (Lorenzi, 2020). Usually, this species occurs in several phytophysiognomies in different phytogeographic domains (Lorenzi, 2020; Duarte et al., 2021; Silva et al., 2022). *P. dubium* seedlings have been indicated for recovering degraded environments. However, information on the species' growth response to light gradients is still scarce. Studies are still aimed at establishing protocols for *ex situ* cultivation.

Therefore, considering the importance of *P. dubium* and that insufficients the studies on light availability associated with Si sources, we hypothesized that the species might be sensitive to increasing shading levels and that the foliar application of Si sources may contribute to obtaining high-quality seedlings. Thus, we aimed to evaluate the effect of SiO_2 and K_2SiO_3 on the growth and quality of seedlings of *P. dubium* under different shading levels.

2. Materials and Methods

2.1. Study conditions and seedling production

Two independent experiments were conducted at different times at the School of Agricultural Sciences of the Universidade Federal da Grande Dourados (22°11'53.2 "S;54°56'02.3 "W). The first, from January to May 2021, and the second, from June to October 2021. According to the Köppen classification, the region's climate is CWa, with hot summers and a rainy season and winters with moderate temperatures and dryness (Fietz et al., 2017).

Thus, *P. dubium* seeds were collected from random matrices distributed in the city of Nova Andradina in the state of Mato Grosso do Sul. Then, we overcame the seeds' dormancy through thermal scarification and soaked them in hot water at 80 ºC, where they remained for 24 hours (Davide and Silva, 2008). Next, sowing was performed in 120 cm^3 polyethylene tubes filled with Bioplant® substrate. At 50 days after sowing, when they presented an average height of 8.0 cm, the seedlings were transplanted into 7-liter pots previously filled with a substrate comprising Dystroferric Red Latosol (Oxisols) and coarse sand (2:1, v/v). Then they were placed in the growing environments during the 10-day acclimatization period before the first application of foliar products.

In the two experiments the growing environment comprised a greenhouse with a 150-micron thick, transparent, low-density polyethylene (LDPE) plastic cover. Inside the environment, the seedlings were placed in adapted structures with 2.00 x 1.20 m with 30% and 50% shading. The direct sunlight seedlings were grown only under the environment's plastic cover. The choice of doses of silicon sources was based on preliminary results (unpublished) with other tree species.

2.2. Experiment I: shading levels and SiO_2 in P. dubium seedlings

The experimental design was entirely randomized in a 3 x 5 factorial scheme with six repetitions. Each experimental unit comprised one pot with two seedlings each. After acclimatization, the seedlings were conditioned under three light availabilities based on the following shading levels: 0% (direct sunlight), 30%, and 50%. In addition, five doses of powdered silicon oxide (SiO_2) with 92% purity were applied: 0.0; 1.0; 2.0; 4.0; and 6.0 g L^{-1} of water. The growth measurements over time were analyzed in split-plots over time.

2.3. Experiment II: shading levels and K_2SiO_3 in P. dubium seedlings

The design was entirely randomized, and the factors under study were arranged in a 3 x 5 factorial scheme with six repetitions. Each experimental unit comprised a pot with two plants each. Seedlings in each environment received five doses of potassium silicate (K_2SiO_3; 12% Si and 15% K_2O; density: 1.40 g L^{-1}): 0.0; 5.0; 10.0; 15.0; and 20.0 mL L^{-1} of distilled water, corresponding to 0.0; 0.84; 1.68; and 3.36 g of Si L^{-1} and 0.0; 1.05; 2.10; and 4.20 g of K_2O L^{-1}. The growth measurements over time were analyzed in split-plots over time.

2.4. Managing the application of Si sources

The products at the corresponding doses were diluted in distilled water and applied via foliar spraying until drip point (10 mL per plant based in pre-test) using a hand sprayer in the morning period. There were two applications. The first, ten days after transplanting (DAT), and the second, 70 DAT.

2.5. Evaluated characteristics

In both experiments, growth evaluations in height, diameter, and robustness index were performed at 30, 60, 90, and 120 days after application (DAA) of SiO_2 and K_2SiO_3. Meanwhile, biomass production and quality standard evaluations were performed at 120 DAA (190 DAT).

Initial growth: plant height - PH (cm) was determined by the distance from the collar to the inflection of the uppermost leaf using a ruler graded in centimeters (cm); stem diameter - SD (mm) was measured with a digital pachymeter inserted 1 cm above the substrate level, and we calculated the robustness index based on the height/diameter ratio (HDR).

Biomass production: the seedlings were removed whole from the pots and separated into aerial parts (leaves + stem) and root systems. The aerial part and the roots were weighed on precision analytical scales (0.001g) to determine the fresh mass of the aerial part (FMAP) and the root fresh mass (RFM). Then, the materials were conditioned separately in Kraft paper bags and dried in a forced air drying oven at 60 ºC for 72 hours to obtain the seedlings' root dry mass (RDM), dry mass of the aerial part (DMAP), and total dry mass (TDM). The root/aerial part ratio (RAPR) was calculated based on these data.

Quality standard: It was based on the Dickson Quality Index (DQI) calculated according to Dickson et al. (1960) using the following Equation 1:

$$DQI = TDM / \left(HDR + RAPR \right) \quad (1)$$

2.6. Statistical analyses

Data from the two experiments were analyzed individually and subjected to analysis of variance (ANOVA, F-test - $P \leq 0.05$). In both experiments, the means were compared using Tukey's test ± standard deviation for shading levels ($P \leq 0.05$) and by regression analysis testing the linear and quadratic mathematical models for evaluation periods, SiO_2 and K_2SiO_3 doses ($P \leq 0.05$) and coefficient of determination ≥ 0.60.

3. Results and Discussion

3.1. Shading levels and SiO_2 in P. dubium seedlings

The interaction between evaluation seasons x shading significantly influenced the height of *P. dubium* seedlings (Figure 1A). In addition, stem diameter (SD) was influenced by a two-way interaction between evaluation seasons and, shading levels for SD (Figure 1B). Overall, all characteristics assessed as a function of evaluation periods and SiO_2 doses showed quadratic fits. Furthermore, we observed that in this first experiment, *P. dubium* seedlings were more responsive to shading levels than to the foliar application of SiO_2.

For plant height, there was an increase in height under 50% shading throughout the growing cycle. However, at 120 DAA, the values were close to those observed in the seedlings in direct sunlight (Figure 1A). Regarding the SD, the values between shading levels were not so discrepant until 60 DAA. However, at 120 DAA, the seedlings grown in direct sunlight and 50% shading showed values close to and greater than those of seedlings under 30% shading (Figure 1B).

Thus, *P. dubium* seedlings adapted to light-intensity variations, indicating potential morpho-physiological plasticity (Botterweg-Paredes et al., 2020). In other words, the species can adjust to different light environments through its phenotypic plasticity, which suggests ecological resilience. First, however, we must consider all the evaluated characteristics because, many times, the plant optimizes resources for its vegetative growth but presents a low potential for photoassimilate production.

When under lower light availability conditions, plants tend to invest in height, aiming for canopy exposure. Thus, they provide a competitive advantage for light access with competing vegetation (Grossnickle and MacDonald, 2018), as observed here with *P. dubium*.

Plant height evaluation generally provides information on the plant's physiological adjustment potential to the growing conditions, especially light availability. Indeed, some species, such as *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S.Moore (Souza and Freire, 2018) and *Cojoba arborea* (L.) Britton & Rose (Carvalho et al., 2021) etiolate under higher shading levels due to their hormonal relationships (Pinho et al., 2022). This fact is also associated with the ecological group of each species, which becomes a negative factor, especially for seedlings in the initial phase.

However, for *P. dubium* seedlings, we cannot say there was no etiolation, especially since the robustness index was not influenced by the factors under study ($P > 0.05$), presenting a 4.31 average. Thus, height growth was followed by an increase in diameter, promoting balance in the plant's development.

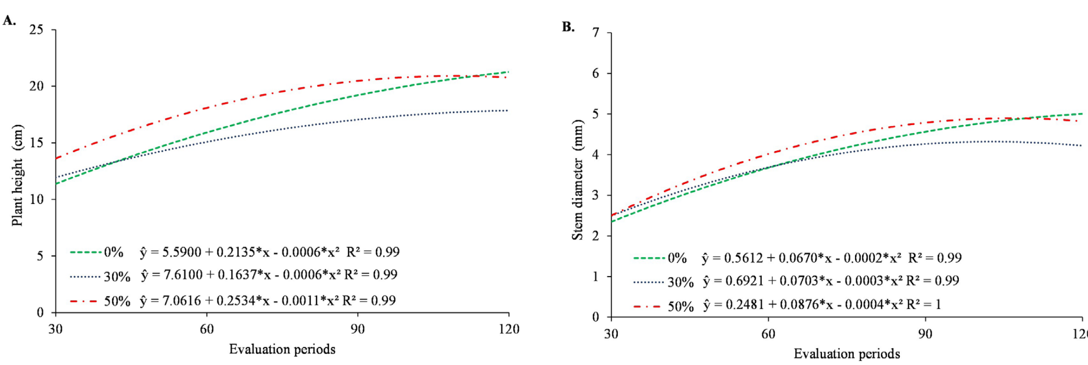

Figure 1. Plant height (cm) (A) and stem diameter (mm) (B) of *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different shading levels as a function of evaluation periods.

Regarding the foliar application of SiO_2, the only dosage influence was observed for SD in the triple interactiono. At the end of 120 DAA, the highest mean value observed was 5.53 mm for the 2 g dose under direct sunlight. The lowest value was 3.94 mm for the 30% shading at the zero doses (control) (Figure 2). At 30 and 60 DAA, SiO_2 doses had no significant effects regardless of the shading level. At 120 DAA, we observed a statistically significant effect of the 2 g dose in seedlings under direct sunlight and the 4 g dose in seedlings grown under direct sunlight and 50% shading. However, there were no differences between the two doses.

For biomass production and seedling quality, we only found the effects of shading levels (Figure 3). Silva et al. (2018) observed similar results when evaluating different doses of Si in *Euterpe precatoria* Mart. seedlings. They found no influence of silicon addition on phytomass production and seedling quality.

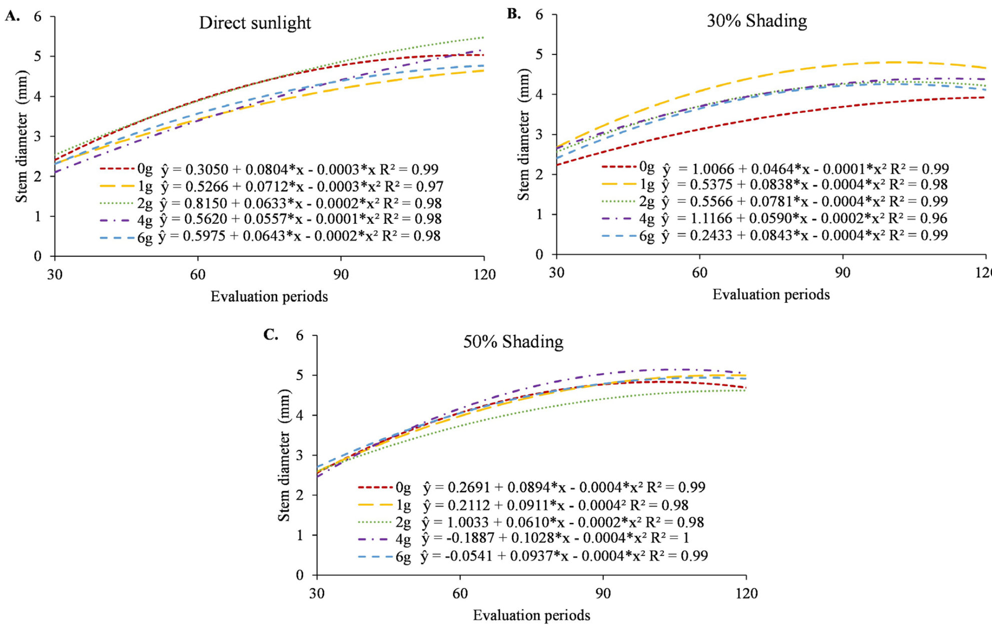

Figure 2. Triple interaction effect for stem diameter (SD) of *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different shading levels: direct sunlight (A); 30% shading (B); 50% shading (C); and SiO_2 doses, as a function of evaluation periods. Dourados-MS, UFGD, 2021.

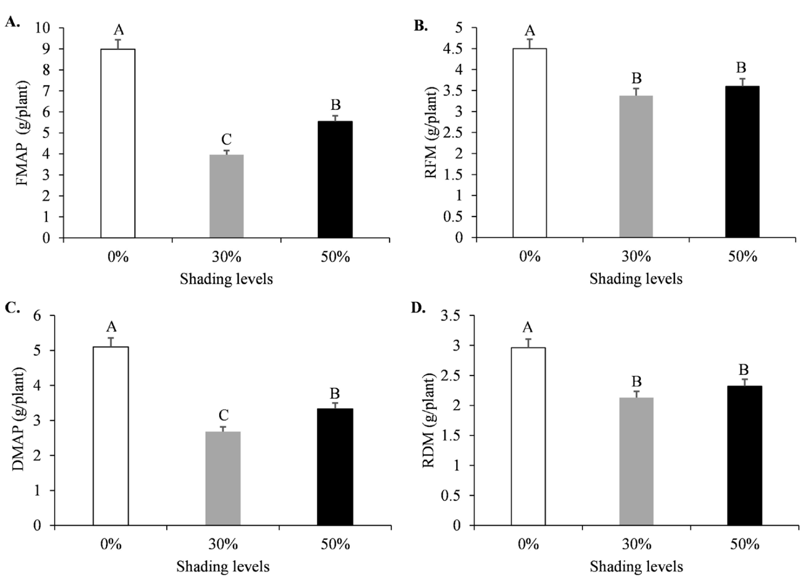

Figure 3. Fresh mass of the aerial part - FMAP (A); root fresh mass - RFM (B); dry mass of the aerial part - DMAP (C); and root dry mass - RDM (D) in *Peltophorum dubium* (Spreng.) Taub. seedlings submitted to different light availability conditions. Different letters differ by Tukey's test ($P \leq 0.05$).

Overall, *P. dubium* seedlings produced under direct sunlight showed higher values of fresh and dry masses for the aerial part and root than the shaded ones. Larraburu et al. (2018) also observed that fresh and dry root masses of *Handroanthus ochraceus* seedlings were influenced by light. Those exposed to higher irradiance levels (0% shading) showed higher biomass productiono. The results for *A. peregrina* seedlings (Santos et al., 2020) were similar to those observed for *P. dubium*. These same authors describe that *A. peregrina* seedlings possibly showed the highest fresh and dry mass values due to the higher amount of Photosynthetically Active Radiation (PAR) under direct sunlight, favoring photoassimilate and biomass productiono. Thus, the increased leaf dry mass under direct sunlight may have occurred because the plant obtained a higher concentration of photoassimilates and adaptation to irradiance compared to the shaded environments (Ajalla et al., 2012).

The highest RAPR and DQI values occurred in seedlings grown under direct sunlight (Figure 4), indicating greater exploration in the aerial part than in the root. This response is associated with the fact that the species is classified as early secondary, with a pioneer characteristic (Oliveira et al., 2018). Similarly, Santos et al. (2020), when evaluating the effect of shading levels (direct sunlight, 30%, 50%, and 70%) on the growth and quality of *Anadenanthera peregrina* L. Speg. seedlings, a pioneer species, observed higher RAPR, biomass, and quality values when produced under direct sunlight. The increase in DQI is desirable because it indicates that the seedlings show greater vigor based on photoassimilate production and growth, contributing to better seedlings to be commercialized or transplanted to field conditions (Santos et al., 2020; Santos et al., 2023b).

From a practical perspective, this information supports that for this species in this experimental period, there is no need for investment in nursery structure, such as shading screen and acquisition of SiO_2, which reduces production costs. Furthermore, another important factor is that it can reduce the acclimatization time and speed up their shipment to the field since the plants will be hardened under direct sunlight. Therefore, even though it is not our objective, considering that it provided good results under direct sunlight, *P. dubium* would be a potential species for insertion in areas with greater light exposures.

The little influence of SiO_2 may be related to this experiment's timeframe and the doses used, in addition to intrinsic factors of the species itself. When considering that for *P. dubium*, there is no specific dose recommendation information yet; perhaps the doses used were low or could have increased the number of applications. Still, little is known about the direct effects of Si on plant growth (Santos et al., 2022; Silva, 2022). Based on this information, we suggest further work with the species aimed at knowing the effects of SiO_2 on leaf metabolism and nutritional aspects.

3.2. Shading levels and K_2SiO_3 in P. dubium seedlings

We observed that in this second experiment, *P. dubium* seedlings were responsive to shading levels when the foliar application of K_2SiO_3 doses occurred. In addition, plant height was significantly influenced by the three-way interaction between evaluation seasons, shading levels, and K_2SiO_3 doses. Similar to exp. I, all characteristics showed quadratic fits when influenced by evaluation periods or K_2SiO_3 doses.

Stem diameter was influenced only by the evaluation periods, with a maximum calculated value of 13 mm at 120 DAA (Figure 5A). The increase in diameter favors the distribution of water and photoassimilates to the different organs, contributing to vegetative growth (Santos et al., 2023a). It is worth noting that the increase in diameter should follow the seedlings' height so that the characteristic aspect of etiolation does not occur in the seedlings as an escape mechanism (Quaresma et al., 2021), as observed in the seedlings under 50% shading, represented by the height/diameter ratio (HDR) (Figure 5B).

This ratio indicates the robustness and/or vigor of the seedlings that will be taken to the field. The more balanced this ratio, the greater the chances of survival (Padilha et al., 2018) because they demonstrate photoassimilate distribution among the different organs. Possibly, these seedlings, under field conditions, would face difficulties in development. Moreover, for the criteria of a homogeneous forest stand, they would not be indicated for field expeditions. Plant growth depends on its degree of adaptability to the type of environment.

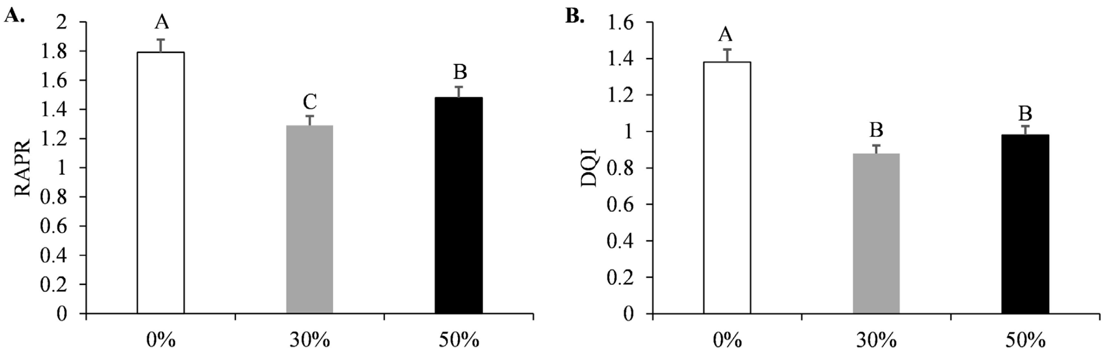

Figure 4. Root/aerial part ratio - RAPR (A) and Dickson Quality Index - DQI (B) in *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different light availability conditions. Different letters differ by Tukey's test ($P \leq 0.05$).

Overall, the application of K_2SiO_3 contributed to the height of *P. dubium* seedlings, varying according to the shading level. For example, seedlings grown under 0% and 30% shading showed greater heights when they received an application of 5.0 mL L^{-1} of K_2SiO_3 at 120 DAA (Figure 6A and 6B). On the other hand, the highest height values in seedlings under 50% shading occurred when they received 5.0 mL L^{-1} of K_2SiO_3 at 120 DAA. However, responses to K_2SiO_3 vary between species. For example, *Coffea arabica* L. seedlings do not show increased growth characteristics in height and diameter as a function of the application of this silicon source.

We emphasize that *P. dubium* seedlings show phenotypic plasticity to different shading levels. However, they show greater potential for expression under direct sunlight, considering their ecological classification as pioneers (Oliveira et al., 2018). Based on our study, it is possible to infer that increasing the shading level begins to promote changes that impair the production and allocation of photoassimilates and that if they had a higher shading level, the responses would be pronounced and stressful.

The 50% shading was a condition in which the *P. dubium* seedlings allocated most of their metabolic resources to grow in height. In contrast, the seedlings under 0% shading were smaller. The reason for this is that in high irradiance conditions, auxin production and transport to the meristematic region is limited, which leads to the formation of short internodes (Fiorucci and Fankhauser, 2017), influencing the production of smaller seedlings, such as those grown under direct sunlight. Moreover, in seedlings exposed to high irradiance, represented here by direct sunlight, in addition to hormonal relations, lower height values represent an adaptive mechanism aimed at reducing canopy exposure to high temperature, minimizing water loss significantly (Santos et al., 2023b), regulating water relations within limiting conditions. According to Santos et al. (2023b), *Alibertia edulis* (Rich.) A. Rich. seedlings also showed lower heights but maintained high biomass production.

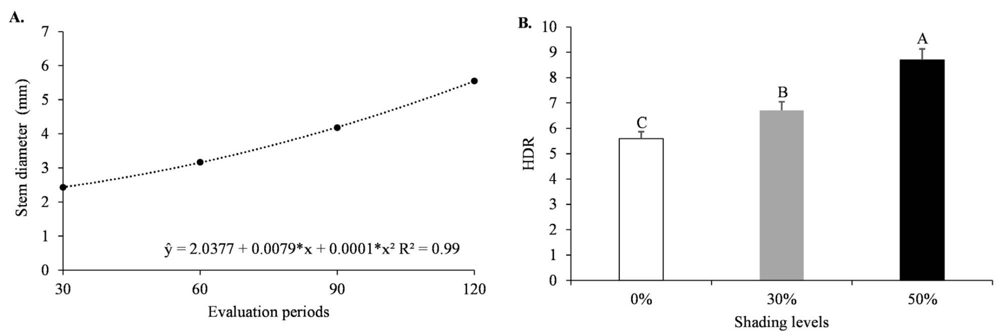

Figure 5. Stem diameter (A), and height/diameter ratio - HDR (B) in *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different shading levels and K_2SiO_3 doses. Different letters differ by Tukey's test ($P \leq 0.05$).

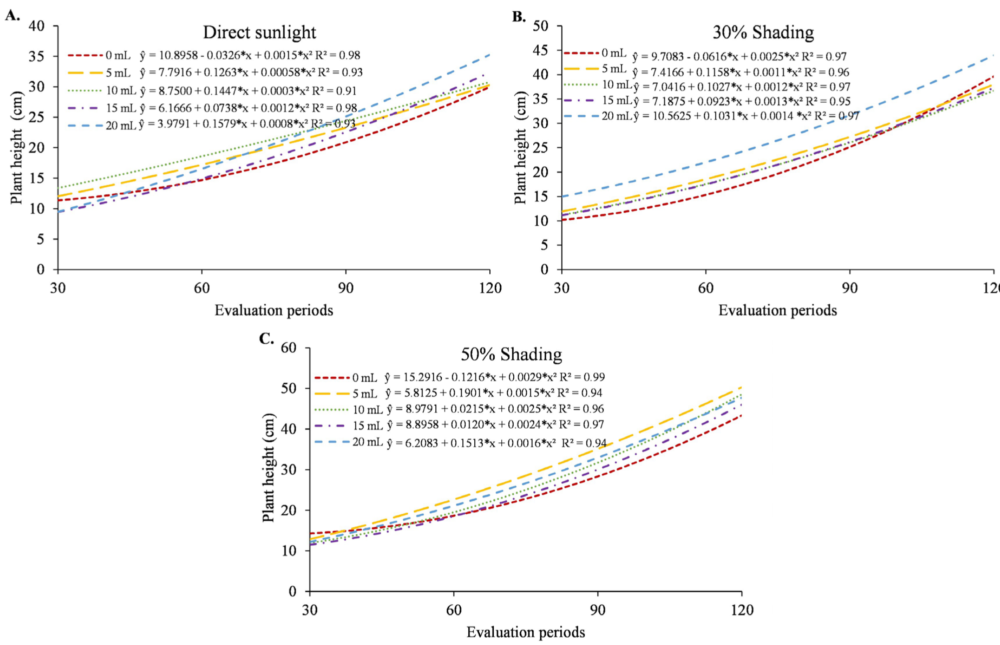

Figure 6. Triple interaction effect for plant height (PH) of *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different shading levels: direct sunlight (A); 30% shading (B); 50% shading (C); and K_2SiO_3 doses, as a function of evaluation periods.

These results corroborate Silveira et al. (2020), who, when evaluating the development of *Anadenanthera macrocarpa* (Benth.) Brenan under different shading levels, observed higher plant height growth under shadier environments, while plants grown under direct sunlight showed the lowest growth.

The fresh mass of the aerial part was influenced by the factors alone, with higher values in shaded seedlings (Figure 7A) and those with 20 mL L^{-1} of K_2SiO_3 (Figure 7B). On the other hand, root fresh mass was highest under 30% shading, not statistically different from those under 0% shading (Figure 7C). The dry mass of the aerial part was influenced only by doses of K_2SiO_3 with a maximum value of 20 mL L^{-1} (Figure 8A). Meanwhile, root dry mass was highest under 0% and 30% shading, regardless of K_2SiO_3 application (Figure 8B).

The higher values of the aerial part masses with the higher dose of K_2SiO_3 were due to the beneficial effect of the Si and K in the product. That is because silicon contributes to plant leaves becoming more erect and rigid (Tubana et al., 2016; Lima et al., 2019; Santos et al., 2022), which favors higher solar interception, reflecting in higher photoassimilate production, leaf increment, and biomass production (Santos et al., 2022). Potassium acts in osmotic adjustment and cell wall structure (Pinto, 2019; Soares, 2022).

Regarding the higher biomass values of the root system under greater light availability, this is because, under these conditions, generally, the environment temperature tends to be higher than under 50% shading, which promotes pronounced evapotranspiration more rapidly. As a result, the plant's water balance is reduced, and consequently, the turgescence decreases due to the lower hydraulic conductivity in the soil because of the lower water status (Oliveira et al., 2021).

The root/aerial part ratio (RAPR) and Dickson quality index (DQI) were influenced only by shading levels (Figure 9A and 9B). The lowest and highest RPAR and DQI values occurred in the seedlings under 0% and 30% shading, respectively. *Enterolobium contortisiliquum* (Vell.) Morong seedlings also showed higher RAPR under 50% shading (Santos et al., 2019).

The results for *P. dubium* demonstrated that in this condition, the plant invests more in the aerial part than in the root system as an adjustment mechanism to the environment since, although possibly having a lower rate of evapotranspiration, it has less light availability for photosynthetic metabolism and photoassimilate productiono.

The seedling quality standard was similar to experiment I, but with good results also under 30% shading, reinforcing the classification of early secondary with a pioneer.

In future perspectives, new studies with *P. dubium* should be developed to increase the information on leaf metabolism and antioxidant and nutritional systems using silicon sources as a function of further doses (even higher and more frequent applications and higher shading levels) to favor the production of high-quality seedlings more tolerant to adverse environmental conditions.

In conclusion, although *P. dubium* seedlings present phenotypic plasticity in light environments, cultivation under 50% shading is an unfavorable condition for biomass production and quality. Foliar application of SiO_2 and K_2SiO_3 did not influence seedling quality. However, K_2SiO_3 at 20 mL L^{-1} favors the aerial part's growth and biomass productiono. The production of *P. dubium* seedlings under 0% shading contributes to seedling quality, regardless of silicon sources.

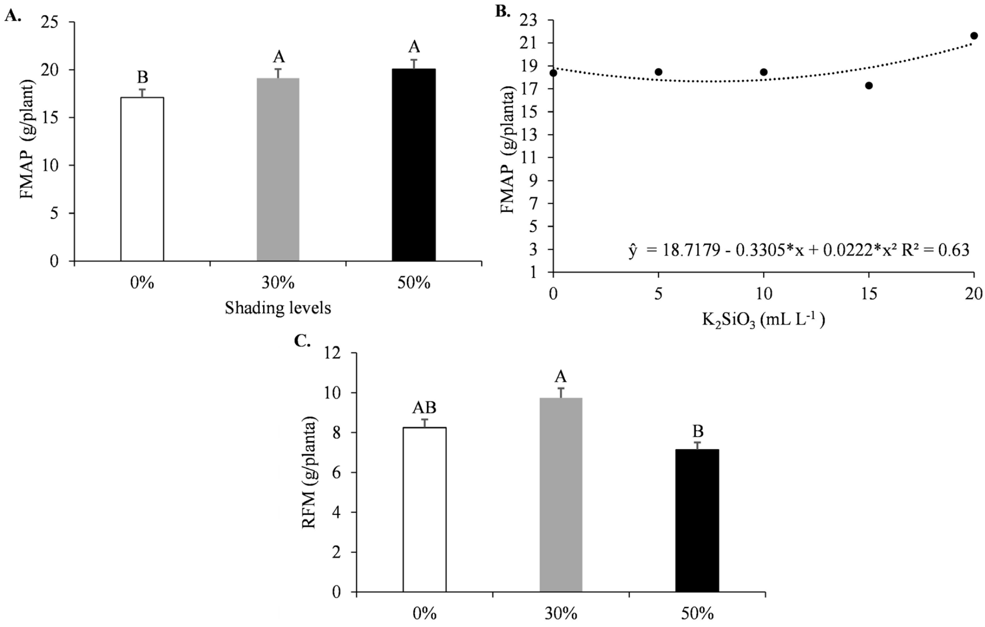

Figure 7. Fresh mass of the aerial part - FMAP (A, B) and root fresh mass - RFM (C) in *Peltophorum dubium* (Spreng.) Taub. seedlings submitted to different light availability conditions and K_2SiO_3 doses. Different letters differ by Tukey's test ($P \leq 0.05$).

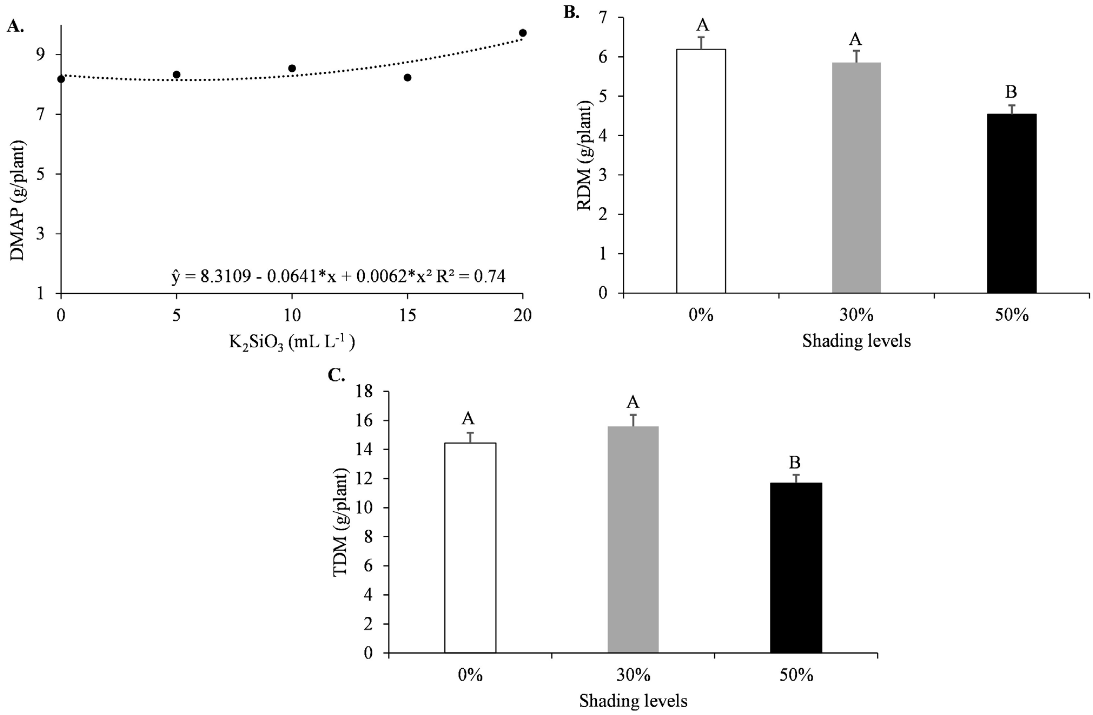

Figure 8. Dry mass of the aerial part - DMAP (A); root dry mass - RDM (B); and total dry mass - TDM (C) in *Peltophorum dubium* (Spreng.) Taub. seedlings submitted to different light availability conditions. Equal letters do not differ by Tukey's test ($p<0.05$).

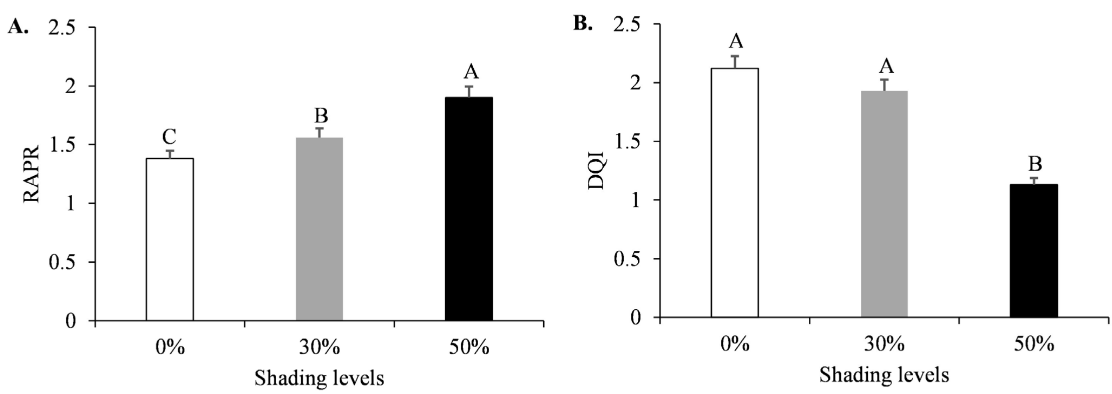

Figure 9. Root/aerial part ratio - RAPR (A) and Dickson Quality Index - DQI (B) in *Peltophorum dubium* (Spreng.) Taub. seedlings cultivated under different light availability conditions. Different letters differ by Tukey's test ($P \leq 0.05$).

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References

AJALLA, A.C.A., VOLPE, E., VIEIRA, M.C. and ZÁRATE, N.A.H., 2012. Production of baru (*Dipteryx alata* Vog.) seedlings under three levels of shading and four textural classes of soil. *Revista Brasileira de Fruticultura*, vol. 34, no. 3, pp. 888-896. http://dx.doi.org/10.1590/S0100-29452012000300031.

ARAÚJO, L.F.B., SCALON, S., DRESCH, D.M., JUNGLOS, F.S., MUSSURY, R.M. and JUNGLOS, M.S., 2020. Water deficit alters morpho-anatomical and antioxidant responses in seedlings of *Campomanesia xanthocarpa* enabling their recovery. *International Journal of Agriculture and Biology*, vol. 24, no. 6, pp. 1431-1438. http://dx.doi.org/10.17957/IJAB/15.1580.

BHAT, J.A., SHIVARAJ, S., SINGH, P., NAVADAGI, D.B., TRIPATHI, D.K., DASH, P.K., SOLANKE, A.U., SONAH, H. and DESHMUKH, R., 2019. Role of silicon in mitigation of heavy metal stresses in crop plants. *Plants*, vol. 8, no. 3, p. 71. http://dx.doi.org/10.3390/plants8030071. PMid:30901942.

BOTTERWEG-PAREDES, E., BLAAKMEER, A., HONG, S.-Y., SUN, B., MINERI, L., KRUUSVEE, V., XIE, Y., STRAUB, D., MÉNARD, D., PESQUET, E. and WENKEL, S., 2020. Light affects tissue patterning of the hypocotyl in the shade-avoidance response. *PLOS Genetics*, vol. 16, no. 3, p. e1008678. http://dx.doi.org/10.1371/journal.pgen.1008678. PMid:32203519.

BUDIASTUTI, M.T.S., PURNOMO, D., SUPRIYONO, S., PUJIASMANTO, B. and SETYANINGRUM, D., 2020. Effects of light intensity and co-inoculation of arbuscular mycorrhizal fungi and rhizobium on root growth and nodulation of *Indigofera tinctoria. Journal of Soil Science and Agroclimatology*, vol. 17, no. 2, pp. 94-99. http://dx.doi.org/10.20961/stjssa.v17i2.40065.

CARVALHO, C.A., OLIVEIRA, R.F.S., RIBEIRO, Í.F.N., ANDRADE, R.A., BRITO, R.S., TEIXEIRA JUNIOR, D.L. and NASCIMENTO, M.M., 2021. Produção de mudas de *Cojoba arborea* (L.) Britton & Rose em diferentes substratos e níveis de sombreamento. *Scientia Naturalis*, vol. 3, no. 1, pp. 124-132. http://dx.doi.org/10.29327/269504.3.1-12.

CAVALCANTI FILHO, P.F.M., 2017. *Silicato de potássio na aclimatação de mudas de Coffea arabica L.* Campos dos Goytaxazes: Universidade Estadual do Norte Fluminense Darcy Ribeiro, 66 p. Dissertação de Mestrado em Produção Vegetal.

DAVIDE, A.C. and SILVA, E.A., 2008. *Produção de sementes e mudas de espécies florestais*. Lavras: Editora UFLA, 180 p.

DICKSON, A., LEAF, A.L. and HOSNER, J.F., 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle*, vol. 36, no. 1, pp. 10-13. http://dx.doi.org/10.5558/tfc36010-1.

DUARTE, D.F., GIACOMELLI, F.B., FERNANDES, S.Y., SOUZA, B.O. and MORAIS, G.A., 2021. Biometria e potencial germinativo em sementes de *Peltophorum dubium* (Sprengel) Taub. *Research, Society and Development*, vol. 10, no. 13, p. e228101321204. http://dx.doi.org/10.33448/rsd-v10i13.21204.

FIETZ, C.R., FISCH, G.F., COMUNELLO, E. and FLUMIGNAN, D.F., 2017. *O clima da região de Dourados, MS*. 3rd ed. Dourados: Embrapa Agropecuária Oeste, 34 p.

FIORUCCI, A.S. and FANKHAUSER, C., 2017. Plant strategies for enhancing access to sunlight. *Current Biology*, vol. 27, no. 17, pp. R931-R940. http://dx.doi.org/10.1016/j.cub.2017.05.085. PMid:28898666.

GARCIA, D.O., SEIFERT, K. and CHASSOT, T., 2021. Sombreamento e recipiente no desenvolvimento inicial de mudas de pata de vaca e canafístula. In: R.J. OLIVEIRA, ed. *Silvicultura e manejo florestal: técnicas de utilização e conservação da natureza*. São Paulo: Editora Científica Digital, pp. 401-413. http://dx.doi.org/10.37885/201202643.

GREGER, M., LANDBERG, T. and VACULÍK, M., 2018. Silicon infuences soil availability and accumulation of mineral nutrients in various plant species. *Plants*, vol. 7, no. 2, p. 41. http://dx.doi.org/10.3390/plants7020041. PMid:29783754.

GROSSNICKLE, S.C. and MACDONALD, J.E., 2018. Seedling quality: history, application, and plant attributes. *Forests*, vol. 9, no. 5, p. 283. http://dx.doi.org/10.3390/f9050283.

LARRABURU, E.E., CORREA, G.S. and LLORENTE, B.E., 2018. In vitro development of yellow lapacho (Bignoniaceae) using high-power light emitting diode. *Revista Árvore*, vol. 42, no. 5, p. e420508. http://dx.doi.org/10.1590/1806-90882018000500008.

LIMA, D.T., SAMPAIO, M.V., ALBUQUERQUE, C.J.B., PEREIRA, H. and MARTINS, W.G., 2019. Acúmulo de silício e seu efeito sobre características agrícolas e incidência de antracnose sorgo lignocelulósico. *Pesquisa Agropecuária Tropical*, vol. 49, p. e54201. http://dx.doi.org/10.1590/1983-40632019v4954201.

LIMA, M.S., ARAUJO, M.M., AIMI, S.C., OLIVEIRA, V.V., BERGHETTI, Á.L., NASCIMENTO, N.F. and TAROUCO, C.P., 2021. Use of physiological attributes to select native forest species for forest restoration in the southern Atlantic forest biome, Brazil. *Forest Ecology and Management*, vol. 501, p. 119659. http://dx.doi.org/10.1016/j.foreco.2021.119659.

LORENZI, H., 2020. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. 8th ed. Nova Odessa: Plantarum, 384 p.

MELOTTO, A.M., LAURA, V.A., BUNGENSTAB, D.J. and FERREIRA, A.D., 2019. Espécies florestais em sistemas de produção em integração. In: D.J. BUNGENSTAB, R.G. ALMEIDA, V.A. LAURA, L.C. BALBINO and A.D. FERREIRA, eds. *ILPF: inovação com integração de lavoura, pecuária e floresta*. Brasília: Embrapa, pp. 429-454.

OLIVEIRA, M.W., NASCIF, C., PEREIRA, M.G., RODRIGUES, T.C., OLIVEIRA, T.B.A., GOMES, R.J. and SANTOS, D.F., 2021. Produção de cana-de-açúcar para a alimentação de bovinos. In: R.L. GALATI, ed. *Alimentos e alimentação animal*. Guarujá: Editora Científica Digital, pp. 81-117. http://dx.doi.org/10.37885/210805744.

OLIVEIRA, T.J.F., BARROSO, D.G., ANDRADE, A.G., FREITAS, I.L.J. and AMIM, R.T., 2018. Banco de sementes do solo para uso na recuperação de matas ciliares degradadas na região noroeste fluminense. *Ciência Florestal*, vol. 28, no. 1, pp. 206-217. http://dx.doi.org/10.5902/1980509831653.

PADILHA, M.S., BARETTA, C.R.D.M., SOBRAL, L.S., KRAFT, E. and OGLIARI, A.J., 2018. Crescimento de mudas de canafístula com o uso de adubação biológica e bioestimulante em diferentes substratos. *Centro Científico Conhecer*, vol. 15, no. 27, pp. 95-106. http://dx.doi.org/10.18677/EnciBio_2018A32.

PINHO, L.L., LACERDA, C.F.D., SOUSA, J.A.D., SANTOS, A.M., BEZERRA, A.M.E., CAVALCANTE, E.S. and SALES, J.R.D.S., 2022. Effects of artificial shading and irrigation with brackish water on the initial development of *Anadenanthera colubrina* (Vell.) brenan plants. *Revista Árvore*, vol. 46, p. e4607. http://dx.doi.org/10.1590/1806-908820220000007.

PINTO, L.E.V., 2019. *Vinhaça como biofertilizantes para fornecimento de potássio a soja com sucessão de milho e capim e impactos sobre o solo*. Presidente Prudente: Universidade do Oeste Paulista, 124 p. Tese de Doutorado em Agronomia.

QUARESMA, E.V.W., OTTO, R.P.A., SANTOS, C.C., SILVERIO, J.M., LOLI, G.H.S. and VIEIRA, C.M., 2021. Níveis de sombreamento influenciam a produção de mudas de *Mentha* x *villosa* huds. (Hortelã). *Revista Brasileira de Engenharia de Biossistemas*, vol. 15, no. 1, pp. 127-141. http://dx.doi.org/10.18011/bioeng2021v15n1p127-141.

SANTOS, C.C., BASSO JÚNIOR, I.J., NAVARRO, V.L., SILVA, W.C., SILVERIO, J.M. and SCALON, S.P.Q., 2023a. Silicon alleviates damages on photosynthetic apparatus and increases resilience in young *Inga vera* plants exposed to water deficit. *Journal of Soil Science and Plant Nutrition*, vol. 23, no. 3, pp. 3219-3231. http://dx.doi.org/10.1007/s42729-023-01339-8.

SANTOS, C.C., GOELZER, A., SILVA, O.B.D., SANTOS, F.H., SILVERIO, J.M., SCALON, S.D.P., VIEIRA, M.D. and ZÁRATE, N.A.H., 2023b. Morphophysiology and quality of *Alibertia edulis* seedlings grown under light contrast and organic residue. *Revista Brasileira de Engenharia Agrícola e Ambiental*, vol. 27, no. 5, pp. 375-382. http://dx.doi.org/10.1590/1807-1929/agriambi.v27n5p375-382.

SANTOS, C.C., JORGE, H.P.G., DIAS, L.G.F. and VIEIRA, M.C., 2020. Shading levels and substrates affect morphophysiological responses and quality of *Anadenanthera peregrina* (L.) Speg seedlings. *Floresta e Ambiente*, vol. 27, no. 2, p. e20190119. http://dx.doi.org/10.1590/2179-8087.011919.

SANTOS, C.C., SCALON, S.P.Q., FORESTI, A.C., REIS, L.C. and DRESCH, D.M., 2022. The role of silicon in the mitigation of water stress in *Eugenia myrcianthes* Nied. seedlings. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 82, p. e260420. http://dx.doi.org/10.1590/1519-6984.260420. PMid:36000691.

SANTOS, L.M., SOUSA, R.M., FONSECA, E.F., PEREIRA, P.G. and SOUZA, P.B., 2019. Níveis de sombreamento na emergência e desenvolvimento inicial de mudas de *Enterolobium contortisiliquum* (Vell.) Morong. *Scientia Agrária Paranaensis*, vol. 18, no. 2, pp. 139-145.

SILVA, K.M.R., MELO, B.M., CARDOSO, J.L.M.S., CUNHA, J.N.B., CORDEIRO, T.O., CAMPESATTO, E.A., ANDRADE, A.P.O., NUNES, G.F., SILVA, A.M. and FERREIRA, A.M.C., 2022. Evaluation of the antimicrobial activity of essential oil and parts factions obtained from the species *Peltophorum dubium* and combretum leprosum. *Research, Society and Development*, vol. 11, no. 10, p. e36111023450. http://dx.doi.org/10.33448/rsd-v11i10.23450.

SILVA, M.S., 2022. *Silício e sombreamento atenuam os efeitos do déficit hídrico no metabolismo e no crescimento foliar de mudas de Dipteryx alata Vog*. Dourados: Universidade Federal da Grande Dourados, 67 p. Tese de Doutorado em Agronomia.

SILVA, W.D.S., SOARES, A.E.S., ALMEIDA, M.H.V. and ALVES, W.W.A., 2018. Fitomassa seca e índice de qualidade de mudas de açaí sob a reposição da evapotranspiração de referência e adubação silicatada. *Centro Científico Conhecer*, vol. 5, no. 9, pp. 244-252. http://dx.doi.org/10.18677/Agrarian_Academy_2018a25.

SILVEIRA, G.V.S., HOLANDA, A.C., ALVES, A.R., SILVA, F.D.S. and OLIVEIRA, J.L.R., 2020. Development of *Tabebuia aurea* and *Anadenanthera macrocarpa* under different levels of shading. *Revista Engenharia na Agricultura*, vol. 28, pp. 357-363. http://dx.doi.org/10.13083/reveng.v29i1.8857.

SOARES, M.R.R., 2022. *Mudas de cambucizeiro (Campomanesia phaea O. Berg Landrum): adubação fosfatada, calagem e deficiência nutricional*. Piracicaba: Universidade de São Paulo, 85 p. Dissertação de Mestrado em Ciências.

SOUZA, R.R. and FREIRE, A.L.O., 2018. Relação entre o sombreamento, o crescimento e a qualidade de mudas de craibeira. *Scientia Agrária Paranaensis*, vol. 17, no. 2, pp. 220-225.

TUBANA, B.S., BABU, T. and DATNOFF, L.E., 2016. Uma revisão do silício em solos e plantas e seu papel na agricultura dos EUA. *Ciência do Solo*, vol. 181, no. 9, pp. 393-411.

VERMA, K.K., SINGH, P., SONG, X.P., MALVIYA, M.K., SINGH, R.K., CHEN, G.L., SOLOMON, S. and LI, Y.R., 2020. Mitigating climate change for sugarcane improvement: role of silicon in alleviating abiotic stresses. *Sugar Tech*, vol. 22, no. 5, pp. 741-749. http://dx.doi.org/10.1007/s12355-020-00831-0.