DOI: 10.5965/223811712142022531

Revista de Ciências Agroveterinárias 21 (4): 2022
Universidade do Estado de Santa Catarina

Temperatures and substrates on the germination and vigor of seeds of *Pilosocereus catingicola* subsp. *salvadorensis* in the Caatinga biome of Paraíba

Temperaturas e substratos na germinação e vigor de sementes de Pilosocereus catingicola subsp. *salvadorensis da Caatinga Paraibana*

Robson Luis Silva de Medeiros[1*] (ORCID 0000-0003-4396-1584), **Vênia Camelo de Souza**[2] (ORCID 0000-0002-1847-9182), **Leandro de Araújo**[2] (ORCID 0000-0001-8744-9027), **Miguel Avelino Barbosa Neto**[3] (ORCID 0000-0001-5367-7697), **Gilvaneide Alves de Azerêdo**[2] (ORCID 0000-0001-7823-8260), **Alex da Silva Barbosa**[2] (ORCID 0000-0002-7343-6134)

[1]Biodiversity Center, National Institute of the Semi-Arid, Serrotão, Campina Grande, PB, Brazil. * Author for correspondence: robsonluissm@gmail.com
[2]Center for Social and Agricultural Human Sciences, Federal University of Paraíba, Bananeiras, PB, Brazil.
[3]Center for Agricultural Sciences, Federal University of Paraíba, Areia, PB, Brazil.

Submission: 15/Apr/2022 | Acceptance: 21/Jun/2022

ABSTRACT

The Caatinga biome is presented in the vegetation where the Brazilian semiarid region predominates, with a great variety of native species, and facheiro is one of the most important species because of its wide range in the semiarid region in northeastern Brazil. Therefore, the knowledge of the germinative behavior of the Caatinga species is essential to subsidize conservationist actions in this ecosystem. This study aimed to determine the effect of temperature and substrate on the germination and vigor of facheiro's seeds. These seeds were obtained from ripe fruits collected in three localities of the Agreste of Paraíba: Arara, Bananeiras, and Boa Vista. After extraction, the seeds were placed to dry on paper for one week in a laboratory environment. Subsequently, the experiment was started by testing four temperatures: 20, 25, 30, and 20-30 °C. The germination test was conducted with four replications of 50 seeds distributed in "gerbox" boxes and placed in bio-oxygen demand (BOD) chambers using as a substrate the germitest paper, with a photoperiod of 12 hours. The statistical design was randomized in a 3 × 4 factorial arrangement (3 localities and 4 temperatures). A significant effect was observed for populations and substrates. The best substrate for germination was the germitest, while the substrate vermiculite presented a good performance, and the substrate soil presented low germination. Therefore, seeds presented the best vigor in the germitest paper, mainly with a temperature of 25 °C where the best performance for all localities was found. The vigor of seeds in the localities of Bananeiras and Boa Vista, temperatures of 25, 30, and 20-30 °C, and substrate germitest paper provided the highest vigor. The germitest substrate is the recommended substrate for the germination of the species, maximizing its physiological potential and being able to accelerate conservation projects for the species.

KEYWORDS: facheiro; physiological potential; semiarid of paraíba.

RESUMO

A Caatinga incide na vegetação onde predomina o Semiárido brasileiro, com grande variedade de espécies nativas, e o facheiro é uma das mais importantes pela grande abundância que ele ocorre no Semiárido nordestino. É de fundamental importância o conhecimento do comportamento germinativo das espécies da Caatinga para subsidiar ações conservacionistas desse ecossistema. O objetivo deste estudo foi avaliar a resposta da temperatura e do substrato sobre a germinação e vigor de sementes de facheiro. As sementes foram provenientes de frutos maduros coletados em três localidades do Agreste paraibano: Arara, Bananeiras e Boa Vista. Após extração das sementes, estas foram colocadas para secar sobre papel durante uma semana em ambiente de laboratório. Em seguida, deu-se início ao ensaio experimental, testando quatro temperaturas: 20, 25, 30 e 20-30 ºC. O teste de germinação foi conduzido com quatro repetições de 50 sementes distribuídas em gerbox e colocadas em câmaras BOD, utilizando como substrato o papel germitest, com fotoperíodo de 12 horas. O delineamento estatístico foi inteiramente casualizado, com arranjo fatorial 3 x 4 (3 localidades e 4 temperaturas). Houve efeito significativo para as populações e substratos. O melhor substrato para germinação foi o germitest, o substrato vermiculita apresentou boa germinação e o solo germinação baixa. No papel germitest as sementes apresentaram melhor vigor. O substrato papel germitest na temperatura de 25 ºC foi melhor para todas as localidades. O vigor das sementes nas localidades de Bananeiras e Boa Vista, nas temperaturas 25 ºC, 30 ºC e 20-30ºC no substrato papel germitest proporcionaram maior vigor. O papel germitest foi o melhor substrato para germinação da espécie, maximizando seu potencial fisiológico, podendo nos projetos de conservação da espécie acelerar a propagação sexuada.

PALAVRAS-CHAVE: facheiro; potencial fisiológico; semiárido paraibano.

INTRODUCTION

Several endemic cacti of great importance for the regional fauna and flora can be found in the Northeast region of Brazil. Among them, the species *Cereus jamacaru* DC., *Pilosocereus pachycladus* Ritter., *Pilocereus gounellei* (A. Weber ex K. Schum.) Bly. ex Rowl., and *Melocactus bahiensis* Britton & Rose (BRITO CAVALCANTI & MILANEZ DE RESENDE 2007) stand out because of their use in animal feed during the dry season in the region. The cacti are in the group of plants adapted to drought, evolving and diversifying in the conditions of these ecosystems (MENEZES et al. 2016, RAMÍREZ-RODRÍGUEZ et al. 2020).

The Brazilian semi-arid region occupies the largest territorial extension of the Northeast region, with irregular rainfall, alternating between years, the resulting water scarcity can cause problems for society (SILVA et al. 2011), which can limit plant growth and development. The caatinga biome has been suffering anthropic pressure, climate changes can increase the dry period, stimulating the use of cacti even more in animal feed. Some cactus species are at risk of extinction, including the genus Pilosocereus (MARTINELLI & MORAES 2013)

This biome has undergone several threats that have compromised the size of natural populations over the years and placed some cactus species at risk of extinction (ZAPPI et al. 2011). The main threats reported for cacti are related to habitat fragmentation, mainly caused by deforestation, agricultural development, and different types of environmental disturbances, such as the movement of people, urban sprawl, trampling by animals, and substrate invasion by Poaceae species. In addition, there is still an illegal collection of large quantities of seeds and plants to supply the market of ornamental species and horticulture, mining, and destroying rocky outcrops (ZAPPI et al. 2011). These threats are more serious for native Cactaceae species, such as *Pilosocereus catingicola* subsp. *salvadorensis*, mainly in the Caatinga of Paraíba state.

The study of germination of this species is justified since there is no information in literature. Therefore, rules and seed testing are necessary. The knowledge of the best conditions for germination, especially the temperature and substrate, are essential since these factors vary between seeds of the same species and different species (GUEDES et al. 2009). Seeds of xerophilic plants are exposed to multiple edaphoclimatic factors that can influence their physiological potential and compromise seedling establishment (SILVA & AZERÊDO 2022).

Among the methods of plant propagation, seed germination stands out as a very important method since it allows the use of the genetic diversity of populations (ROJAS-ARÉCHIGA & VÁSQUEZ-YANES 2000). Furthermore, according to GUEDES et al. (2009), seeds present a variable physiological response at different temperatures and substrates, thus being recommended that the influence of these components be studied on the germination of each species of interest, providing subsidies for the analysis of these seeds.

Studies that allow knowing the germinative behavior of native species from the Caatinga aiming at subsidizing conservationist actions of these ecosystems are necessary and, in the case of this study, mainly because they are natural populations of native Cactaceae. In this sense, the determination of adequate technologies to enable the use of seeds of native forest species in these regions will be an important tool for implementing afforestation and reforestation programs in Brazil. Unfortunately, studies related to the germination of native cactus seeds in the Northeast are still scarce, and few results can be found in the literature (ABUD et al. 2012a).

Although there are studies in the literature on seed germination characteristics and reproductive biology of other cactus seeds, little information on *P. catingicola* subsp. *salvadorensis* is available. Few studies involving germination and substrates in cacti can be found in Brazil, mainly in the country's Northeast region. Considering the lack of information on the sexual propagation of *P. catingicola* subsp. *salvadorensis* in the Caatinga of Paraíba, this study aimed to determine the effect of temperature and substrate on germination and vigor of seeds *P. catingicola* (Gürke) Byles & Rowley subsp. *salvadorensis* (Werderm.) Zappi (Cactaceae).

MATERIAL AND METHODS

The seeds used in the experiment were obtained from ripe fruits harvested in December 2014 from individuals of natural populations in the municipalities of Arara (25 M 192007 9243179 UTM), Bananeiras (25 M 203813.08 9259923.81 UTM) and Boa Vista (24 M 698981 9133272 UTM), State of Paraíba. Thirty fruits were collected by areas and transported in paper bags. Later, the seed processing was carried out, where the lot was constituted by the homogeneity of the seeds collected in the locality (Figure 1). The sampled Caatinga forest fragments are located in the mesoregion of the Agreste of Paraíba (Figure 1).

Figure 1. *Pilosocereus catingicola* (Gürke) Byles & Rowley subsp. *salvadorensis* (Werderm.) Zappi (Cactaceae) in areas of Caatinga in the municipalities of Arara, Areial and Boa Vista, Agreste of the State of Paraíba, Brazil. (A) Mother plant, (B) collection of fruits, (C) fruits and (D) seeds in the fruit.

The three areas were chosen based on the high density of *P. catingicola* (Figure 2) along the landscape and differeach other in terms of land use and conservation, but all sites are considered private rural properties.

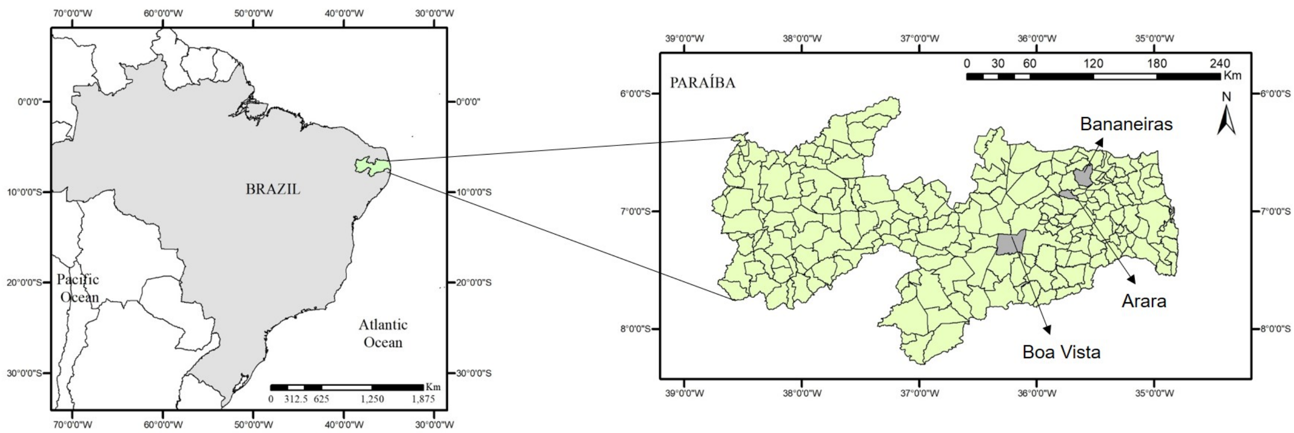

Figure 2. Geographical location of *P. catingicola* subsp. *salvadorensis* in the different municipalities of the Agreste of the Paraíba State, Brazil.

Germination test

The germination test was conducted at the Laboratory Seed Technology of the CCHSA/UFPB from December 2014 to April 2015. The seeds from the three localities were germinated in “gerbox” boxes using as substrates the germitest paper, vermiculite, and soil (collected in the area of fruit origin). The germitest paper was moistened with distilled water in the proportion of 2.5 times the weight of the dry paper (BRASIL 2009). This moistening was carried out for sand and vermiculite by a water retention capacity of 60%. The substrates were sterilized in an oven at 105 °C for one hour (BRASIL 2009), and the seeds were sown 0.3 cm deep. The germination test on different substrates was placed in germinators regulated at constant temperatures of 20, 25, and 30 °C and at an alternating temperature of 20-30 °C, with a 12-hour photoperiod for each temperature. Seeds with radicle emergence were considered as germinated. Counts were performed until the 30th day after sowing, when the stabilization of germination occurred. For the germination speed index (GSI), daily counts of germinated seeds were carried out by means of the methodology recommended by MAGUIRE (1962). LABOURIAU & VALADARES (1976) methodology was used for the average germination time. The experimental design was a completely randomized design with four replications of 50 seeds and treatments arranged in a 3 × 4 factorial arrangement (three localities and four temperatures). The data were submitted to ANOVA and mean the Tukey’s test performed comparison at 5% probability.

RESULTS AND DISCUSSION

The data of germination of seeds of *P. catingicola* subsp. *salvadorensis* from Arara at the different substrates and temperatures are shown in Figure 3. The substrate that provided the highest germination percentage was the germitest paper at all tested temperatures. At temperatures of 20 and 25 °C, the germination was higher, reaching a value of 96%, while the lowest germination was observed at the alternating temperature (20-30 °C), with a percentage of 79%. GUEDES et al. (2009) assessed the effect of temperatures and substrates on seeds of *Cereus jamacaru* DC. sown on a roll of paper and found the seeds need temperatures higher than 25 °C to reach a percentage of germination above 60%, considering the high temperatures in their natural habitat. SILVA & AZERÊDO (2022), studying germination of *Pilosocereus pachycladus* subsp. *pernambucoensis* (F. Ritter) Zappi, the temperature of 25 °C provided 94% of germination, with origin of Bananeiras, PB.

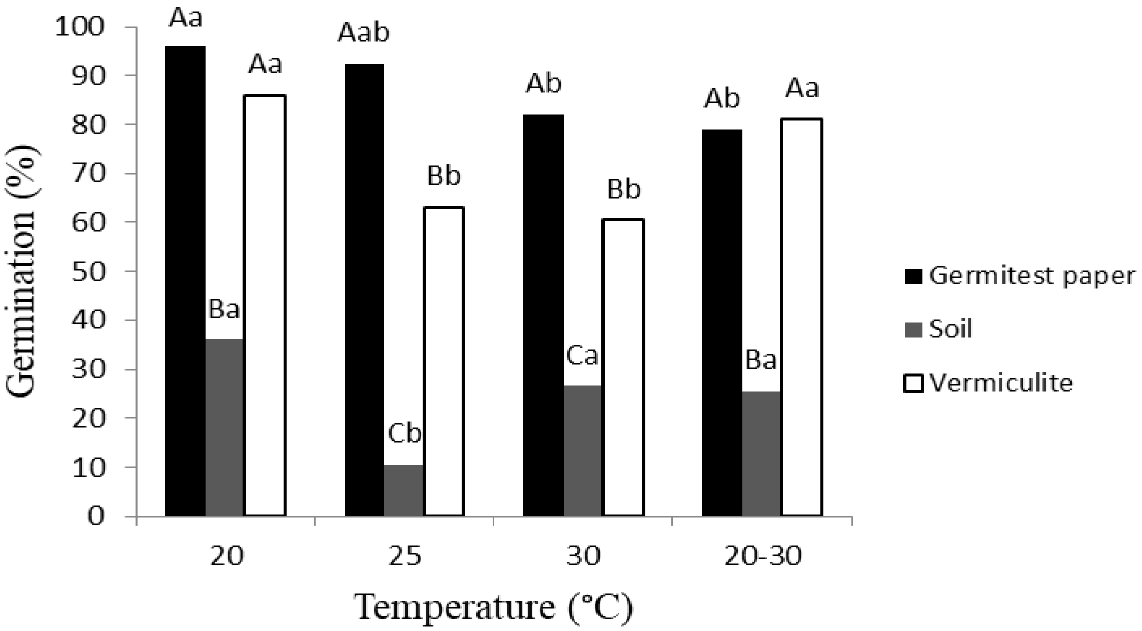

Figure 3. Germination of seeds of *P. catingicola* subsp. *salvadorensis* from Arara, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey’s test at 5% probability.

Still, considering Figure 3, the substrate soil provided the lowest germination rates regardless of the tested temperature, with germination lower than 37%. The fruit of *P. catingicola* subsp. *salvadorensis* is fleshy and its dispersers, when feeding on it, eliminate the seeds together with their feces. In this case, its seeds are released on the soil surface, and then, the germination occurs. In addition, the soil of the areas where the fruits were collected has a clayey texture, which may also have hampered seed germination. Another aspect to consider is that in the germination test, the seed was not placed on the soil (as in its natural habitat) but between the soil (during the assessments, a certain degree of substrate compaction was perceptible in the "gerbox"). Moreover, the percentages of germination (above 80%) in the substrate vermiculate at temperatures of 20 and 20-30 °C did not differ statistically from those reached in the germitest paper at these same temperatures. These results indicate the difficulty of seed germination in their natural habitat.

The data of germination of seeds of *P. catingicola* subsp. *salvadorensis* from Bananeiras are shown in Figure 4. The temperature of 20 °C was unfavorable for all substrates. The temperature of 25 °C was the most favorable for seed germination when the substrate germitest paper (96%) was used, differing statistically from 30 °C and the alternating temperature (20-30 °C). In a study carried out with the same taxon in the substrate filter paper, MEIADO et al. (2016) observed that the germination was higher than 50% at 25 °C. The substrate soil and vermiculite had an inferior performance at all tested temperatures. This inferior soil performance can be justified for the reasons previously described above.

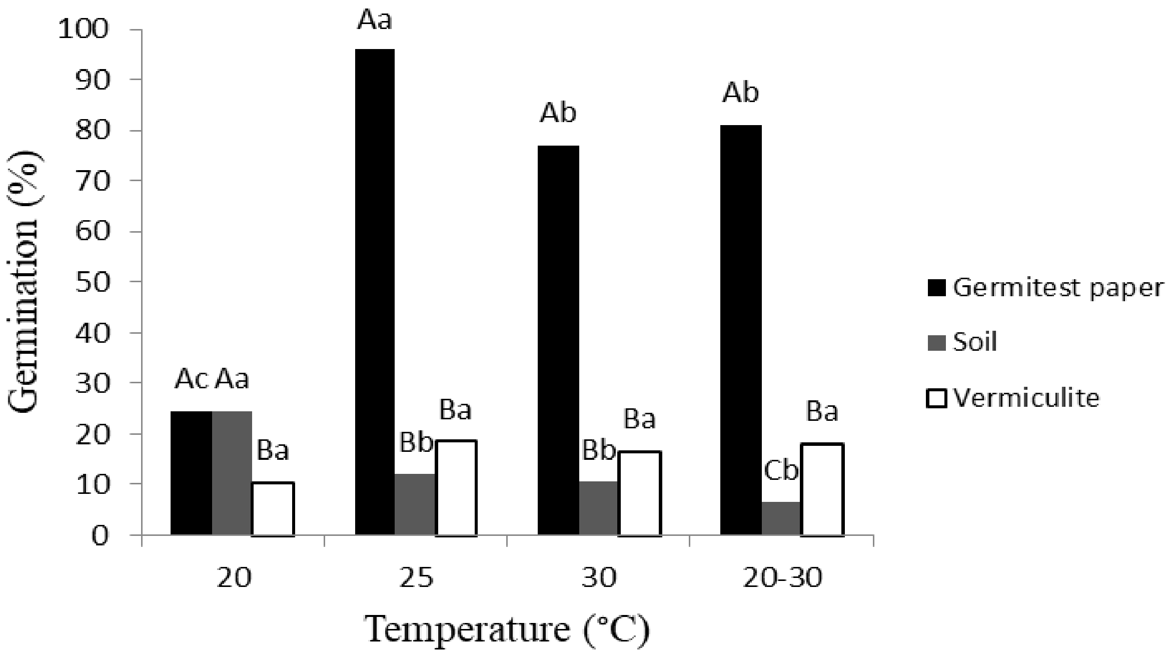

Figure 4. Germination of seeds of *P. catingicola* subsp. *salvadorensis* from Bananeiras, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

MEIADO et al. (2010) assessed the germination of 30 taxa of Cactaceae collected in the Northeast region of Brazil and concluded that no alternate temperature treatment was more favorable to germination when compared to regular temperature treatments. In addition, this author observed that the optimal temperatures for germination of cactus seeds were between 20 and 35 °C. ROJAS-ARÉCHIGA & VÁSQUEZ-YANES (2000), for instance, concluded that the optimal temperature for germination of cactus seeds is around 25 °C. Considering Boa Vista (Figure 5), the substrate germitest at 25 °C provided the highest germination (92.5%), being statistically similar to that obtained in the same substrate at the alternate temperature.

However, the temperature of 20 °C was unfavorable to seed germination for all substrates, with values lower than 40%. Interestingly, both soil and vermiculite were unfavorable to germination at all temperatures, except for 25 °C, in which vermiculite provided a percentage of germination of around 60%. BRITO CAVALCANTI & MILANEZ DE RESENDE (2007) assessed the effect of substrates on cactus development and concluded that the substrate (sand and soil), when mixed with manure, provided the best growth conditions. On the other hand, BEVILAQUA et al. (2015) verified that the temperature of 20 °C did not promote the germination of seeds of *Cereus jamacaru*. According to their findings, the temperature of 30 °C was more efficient when compared to 25 °C, with an average germination rate of 89% and 82%, respectively.

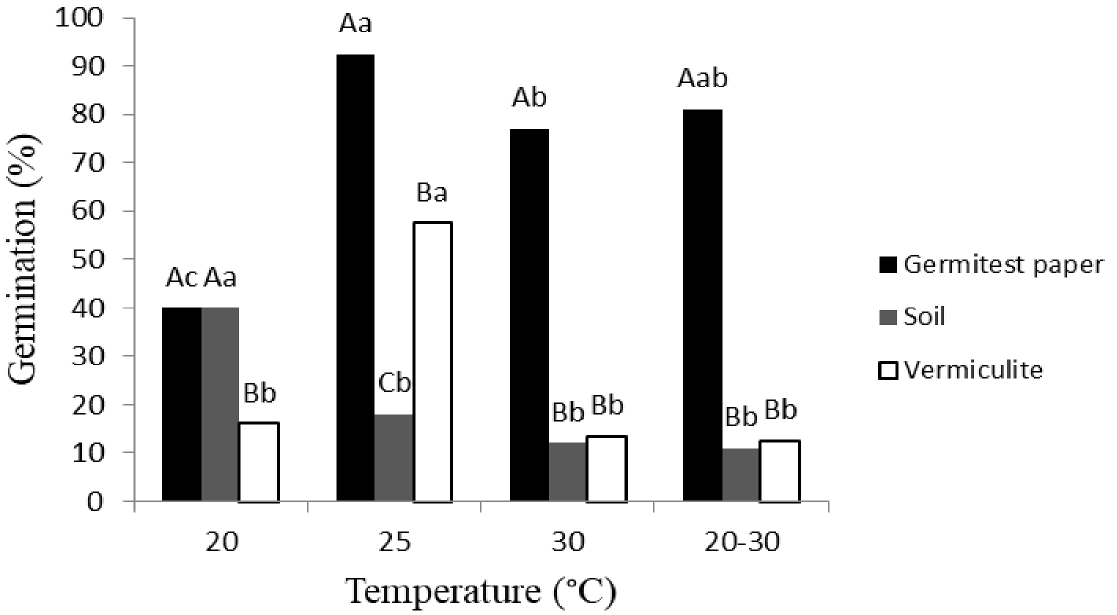

Figure 5. Germination of seeds of *P. catingicola* subsp. *salvadorensis* from Boa Vista, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

GUEDES et al. (2009) found that the substrate paper roll at a temperature of 30 °C was adequate for conducting germination and vigor tests in seeds of *Cereus jamacaru* DC. According to ABUD et al. (2013), the best temperature for germination seeds of *Cereus jamacaru* DC. from the Ceará State was 25 °C. Figure 6 shows the results of the germination speed index (GSI) at different temperatures and substrates for locality Arara, where a significant difference was found between treatments. The substrate germitest and the temperature of 25 °C promoted the highest GSI (15.90), differing statistically from the other substrates. The substrate soil showed the lowest GSI values regardless of the used temperature. For vermiculite, the highest GSI was obtained at 25 °C (10.38). MEDEIROS et al. (2015) developed a research with the same species and observed that the highest GSI (10.1) was observed at a temperature of 20-30 °C in detriment of a temperature of 30 °C, which presented a GSI value of 8.7.

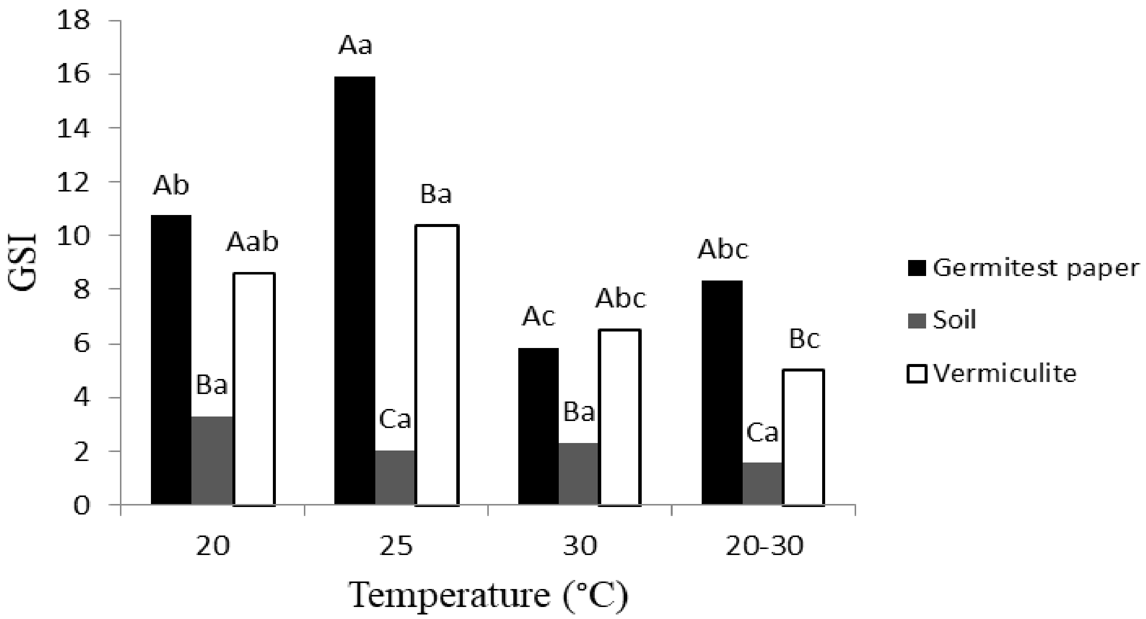

Figure 6. Germination rate index of seeds of *P. catingicola* subsp. *salvadorensis* from Arara, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

Constant temperatures of 25 and 30 °C and alternate temperatures of 20-30 °C are adequate for germinating seeds of *Hylocereus undatus* and *H. undatus* × *Hylocereus costaricensis* (LONE et al. 2014), differentiating from this research. Studies on climate change indicate that the suitable habitat for the population of *P. pachycladus* F. Ritter subsp. *pernambucoensis* (F. Ritter) Zappi (CARVALHO et al. 2021), placing the species at greater vulnerability, possibly compromising its spatial distribution in ecosystems. Studies on the behavior in different substrates x temperatures, collaborate with information, for the taking of decisions and accelerate the production of seedlings, for projects of recovery of degraded areas.

For the locality of Bananeiras, PB (Figure 7), the substrate germitest provided the highest GSI values at the alternating temperature and 30 °C. Among the tested substrates, soil and vermiculite showed an inferior performance regarding GSI at any of the tested temperatures. Elevated temperatures favor the increase of vigor, causes the establishment to be uniform and faster, minimizes the contact time of the seed with the soil, it can contain pathogens and pests (MORESCO et al. 2021).

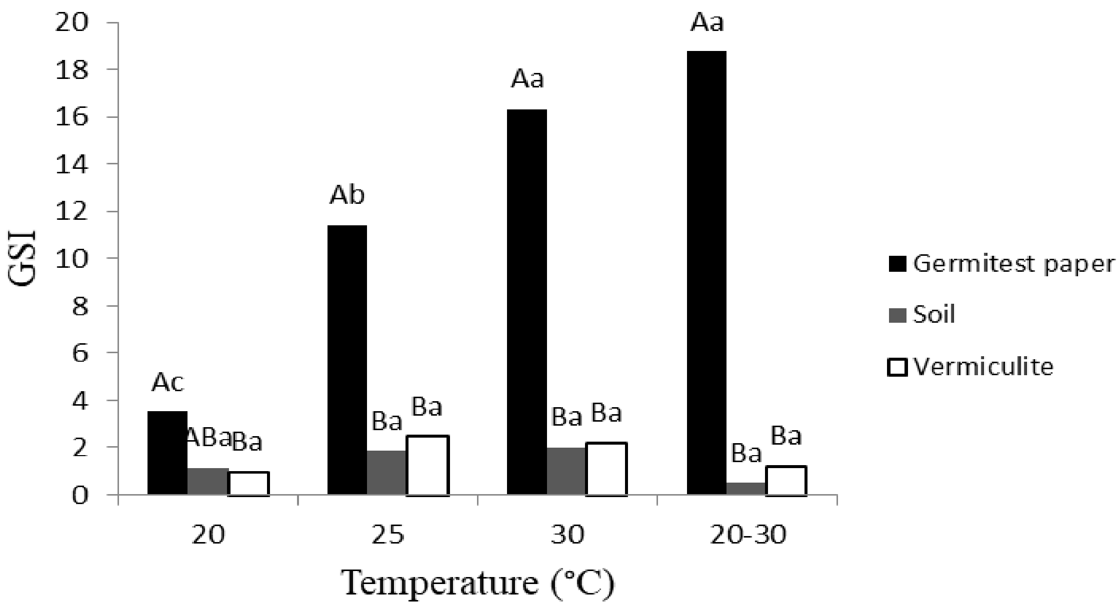

Figure 7. Germination rate index of seeds of *P. catingicola* subsp. *salvadorensis* from Bananeiras, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

A significant difference of GSI values was observed between temperatures for the locality of Boa Vista, PB (Figure 8). Considering the substrate germitest, the alternating temperature promoted the highest GSI value (17.92), which is similar to those obtained at temperatures of 30 °C (16.41) and 25 °C (15.45). The lower GSI values were reached when the substrate soil was used. For the substrate vermiculite, the temperature of 25 °C provided the highest GSI (7.15), being higher than those observed in the other temperatures, which did not present significant differences. ABUD et al. (2010) worked with seeds of *Pilosocereus* species collected in Pentecoste, Ceará State, and obtained a GSI of 5.65 at 20-30 and 30 °C. Seeds that delay their germination may encounter adverse climatic factors for their germination (BECKER et al. 2021), the seedlings may have an uneven pattern and are susceptible to environmental factors.

The values of mean germination time (MGT) for seeds from Arara are shown in Figure 9, where a significant difference can be observed between treatments. Interestingly, 25 °C provided the lowest MGT among the tested temperatures regardless of the used substrate. At temperatures of 20 and 20-30ºC, the germitest paper effectively promoted the shortest mean germination time. In general, vermiculite and soil provided high values of MGT at all temperatures, except for 25 °C, promoting greater unidormity of the seedlings.

For the localities of Bananeiras and Boa Vista (Figures 10 and 11, respectively), the obtained MGT at 25 °C for the three substrates was similar to those found in Arara (Figure 9). However, considering the locality of Boa Vista (Figure 10), except for the temperature of 20 °C, the MGT obtained by the substrate germitest paper was even lower and the substrates soil and vermiculite were inefficient, promoting high MGT values, which was also verified in Arara (Figure 9). Researches on the physiological potential of Cactaceae native to the Caatinga are essential for understanding the behavior and establishment of seedlings in adverse environments, conservation programs on biodiversity should take scenarios of climate change, which in addition to human intervention may affect the natural regeneration of taxa natives (SILVA & AZERÊDO 2022).

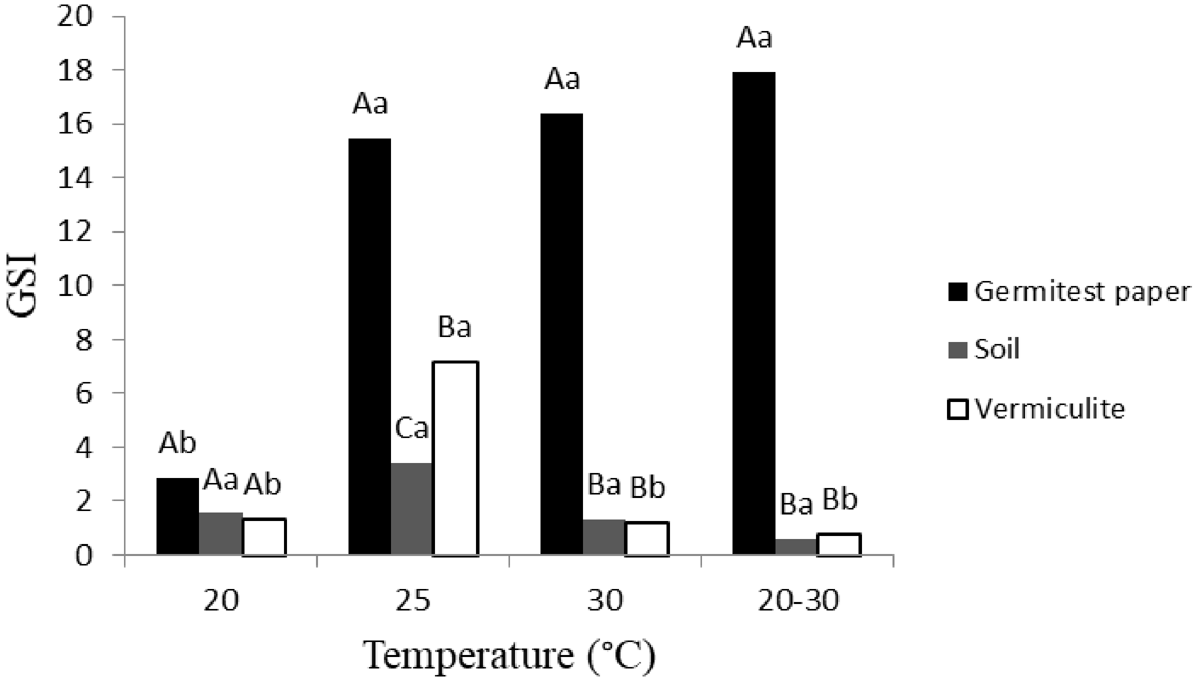

Figure 8. Germination rate index of seeds of *P. catingicola* subsp. *salvadorensis* from Boa Vista, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

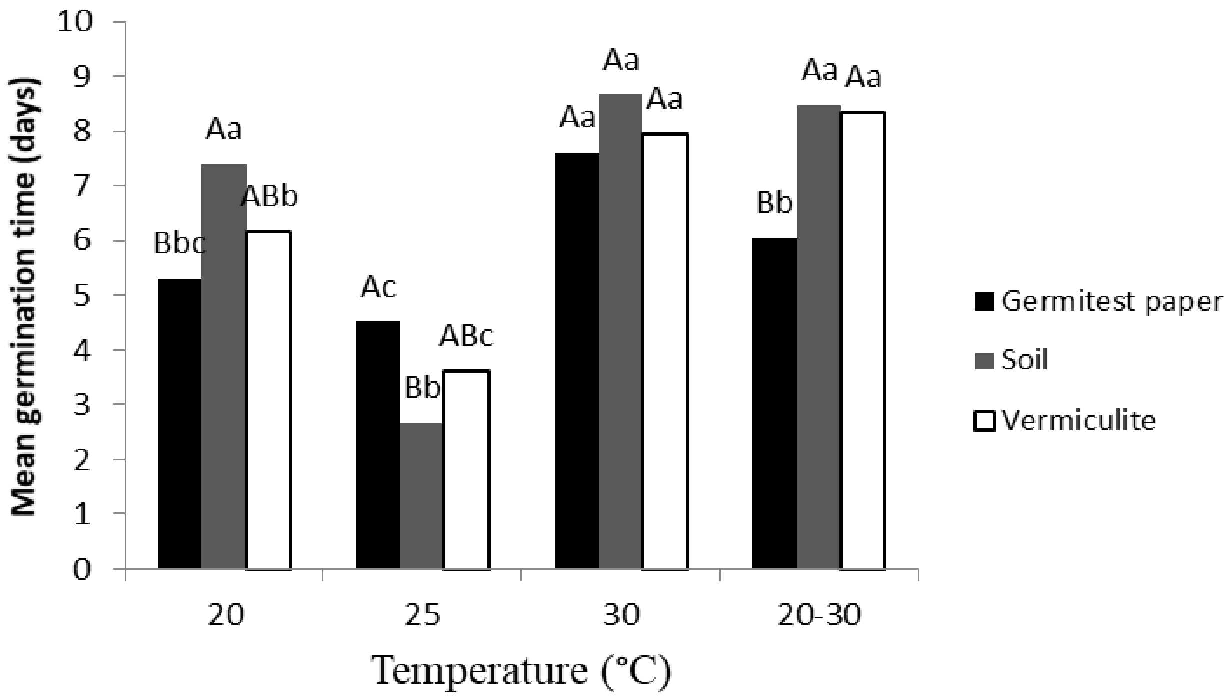

Figure 9. Mean germination time of seeds of *P. catingicola* subsp. *salvadorensis* from Arara, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

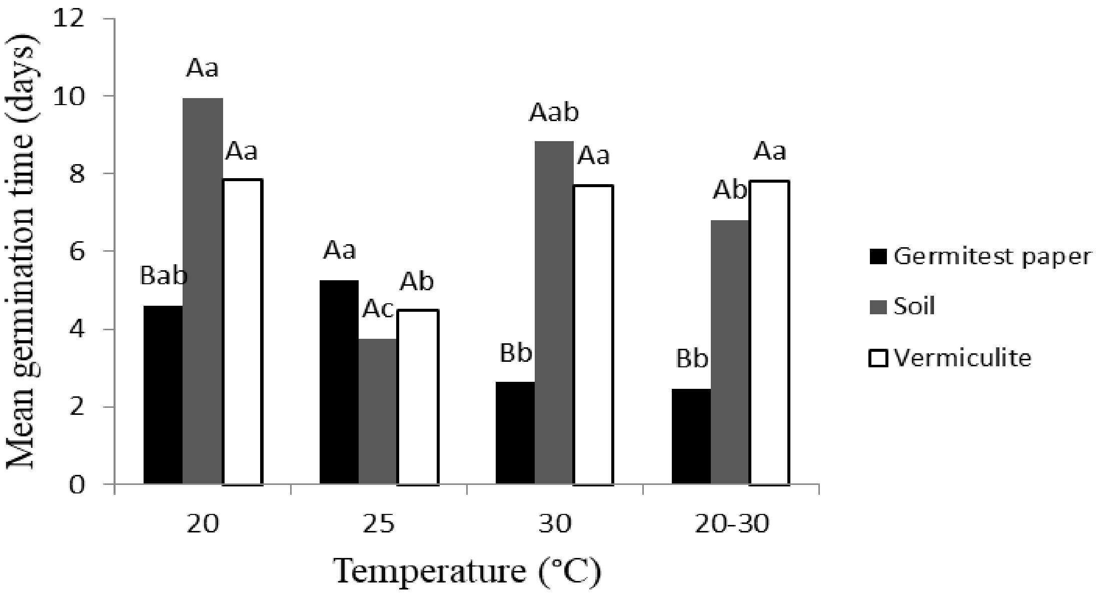

Figure 10. Mean germination time of seeds of *P. catingicola* subsp. *salvadorensis* from Bananeiras, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

LONE et al. (2010) developed a study with the Cactaceae *Schlumbergera truncata* and found values above ten days for the MGT of these seeds on the substrate paper and at different temperatures, which is different from that observed in our study, whose lowest MGT was around five days at 25 °C. In addition, the mean germination time of 30 Cactaceae species was favored when the germination test was carried out at a temperature of 30 °C (MEIADO et al. 2010). ABUD et al. (2012b) assessed the germination and MGT of *Pilosocereus gounellei* at three temperatures and concluded that the best MGT was found at 30 °C (5.0). LONE et al. (2010) worked with seeds of *S. truncata* and found MGT values in the range of 8 to 10 days at temperatures of 20 and 25 °C, respectively, and 15 days at 30 °C when the sand was used as a substrate.

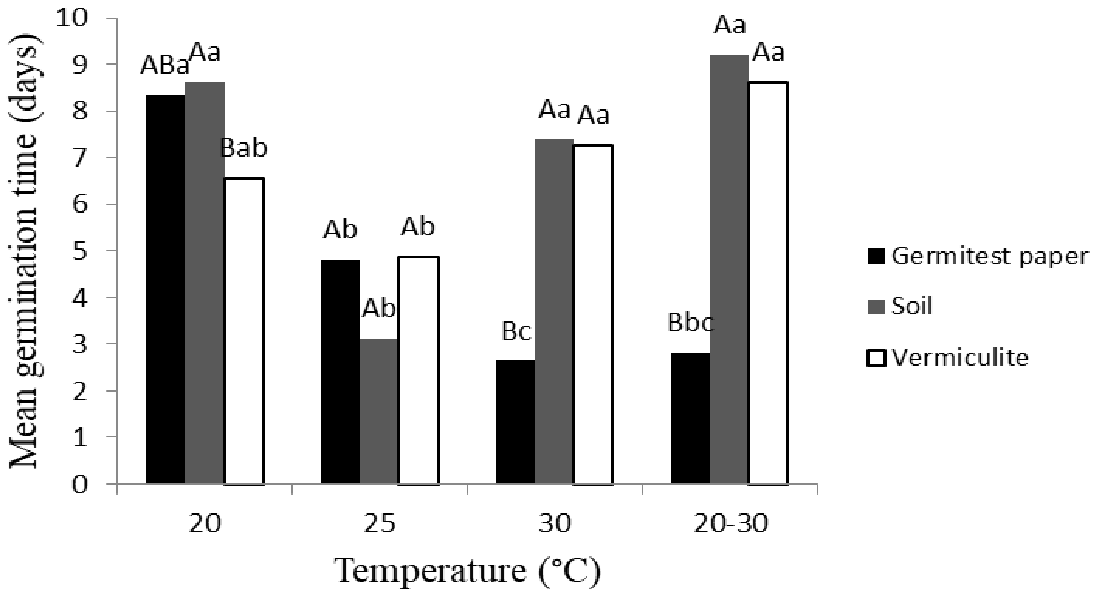

Figure 11. Mean germination time of seeds of *P. catingicola* subsp. *salvadorensis* from Boa Vista, PB. Equal lowercase letters for temperatures within the substrate and uppercase letters for substrates within the temperature do not differ from each other by the Tukey's test at 5% probability.

MEIADO et al. (2016) assessed the MGT of 30 Cactaceae species and observed that there was a faster germination at high temperatures in most of them. This may be favorable for the germination of

Brazilian cactus species because even with a rainy season, the temperature interface soil can be high over the day in several ecosystems of the Northeast region of Brazil.

The germitest paper substrate provided the greatest physiological potential in the seeds, being recommended for seedling production. The vermiculite substrate promoted higher germination, in the locality of Arara and Boa Vista, in relation to the soil substrate in the region. Therefore, the physiological potential was affected by the different substrates. The soil substrate (collected in the agroecosystem with occurrence of the species) had the lowest physiological potential among the evaluated substrates, which may hinder the establishment of seedlings and compromise the natural regeneration of the species, which in the dry period is used in animal feed. These results provide data for projects to conserve biodiversity and restore degraded areas.

CONCLUSION

The physiological potential of seeds are affected by different substrates.

The germitest paper at 25 °C is efficient in assessing the quality of seeds of *P. catingicola* subsp. *salvadorensis*, considering the three localities.

The substrate soil is inadequate to assess the germination and vigor of seeds of *P. catingicola* subsp. *salvadorensis* at all tested temperatures, regardless of the locality.

The substrates soil and vermiculite under laboratory conditions were inefficient, promoting high values of mean germination time.

In general, seeds from Arara were more vigorous in most of the tested substrates and temperatures. The germitest paper substrate is recommended for obtaining seedlings in laboratory.

ACKNOWLEDGEMENTS

To the Laboratory of Seed Technology of the Center for Human, Social and Agrarian Sciences of the Federal University of Paraíba. To Mr. Marizinho, Mr. Nemécio, and Mr. Antenor (Nocha) for providing the areas of Caatinga used for research development. To CNPq/PRPG/UFPB for granting the scholarship.

REFERENCES

ABUD HF et al. 2010. Germinação e expressão morfológica de frutos, sementes e plântulas de *Pilosocereus pachycladus* Ritter. Revista Ciência Agronômica 41: 468-474.

ABUD HF et al. 2012a. Armazenamento de sementes de xique-xique. Revista Brasileira de Sementes 34: 473-479.

ABUD HF et al. 2012b. Germination and morphological characterization of the fruits, seeds, and seedlings of *Pilosocereus gounellei*. Brazilian Journal of Botany 35: 11-16.

ABUD HF et al. 2013. Germination and morphology of fruits, seeds and plants of *Cereus jamacaru* DC. Journal of Seed Science 35: 310-315.

BECKER R et al. 2021. Unveiling the germination requirements for *Cereus hildmannianus* (Cactaceae), a potential new crop from southern and southeastern Brazil. Acta Botanica Brasilica 34: 765-771.

BEVILAQUA MR et al. 2015. Genetic and chemical diversity in seeds of cactus mandacaru (*Cereus* sp.) from two edaphoclimatic regions contrasting. Anais da Academia Brasileira de Ciências 87: 765-776.

BRASIL. 2009. Ministério da Agricultura e Reforma Agrária. Regras para análises de sementes. Brasília: SNDA/DNDV/CLAV. 399p.

BRITO CAVALCANTI N & MILANEZ DE RESENDE G. 2007. Efeito de diferentes substratos no desenvolvimento de mandacaru (*Cereus jamacaru* P. DC.), facheiro (*Pilosocereus pachycladus* RITTER), xiquexique (*Pilosocereus gounellei* (A. WEBWR EX K. SCHUM.) BLY. EX ROWL.) e coroa-de-frade (*Melocactus bahiensis* BRITTON & ROSE). Revista Caatinga 20: 28-35.

CARVALHO T et al. 2021. *Cereus jamacaru* DC. and *Pilosocereus pachycladus* F. Ritter (Cactaceae) in the Northeast region of Brazil: future perspectives and distribution. Revista Brasileira de Geografia Física 14: 126-134.

GUEDES RS et al. 2009. Germinação de sementes de *Cereus jamacaru* DC. em diferentes substratos e temperaturas. Acta Scientiarum. Biological Sciences 31: 159-164.

LABOURIAU LG & VALADARES MEB. 1976. On the germination of seeds of Calotropis procera (Ait.) Ait.f. Anais da Academia Brasileira de Ciências 48: 263-284.

LONE AB et al. 2014. Temperatura na germinação de sementes de genótipos de pitaya. Semina: Ciências Agrárias 35: 2251-2258.

LONE AB et al. 2010.Temperatura e substrato para germinação de sementes de flor-de-maio (*Schlumbergera truncata* (Haw.) Moran). Revista Ceres 57: 367-371.

MAGUIRE JD. 1962. Speedofgermination-aid in selection and evaluation for seedling emergence and vigor. Crop Science 2: 176-177.

MARTINELLI G & MORAES MA. 2013. Livro vermelho da flora do Brasil. Rio de Janeiro: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. 1100p.

MEDEIROS RLS et al. 2015. Germinação e Vigor de Sementes de *Pilosocereus catingicola* (Gürke) Byles & Rowley subsp. *salvadorensis* (Werderm.) Zappi (Cactaceae) da Caatinga Paraibana. Gaia Scientia 9: 61-66.

MEIADO MV et al. 2010. Seed germination responses of *Cereus jamacaru* DC. ssp. *jamacaru* (Cactaceae) to environmental factors. Plant Species Biology 25: 120-128.

MEIADO MV et al. 2016. Effects of light and temperature on seed germination of cacti of Brazilian ecosystems. Plant Species Biology 31: 87-97.

MENEZES MO et al. 2016. Pleistocene radiation of coastal species of *Pilosocereus* (Cactaceae) in eastern Brazil. Journal of Arid Environments 135: 22-32.

MORESCO VP et al. 2021. Physiological potential of *Dyckia* spp. bromeliad seeds under different temperatures. Semina: Ciências Agrárias 42: 2639-2650.

RAMÍREZ-RODRÍGUEZ Y et al. 2020. Engineering biomimetic calcium phosphate nanoparticles: a green synthesis of slow-release multinutrient (NPK) nanofertilizers. ACS Applied Bio Materials 3: 1344-1353.

ROJAS-ARÉCHIGA ME & VÁSQUEZ-YANES C. 2000. Cactus seed germination: a review. Journal of Arid Environments 44: 85-104.

SILVA JHCS & AZERÊDO GA. 2022. Germinação de sementes de cactáceas sob estresse salino. Revista Caatinga 35: 79-86.

SILVA VP. 2011. Análise da pluviometria e dias chuvosos na região Nordeste do Brasil. Revista Brasileira de Engenharia Agrícola e Ambiental 15: 131-138.

ZAPPI D et al. 2011. Plano de ação nacional para a conservação das cactáceas. Instituto Chico Mendes de Conservação da Biodiversidade. Brasília: ICMBIO. 112p.