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Conservation of seeds of cactaceae species endemic to the caatinga biome: *Pilosocereus pachycladus* and *Tacinga inamoena*

Conservação de sementes das cactáceas endêmicas da caatinga *Pilosocereus pachycladus* e *Tacinga inamoena*

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ABSTRACT - Ecosystems with dry soils are particularly sensitive to climate changes and anthropogenic actions, which represents a threat to the survival of many cactus species. Ex situ seed conservation strategies should be adopted to support in situ conservation. This study evaluated the effect of conservation conditions on germination and vigor of seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* and *Tacinga inamoena*. The seeds were packaged in paper bags and glass containers and stored under controlled (8 ± 1 °C; 56 ± 2% relative humidity) and non-controlled (24 ± 2 °C; 75 ± 5% relative humidity) environmental conditions for 0 (control), 12, 16, and 20 months. The experiment was conducted in a completely randomized design, in a 2 × 2 × 4 factorial arrangement (conservation environment × packaging × storage period) for each species. The variables evaluated were: water content (%), germination (%), germination speed index (GSI), and mean germination time (MGT). The physiological quality of seeds of both species were preserved when seeds were maintained under controlled environment, regardless of the packaging. However, when stored under non-controlled environment, the packaging in paper bags was more efficient for the conservation of seeds of *P. pachycladus* subsp. *pernambucoensis*, and the glass container was more efficient for *T. inamoena*. This information may be needed for ex situ conservation of these species and to support the recovery of degraded areas susceptible to desertification in the Caatinga biome.

Keywords: Cactaceae, Germination, *Pilosocereus pachycladus*, *Tacinga inamoena*, viability.

RESUMO - Os ecossistemas de terra seca são particularmente sensíveis às mudanças climáticas e às ações antrópicas, que representam uma ameaça à sobrevivência de muitas espécies de cactos. Estratégias de conservação de sementes *ex situ* devem ser adotadas para apoiar a conservação *in situ*. Este estudo avaliou a influência da condição de conservação sobre a germinação e o vigor de sementes de *Pilosocereus pachycladus* subsp. *pernambucoensis* e *Tacinga inamoena*. As sementes foram acondicionadas em embalagem de papel e vidro e armazenadas em condições ambientais controladas (8 ± 1 °C; 56 ± 2% de UR) e não controladas (24 ± 2 °C; 75 ± 5% UR) por um período de 0 (controle), 12, 16 e 20 meses. O experimento foi conduzido em delineamento inteiramente casualizado, em esquema fatorial 2 × 2 × 4 (ambiente de conservação × embalagem × período de armazenamento), para cada espécie. As variáveis avaliadas foram: teor de água (%), germinação (%), índice de velocidade de germinação (IVG) e tempo médio de germinação (TMG). As sementes de ambas as espécies têm sua qualidade fisiológica preservada quando conservadas em ambiente controlado, independente da forma que foram embaladas. Entretanto, quando armazenadas em condições não controladas, a embalagem de papel foi mais eficiente para a conservação das sementes de *P. pachycladus* subsp. *pernambucoensis* e a embalagem de vidro para *T. inamoena*. Esses conhecimentos podem ser necessários na conservação *ex situ* dessas espécies e apoiar a recuperação de áreas degradadas suscetíveis à desertificação na Caatinga.

Palavras-chave: Cactaceae, Germinação, *Pilosocereus pachycladus*, *Tacinga inamoena*, viabilidade.

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INTRODUCTION

There are 484 cactus species (Cactaceae) distributed throughout the Brazilian territory, including *Pilosocereus pachycladus* subsp. *pernambucoensis* (Ritter) Zappi and *Tacinga inamoena* (K.Schum.) N.P.Taylor & Stuppy, which are two species endemic to dry tropical forests of the Caatinga biome (ZAPPI; TAYLOR, 2020). *P. pachycladus* subsp. *pernambucoensis* is an arboreal columnar cactus that can reach up to 6.0 m height, and *T. inamoena* is a subshrub cactus that presents plain cladodes and red-orangish flowers (BATISTA et al., 2018). Both species are found over almost the whole Semiarid region of Brazil and have a high importance for the sustainability and conservation of the Caatinga biodiversity, as their flowers and fruits serve as food for the local fauna (NASCIMENTO et al., 2015; SOUSA NETO; GOMES; QUIRINO, 2021; PAIXÃO; GOMES; VENTICINQUE, 2021).

Although Cactaceae species are an important component of the Caatinga flora (BARBOSA et al., 2020a), populations of many species have been subjected to predatory exploitation and degradation of their habitats (MEIADO;

ALMEIDA, 2022), making Cactaceae one of the ten most threatened botanical families in the Brazilian flora (GOMES et al., 2020). Natural Cactaceae populations are subjected to strong anthropogenic pressures, which considerably increases risks of extinction (OLIVEIRA et al., 2020). Natural disturbances by herbivory or anthropogenic causes, environmental conditions, and availability of resources affect the populational structure and distribution of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena* (BARBOSA et al., 2020b; OLIVEIRA et al., 2020). Despite the current conservation status of these two species are "little worrisome", recent studies indicate a significant decrease in the distribution of these and other cactus species in their original sites of occurrence, mainly for the future scenario of climate changes (CARVALHO et al., 2021; CAVALCANTE; SAMPAIO, 2022).

Considering that Cactaceae species present long reproduction cycles, lasting several years to start their reproduction phenological phase, seed storage is an alternative for the maintenance of seed stocks for these species (SILVA; AMARIZ; KIILL, 2018). Understanding long-term effects of storage on seed germination is important to assess the dynamics of the soil seed bank regarding its preservation capacity. However, information about the family Cactaceae is scarce, although essential for conservation programs (GURVICH et al., 2021; ROJAS-ARÉCHIGA; GARCÍA-MORALES, 2022).

Researches correlating packaging and conservation environment for seeds of native Cactaceae species are incipient in Brazil, and some studies on the species *Pilosocereus gounellei* (*Xiquexique gounellei*) (ABUD et al., 2012) and *Cereus jamacaru* (ABUD et al., 2016; TARGINO et al., 2021) are highlighted for presenting important contributions about conservation methods. According to these studies, the seed viability was maintained when the seeds were packaged in paper, plastic, and glass containers and stored under low-temperature environments. However, under natural environment, the kraft paper bag provided the ideal conditions for conservation of seed viability for these species.

The storage of seeds in adequate temperature and relative air humidity conditions favors the maintenance of their physiological potential, decreasing the respiratory process and, thus, decreasing the seed deterioration process (CARVALHO; NAKAGAWA, 2000; MARCOS-FILHO, 2015). This deterioration also depends on the packaging used for seed storage, which are classified as permeable (porous), semipermeable (semiporous), and impermeable (hermetic), facilitating or inhibiting gas and water vapor exchanges between the seeds and the storage environment (SILVA; FERRAZ, 2015).

The increasing threats to the family Cactaceae show the need to seek safe alternatives for long-term preservation, which can be even simple ways that are within the reach of anyone who wants to preserve these seeds at home. In addition, despite some studies evaluated Cactaceae seeds in other areas of the Caatinga biome, it is important to investigate these seeds in the municipalities of Bananeiras and São João do Cariri, state of Paraíba, Brazil, mainly focused on their physiological potential, and whether they can maintain their viability and vigor over time.

The objective of this study was to evaluate the effect of conservation conditions on germination and vigor of seeds of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena*.

MATERIAL AND METHODS

The experiment was conducted at the Laboratory of Seed Technology of the Center for Human, Social, and Agricultural Sciences of the Federal University of Paraíba, Campus III, Bananeiras, Paraíba (PB), Brazil. The seeds of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena* used were from mature fruits collected from adult individuals from two populations of natural occurrence in the municipalities of Bananeiras and São João do Cariri, PB, Brazil, respectively (Figure 1). The predominant vegetation in these municipalities is formed by Deciduous and Semideciduous Forests typical of the Agreste, which is a spatial region between the Sertão (a semiarid region with predominance of caatinga vegetation) and the Zona da Mata region (consisted of Atlantic Forest).

The pulp was removed from the fruits through maceration in a fine-mesh metal sieve, with subsequent washing in running water. The seeds were then homogenized and shade dried (24 ± 2 °C) for four days. The seeds were then packaged in two package types (paper bags and glass containers), except those of the control group, and stored under controlled environment (refrigerator 8 ± 1 °C; 56 ± 2% relative humidity) and non-controlled environment (laboratory 24 ± 2 °C; 75 ± 5% relative humidity) for 0, 12, 16, and 20 months. Glass containers were filled with cotton up to the top to avoid empty spaces inside them and sealed with a rubber cover and adhesive tape.

A completely randomized statistical design was used, in a 2 × 2 × 4 factorial arrangement (conservation environment × packaging × storage period), resulting in 16 treatments for each species.

The seeds (four replications of 50 seeds) were germinated in paper substrate (between blotting papers) previously sterilized and moistened with distilled water at the volume (mL) of 2.5-fold the paper dry weight inside transparent plastic boxes with lids (11 × 11 × 3.5 cm). The seeds were maintained in a germinator under constant temperature (25 ± 1 °C) and light, based on preliminary tests.

The number of germinated seeds in each experimental test was counted daily for 21 days for *P. pachycladus* subsp. *pernambucoensis*, and for 30 days for *T. inamoena*; the root protrusion was the criterion adopted to consider the seeds as germinated. Water content (%), germination (%), and germination speed index (GSI) were evaluated according to equation proposed by Maguire (1962); and mean germination time (MGT) was calculated using the formula proposed by Labouriau (1983). The seed water content was determined by

placing them in an oven at 105 ± 3 °C for 24 hours, using two replications of approximately 100 seeds. The evaluations were carried out following the criteria established by the Rules for Seed Analysis (BRASIL, 2009).

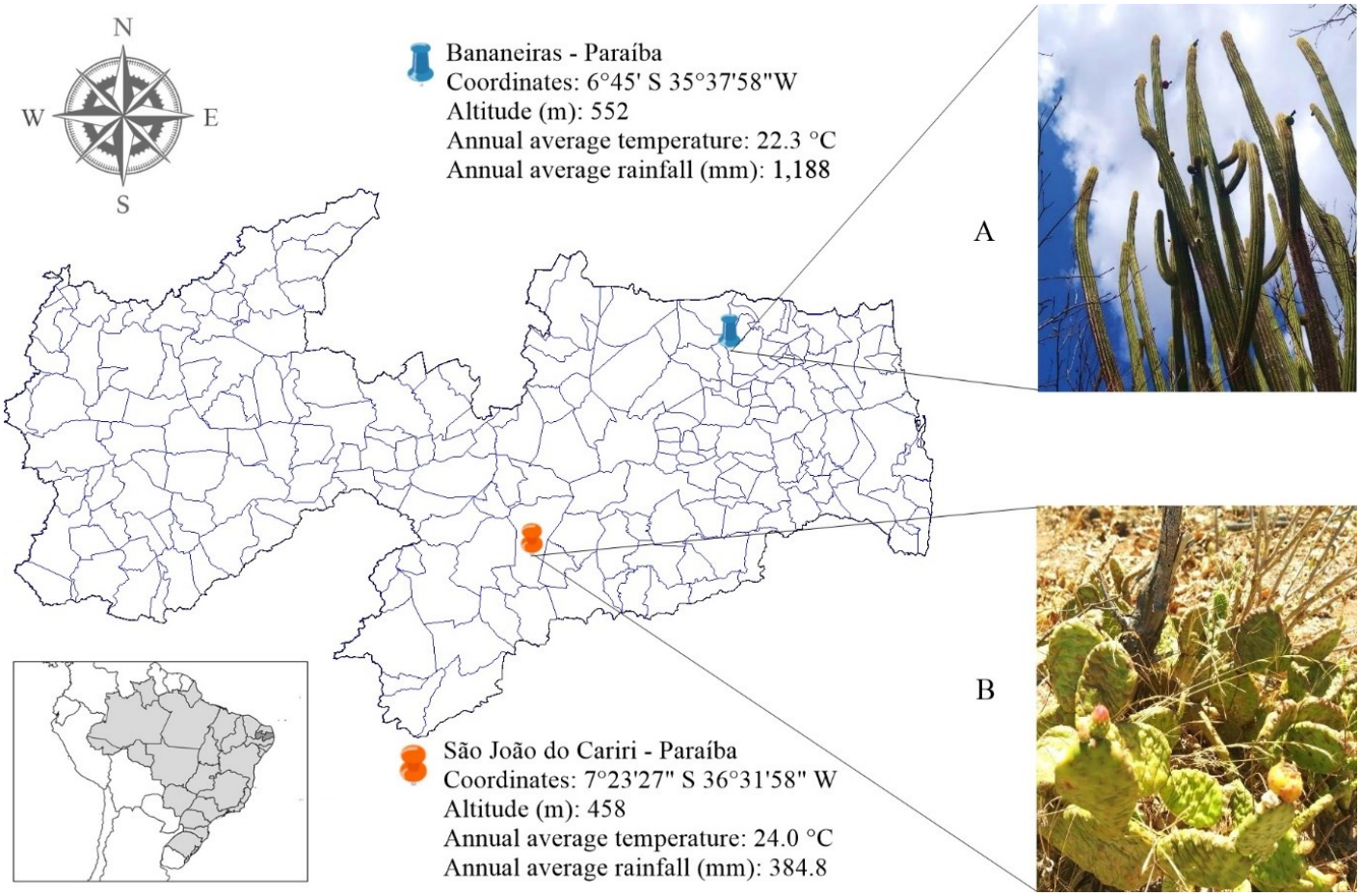

Figure 1. Locations of the collections of seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* (Ritter) Zappi (A) and *Tacinga inamoena* (K.Schum.) N.P.Taylor & Stuppy (B) from populations in areas with caatinga vegetation, state of Paraíba, Brazil.

The statistical analyses were carried out using the softwares ESTAT/Jaboticabal® and Microcal Origin® 6.0. The data of normality and homogeneity of variances were assessed using the Shapiro-Wilk and Bartlett tests, respectively. The data were subjected to analysis of variance by the F test and the means were then compared by the Tukey's test ($p \leq 0.05$). First, the fit of the data to polynomial and linear equations was carried out, but the data was fitted according to the methodology used by Targino et al. (2021) due to the occurrence of negative estimates for some characteristics.

RESULTS AND DISCUSSION

The results obtained for the variables as a function of the two species studied and seed storage conditions are presented in Table 1. According to the analysis of variance, the effect of the interaction between the factors and the isolated factors were significant for germination (%) and MGT for seeds of *P. pachycladus* subsp. *pernambucoensis* (Table 1). However, only the effects of the interaction conservation conditions × storage period and the isolated effects of the factors conditions and storage period were significant for GSI. Regarding the species *Tacinga inamoena*, the effects of all factors, isolated and their interactions, were significant for MGT and GSI, except for the factor packaging. The effects of conservation conditions × storage period, and packaging × storage period, and factor conservation conditions were significant for germination (Table 1).

Table 1. Analysis of variance for germination (G), germination speed index (GSI), and mean germination time (MGT) of seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* and *Tacinga inamoena* in the factorial arrangement: storage conditions (C) × packaging (E) × period (P).

Source of variation	G. L.	Mean squares		
		P. pachycladus subsp. *pernambucoensis*		
		G	GSI	MGT
Conditions (C)	1	47961.0000**	495.6189**	12.0756**
Packaging (E)	1	72.2500*	0.2889^{ns}	155.6256**
Period (P)	3	11862.1667**	208.4631**	37.0519**
C × E	1	380.2500**	3.1952^{ns}	151.9056**
C × P	3	5587.1667**	57.3564**	33.4319**
E × P	3	147.4167**	0.9456^{ns}	61.1010**
C × E × P	3	336.7500**	0.8493^{ns}	43.4677**
Residue	48	13.0417	0.9617	0.7377
Mean		54.50	5.69	4.69
CV (%)		6.62	17.21	18.31
		Tacinga inamoena		
Conditions (C)	1	2730.0625**	1.8394**	MGT
Packaging (E)	1	39.0625^{ns}	0.0001^{ns}	386.1225**
Period (P)	3	11.7292^{ns}	0.3296**	910.5306**
C × E	1	162.5625^{ns}	0.1796*	111.7727**
C × P	3	304.3958**	0.2136**	663.0625**
E × P	3	189.0625*	0.1818**	71.8762**
C × E × P	3	124.2292^{ns}	0.1319**	150.3719**
Residue	48	58.3542	0.0309	131.7038**
Mean		12.78	0.36	11.9321
CV (%)		59.76	47.56	17.02

**and * = significant at 1% and 5% probability by the F test, respectively; ^{ns}= not significant.

Seed water content

The water contents before the experimental tests (period zero) were 12.79% and 11.48% for seeds of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena*, respectively. The water contents, ranging from 8.6% to 15.9% for *P. pachycladus* subsp. *pernambucoensis* seeds and from 7.4% to 12.4% for *T. inamoena* seeds over the storage period, depending on the packaging type and storage environment (Table 2).

Table 2. Water contents (%) in seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* and *Tacinga inamoena*, packaged in two packaging types and stored in two conservation conditions for twenty months.

Taxon	Conditions	Packaging	Storage period (months)			
			0	12	16	20
P. pachycladus subsp. *pernambucoensis*	Controlled environment	Paper	12.79	8.63	13.92	10.08
		Glass		13.84	15.91	15.40
	Non-controlled environment	Paper		10.85	10.35	11.76
		Glass		14.13	15.90	15.23
Tacinga inamoena	Controlled environment	Paper	11.48	9.31	10.00	9.73
		Glass		11.03	11.67	11.97
	Non-controlled environment	Paper		10.82	10.98	7.47
		Glass		11.04	10.95	12.44

The water content in seeds of *P. pachycladus* subsp. *pernambucoensis* was higher in the glass containers, ranging from 14% to 16% in the two storage environments (Table 2). The recommended seed water content for impermeable packages is lower than or equal to 10%. According to Marcos-Filho (2015), the seed moisture and the environment air temperature and relative humidity are factors that significantly affect the deterioration process over the storage period. The water content found in the present work were higher than that recommended for the storage period, which probably triggered changes in moisture over the storage period and accelerated the respiratory activity of seeds.

Conservation of seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis*

The germination of seeds of *P. pachycladus* subsp. *pernambucoensis* at the beginning of the storage period under controlled environment was high (95%) (Figure 2A). However, it decreased over the storage period, reaching 80% for those seeds packaged in glass containers and 88% for those packaged in paper bags. This decrease in germination

potential of seeds packaged in glass containers is probably connected to the initial seed water content (12.7%), which increased the seed metabolic activity over the storage period, as explained by Silva and Ferraz (2015). The data of seeds packaged in paper bags fitted to a quadratic equation and those of seeds packaged in glass containers fitted to a decreasing linear equation. The decrease in germination percentage of seeds stored under non-controlled environment (Figure 2B) was even more pronounced, mainly for those packaged in glass containers, whose germination percentage was zero for all tested periods, except for the control. The germination percentage of seeds packaged in paper bags and stored under non-controlled environmental conditions decreased 50%, compared to that obtained before storage (control), within only 11 months (Figure 2B).

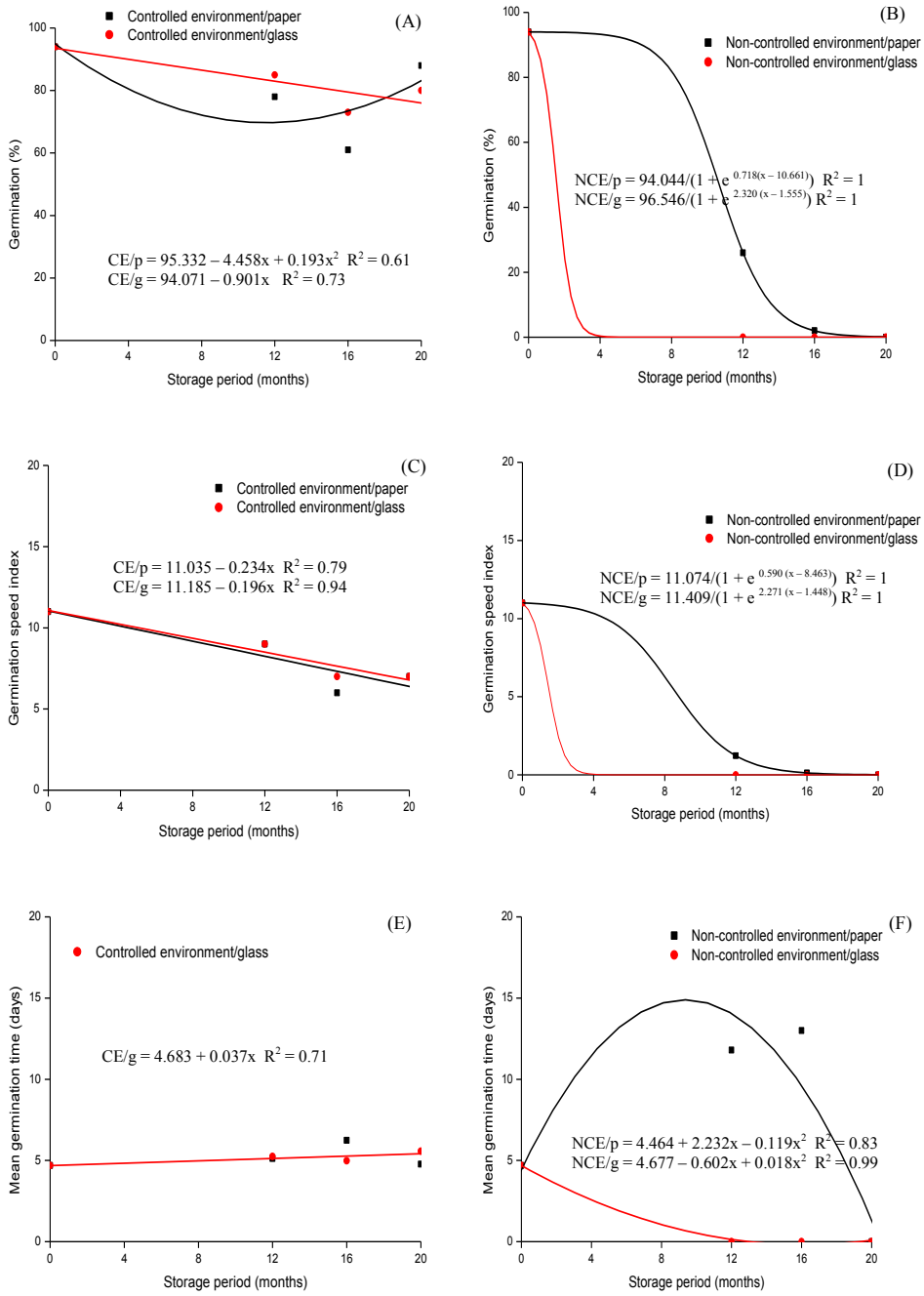

Figure 2. Germination (%), germination speed index (GSI), and mean germination time (MGT) of seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* (Ritter) Zappi packaged in paper bags and glass containers and stored under room temperature and in a refrigerator for twenty months. Germination – controlled environment (A); Germination – non-controlled environment (B); GSI – controlled environment (D); GSI – non-controlled environment (F); MGT – controlled environment (E); MGT – non-controlled environment (F).

Germination speed index (GSI) of seeds stored under controlled environment presented small decreases for both packaging; the data fitted to the linear model (Figure 2C). GSI of seeds before storage was 11.08; after 20 months of storage, it was 7.14 and 7.34 for seeds packaged in paper bags and glass containers, respectively. Considering the equations obtained by the logistic-1 model, the storing of *P. pachycladus* subsp. *pernambucoensis* seeds packaged in glass containers and paper bags for 1.4 and 8.4 months resulted in a decrease of 50% in GSI (Figure 2D). According to Marcos-Filho (2015), a low germination speed is one of the indicators of low physiological potential, and one of the most frequent symptoms of the deterioration process.

The seeds with higher germination and GSI were those stored under controlled environment, regardless of the packaging and storage periods (Figures 2A and 2C). This response can be due to a decrease in seed metabolism and to degradation of reserve compounds in seeds under low temperatures (SANTOS; HASSEMER; MEIADO, 2018).

Regarding the mean germination time (MGT), the data of seeds stored under controlled environment fitted to a decreasing linear equation and the data of seeds stored under non-controlled environment fitted to the logistic-1 model, for both packaging. Seeds stored under controlled environment (Figure 2E) needed approximately 4 to 6 days to germinate, depending on the packaging type and storage period. The MGT data were significant only for seeds packaged in glass containers (Figure 2E). MGT of seeds packaged in glass containers and paper bags and stored under non-controlled environment increased during the storage period (Figure 2F) from four days (control) to 11 and 13 days after 12 and 16 months, respectively.

The paper bags were more efficient than the glass containers for storing seeds under non-controlled environment (Figures 2B, 2D and 2F). This result reinforces the results found by Abud et al. (2016) and Targino et al. (2021), who evaluated the storing of seeds of *Cereus jamacaru* and reported that the germination and vigor of seeds stored under non-controlled environment decreased over the storage period, mainly for those packaged in glass containers.

The viability of seeds of Cactaceae species varies significantly, as the seeds of some species can remain viable for one or two years under non-controlled environment, whereas others remain viable for almost a decade (TRUJILLO et al., 2014; GURVICH et al., 2021). Seeds of *Cephalocereus polylophus* germinated above 90% under laboratory conditions, even two years after they were packaged in paper bags and stored under room conditions (ORTIZ-MARTÍNEZ et al., 2021). Other studies showed increases in germination of seeds of *Ferocactus peninsulae* after 10 months of storage under room temperature (20 ± 2 °C), with viability maintained for 48 months (ROJAS-ARÉCHIGA; GARCÍA-MORALES, 2022). According to these studies, the germination speed also increased over the storage time, denoting that the seed physiological dormancy was overcome over the post-maturation period, i.e., the germination can increase over the storage time under adequate conditions, maintaining the seed viability for long periods, depending on the cactus species.

Other studies on Cactaceae species reported decreases in seed viability over the storage period when the seeds were stored under non-controlled environment, regardless of the packaging used (ABUD et al., 2012; SANTOS; HASSEMER; MEIADO, 2018; GURVICH et al., 2021). Seeds of *Pilosocereus* and *Cereus* species lose their viability and vigor when stored under room temperature (25-27 °C) for 13 months, but when stored in low temperature environments (≤ 8 °C) they can have germination similar to that of freshly-collected seeds (SANTOS; HASSEMER; MEIADO, 2018). Similarly, Silva, Amariz, and Kiill (2018) found that the storage of seeds of *Melocactus bahiensis* and *Harrisia adscendens* in cold chamber (10 ± 2 °C) maintained their physiological quality for 7 years, despite the low germination percentage, which did not exceed 35% for any of the species or treatments evaluated. These findings indicate that ex situ conservation under low temperatures is the most efficient form to maintain the viability of seeds of most cactus species, mainly endangered species.

Tacinga inamoena seed conservation

The germination of *T. inamoena* seeds before storage was 14% (Figure 3A); however, this percentage varied from 14% to 28% under controlled conditions over the storage period, depending on the packaging type and storage period. Under non-controlled conditions, the germination after 12 months was 2% and 6% for seeds packaged in paper bags and glass containers, respectively, but after 16 and 20 months, only the seeds packaged in glass containers germinated, reaching 6% and 9%, respectively (Figure 3B).

The germination percentage of seeds packaged in paper bags fitted to quadratic (controlled environment) (Figure 3A) and logistic (non-controlled environment) (Figure 3B) equations. The germination data of seeds packaged in glass containers in the two conservation conditions were not significant (Figures 3A and 3B). According to the logistic equation, the *xc* value that resulted in 50% of the maximum value of the characteristic (G%) for seeds packaged in paper bags under non-controlled environment was approximately 10 months (Figure 3B), which is equivalent to 7% germination. Seeds stored under controlled environment expressed higher germination percentage than those under non-controlled environment; however, this percentage did not exceed 30% in any of the treatments evaluated.

Meiado (2012) investigated the formation of cactus seed banks in areas with caatinga vegetation and found low germination for the species *T. inamoena* subsp. *inamoena* and *T. palmadora* in the first evaluation (≤ 10%), but a significant increase in germinability after 12 and 24 months (periods when the seeds remained buried in the soil), which did not exceed 50% for any of the species or treatments evaluated.

Nascimento et al. (2015) found low germination (≤ 32%) for *T. inamoena* seeds from freshly-collected fruits and after passing through the digestive tract of *Chelonoidis carbonaria*; they reported that the low germinability of this species may be connected to the production of seeds without embryo or to presence of some type of dormancy, common characteristics in the subfamily Opuntioideae.

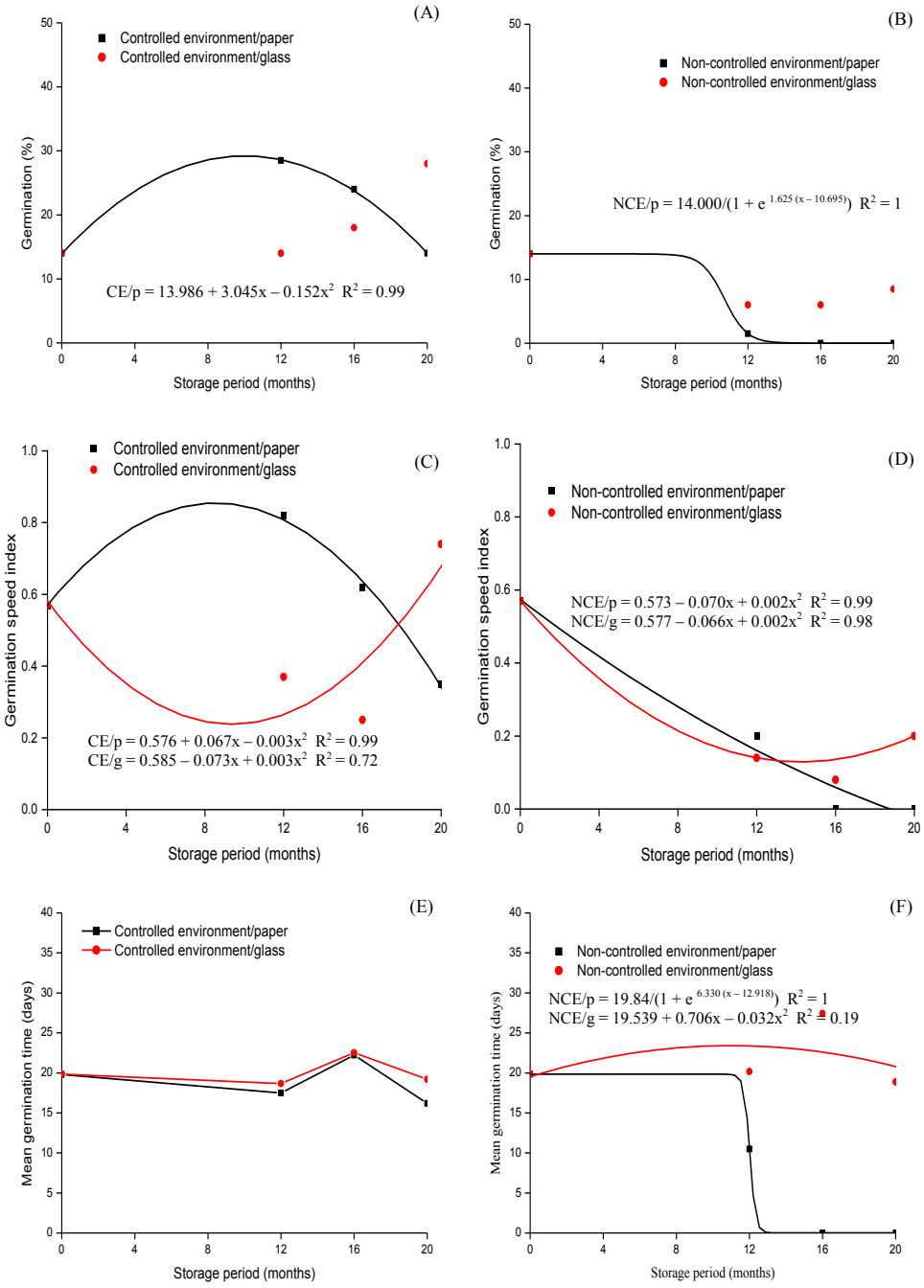

Figure 3. Germination (%), germination speed index (GSI), and mean germination time (MGT) of seeds of *Tacinga inamoena* (K.Schum.) N.P.Taylor & Stuppy packaged in paper bags and glass containers and stored under room temperature and in a refrigerator for twenty months. Germination – controlled environment (A); Germination – non-controlled environment (B); GSI – controlled environment (C); GSI – non-controlled environment (D); MGT – environment controlled (E); MGT – non-controlled environment (F).

The GSI data fitted to the quadratic model in all packaging and conservation conditions evaluated. GSI of seeds stored under controlled environment (Figure 3C) varied from 0.26 to 0.74 (glass containers) and 0.35 to 0.83 (paper bags) over the storage period. GSI of seeds stored under non-controlled environment (Figure 3D) was even lower, varying from 0.08 to 0.21 (glass containers). The GSI of seeds packaged in paper bags and stored under non-controlled environment (Figure 3D) was 0.2 after 12 months of storage, reaching zero in the following periods.

MGT of seeds packaged in paper bags and glass containers were similar when stored under controlled environment (Figure 3E), varying from 16 to 22 days, depending on the storage period and packaging type. MGT of seeds packaged in paper bags and stored under non-controlled environment (Figure 3F) was 10 days after 12 months, i.e., 50% of the maximum value obtained before storage; MGT of seeds packaged in glass containers varied from 18 to 27 days, depending on the storage period.

Attention to factors that increase the probability of deterioration is important, such as air temperature and relative humidity and seed water content during the storage period, considering that one of the primary objectives of storage is to keep the germination percentage at the end of the period as close as possible to the initial (SILVA et al., 2022). Soon after reaching the physiological maturity, the seed entries a progressive stage of natural deterioration, whose intensity is dependent on its genetic constitution and physiological, environmental, and stresses conditions over the storage period, among other factors (COSTA, 2012). Such process involves several biochemical, physiological, and physical degenerative transformations, which culminate in a gradual decrease of germination and vigor until the complete loss of viability. Environments that present low air temperatures and relative humidity are more favorable for conservation of seeds (MARCOS-FILHO, 2015), mainly those that tolerate drying, such as most Cactaceae species, considered orthodox.

The present study on storage of *T. inamoena* seeds also showed the emergence of more than one seedling from a single seed (polyembryony) in some treatments, denoting new paths for the formation and germination of seeds of this species to be investigated.

The results found are essential information for researches on propagation and conservation of seeds of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena* and allows to infer that these species form a persistent seed bank in the short-term. The capacity of these seeds in preserving their viability in low-temperature environments provides a viable option for their conservation in the long-term in artificial seed banks, representing an important strategy for ex situ conservation of seeds of cacti from tropical dry environments. In addition, this information can support the recovery of degraded areas susceptible to desertification in the Caatinga biome.

CONCLUSIONS

Seeds of *Pilosocereus pachycladus* subsp. *pernambucoensis* and *Tacinga inamoena* can be stored under controlled environment (refrigerator; 8 ± 1 °C) when packaged in paper bags or glass containers.

Seeds of *P. pachycladus* subsp. *pernambucoensis* and *T. inamoena* should not be stored under non-controlled environments, either in paper bags or glass containers.

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