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RESEARCH ARTICLE

PHYSIOLOGICAL QUALITY OF MANDACARU SEEDS STORED IN DIFFERENT ENVIRONMENTS AND PACKAGES

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ABSTRACT

The storage of seeds under appropriated conditions of temperature and relative humidity reduces the breathing process and thus decreases the process of deterioration. It was aimed to evaluate the physiological quality of mandacaru seeds stored in two different environments and three packages. The treatments were disposed in a split-plot arrangement, in a completely randomized design with four repetitions. The plots received the combination of two storage environments (cold chamber and natural environment) and three packages (multilayer paper bag, plastic bag and glass), while in the subplots consisted the periods of storage (0, 2, 4 and 6 months). After each storage period, were evaluated the seeds moisture, the percentage, speed index and mean time of germination. The cold chamber is more adequate than the natural environment to storage of mandacaru seeds during six months. In the cold chamber, the three packages are efficient to maintain the physiological quality of mandacaru seeds. In the natural environment, it is recommended to use of permeable packages to remain the viability of mandacaru seeds during six months.

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INTRODUCTION

The knowledge about the relations among the storage temperature, air relative humidity and seed moisture are essentials to the development of seed storage protocols (Merrit *et al.,* 2003). The storage of seeds in adequate conditions of temperature and relative humidity contributes to the maintenance of the physiological potential, reducing the breathing process and the deterioration (Bewley *et al.,* 2013). The oil seeds present smaller storage potential than the starchy seeds, because the lipids have lower chemical stability (Nery *et al.,* 2007; Bewley *et al.,* 2013). So, seed with high oil content should be stored in places with controlled temperature and air relative humidity, avoiding damages to the seeds physiological potential. These conditions prevent degenerative changes on the enzyme activity and loss of membrane integrity, mainly, due to lipids peroxidation (Graham, 2008).

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Studies about the germination and viability of cacti seeds from Brazilian Northeast are scarce, however some researches were realized, revealing some particularities of cacti species, as *Stenocereus queretaroensis* Weber (Barrera and Nobel, 2003), *Hylocereus setaceus* (Salm-Dick ex DC.) Ralf Bauer (Simão *et al*. 2007), *Denmoza rhodacantha* (Salm-Dyck) Britton & Rose (MÉNDEZ, 2007), *Trichocereus terscheckii* (Ortega-Baes and Rojas-Aréchiga, 2007), *Cereus fernambucensis* Lem., *Coleocephalocereus fluminensis* (Miq.) Backeb., *Pilosocereus arrabidae* (Lem.) Byles & Rowley and *Pilosocereus ulei* (K. Schum.) Byles & Rowley (Almeida *et al*. 2009), *Pilosocereus pachycladus* (ABUD *et al*., 2010a), *Pilosocereus gounellei* Ritter (Abud *et al.,* 2012a, 2012b), *Cereus jamacaru* L. (Abud *et al.,* 2013; Alencar *et al.,* 2012a; 2012b). About the conservation and viability of cacti seeds little information are found in the literature. Goldínez-Alvarez (2003) told that there are little information's about the viability of cacti seeds for long periods, as about controlled conditions as about the development of a seed bank in the soil. Following this thought line, Andrade *et al*. (2005) evaluated different storage conditions, such as natural environment, dry chamber (16-18

ºC e 60% RH) and cold chamber (10 ºC and 70% RH) in red pitaya [*Hylocereus undatus* (Haw.) Britton & Rose] and they found that the cold chamber was the best condition for the conservation of seeds physiological quality. Flores-Martinez *et al*. (2008) evaluated the germination of *Mammillaria huitzilopochtli* seeds under controlled conditions and they found that the germination decreases during the storage, which indicates that this specie can develop a temporary seed bank in the soil, for at least one year. Veiga-Barbosa *et al*. (2010) evaluated the germination and cryopreservation of many species of cacti from Brazilian Northeast and they told that the cryopreservation can be an efficient storage method, because they did not find damage on the germination and the seedlings did not present morphologic abnormality. Information about the viability and vigor of cacti during storage are scarce. In front of this, the objective of the present work was to evaluate the physiological quality of mandacaru seeds during the storage in two environments and in three packages.

MATERIALS AND METHODS

The mandacaru seeds used in the experiment were obtained of matured fruits, collected from plants existing at the Experimental Farm Vale do Curu, Federal University of Ceara (UFC), located in Pentecoste, State of Ceara, Brazil. After the harvest, the fruits were packed in plastic bags and transported to the Laboratory of Seeds Analysis (UFC), in Fortaleza, Ceara, where the experiment was carried out. The treatments were disposed in a split-plot arrangement, in a completely randomized design with four repetitions. At the parcels, were randomized the combination of two storage environments (cold chamber – 10 ºC and 60% RH; natural environment – 26.6 ºC and 76.9% RH) and three types of packages (permeable, represented by multilayer paper bag; semi-permeable, represented by plastic bag; and impermeable, represented by glass), while at the subplots were arranged the storage periods (0, 2, 4 and 6 months). Each experimental unity received 5 g of seeds, in individual containers, which remained sealed until each evaluation.

The meteorological data concerning to the temperature and relative humidity during the experimental period, in Fortaleza, Ceara, Brazil, were gave by the Meteorological Station (UFC), located at Pici Campus (Figure 1). The seed moisture, obtained for characterize the seeds during the storage, was performed with two samples of 0.5 g of each treatment were packed in aluminum packs in an oven with air circulation, regulated to 105 ± 3 °C for 24 h, according to rules for seed testing (Brasil, 2009). To evaluate the germination, the seeds were sowed in Petri dishes, with 14 cm of diameter, on two filter-papers, humidified with distilled water in a proportion of 2.5 times the paper weight. Were considered germinated the seeds that originated seedling with root equal or bigger than 1 mm. The Petri dishes were put in BOD chambers regulated to 25 ºC (Alencar *et al.,* 2012b), under photoperiod of 16 h of dark and 8 h of light. To verify the effect of the treatments, the germinated seeds were counted daily until the 16th day after the sowing, determined in previous tests. Thus, the following variable were obtained: germination percentage (GP) – realized through the counting of normal seedling of each experimental unit in the last counting, the results were expressed in percentage; speed of germination (SG) – realized through of daily counting, according to the methodology recommended by Maguire (1962); mean time of germination (MTG) – realized through of daily counting, according to the methodology proposed by Labouriau (1983), the results were expressed in days. The variables were submitted to the variance analysis and the means were submitted to the polynomial regression.

RESULTS AND DISCUSSION

It is observed that seed moisture remained between 9 and 13% (Table 1). Generally, the orthodox seeds should be maintained with moisture around 10 to 12% to the storage during six to eight months, and lower values are indicated to species rich in lipid reserves (Marcos Filho, 2005), as observed in many cacti species (Alencar *et al.,* 2012a). The seeds stored in cold chamber in the three types of packages evaluated presented exchange minimal of moisture between the environment and the seeds, because the relative humidity at the cold chamber remained constant, around 60% RH, in all the storage period (Table 1).

Table 1. Moisture (%) of mandacaru seeds packed in three types of packages and stored in two environments during six months

Environment	Package	Months			
		0	2	4	6
Cold chamber	Multilayer Paper bag	10.0	9.6	11.9	9.4
	Plastic bag	10.9	10.9	11.9	11.7
	Glass	12.0	11.8	10.3	12.5
Natural environment	Multilayer Paper bag	9.0	8.7	10.2	9.1
	Plastic bag	12.9	12.4	11.4	10.7
	Glass	12.0	12.1	12.5	12.3

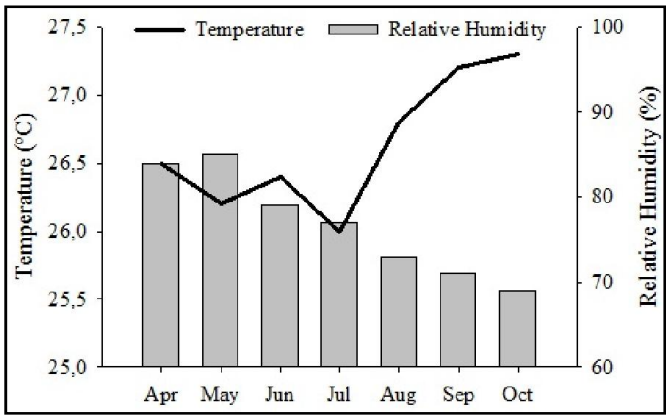

Figure 1. Monthly averages for temperature (°C) and relative humidity (%) recorded in Fortaleza-CE

The cold chamber is a propitious environment to conserve seeds, because made possible the control of the temperature and of the relative humidity, considering that maintained the physiological seed quality high during the entire period of storage. In the natural environment, without control of temperature and relative humidity, was observed that the multilayer paper bag presented small variations in the seed moisture during the storage, standing around 9.2%. According to Marcos Filho (2005) this moisture is inserted of an ideal limit for oil seeds. Similar behavior was observed to plastic bag, whose seeds moisture remained around 11.9% (Table 1).

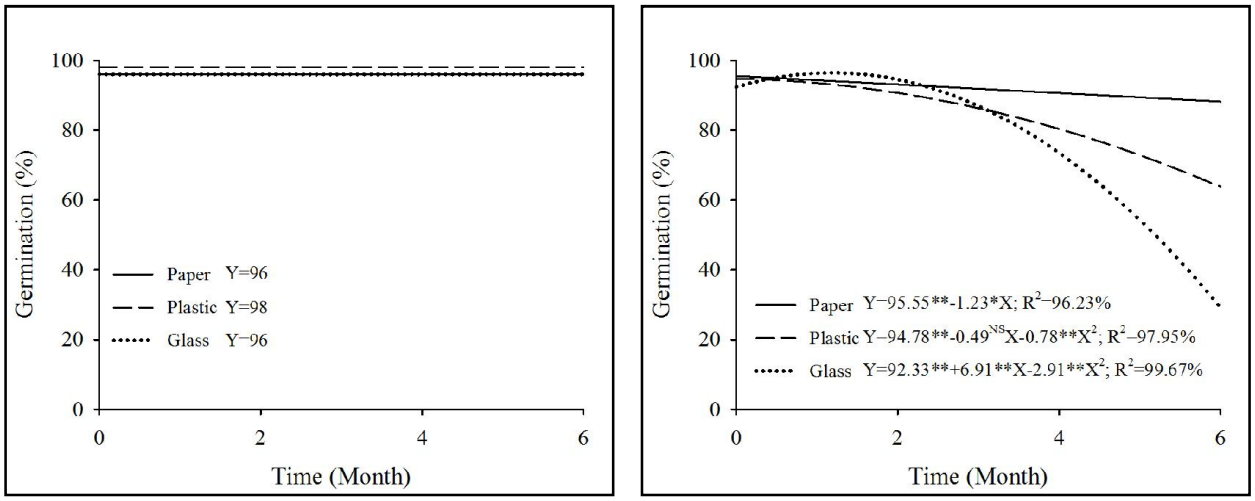

Figure 2. Germination percentage of mandacaru seeds packed in three types of package and stored in cold chamber (A) and in natural environment (B) during six months

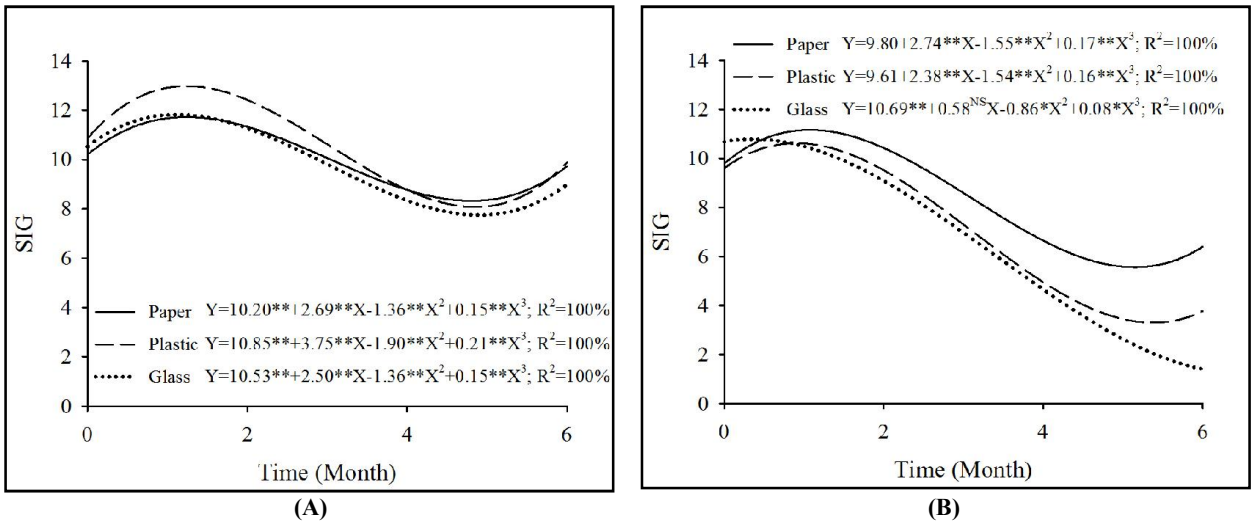

Figure 3. Speed of germination (SG) of mandacaru seeds packed in three types of packages and stored in cold chamber (A) and in natural environment (B) during six months

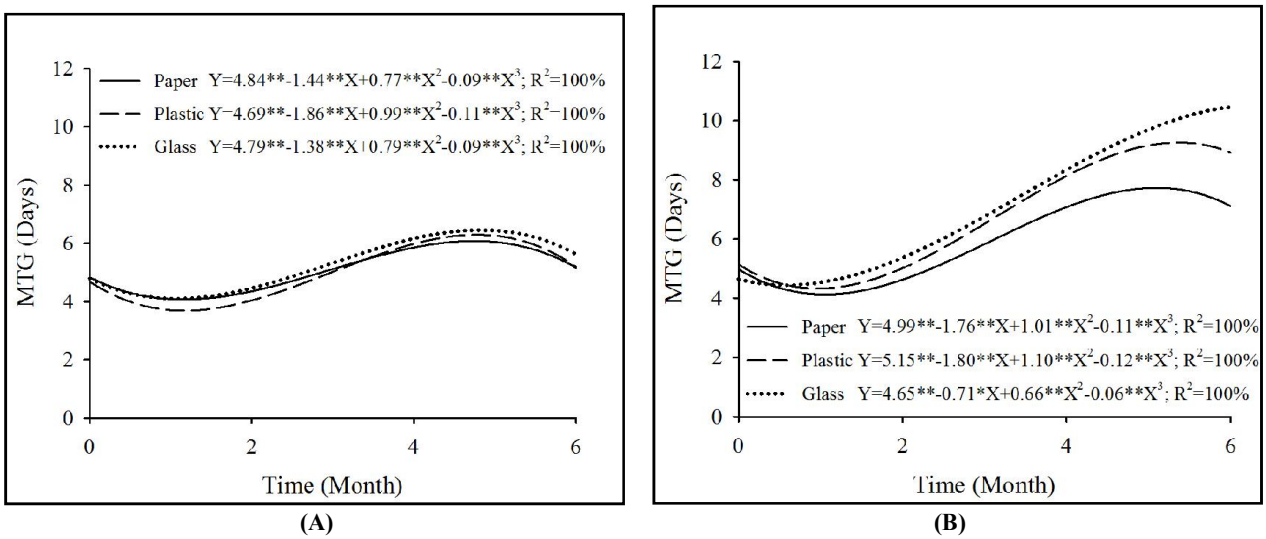

Figure 4. Mean time of germination (MTG) of mandacaru seeds packed in three types of package and stored in cold chamber (A) and in natural environment (B) during six months

At the end of six months of storage, it was verified that the seeds packed in glass presented higher moisture, with 12.3%, followed for the plastic bag, with 10.7%, and multilayer paper bag, with 9.1% (Table 1). Bewley *et al.* (2013) affirm that the deterioration process is faster when the seeds with moisture above 10% are stored in impermeable packages, under tropical weather conditions. The percentage of germination of the seeds stored in the cold chamber remained constant, with means higher than 96% in all the storage period and in all the packages tested (Figure 2A). The seeds packed in plastic bag had the highest percentages of germination, remaining a mean equal to 98% until the end of the storage period. To the seeds stored in natural environment (Figure 2B) was observed different behavior for each package tested. It was verified linear adjustment to the percentage of germination of seeds packed in multilayer paper bag and quadratic tendency to the germination of seeds packed in plastic bag and glass.

The percentage of germination of mandacaru seeds packed in multilayer paper bag under natural condition of Fortaleza, decreased to a rate of 1.22% to the month, but with germination above 80% until the end of the experiment. Similar behavior was observed to plastic bag and glass, and the germination until the second month equal to 93 and 92.5%, respectively, from when were observed marked decreases, reaching 28.5% of germination in the glass package at the sixth month of storage. The glass is an impermeable package, thus it prevents the exchange of moisture between the environment and the seeds. The glass stored in natural environment with high variation in the temperature caused the increase of the metabolic activities and of the deterioration of seeds, presenting a marked decrease in the seeds viability. The reduction observed in the germination of mandacaru seeds from second month during storage can be justified by production of reactive oxygen species (ROS), changing the structure of enzymes of the antioxidant complex, thus a higher decrease of the seed viability is observed (Graham, 2008). About the speed of germination of mandacaru seeds (Figure 3), was observed cubic adjustment in all the treatments. In cold chamber, was verified that until the second month, the plastic bag presented the highest speed. At the end of the experiment, it was found that the seeds packed in multilayer paper bag and plastic bag with speeds equals to 9.7 and 9.9 (Figure 3A). It was observed that the seeds stored in multilayer paper bag presented smaller variation to this speed, with values between 10.2 and 9.7.

To the packages stored in natural environment was verified a marked loss of vigor, expressed by the speed of germination (Figure 3B). It was found that the multilayer paper bag presented highest speed of germination, equal to 6.4, at the sixth month. To the glass, it was verified a decrease in this variable since the beginning of the experiment, presenting initially speed equal to 10.7, and after six months of storage, the speed was 1.4. It was observed, that at the natural environment, the speed of germination, as well as the percentage (Figure 2B), was more affected in the impermeable package. This result can be explained by the fact of the deterioration of the seeds reserves occur faster when stored in impermeable packages under tropical conditions (Carvalho and Nakagawa, 2012). Besides this, in the Table 1, it was verified that to seeds stored in this package the moisture was remained above 10%, during all the storage period, with average of 12.2%. Carvalho and Nakagawa (2012) affirm that this condition accelerates the deterioration process. In the Figure 1, can be observed that in Fortaleza, from July to October, had an increase in the temperature and a decrease in the relative humidity. These conditions were favorable to reduction of the physiological quality of seeds. This result suggests that the cold chamber is an adequate environment to storage mandacaru seeds during six months, keeping high the seeds physiological quality, as was observed through of the percentage (Figure 2A) and of the speed of germination (Figure 3A). According to Marcos Filho (2005), the slow speed of germination is an indicative of low physiological potential, being one of the most evident manifestations of the deteriorative process.

All treatments studied presented cubic tendency for mean time of germination (Figure 4). At cold chamber, it was found similar behavior among the packages, perceiving that from the beginning to the second month there was a short reduction in this variable, observing increase in the mean time of germination until the sixth month. It was observed that the seeds stored at cold chamber remained low mean time of germination. Initially, the seeds needed 4.8, 4.7 and 4.8 days to express the maximal germination and, at the end of six months of storage, it was necessary 5.2, 5.2 and 5.6 days for the seeds stored in multilayer paper bag, plastic bag and glass, respectively (Figure 4A). To the seeds stored at natural environment, the increase in the mean time of germination was very expressive. Initially, to the seeds stored in glass was verified that the seeds needed 4.6 days to express maximal germination and, after six months of storage, was necessary 10.5 days (Figure 4B). At this environment, the glass package provided the shortest germination rate (Figure 2B) and speed index of germination (Figure 3B), increasing markedly the mean time of germination until the sixth month of storage (Figure 4B). Thus, the glass package is not recommended to the storage of mandacaru seeds. Azevedo *et al.* (2003), evaluating the influence of the package and of the storage conditions under the vigor of sesame seeds, found contrary results, where impermeable packages were more adequate to conserve the vigor of seeds for six months.

Conclusions

The physiology quality of seeds is maintained until two months of storage, in every conditions. Thereafter, it's affected by packing and environment during in storage. The cold chamber is more adequate than the natural environment to storage mandacaru seeds during six months. In cold chamber, the three packages studied are efficient to remain the physiological quality of mandacaru seeds. In natural environment, it is recommended to use of permeable packages for remain the viability of mandacaru seeds during six months.

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