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Temperature requirements for seed germination of *Pereskia aculeata* and *Pereskia grandifolia*

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A B S T R A C T

Pereskia aculeata and *Pereskia grandifolia* have been studied widely due to their high nutritional and therapeutic values. However, little is known about the biological requirements of their seeds for the various germination factors. Thus, this experiment aimed to evaluate the thermal effects on the germination of these species at the temperatures of 24 °C, 27 °C, 30 °C, 33 °C and 36 °C. After verification of the existence of differences in the performance of germination, a non-linear regression was carried out, relating the germination to temperature and identifying its point of maximum efficiency. We found that the lowest synchronization indexes of germination were observed close to 30 °C. The best germination response of the *P. aculeata* and *P. grandifolia* was observed at 30 °C and 33 °C, respectively, with greater germination strength and fewer days to attain 63.21% of germinations. The results obtained from the germination of *P. aculeata* and *P. grandifolia* can be described by the Weindull distribution model with three parameters, as proposed by Carneiro and Guedes (1992).

1. Introduction

The genus *Pereskia* is considered the least advanced of the Cactaceae family; it contains 17 species with two sub groups, mainly distributed in the regions between Brazil and Mexico (Sharif et al., 2013, Harlev et al., 2012).

Pereskia aculeata leaves are considered to be a nutritional supplement due to their protein content, fibers, iron, calcium and minerals (Kinupp and Barros, 2007; Martinevski et al., 2013; Carvalho et al., 2014). This species is used as a vegetable and has edible and succulent leaves that can be used in various preparations such as flours, salads, stews, pies and pasta (Brasil, 2010; Martinevski et al., 2013). *Pereskia grandifolia* is known for its medicinal, edible and ornamental uses (Abdelwahab, 2013; Sharif et al. 2013). The leaves of these species are traditionally used in the treatment of cancer, hypertension, diabetes and associated diseases, such as rheumatism and inflammation (Harlev et al., 2012; Sharif et al. 2013).

Pereskia grandifolia and *Pereskia aculeata* are perennial plants that have mucilaginous leaves and differ in the color of their flowers, the *Pereskia grandifolia* flower being pink and the *Pereskia aculeata* being white (Kinupp and Lorenzi, 2014). They produce fruits with few seeds that are eaten and dispersed by birds. The propagation of these cacti can be performed sexually or asexually, although the first is a little used method, due to the scarcity of information and expertise about such propagation. Despite the production time being slower in sexual propagation, plants with desirable morphological characteristics are needed to ensure sustainable cultivation and identify the existing genetic diversity in these species (Gibson and Nobel, 1990).

The ideal conditions of germination of many species of cacti are not well known. According to Rojas-Arechiga and Vazquez-Yanes (2000), among the main environmental factors affecting the germination of cactus are light, water availability and temperature. According to Rojas-Arechiga et al. (1997), globular cacti are positive photoblastic and columnar cacti can be positive or neutral photoblastic. This is due to the climatic conditions that prevail during seed development that promote a maternal effect, thereby creating different light requirements. According to Rojas-Arechiga and Vazquez-Yanes (2000), small seeds and positive photoblastic, such as the seeds of some species of cactaceae that need light to germinate, may have reduced germination when they do not receive sufficient amounts of light to activate the germination process. The water availability is also one of the abiotic factors contributing to seed germination and establishment of plants. Many cactus species germinate even in low availability of water. Such characteristic demonstrates a high tolerance to water deficits during the development phase, as observable in *Cereus jamacaru* DC seeds. (Subspecies jamacaru; Cactaceae) (Rito et al., 2009).

With regards to temperature, most species of cacti respond

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positively to a wide temperature range (Rojas-Arechiga and Vazquez-Yanes, 2000). In some studies, the optimum temperature for germination of cactus was found to be around 25 °C and the most favorable temperature range varying from 15 °C for columnar cacti to 33 °C for *Pereskia aculeta* (Rojas-Arechiga and Vazquez-Yanes, 2000; De La Barrera and Nobel, 2003). A decrease in the temperature delays the rate of metabolic activities, to the point (minimal temperature) that invalidates the development phases, such as germination. By increasing the temperature, the metabolic speed increases to an optimal temperature, from which it reduces until the germination process ends again at a maximum temperature (Trudgill et al., 2005).

According to Castro et al. (2004), germination occurs at a specific thermal rate and, in this way, the temperature is the determining factor for germination and is directly associated with ecological characteristics of species.

These characteristics are interesting not only for physiologists and for seed technicians, but also for ecologists, since it is possible to foretell the degree of success of the species, based on its capacity to produce seeds and distribute germination through time, allowing for the capture in the environment of part of the formed seedlings (Ranal and Santana, 2006).

In order to provide information about germination requirements we studied the effect of temperature in two species of the *Pereskia* genus using the maximum expression of germination power.

2. Material and methods

The experiment was conducted at the Laboratory of Biotechnology, at the Department of Horticulture and Silviculture of the Faculty of Agronomy of the Federal University of Rio Grande do Sul. 165 fruits of the *Pereskia grandifolia* were collected from a single plant and 228 fruits of the *Pereskia aculeata* were collected from two plants on a farm in the city of Porto Alegre (30S 13′ 14.00″ 51W 04′ 30.07″).

The seeds were washed and stored in water for 24 h at room temperature. After this period, they were disinfected for 30 s in a solution containing 20% sodium hypochlorite as per the norms of the Rules for Seed Analysis (Brasil, 2009).

The optimal thermal conditions were determined using five constant temperatures of 24 °C, 27 °C, 30 °C, 33 °C and 36 °C under 8 h of light and 16 h of darkness. Light was provided by fluorescent bulbs located inside the germinators. We evaluated the following traits: germination using four replications sewed onto two sheets of blotting paper, moistened with distilled water at 2.5 times the weight of dry paper. The same amount of water was added every day until the end of the experiment. The number of plants that had germinated was counted daily over a period of 21 days, whereby germination was considered to have occurred when they had developed a primary root greater than or equal to 2 mm.

To identify if there are differences between the percentage of plants that germinated, average number of days and entropy, we calculated these indicators using the formulas proposed by Labouriau and Valadares (1976), for subsequent application of Analysis of Variance:

– Percentage germination:

$$G = \left(\frac{N}{A}\right) \cdot 100$$

where: G=percentage germination; N=number of germinated seeds; A=total number of seeds submitted to germination.

– Average germination time:

$$t = \frac{(\sum_{i=1}^{k} ni \cdot ti)}{\sum_{i=1}^{k} ni}$$

where: t=average incubation time; ni=number of seeds that germinated daily; ti=incubation time (days).

– Average germination rate:

$$R = 1/T$$

where: R=average germination rate; t=average germination time

– Relative germination frequency:

$$Fr = \frac{ni}{\sum_{i=1}^{k} ni}$$

where: Fr=relative germination frequency; ni=number of seeds that germinated daily; Σni=total number of germinated seeds.

The entropy of frequency distribution of seed germination was calculated using the following formula from Labouriau and Pacheco (1978):

$$E = \sum_{i=1}^{k} fi \cdot \log_2 fi$$

where: E=entropy; fi=relative germination frequency; $\log_2$=base-2 logarithm.

Having calculated the indicators, we applied Analysis of Variance (ANOVA) to see if there was a significant difference between how average number of germinations (G), germination speeds (S) and entropy (E) values, at different temperatures. The mathematical model applied in the analyses was represented by: Yijk=μ+Ti+εijk; where Yijk=independent variable (germination percentage, germination speed, germination speed index, germination frequency and germination informational entropy); μ=average of all observations; Ti=effect of tempertaure i=24 °C, 27 °C, 30 °C, 33 °C and 36 °C; εijk=random error associated with every observation ij. It is assumed that εijk∼NID (0,s2). Once significant results have been identified, we will complement the analysis with the Tukey test at 5%.

The germination response at different temperatures was evaluated along with the relationship between temperature and index of germination using the parameters of Labouriau and Valadares (1976), and the parameter for Weibull distribution, as suggested by Carneiro and Guedes (1992):

$$Gi = M\left(1 - e^{-\left(\frac{ti}{b}\right)^c}\right)$$

Regarding the coefficients, according to Carneiro and Guedes (1992), M (average maximum germination observed in repeats) is derived from experimental data, and ti represents the number of days of the experiment. B represents the time required for obtaining 63.21% of the maximum germination, being called the scale parameter of Weibull distribution. OC is the dispersion of the data in time, and is called a shape parameter. Both were estimated by iterative processes in the non-linear regression.

The experimental design was completely random, with four replications per treatment. Each species was analyzed separately. The data were submitted to analysis of variance using the routines PROC GLM and PROC NLIN for the Weibull distribution in the Statistical Analysis System™ program, version 9.1.3 (SAS Institute, Inc.).

3. Results and discussion

The *P. aculeata* and *P. grandifolia* seeds germinated at all temperatures in the test (Table 1). All of the *P. aculeata* variables and