Effects of temperature and substrate on the germination of *Hamatocactus setispinus* (Cactaceae) [1]

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ABSTRACT

Cacti are widely used as ornamental plants and seed germination is a major method for preserving genetic diversity. Thus, an experiment was carried out to evaluate the effects of different temperatures and substrates on seed germination of *Hamatocactus setispinus*. Seeds were sown in gerbox boxes containing either germination paper (S1), sand (S2) or vermiculite (S3). After placing the seeds on the substrates, the boxes were kept in germination chambers at 20, 25, 30 and 35° C for 30 days, under a photoperiod of 16 hours. The experiment was in a completely randomized design with four replicates. The speed germination index (SGI), mean germination time (MT) and germination rates (%) were evaluated. The best results were observed at 25º C. The highest SGI (3.94) was observed on seed germination paper, but MT values and germination rates on this substrate did not differ from those obtained on sand. Therefore, both substrates could be used for germination of this cactus species.
Keywords: germination paper, sand, vermiculite, cacti.

RESUMO

Efeito da temperatura e do substrato na germinação de *Hamatocactus setispinus* (Cactaceae)

Cactos são amplamente utilizados como plantas ornamentais e a germinação das sementes é um método importante para a preservação da diversidade genética. Assim, esse estudo foi realizado para avaliar os efeitos de diferentes temperaturas e substratos na germinação de sementes de *Hamatocactus setispinus*. As sementes foram semeadas em caixas gerbox contendo papel de germinação (S1), areia (S2) ou vermiculita (S3). Em seguida, as caixas foram mantidas em câmara de germinação a 20, 25, 30 e 35° C por 30 dias, sob fotoperíodo de 16 horas. O delineamento experimental foi inteiramente casualizado com quatro repetições. O índice de velocidade de germinação (IVG), tempo médio (Tm) e taxas de germinação (%) foram avaliados. Os melhores resultados foram observados a 25º C. O maior IVG (3,94) foi observado em papel de germinação de sementes, porém os valores de Tm e as taxas de germinação neste substrato não diferiram daqueles obtidos utilizando areia. Portanto, ambos os substratos podem ser utilizados para a germinação desta espécie de cactos.
Palavras-chave: papel para germinação, areia, vermiculita, cacto.

1. INTRODUCTION

Cacti, despite known for multiple and diverse uses, are mostly used for ornamental purposes (ROBBINS, 2003). The barrel cactus (*Ferocactus* spp.), the prickly pear cactus (*Opuntia* spp.) and the saguaro cactus (*Carnegiea gigantea*), are examples that, due to their large and showy appearance, are widely used for landscaping projects. Most miniature cacti are grown from seed to supply the local market, but are also exported for indoor decoration (ROBBINS, 2003).

Hamatocactus setispinus, a miniature barrel cactus species, is originally from southern Texas, USA and Coahuila, Nuevo Leon and Tamaulipas, Mexico. It is a globular plant with yellow flowers with reddish base, very small and shriveled seeds, and the fruits are round, red, indehiscent and fleshy at maturity; characteristics that make this species attractive as ornamental (ANDERSON, 2008).

Seed germination is a major method for the propagation of cacti since it allows the preservation of the genetic diversity of populations (ROJAS-ARÉCHIGA and VÁSQUEZ-YANES, 2000), which might help selecting desirable features, such as biomass yield, fruit quality, tolerance to stress-promoting factors, etc (ALTARE et al., 2006).

Seed germination speed, rate and uniformity can be affected by the environmental temperature, the range of which depends on the plant species (TOLEDO and MARCOS FILHO, 1977; CARVALHO and NAKAGAWA, 2000). According to Rojas-Aréchiga and Vásquez-Yanes (2000), extreme environmental temperatures (below 12° C or above 28° C) do not stimulate cacti seed germination. Moreover, for a wide range of cacti genera, the temperature of 20 ± 2° C leads to good germination rates.

Besides other environmental factors, the substrate is also critical for the germination process (BRASIL, 2009). The physical and chemical properties of the substrate, such as porosity, structure, water holding capacity, pH, among others that may enhance or inhibit seed germination, are of major importance (POPINIGIS, 1985).

According to the Brazilian procedures for seed analyses (BRASIL, 2009), the substrates most frequently used for the germination process in the laboratory are germination

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paper, cloth, sand and soil. Although the Brazilian procedures for seed analyses contain information about the conditions for conducting germination test for several species, there is no indication about the species in study yet.

The objective of this research was to evaluate the effect of different substrates and temperatures on the seed germination of *Hamatocactus setispinus*.

2. MATERIALS AND METHODS

Plant material

The seeds were obtained from mature red fruits of *Hamatocactus setispinus* harvested in October 2009, in Maricá-RJ, Brazil. Immediately after harvesting, the fruits were packed in paper bags and transported to the laboratory where they were kept at a temperature of 25 ± 2° C.

Eleven days after harvesting, time taken to mail fruits to the laboratory, the fruits were opened and their seeds were carefully extracted. After removing their mucilage by scratching them on Kraft paper, the seeds were immersed in 10% bleach solution (2.5% active chlorine) for 20 seconds. After the immersion, the solution was drained out, however seeds were not washed again.

Effects of temperature and substrate

The experiment was in a 4 x 3 factorial scheme consisting of four germination chamber temperatures (20, 25, 30 and 35° C) and three substrates (washed and autoclaved sand, two sheets of seed germination paper and vermiculite) in a completely randomized design with four replicates, each one with 50 seeds.

The clean seeds were placed in transparent plastic germination (gerbox) boxes containing either sand, two sheets of germination paper or vermiculite as substrate. The sand was washed and autoclaved at 121° C and 1.5 atm for 2 hours; the two sheets of germination paper were moistened with deionized water at a ratio of 2.5 times the paper dry weight (BRASIL, 2009). The vermiculite was washed several times, soaked in tap water for 24 hours, and then let to dry out at room temperature. The sand and vermiculite were moistened with deionized water until the substrate capacity, at the beginning of the experiment. All substrates were remoistened when necessary during the experimental period to keep the substrate capacity. Subsequently, the boxes containing the seeds were taken to separate germination chambers, where they were kept for 30 days at constant temperatures of 20, 25, 30 and 35° C, under a photoperiod of 16 hours. Seed germination was considered at radicle emission.

The speed of germination index (SGI) was determined with the equation $SGI = G_1/N_1 + G_2/N_2 +...+ G_n/N_n$ where G_1, G_2, ... G_n = number of germinated seeds from the first, second to the last germination count; N_1, N_2, ... N_n = number of days from sowing to first, second to the last germination count, suggested by Maguire (1962); the seed germination rate (%) was obtained by the total percentage of germinated seeds after 30 days; the mean germination time (MT) was estimated as suggested by Edmond and Drapala (1958) by the equation $MT = (G_1T_1 + G_2T_2 + ... G_nT_n)/ (G_1 + G_2 + ...Gn)$ where G_1, G_2 and G_n are the numbers of seeds germinated at T_1, T_2 and T_n time, respectively.

The data were subjected to variance analysis and the means were compared by Tukey test at 5% significance. The germination rate data were transformed to arcsine $(x/100)^{½}$ for statistical analysis.

3. RESULTS AND DISCUSSION

The *Hamatocactus setispinus* seed highest SGI and lowest MT values were observed at 25° C. The lowest SGI values were observed at 35º C and the highest MT values were obtained at 30 and 35º C for all substrates (Table 1). Different results were observed with seeds of *Pilosocereus arrabidae* (MARTINS, 2007), which showed the highest SGI and germination rates at 20° C, whereas seed germination was completely inhibited at 35° C.

Table 1. Speed germination index (SGI) and average germination time (MT) of *Hamatocactus setispinus* seeds on two sheets of germination paper (S1), sand (S2) or vermiculite (S3) under constant temperatures of 20, 25, 30 and 35º C.
Tabela 1. Índice de velocidade de germinação (IVG) e tempo médio de germinação (TM) de sementes de *Hamatocactus setispinus* em duas folhas de papel de germinação (S1), areia (S2) ou vermiculita (S3) sob temperaturas constantes de 20, 25, 30 e 35º C.

	SGI				MT			
	Substrates							
Temperature	S1	S2	S3	Average	S1	S2	S3	Average
20º C	2,18 Ba	1,78 Bb	1,68 Bb	1,88	19,23 Aa	19,00 Ba	20,02 Ba	19,42
25º C	3,94 Aa	3,43 Ab	2,87 Ac	3,41	11,69 Ba	11,20 Ca	13,16 Ca	12,01
30º C	1,92 Ba	1,53 Bb	0,79 Cc	1,41	21,85 Ab	22,29 Ab	27,32 Aa	23,82
35º C	1,36 Ca	0,92 Cb	0,36 Dc	0,88	21,31 Ab	21,35 ABb	26,64 Aa	23,10
Average	2,35	1,91	1,43	1,90	18,52	18,46	21,78	19,59
CV (%)	8,86				7,35			

Upper-case letters compare temperatures and lower-case letters compare substrates. Averages followed by the same letters do not differ significantly at 5% probability by Tukey test.

Seeds of *H. setispinus* germinated on paper showed the highest SGI values at all temperatures, whereas the lowest values were obtained on vermiculite (Table 1). Similar results were reported for *Rhipsalis floccosa* seeds, which showed the lowest SGI values when germinated on vermiculite, although there were no significant differences between the SGI values observed on paper and sand (LONE et al., 2009).

There was no difference among MT values of seeds germinated on different substrates except at 30 and 35º C. At these temperatures vermiculite was the worst substrate leading to the highest MT values**.** Similar results were obtained in a *R. floccosa* experiment, in which the highest MT values were observed when seeds were germinated on vermiculite, at 25º C, and on germination paper (LONE et al., 2009).

The highest germination rate was observed at 25° C, whereas the lowest one was at 35º C, regardless of the substrate (Table 2).

Table 2. Germination rate of *Hamatocactus setispinus* on two sheets of germination paper(S1), sand(S2) or vermiculite(S3) under constant temperatures of 20, 25, 30 and 35º C.
Tabela 2. Taxa de germinação de *Hamatocactus setispinus* em duas folhas de papel de germinação(S1), areia(S2) ou vermiculita(S3) sob temperaturas constantes de 20, 25, 30 e 35º C.

	Germination (%)			
	Substrates			
Temperature	S1	S2	S3	Average
20ºC	67 Ba	64 Aa	64 Aa	66
25ºC	83 Aa	74 Aab	72 Ab	76
30ºC	79 Aa	66 Ab	42 Bc	61
35ºC	52 Ca	36 Bb	18 Cc	34
Average	71	60	49	60
CV (%)	4,69			

Upper-case letters compare temperatures and lower-case letters compare substrates. Averages followed by the same letters do not differ significantly at 5% probability by Tukey test.

Similar results were obtained with *Ferocactus recurvus* and *Echinocactus platyacanthus*, reaching the highest germination rates at 25 °C (ROJAS-ARÉCHIGA et al., 1998). On the other hand, the best germination temperature for *Ferocactus robustus* was 30º C and no differences were observed in germination rates at 20, 25 and 35º C. These cacti, similarly to *Hamatocactus setispinus*, are barrel shaped ones and showed a very similar and relatively high range of germination temperatures, when compared to the range normally found in the literature as reference for columnar cactus (15-30° C). Moreover, Rojas-Aréchiga et al. (1998) point out that barrel cacti seeds are less tolerant to low temperatures than seeds of columnar cacti and suggest that this could be associated with vertical distribution of environmental temperatures during seed development. Therefore, lower temperatures might not stimulate their germination.

There were no significant differences among substrate effects on the seed germination rates at 20° C, but at 25, 30 and 35° C, the seeds on vermiculite had the lowest germination rates, while seeds on germination paper showed the highest ones. The highest germination rate was observed on germination paper and sand at 25º C and 30º C on paper (Table 2). Similarly, for the species *Rhipsalis floccosa* and *Rhipsalis pilocarpa*, seed germination rates on germination paper and sand did not differ at 25º C, but the lowest germination rates were obtained with vermiculite (LONE et al., 2009). However, *Hylocereus undatus* seeds showed the highest germination rate on paper, while there was no difference between values observed either on sand or vermiculite (ANDRADE et al., 2008).

4. CONCLUSIONS

The best temperatures for germination of *H. setispinus* were 25° C. Two sheets of germination paper and sand provided the best results and can be used for germination tests of the species, although the sheets paper are easier for handling than the sand.

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