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SIMÃO, EDSON; NAKAMURA, ADRIANA T.; TAKAKI, MASSANORI

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Germination of *Styrax camporum* Pohl. seeds in response to substrate types, moisture contents and the seed morphology

EDSON SIMÃO^{1,2,4}, ADRIANA T. NAKAMURA³ and MASSANORI TAKAKI²

¹Programa de Pós-Graduação em Biologia Vegetal, Universidade Estadual Paulista, Instituto de Biociências, Campus de Rio Claro, Avenida 24-A, 1515, 13506-900 Bela Vista, Rio Claro, SP, Brasil

²Universidade Estadual Paulista, Instituto de Biociências, Departamento de Botânica, Avenida 24-A, 1515, 13506-900 Bela Vista, Rio Claro, SP, Brasil

³Universidade Federal de Lavras, Departamento de Biologia, Caixa Postal 3037, 37200-000 Lavras, MG, Brasil

⁴Universidade Federal de Uberlândia, Campus Monte Carmelo, Instituto de Ciências Agrárias, Avenida Amazonas s/n, Bloco E Sala 01, Bairro Umuarama, Caixa Postal 593, 38400-902 Uberlândia, MG, Brasil

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ABSTRACT

This study evaluated the contributions of *Styrax camporum* seed morphology (size of seeds, presence or absence of endocarp attached to the seed), different substrates (filter paper, vermiculite, sand and the soils of cerrado s. str., cerrado and a riparian forest), different water potentials (0, -0.1, -0.2, -0.3, -0.4 and -0.5 MPa), light and temperature to seed germination. Seed size did not affect the germination percentage when seeds were sown on vermiculite. Seeds were affected by small variations in the moisture content of the tested substrates, showing a significant decrease in germination under water potentials lower than -0.1 MPa, close to the field capacity of cerrado s. str. soils. At the temperatures of 15 and 20°C, a significant decrease in germination was observed. Thus, the availability of water in cerrado soils associated to temperature modulate the distribution of germination in this species. Seed morphology contributes to the maintenance of seeds in the soil, and the lack of synchrony in seed germination spreads the distribution of germination in time. These peculiarities allow the emergency of seedlings at different time periods and establishment conditions, an adaptative response of *S. camporum* to the cerrado environment.

Key words: cerrado, water stress, morphophysiology, Styracaceae, vermiculite.

INTRODUCTION

One of the main difficulties in management, conservation and recovery practices in cerrado areas is the scarcity of ecophysiological information on their species, especially seed germination responses. Such responses may be crucial to the selection of adapted species. In the cerrado, seeds face adverse conditions of light, temperature, soil

and water availability, imposed by the seasonality of the environment. Thus, the success to occupy the cerrado depends on the recruitment capacity of species in response to adverse factors.

For the germination of a quiescent, viable seed, water must be available for its tissues to rehydrate. Soil moisture at the field capacity usually provides adequate conditions for this process to occur. Germination events may begin under optimum moisture contents or even under high

Correspondence to: Edson Simão
E-mail: simao@iciag.ufu.br

moisture conditions. Under inadequate conditions, germination is not completed (Malavasi 1988), although in some cases it may begin even when water availability is low.

However, water entry and the rate of seed imbibition are conditioned by morphological features, especially by the integument, as well as by seed physiological traits associated to temperature, light and to the substrate water availability. The necessary amount of substrate moisture to trigger germination may vary depending on species and on the characteristics of the substrate on which seeds were dispersed (Andrade et al. 2000). Thereby, some substrate traits must be observed: aeration, structure, water retention capacity and the degree of pathogen infestation (Popiningis 1985), tending to vary from one substrate to the other.

For laboratories, the most used and recommended substrates for the germination of forest seeds are: filter paper, vermiculite and sand. The efficiency of these substrates varies depending on the size and shape of seeds, as well as on temperature (Figliolia et al. 1993, Andrade et al. 2000, Silva and Aguiar 2004).

Thus, a suitable substrate should be capable of maintaining adequate moisture and aeration conditions, avoiding excess water. Excess water could prevent the entry and absorption of oxygen (Figliolia et al. 1993), retarding germination or even causing the embryo death. Similarly, the substrate should be adequate to the morphological features of the seed.

This work objective was to evaluate the contributions of seed morphology, substrate type and water availability to *Styrax camporum* Pohl. (Styracaceae) seed germination under different temperature and light, based on the following hypothesis:

The production of seeds of different sizes in *Styrax camporum* annual yield is an adaptative response of the species to the cerrado environment. This differentiation allows the distribution of

germination of quiescent seeds to spread in time, even when moisture and substrate conditions are ideal to germination.

MATERIALS AND METHODS

The fruits of *Styrax camporum* Pohl., a typical species of open cerrado areas, were collected from March to June 2007, at the Mogi-Guaçu Biological Reserve, São Paulo, Brazil. Several branches were isolated in the plant with a white mosquito net, thereby avoiding their contact with the soil and the consumption by birds.

Fruits were collected during the color change from green to purple, previous to the beginning of seed dispersal, and processed at the Plant Photomorphogenesis Laboratory, at Universidade Estadual Paulista (UNESP), Rio Claro, Brazil. After pulp removal and washing with running water, seeds were shadow-dried at ambient temperature, and then homogeneized to form one batch of seeds. Seeds with approximately 12% of water were stored in a refrigerator at 10°C in sealed glass recipients.

To evaluate the contribution of the substrate to germination, two experiments were conducted: the first used sieved cerrado soils collected at the depth of 0-20 cm at the Mogi-Guaçu Biological Reserve, filter paper and vermiculite; the second used vermiculite and soil from three different regions of the Mogi-Guaçu Biological Reserve: cerrado, cerradão and a Riparian Forest, collected at the same depth of 0-20 cm, after removing leaves and vegetal debris.

The first experiment was conducted at the constant temperature of $25 \pm 2^\circ\text{C}$, under white light obtained with fluorescent lamps ($32.85 \mu\text{mol.m}^{-1}.\text{s}^{-1}$ at the substrate level) or continuous darkness. Four repetitions of 25 seeds per treatment were tested, using germination boxes. The germination percentage was observed at the end of 77 days.

In the second experiment, the three types of soil were tested both at the laboratory and under

two simulated natural conditions; vermiculite was only tested under laboratory conditions. Laboratory conditions consisted of temperatures of $30 \pm 2^{\circ}\text{C}$, and a 12-hour photoperiod. The evaluated soils had their physical characteristics analyzed at the Soil Laboratory of Universidade Federal de São Carlos, at Araras, São Paulo, Brazil.

To simulate field conditions, two greenhouses in the Experimental Garden at UNESP, Rio Claro, were used, one covered with a transparent plastic simulating full sunlight, and the other with the transparent plastic covered by Insulfilm® (SPfilm, Brasil; plastic film 1), simulating under canopy conditions (Simão et al. 2008). Experiments were conducted using 3.8 L citrus vases, which were watered daily. Minimum and maximum temperatures were recorded. The position of the vases was modified at each evaluation. Four vases with 25 seeds each were used for each treatment. In all experiments described above, seeds were considered germinated when cotyledons were seen above the soil surface.

To evaluate the effect of water availability in the substrate, experiments were conducted in BOD incubators at 20, 25 or 30°C , under light or darkness conditions. The following water potentials were tested: 0, -0.1, -0.2, -0.3, -0.4 and -0.5 MPa, obtained with polyethyleneglycol (PEG - 6000) (Villela et al. 1991). Here, the used substrate was thick sand treated with 0.1% chloridric acid for 24h, followed by washing with running water in order to eliminate the acid. Next, the substrate was subjected to a 0.1% sodium hypochloride solution, followed once again by washing with running water.

The experiments on water availability were conducted in Petri dishes, 50 mm in diameter. For each plate, 40 mL of sand and 20 mL of each test-solution were used. The level of the solutions was marked in the Petri dishes, so that initial levels could be completed with distilled water, after evaporation. Plates were placed inside germination boxes to minimize water loss. To evaluate germination, germinated seeds were counted weekly and removed

from plates. For treatments under the darkness condition, plates were put inside black germination boxes and countings were undertaken using a security green light (Amaral-Baroli and Takaki 2001). Seeds whose roots reached one milimeter in length, as well as a geotropic curvature, were considered germinated. At the end of the experiment, apparently viable seeds were subjected to the 0.1% Tetrazolium test (Rodrigues and Santos 1988).

To evaluate the effect of seed size on germination, a seed lot was separated using a Granutest® sieve, with an aperture of 4 mm. Thereby, two groups of seeds were obtained: one with small seeds (up to 4 mm) and another with large ones (more than 4 mm of diameter); both had their pericarps removed. In this experiment, two control groups with seeds that were not selected by size were also evaluated, one with and one without endocarp. For this evaluation vermiculite was used as substrate. Transparent and black germination boxes were used to simulate the light and darkness conditions, respectively. Four repetitions of 25 seeds were used for each treatment. Germination consisted of the emission of a primary root with approximate 1 mm of length and a geotropic curvature.

The percentage, mean time, mean rate, relative frequency and synchronization index of germination were calculated according to Labouriau and Agudo (1987). An Analysis of Variance and the Tukey test were undertaken, considering $\alpha = 0.05$. Residue normality and variance homogeneity were previously tested. The data on the germination percentage testing 'seed size' and 'water potentials' was transformed to arc sine $\sqrt{p/100}$ before analysis (Sokal and Rohlf 1981). Transformed data with an abnormal distribution was subjected to the non-parametric Kruskal-Wallis test, followed by the Nemenyi test (Zar 1999).

RESULTS AND DISCUSSION

In the first experiment testing the effect of substrate types on *Styrax camporum* seed germination, it was shown that vermiculite was the most efficient in the

promotion of germination ($94.3 \pm 2.3\%$); responses were not significantly different when the light and darkness conditions were compared ($\alpha \leq 0.05$). However, a significant difference was observed between vermiculite and the other treatments (cerrado soil and filter paper), according to the Tukey test.

The cerrado soil and filter paper resulted in the lowest germination percentages, which did not differ between one another under the light condition ($55.1 \pm 3.6\%$ for the cerrado soil; $52.0 \pm 7.5\%$ for filter paper) but did so under the darkness condition ($53.3 \pm 3.6\%$ for the cerrado soil; $34.4 \pm 3.1\%$ for filter paper).

Results indicate that substrates control the fate of dispersed seeds, as much as climatic factors. Thus, seeds have to reach favorable substrates or soils with adequate moisture conditions and available water, light and temperature. Soil traits such as texture, depth, aeration, temperature and water content, isolated or in combination, may restrict germination or even favor the maintenance of viable seeds in the environment.

The thickening of the integument of *S. camporum* seeds, their rounded shape and the presence of specific regions that allow water entry into the seed (raphe and micropyle) all restrict the imbibition process. On filter paper, the contact area between the seed and the substrate is limited. Thereby, the position at which seeds lay on the substrate could prevent the contact of these regions with water, a possible explanation for the low germinability of this species on filter paper.

For the cerrado soil, low germination percentages may be attributed to soil compaction, with a subsequent reduction in aeration (Figliolia et al. 1993). In addition, the presence of pathogens in cerrado soils may also influence germination, as suggested for *S. ferrugineus* seeds (Barbosa et al. 1985). This hypothesis is corroborated in the present study, since a darkening of the seed integument and the deterioration of both the endosperm and the embryo were observed shortly after the beginning of the experiment. The non-viability of seeds sown

on cerrado soils was also corroborated through the Tetrazolium test. Results indicate that even under ideal conditions, the substrate is crucial in the germination process.

In the second experiment testing the effect of different substrates on germination, once again the best responses were seen with vermiculite, at the constant temperature of 30°C (Table I, Figure 1a). In turn, for the cerrado soil, germination was higher and faster both under the fluctuating laboratory temperatures of greenhouses, as well as at the constant temperature of 30°C .

During the experiments, the greatest temperature amplitude was recorded under the full sunlight condition. Under this condition, maximum temperature varied from 31.5 to 34.8°C ; for minimal temperature, values of 16.1 to 18.6°C were seen. For the shadow-simulated environment using insulfilm, a maximum of 30.1 to 33.5°C and a minimum of 19.3 to 21.2°C were recorded. This could be attributed to the insulfilm, which provides an environment that filters direct sunlight (Garcia and Smith 1993, Simão et al. 2008). The effect of the interaction between 'substrate type' and 'incubation temperature' on seed germination has been reported by several investigators (Andrade et al. 2000, Silva and Aguiar 2004).

The temperature and moisture of substrates may be influenced by the incidence of direct light, which causes a greater temperature variation at the soil level, resulting in water loss to the atmosphere. In shadowed environments, the conditions found by seeds at the substrate level are quite different from those found under the full sunlight condition of open areas, as seen in the cerrado, where temperature amplitude and variation, and light intensity, are high (Eiten 1972). Additionally, the rain seasonality of cerrado areas influences water availability at the soil superficial layers, where most viable seeds are (Sasaki 1999).

The parameters mean time, rate, relative frequency and the synchronization index of germination (Table I, Figures 1b and 2) all showed that

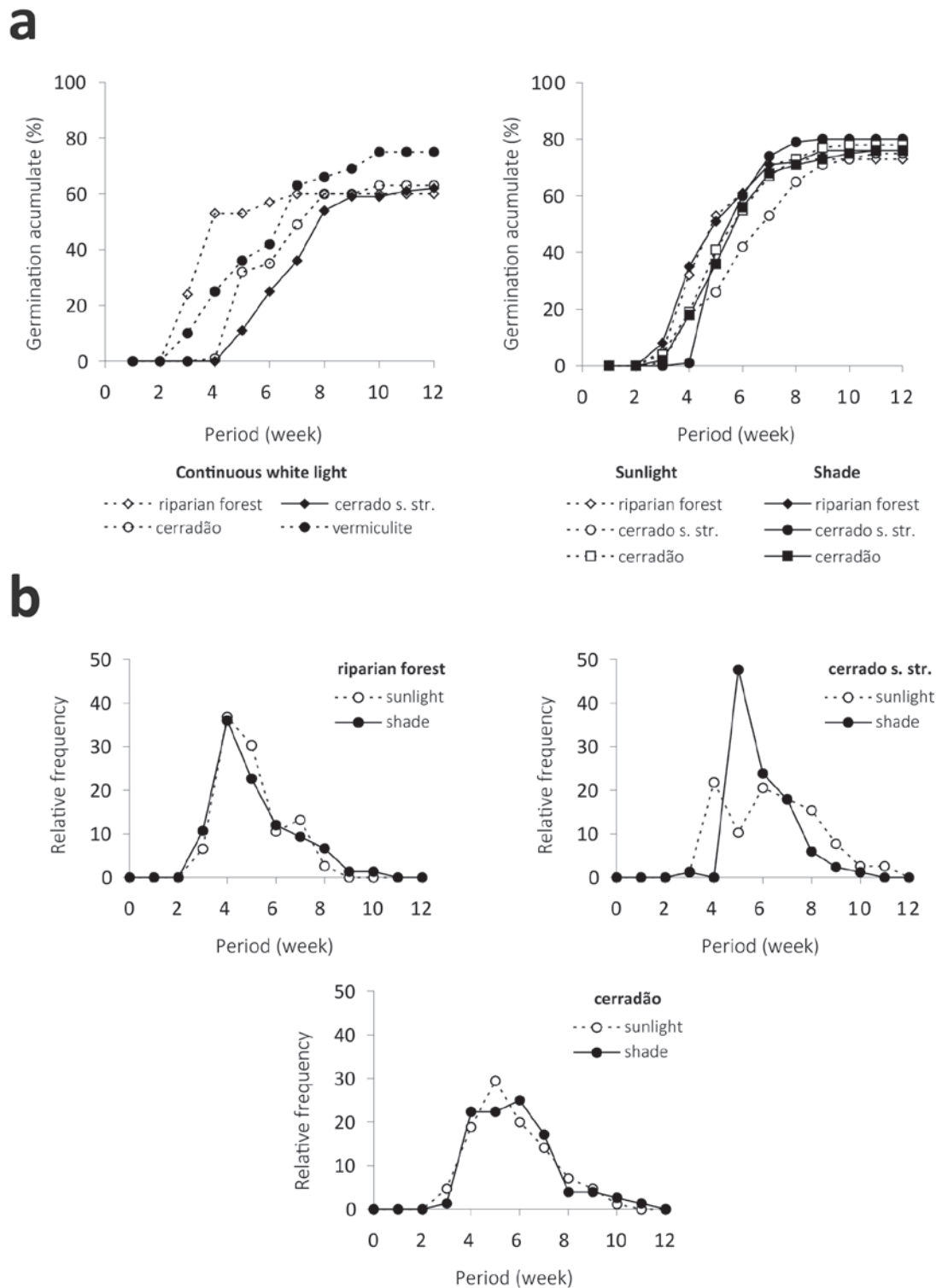


Figure 1 - a) Accumulated germination percentages of *S. camporum* seeds under three experimental conditions: laboratory (left), full sunlight and shadow (right). **b)** Polygons of the relative germination frequencies of *S. camporum* seeds under different light conditions (sunlight and shadow) and three substrate types (riparian forest, cerrado s. str. and cerradão), simulating natural light and the fluctuation of temperature.

TABLE I
Mean time, mean rate and synchronization index of germination of *Styrax camporum* seeds, under three experimental conditions and different substrate types.

* Means (\pm standard error) followed by distinct letters indicate significant differences according to the Tukey test.

Evaluated conditions	Mean time (days)	Mean germination rate (1/time)	Mean synchronization index (bits)
a) Laboratory			
Vermiculite	34.2 \pm 1.42 ab*	0.029 \pm 0.001 a	2.45 \pm 0.14 c
Riparian forest	27.3 \pm 0.62 a	0.037 \pm 0.001 b	1.43 \pm 0.14 a
Cerrado s. str.	35.6 \pm 1.07 b	0.028 \pm 0.001 b	2.13 \pm 0.12 bc
Cerradão	37.0 \pm 1.32 b	0.027 \pm 0.001 b	1.70 \pm 0.15 ab
b) Full sunlight (greenhouse)			
Riparian forest	34.6 \pm 0.87 a	0.029 \pm 0.001 a	2.05 \pm 0.10 a
Cerrado s. str.	44.8 \pm 1.46 b	0.022 \pm 0.001 b	2.28 \pm 0.27 a
Cerradão	39.8 \pm 1.54 ab	0.025 \pm 0.001 b	2.35 \pm 0.15 a
c) Plastic film (greenhouse)			
Riparian forest	34.5 \pm 2.07 a	0.029 \pm 0.002 a	2.12 \pm 0.13 a
Cerrado s. str.	41.3 \pm 0.87 b	0.024 \pm 0.001 b	1.80 \pm 0.20 a
Cerradão	40.6 \pm 1.81 ab	0.025 \pm 0.001 ab	2.25 \pm 0.09 a

the distribution and synchronization of germination differed depending on the tested substrates. Values were more pronounced for the cerrado soil, both at fluctuating (Figure 1b) and at constant (Figure 2) temperatures, in which light conditions also influenced the distribution of germination.

The lowest synchronization index and the greatest rate of germination were observed when the Riparian Forest soil was used. When subjected to daily fluctuating temperatures, seeds sown on this soil showed the best germination responses, followed by the cerradão soil. Yet, the synchronization indexes were not different for these two types of soil. The same responses were seen under the full sunlight and shadow-simulated conditions (Table I).

Such responses may be attributed to the different physical composition of the substrates, especially their organic matter and clay contents, components known for their ability to retain water in the soil.

The cerrado and cerradão soils have virtually no organic matter in their composition, presenting low

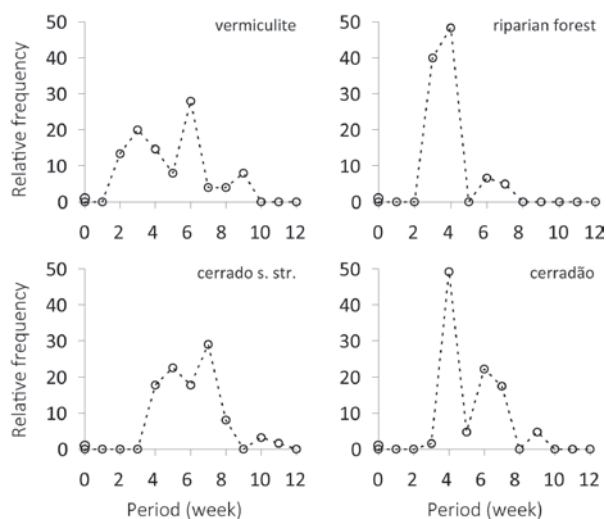


Fig. 2 - Polygons of the relative germination frequencies of *S. camporum* seeds on different substrates, at 30°C and under a 12-hour photoperiod.

clay contents (17 and 15%, respectively) and high amounts of thick sand (47 and 60%); sand sums 70 to 75% of the total composition of such soils. These traits favor the drainage and infiltration of water to the deeper layers of the soil. In turn, the Riparian

Forest soil presented 29% of organic matter, 38% of clay and only 8% of sand, which may have allowed a greater water retention and availability to seeds, producing the best germination responses.

In addition to rapid drainage, higher sand contents may contribute to an increase in temperature due to the easy drying of the substrate superficial layers, especially under the full sunlight condition. Thereby, seeds may be subjected to different moisture and temperature conditions depending on their position and depth in the substrate. These differences are possibly small, but enough to induce, accelerate or restrict the germination process.

Thus, the optimum condition for each seed to germinate (considering the same substrate) may have varied during the experiments, especially the longer ones. That would explain the asynchronous distribution of germination of *S. camporum* seeds in time, as observed in this study and for other cerrado species, such as *Styrax ferrugineus* (Barbosa et al. 1985), *Vochysia tucanorum* (Barbosa et al. 1999) and *Annona crassiflora* (Silva et al. 2007).

In cerrado areas, these substrate variations take place during the interval of one day, throughout months and the year, due to the climatic seasonality seen in this environment (Kanegae et al. 2000). Such a seasonality is more pronounced during the dry season, which coincides with the dispersal period of *S. camporum* seeds.

Thereby, the distribution of germination in *S. camporum* and in other species of this genus such as *S. ferrugineus* (Barbosa et al. 1985) and *S. japonicus* (Roh et al. 2004), may be an adaptation of these plants to the cerrado or savanna environments. This feature may have evolved as a way to monitorate environmental conditions, allowing seeds to germinate and seedlings to establish at favorable times. Such a strategy may guarantee that at least part of the seed population produced annually germinates under adequate conditions to their establishment.

During the dry season, isolated rains may trigger the germination process, although a rapid

water loss from the soil superficial layers may restrict the establishment of seedlings. The present study suggests that substrate traits such as its retention capacity and the availability of water associated to temperature, are determining in the germination of seeds in this environment.

Temperature influenced the germination of seeds subjected to the different conditions of water availability in the substrate (Table II). The best germination responses were seen under the water potential of -0.1 MPa. Final germination percentages diminished significantly as water potentials and the temperature (both under the light and darkness conditions) decreased. However, no significant differences in seed germination were seen between the light and darkness conditions, at the same temperatures and water potentials.

In the experiment testing different water potentials, a film of each test-solution was kept at a level above the surface of the seeds to avoid the excessive water drainage and subsequent drying of the substrate surface. Such a methodology may have altered the aeration capacity of the substrate, preventing gas exchange between the interior and exterior of the seed. This may have restricted germination or caused seed death, especially when solutions with lower water potentials were used.

The significant differences seen between treatments for mean time, mean rate and the synchronization index of germination (Table II) did not reflect germination responses adequately. The lower synchronization indexes were observed in the treatments with lower germination percentages, where germination took place at the beginning of the experiments only. This fact also contributed to a reduction in time and in an increase in the germination rate, especially for lower water potentials.

Results show that substrate type, temperature and moisture all affect germination in this species (Table II). Seeds do not tolerate low water potentials, for this makes the imbibition process more difficult. Thus, germination does not take

TABLE II
Germination of *Styrax camporum* seeds under different temperatures and water potentials (-MPa), at constant light. Data on the darkness condition are not presented since no significant differences were seen compared to the light condition.
*** Distinct letters following means and their respective ***standard deviation indicate significant differences at $\alpha \leq 0.05$. Tukey test* (Sokal and Rolf 1981) and ** Nemenyi (Zar 1999).**

	Temperatures					
	15 °C		20°C		25°C	
Potentials	% germination					
0	41.5 ± 7.9***	a*	53.6 ± 19.2	a*	62.2 ± 13.8	a*
-0.1	20.1 ± 5.8	b	41.0 ± 13.7	ab	43.3 ± 6.1	Bc
-0.2	13.0 ± 12.9	bc	25.9 ± 6.7	b	37.2 ± 4.6	Bc
-0.3	23.7 ± 6.8	bc	16.3 ± 8.7	bc	30.0 ± 12.7	Bc
-0.4	6.0 ± 8.5	c	10.2 ± 12.0	bc	27.6 ± 9.9	C
-0.5	0.0 ± 0.0	-	11.2 ± 13.6	c	11.8 ± 10.0	D
	Mean germination time					
0	96.4 ± 9.0	ab**	103.7 ± 8.2	c**	76.0 ± 9.3	ab**
-0.1	100.3 ± 13.8	a	95.6 ± 5.2	b	75.5 ± 10.9	Ab
-0.2	112.4 ± 9.7	a	88.0 ± 22.0	ab	80.6 ± 6.2	Ab
-0.3	102.5 ± 13.3	ab	102.3 ± 42.6	a	96.6 ± 18.4	B
-0.4	38.5 ± 56.2	a	53.9 ± 59.9	a	81.5 ± 14.7	Ab
-0.5	0.0 ± 0.0	-	53.6 ± 58.0	a	48.5 ± 41.3	A
	Mean germination rate (1/time)					
0	0.0105 ± 0.001	a**	0.0097 ± 0.001	ab**	0.0133 ± 0.002	a*
-0.1	0.0101 ± 0.001	a	0.0105 ± 0.001	ab	0.0135 ± 0.002	A
-0.2	0.0090 ± 0.001	a	0.0125 ± 0.005	a	0.0125 ± 0.001	Ab
-0.3	0.0099 ± 0.001	a	0.0076 ± 0.003	b	0.0107 ± 0.002	Ab
-0.4	0.0040 ± 0.006	b	0.0049 ± 0.006	b	0.0126 ± 0.002	Ab
-0.5	0.0000 ± 0.000	-	0.0047 ± 0.005	b	0.0082 ± 0.007	B
	Mean synchronization index (bits)					
0	2.04 ± 0.6	b**	2.60 ± 0.4	c*	2.77 ± 0.4	c**
-0.1	0.94 ± 0.8	ab	1.88 ± 0.8	b	2.31 ± 0.4	Bc
-0.2	0.41 ± 0.7	a	1.20 ± 0.9	ab	1.97 ± 0.3	Bc
-0.3	0.94 ± 0.8	ab	0.47 ± 0.6	a	1.44 ± 1.1	Bc
-0.4	0.14 ± 0.4	a	0.31 ± 0.6	a	1.26 ± 0.9	B
-0.5	0.00 ± 0.0	-	0.32 ± 0.6	a	0.17 ± 0.4	A

place or is not completed in the field in periods of limited rains and low moisture contents in the soil superficial layers. This may contribute to the formation of a temporary seed bank of the species, even if part of the seeds germinate under

low water potentials. Therefore, the thickening of the integument and the presence of phenolic compounds (Julio and Oliveira 2007) would confer protection to the embryo during the waiting period for favorable conditions for seed germination.

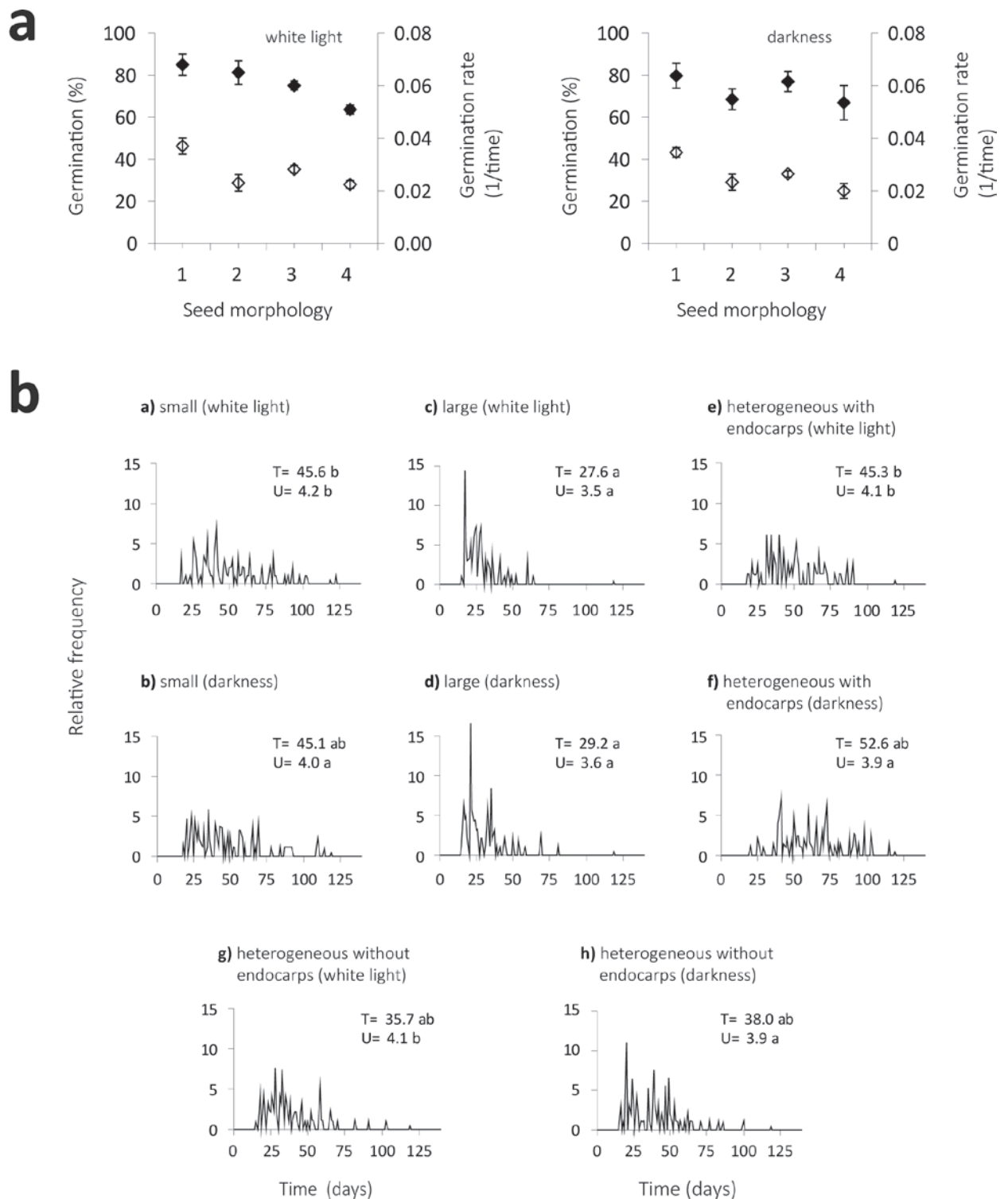


Figure 3 - a) Germination percentages (♦) and rate (◇) of *S. camporum* seeds, in different seed groups: large (1), small (2), heterogeneous without endocarps (3) and heterogeneous with endocarps (4). Means followed by distinct letters differ at $\alpha \leq 0.05$. Bars stand for standard errors.

b) Polygons of the relative germination frequencies of *S. camporum* seeds in different seed morphology groups, under continuous white light or darkness conditions (T=mean time, U=index of germination synchronization). T and U means followed by distinct letters differ at $\alpha \leq 0.05$.

Seed morphological traits have a direct relation with the substrate, facilitating or restricting water imbibition and gas exchange. Thereby, seed morphology contributes to germination responses significantly, although the different sizes of *S. camporum* seeds did not affect the final germination percentage when the two size groups were compared (Figure 3a). However, germination was more synchronous in larger seeds.

The distribution of germination accumulated in larger peaks (Figure 3b). Larger seeds also showed a lower time and rate of germination, differing significantly from other treatments (Figures 3a and 3b).

Figure 3a also shows the influence of the endocarp in seed germination. The percentage of germination was significantly lower under the light condition in which seeds presented pericarpial parts. According to Julio and Oliveira (2007), the pericarp of *S. camporum* contains phenolic compounds, which may influence the imbibition and seed germination processes.

Results suggest that germination depends on the interaction between 'presence of endocarp' and 'light' (Figure 3b). In the presence of light, both the percentage and the rate of germination decreased significantly compared to the other treatments, while in the absence of light the germination rate was the only parameter affected.

Small seeds presented similar germination percentages compared to other treatments, both under the light and darkness conditions, presenting (along with seeds with endocarp) the lower germination rate (Figure 3b). This response may be associated to a smaller amount of reserves in small seeds, providing less energy during germination, which would limit the vigorous development of the embryo and prevent the radicle from disrupting the integument.

Labouriau et al. (1963) reported that in cerrado species developing from seeds, these have reserves capable of nurturing the embryo during the initial developmental phases, independent of

the environment. Thus, species that produce large seeds have an advantage because they present a higher seedling survivorship in the initial establishment stages compared to the species with small seeds. Additionally, they are more tolerant to unfavorable conditions during establishment, such as competition with the already existing vegetation, shadowing, leaf loss to herbivory, low nutrient availability and burrying by the substrate (Moles and Westoby 2004).

Differences in seed size affect germination directly (Foster 1986). Usually, small seeds are photoblastic and large ones, non-photoblastic (Vázquez-Yanes and Orozco-Segovia 1993). This results in different needs of light, temperature, substrate and moisture conditions for seeds to overcome dormancy and to germinate, or yet in different sets of conditions for the beginning of germination in quiescent seeds.

CONCLUSIONS

1. The substrate on which seeds are dispersed has a direct influence on germination and determines its rate and synchronization;
2. *Styrax camporum* seeds germinate preferably at moisture contents close to the field capacity of cerrado soils, while low moisture contents reduce the germination percentage significantly;
3. The temperatures of 25 and 30°C potentialize germination, with temperature fluctuations seaming necessary to accelerate and synchronize seed germination on cerrado soils;
4. Seed morphology alters the mean and synchronization of germination, spreading its distribution in time and contributing to the maintenance of seeds in the soil.
5. The lack of synchrony in germination allows the emergency of seedlings at different time periods and establishment conditions in the cerrado environment, an adaptive response of *S. camporum* to this biome.

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RESUMO

Este estudo avaliou a contribuição da morfologia da semente de *Styrax camporum* (tamanho de sementes, presença ou ausência do endocarpo aderido à semente), diferentes substratos (papel filtro, vermiculita, areia e solo: cerrado, cerradão, mata de brejo), diferentes potenciais de água (0; -0,1; -0,2; -0,3; -0,4 e -0,5 MPa), luz e temperatura na germinação. O tamanho das sementes não influencia na porcentagem de germinação quando semeadas sob vermiculita. As sementes foram sensíveis a pequenas variações de umidade no substrato, mostrando redução significativa da germinação em potenciais de água abaixo de -0,1 MPa, o qual é próximo à capacidade de campo do solo de cerrado. Sob temperaturas de 15 e 20°C houve redução significativa da germinação. Dessa forma, a disponibilidade de água no solo de cerrado juntamente com a temperatura modulam a distribuição da germinação da espécie. A morfologia contribui para a permanência das sementes no solo e a falta de sincronismo de germinação permite a distribuição da germinação ao longo do tempo. Estas características proporcionam a emergência de plântulas em diferentes períodos e condições para estabelecimento e configuram-se como uma adaptação da espécie ao cerrado.

Palavras-chave: cerrado, estresse hídrico, morfofisiologia, Styracaceae, vermiculita.

REFERENCES

- AMARAL-BAROLI A AND TAKAKI M. 2001. Phytochrome controls achene germination in *Bidens pilosa* L. (Asteraceae) by very low fluence response. *Braz Arch Biol Technol* 44: 121-124.
- ANDRADE ACS, SOUZA AF, RAMOS FN, PEREIRA TS AND CRUZ APM. 2000. Germinação de sementes de jenipapo: temperatura, substrato e morfologia do desenvolvimento pós-seminal. *Pesq Agrop Bras* 15: 609-615.
- BARBOSA AR, YAMAMOTO K AND VÁLIO IFM. 1999. Effect of light and temperature on germination and early growth of *Vochysia tucanorum* Mart., Vochysiaceae, in cerrado and forest soil under different radiation levels. *Rev Bras Bot* 22: 275-280.
- BARBOSA LM, BARBOSA JM, DOMINGOS M AND ESTEFANO E. 1985. Ensaios de germinação de *Styrax ferrugineus* Ness Mart *Ecossistema* 10: 55-63.
- EITEN G. 1972. The cerrado vegetation of Brazil. *Bot Rev* 38: 201-341.
- FIGLIOLIA MB, OLIVEIRA EC AND PIÑA-RODRIGUES FCM. 1993. Análise de sementes. In: AGUIAR IB, PIÑA-RODRIGUES FCM and FIGLIOLIA MB (Coord), *Sementes florestais tropicais*. Brasília: ABRATES, p. 137-174.
- FOSTER SA. 1986. On the adaptative value of large seeds for tropical moist forest trees: a review and synthesis. *Bot Rev* 52: 260-299.
- GARCIA MN AND SMITH AP. 1993. Un filtro que puede ser utilizado para similar condiciones de luz del sotobosque. *Biotropica* 25: 356-359.
- JULIO PGS AND OLIVEIRA DMT. 2007. Morfoanatomia e ontogênese do fruto e semente de *Styrax camporum* Pohl. (Styracaceae), espécie de cerrado do Estado de São Paulo. *Rev Bras Bot* 30: 189-203.
- KANEGAE MF, BRAZ VF AND FRANCO AC. 2000. Efeitos da seca sazonal e disponibilidade de luz na sobrevivência e crescimento de *Bowdichia virgilioides* em duas fitofisionomias típicas dos cerrados do Brasil Central. *Rev Bras Bot* 23: 459-468.
- LABOURIAU LG AND AGUDO M. 1987. On the physiology of seed germination in *Salvia hispanica* L. I. Temperature effects. *An Acad Bras Cienc* 59: 37-56.
- LABOURIAU LG, VÁLIO IFM, SALGADO-LABOURIAU ML AND HANDRO W. 1963. Nota sobre a germinação de sementes de plantas de cerrados em condições naturais. *Rev Bras Biol* 23: 227-237.
- MALAVASI MM. 1988. Germinação de sementes. In: PIÑA-RODRIGUES FCM (Ed), *Manual de análise de sementes florestais*. Fundação Cargil, Campinas, SP, p. 25-39.
- MOLES AT AND WESTOBY M. 2004. Seedling survival and seed size: a synthesis of the literature. *J Ecol* 92: 372-383.
- POPININGIS F. 1985. Fisiologia das sementes. Ministério da Agricultura-Agriplan, Brasília. 2ª ed., 289 p.
- RODRIGUES FCM AND SANTOS NRF. 1988. Teste de tetrazólio. In: RODRIGUES FCM. *Manual de análise de sementes florestais*. Fundação Cargil, Campinas, SP, p. 91-100.
- ROH MS, BETZ JOA, WANG P, LI E AND KOSHIOKA M. 2004. Maturity and temperature stratification affect the germination of *Styrax japonicus* seeds. *J Hortic Scien Biotec* 79: 645-651.
- SASSAKI RM, RONDON JN, ZAIDAN LBP AND FELIPE GM. 1999. Number of seeds and seedlings emergence in cerradão, cerrado and gallery forest soils at Pedregulho, Itirapina (SP), Brazil. *Rev Bras Bot* 22: 147-152.
- SILVA EAA, MELO DLB, DAVIDE AC, BODE N, ABREU G, FARIA JMR AND HILHORST HWM. 2007. Germination ecophysiology of *Annona crassiflora* seeds. *Ann Bot* 99: 823-830.

- SILVA LMM AND AGUIAR IB. 2004. Efeito dos substratos e temperaturas na germinação de sementes de *Cnidoscylus phyllacanthus* Pax & K. Hoffm. (faveleira). Rev Bras Sementes 26: 9-14.
- SIMÃO E, NAKAMURA AT AND TAKAKI M. 2008. Use of insulfim like plastic filter to simulate canopy filtered light for germination tests. Naturalia 31: 28-33.
- SOKAL RR AND ROHLF FJ. 1981. Biometry. New York: W.H. Freeman. 2nd ed., 859 p.
- VAZQUEZ-YANES C AND OROZCO-SEGOVIA A. 1993. Patterns of seed longevity and germination in the tropical rainforest. Ann Rev Ecol Syst 24: 69-87.
- VILLELA FA, DONI FILHO L AND SEQUEIRA EL. 1991. Tabela de Potencial osmótico em função da concentração de polietileno glicol 6000 e da temperatura. Pesq Agrop Bras 26: 1957-1968.
- ZAR JH. 1999. Biostatistical analysis. Upper Saddle River, New Jersey, USA: Prentice Hall. 4th ed., 663 p.