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Effect of light and temperature on germination and early growth of *Vochysia tucanorum* Mart., Vochysiaceae, in cerrado and forest soil under different radiation levels

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ABSTRACT - (Effect of light and temperature on germination and early growth of *Vochysia tucanorum* Mart., Vochysiaceae, in cerrado and forest soil under different radiation levels). *Vochysia tucanorum* Mart. (Vochysiaceae) is a very widely distributed species in the cerrado and forests in Brazil, from the State of Bahia to Paraná. Its seed germination was analysed under eight treatments using different conditions of light and temperature. Up to 73 days, at least ca. 93% of the seeds germinated in all treatments, except under alternating temperatures of 35°/10°C (62%). Light enhanced germination, except under constant temperature of 25°C when seeds are not photoblastic. At this temperature, the highest percentage of germination was found. Initial vegetative growth was analysed by comparing the effects of shading, by means of different percentages of full daylight (100%, 45%, 10.6%, 4.8%), and soils from cerrado and forest. During 123 days, no mortality was recorded and cotyledons persisted on the seedlings of all treatments. In general, the seedlings of *V. tucanorum* were found to be more or less indifferent to the soil from cerrado or forest and shading seems to promote height increment. However, total dry mass was larger under a radiation of 45% full daylight and smaller under extreme conditions (100% or 4.8% full daylight).

RESUMO - (Efeito da luz e temperatura na germinação e crescimento inicial de *Vochysia tucanorum* Mart., Vochysiaceae, em solo de cerrado e mata sob diferentes níveis de radiação). *Vochysia tucanorum* Mart. (Vochysiaceae) é uma espécie amplamente distribuída em cerrado e florestas do Brasil, do estado da Bahia até o Paraná. Sua germinação foi analisada sob oito tratamentos usando diferentes condições de luz e temperatura. Até o 73º dia, pelo menos cerca de 93% das sementes germinaram em todos os tratamentos, exceto em alternância de temperaturas de 35°/10°C (62%). A luz favoreceu a germinação, exceto sob temperatura constante de 25ºC, na qual as sementes não se mostraram fotoblásticas. Nesta temperatura, foi encontrada a maior porcentagem de germinação. O crescimento inicial foi analisado comparando-se os efeitos de diferentes porcentagens da luz do dia (100%, 45%, 10,6%, 4,8%), e do solo de cerrado e mata. Durante 123 dias não houve mortalidade e os cotilédones persistiram em plântulas de todos os tratamentos. Em geral, as plântulas de *V. tucanorum* foram indiferentes ao tipo de solo, sendo que o sombreamento parece ter promovido incremento na altura das plantas. Entretanto, a massa seca total foi maior sob a radiação de 45% da luz solar e menor sob as condições extremas utilizadas (100% ou 4,8% de pleno sol).

Key words - Germination, seedling growth, shading, *Vochysia tucanorum*, soil, cerrado

Introduction

Cerrado (savannah-like vegetation) and riparian forests present high diversity and extensive genetic variability which, due to human activities, has been degraded to undesirably high levels and now require urgent studies in order to establish criteria for its regeneration (Labouriau 1966, Nascimento & Saddi 1992). Several authors have studied the regenerative strategies involving seed germination and seedling growth of suitable species for different degraded areas (Ng 1976, Whitmore 1991, 1996, Almeida et al. 1994).

Although shade is not imposed by the physical environment it becomes very important in the initial establishment of seedlings. The effect of shading upon growth and morphogenesis of tropical tree species has been examined in a large number of species (Denslow 1980, Augspurger 1984, Swaine & Whitmore 1988). Rezende et al. (1998) studied the effect of shading on survival and growth pattern of seedlings of *Cryptocaria aschersoniana* Mez. with the specific aim of regeneration of degraded riparian forests.

Plants of Vochysiaceae, an important floristic and phytophysionomic family in South America, are frequent in cerrado areas. The four Brazilian non-amazonic genera of the family present some species considered to be characteristic elements of the cerrado vegetation of Brazil (Stafleu 1948, Oliveira & Gibbs 1994). Besides this importance, few studies have been carried out on the initial seedling growth of Vochysiaceae aimed at the regeneration of the cerrados (Godoy & Felippe 1992, Paulilo et al. 1993).

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Vochysia tucanorum Mart. presents high competitive ability, high frequency and wide distribution in Brazil, from Bahia to Paraná and from Rio de Janeiro to Mato Grosso do Sul occurring in different types of forests (Stafleu 1948, Vianna 1980). This appears to favour this species in regenerative programs of degraded areas.

The main objectives of this research were to study the germination process of seeds of *V. tucanorum*, as well as the effect of shading and quality of soil on initial growth of its seedlings.

Material and methods

Germination - Seeds of *Vochysia tucanorum* Mart. were collected from dehiscent fruits of two trees in Rio Claro (SP), Brazil (22°20'82"S and 47°40'43"W). The seeds were randomized and stored in paper bags for 45 days under laboratory conditions until the beginning of the experiments. Material from the parental plants was dried and included in the UEC Herbarium (Rio Claro, I/1996, A.R.Barbosa 34188 and 34192).

Intact seeds were sterilized with 5% sodium hypochloride for 10 minutes, thoroughly washed and then placed in Petri-dishes on filter paper wetted with distilled water. The Petri-dishes were maintained in germinators under constant temperatures of 25ºC or 30ºC and continuous white fluorescent light or darkness and also alternate temperatures of 30º/15ºC, 30º/10ºC and 35º/10ºC (12 hours of higher temperature in light and 12 hours of lower temperature in darkness). Three replicates of 15 seeds were used in each treatment. Protrusion of the radicle was the criterion used for a germinated seed. Germination index (GI) was calculated according Czabator (1962 apud Gonzalez J. & Fisher 1997) were GI = ADG x PV (ADG = average daily germination; PV = higher value of germination).

The viability of the apparently healthy non-germinated seeds was examined in all treatments through tetrazolium test (Delouche et al. 1962).

Seedling growth - Germinated seeds were transferred to trays with vermiculite in a humidifier in the glasshouse for 30 days until total expansion of the cotyledons. Uniform seedlings were then selected. Ten seedlings were harvested and dried at 80ºC for 48 hours to obtain the T_0 dry mass. Other seedlings were transplanted in white plastic pots (0.5 l) filled with forest or cerrado soil. Forest soil was collected in the Mata de Santa Genebra, Campinas (SP) and cerrado soil in the cerrado region of Itirapina (SP). Soil samples were collected after removal of the litter to a depth of 10 cm. Seedlings were subjected to four photon flux densities (PPD) (PAR = 400 – 700 nm): treatment 1 = 1640 $\mu mol.m^{-2}.s^{-1}$ (full sunlight = 100% radiation); treatment 2 = 740 $\mu mol.m^{-2}.s^{-1}$ (glasshouse = 45% radiation); treatment 3 = 174 $\mu mol.m^{-2}.s^{-1}$ (glasshouse + one layer of black plastic screen = 10.6% radiation); treatment 4 = 80 $\mu mol.m^{-2}.s^{-1}$ (glasshouse + two layers of black plastic screen = 4.8% radiation). Radiation was measured on a clear day without clouds around midday using a line quantum sensor (LI191SA) attached to a datalogger (LI1000). Five seedlings per treatment were used in experiment 1 and 15 seedlings per treatment in the other experiments. Seedlings were watered every day. After 123 days seedling height and persistence of cotyledons were recorded. Seedlings were then carefully removed from the pots, roots thoroughly washed and separated into leaves, stems and roots before drying at 80ºC for 48 hours. From the recorded data the following indices were calculated: root:aerial ratio; robustness index = stem dry mass:stem length (RI = SDM/SL) (Lee et al. 1996); allocation of photosynthates to leaves, stem and roots (% of total); relative growth rate [$RGR = (\ln M_1 - \ln M_0)/(T_1 - T_0)$] were M_0 is the total dry mass at the beginning of the experiment, T_0, and M_1 is the total dry mass at the end of the experiment, T_1 (Hunt 1982). Statistical analyses - In the germination experiments the main factors were temperature (ºC), light (light or darkness, continuous or alternate each 12 hours) and time (days). The variable response was the proportion of germinated seed. For each time, one factor ANOVA was applied to test the effect of light at the temperatures of 25ºC, 30ºC, and 30/15ºC. In the seedling growth experiments, the main factors were type of soil (forest or cerrado) and radiation (PPD - % of radiation). The variable responses (height, dry mass) were transformed into $\log_{10}$. To each radiation level one factor ANOVA was applied to test the effect of treatments. Multiple comparisons were obtained from ANOVA using the Duncan test at 5% level of significance. All analyses were carried out using the General Linear Models (GLM) of the Statistical Analysis System (SAS Institute 1986).

Results and Discussion

Germination - Fruiting of *V. tucanorum* is abundant with a massive production of uniform seeds, not light and dark coloured as it occurs in *Qualea cordata* Spreng. seeds (Godoy & Felippe 1992) and *Q. grandiflora* Mart. (Felippe 1990). The seeds with 1.3-2.8 x 0.4-0.7 cm bear a lateral wing consisting of interlaced trichomes inserted in the coat. The beginning of germination of intact seeds takes ca. 13 days. Removal of seed coat reduces this time to half.

The most efficient treatment in promoting germination was 25ºC, under continuous light or darkness, showing that the seeds are not photoblastic at this temperature. Arasaki & Felippe (1987) found similar result in *Dalbergia violacea* (Vog.) Malme (= *D. miscolobium* Benth., Carvalho 1989 apud Sassaki 1995), a common tree species from cerrado. Some degree of photoblastism was observed in all remaining treatments (figures 1A, 1B, 2A). Among them, constant 30ºC and continuous light produced the best results. Until up to ca. 2-4 weeks, the percentage of germination were smaller under alternate temperatures of 30º/10ºC or 30º/15ºC and alternate light and darkness. Furthermore, the germination delayed for 20 days under continuous darkness and alternate temperatures of 30º/15ºC. When temperatures are alternated, lower temperatures of 10ºC or 15ºC produced no significant differences. When the constant or the highest temperature is 30ºC, light enhances germination (figure 1B). But at last, more than 93% of germination was attained in all these treatments.

Under 35°/10°C, the maximum germination percentage after 73 days was as low as 62%, the remaining 38% of the seeds being completely deteriorated by this time (figure 2B). This result may be due to the increase of 5°C in the highest temperature, from 30°C to 35°C, which may probably caused protein denaturation to an irreversible stage, as found by Bewley & Black (1994) and Heydecker (apud Dell'Aquilla & Spada 1994).

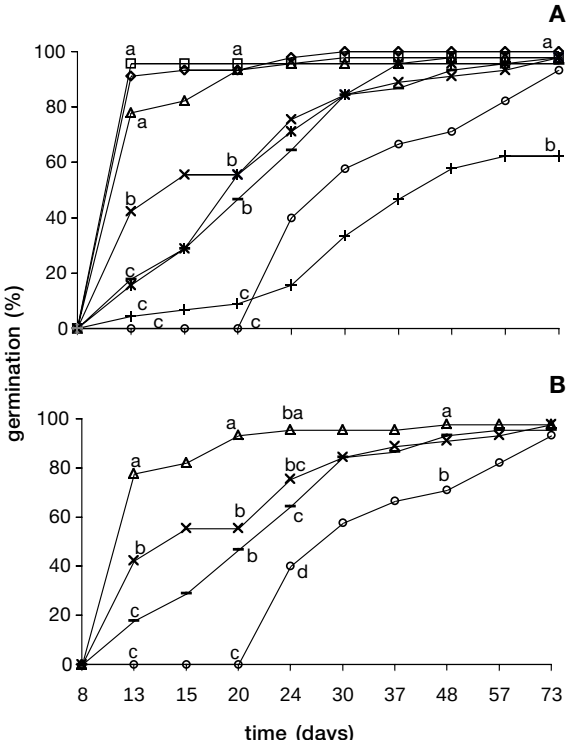

Figure 1. Germination of seeds of *V. tucanorum*: A - germination under different temperatures and light conditions; B - germination under temperature and constant and alternate light. Vertical comparison by Duncan's test (a = 0,05): same letters are not statistically different. L = light; D = darkness. Treatments: 25ºC L (□), 25ºC D (◇), 30ºC L (△), 30ºC D (X), 30/15ºC D (○), 30/15ºC L/D (–), 30/10ºC L/D (✳), 35/10ºC L/D (+).

Therefore, the seeds of *V. tucanorum* germinate under a wide range of temperature (10 to 35°C), a characteristic shared with other species of cerrado (Arasaki & Felippe 1987). Photoblastism was detected by means of a delay or a lower germination percentage during the earlier 2-4 weeks when the constant or the highest temperature in alternate conditions was 30°C. In these cases, light enhances germination. It may be

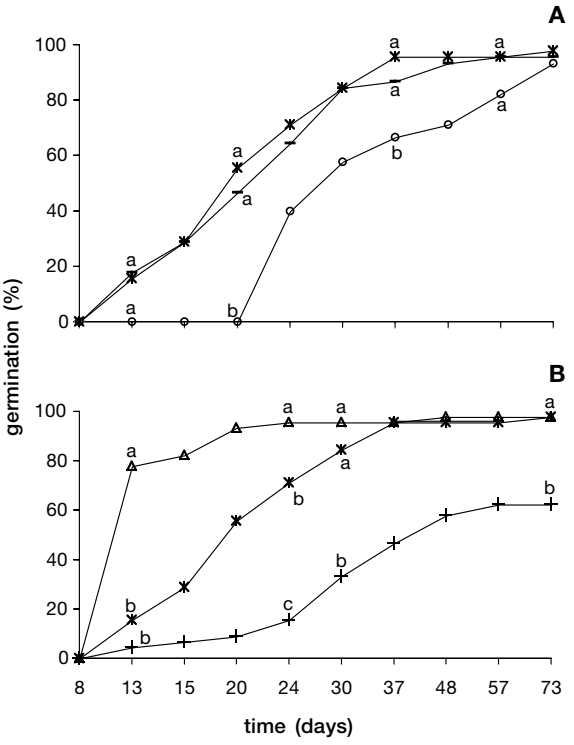

Figure 2. Germination of seeds of *V. tucanorum*: A - under alternate light and temperature and alternate temperature under continuous darkness; B - under constant light and temperature and alternate ligh and temperature. Vertical comparison by Duncan's test (a = 0,05): same letters are not statistically different. L = light; D = darkness. Treatments: 30ºC L (△), 30/15ºC D (○), 30/15ºC L/D (–), 30/10ºC L/D (✳), 35/10ºC L/D (+).

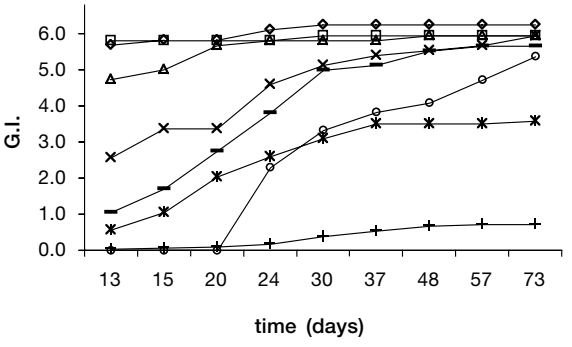

Figure 3. Germination Index (G.I.) of seeds of *V. tucanorum* under different temperatures and light conditions. L = light; D = darkness. Treatments: 25ºC L (□), 25ºC D (◇), 30ºC L (△), 30ºC D (X), 30/15ºC D (○),30/15ºC L/D (–), 30/10ºC L/D (✳), 35/10ºC L/D (+).

Table 1. Chemical analyses of the soil used in the experiments.

Soil	pH	Carbon	$P_{res.}$	MEq.100cm^{-3}					V
	$CaCl_2$	%	(mg.cm^{-3})	H + Al	K	Ca	Mg	CEC	%
forest	5.2	5.7	42	4.7	0.12	7.6	1.1	13.50	65.0
cerrado	4.2	1.5	0.019	5.2	0.08	0.3	0.2	5.78	10.0

Analyses by: Instituto Agronômico de Campinas (forest soil) and Instituto Campineiro de Análise de Solo e Adubo (cerrado soil). CEC = Cationic Exchange Capacity; V = Saturation base.

seen by the highest germination index (GI) found under continuous light at constant 30°C, at least up to 20th day of the experiments. After ca. 48 days, this index was not high only in the 30°/15°C and 30°C continuous darkness treatments. In these treatments germination lasted 73 days (figure 3).

Early growth of seedlings - *V. tucanorum* shows epigeal germination with leafy cotyledons that persisted until the end of the treatments (123 days), when no mortality was recorded. Cotyledon longevity was already observed in seedlings of other Vochysiaceae (Paulilo et al. 1993, Almeida et al. 1994). According to Fenner (1985), this kind of seedling is partly light dependent during the beginning of growth, due to the paucity of reserves. In this way, the persistent cotyledons may be important as a source of photosynthates.

The soil of cerrado is less fertile (highly acidic with high concentration of Al and reduced availability of P, K, Ca and Mg) than that from the forest floor (table 1). Radiation level was found to affect growth parameters, sometimes in a different way according to the soil type (table 2).

The lowest gain in biomass was found under full sunlight (radiation of 100%) or strong shading (radiation of 4.8%). The lowest and the highest increment in height were respectively observed under radiation levels of 100% and 10.6% or lower (table 3). Under full sunlight, similar values of growth parameters were found in forest and in cerrado soils. Under radiation of 4.8%, the thinnest seedlings with similar and very low values of RI in the two soil types were

Table 2. Effect of different soil and radiation levels on growth of seedlings of *V. tucanorum* (mean + SD). GH = glasshouse; S = screen.

Treatment	Soil	Height (cm)	Dry mass (mg)			Total dry mass
(% solar radiation)			Leaf	Stem	Root	(mg)
treatment 1	forest	6.45 ± 1.56 *	86.00 ± 18.89 *	37.15 ± 22.32 *	66.45 ± 31.58 *	189.60 ± 67.74 *
(full sun –100%)	cerrado	6.10 ± 0.82 d	119.00 ± 14.46 c	40.82 ± 8.77 c	76.72 ± 19.10 d	236.54 ± 28.39 d
treatment 2	forest	10.85 ± 2.50 b	318.07 ± 88.78 a	102.11 ± 39.17 a	264.27 ± 68.13 a	684.45 ± 170.53 a
(GH – 45%)	cerrado	8.49 ± 1.61 c	344.20 ± 162.54 a	59.77 ± 20.69 bc	159.73 ± 61.30 b	563.71 ± 236.82 ba
treatment 3	forest	13.23 ± 4.29 ba	228.13 ± 87.46 a	74.79 ± 46.01 ba	114.49 ± 43.90 c	417.41 ± 170.37 bc
(GH + 1S – 10.6%)	cerrado	15.34 ± 3.20 a	352.71 ± 99.82 a	91.41 ± 30.78 a	136.79 ± 33.90 cb	580.91 ± 148.04 a
treatment 4	forest	12.77 ± 2.21 ba	142.67 ± 28.78 b	47.71 ± 13.01 bc	55.05 ± 11.22 e	245.43 ± 50.52 d
(GH + 2S – 4.8%)	cerrado	13.96 ± 2.58 a	226.53 ± 62.56 a	58.23 ± 17.98 bc	56.80 ± 18.57 e	341.56 ± 93.21 c

Variable response of ANOVA for each parameter was transformed to $\log_{10}$. For each parameter, mean followed by at least one equal letter are not statistically significant by Duncan's test ($\alpha = 0.05$).
* Mean not included in the statistical test.

Table 3. Effect of radiation on the growth parameters of *V. tucanorum* seedlings (mean ± SD). GH = glasshouse; S = screen.

Treatment (% solar radiation)	Height (cm)	Dry mass (mg)			Total dry mass (mg)
		Leaf	Stem	Root	
treatment 1 – full sun (100%)	6.89 ± 2.27 c	129.2 ± 81.6 c	48.43 ± 32.24 b	79.88 ± 32.42 c	257.41 ± 140.88 c
treatment 2 – GH (45%)	9.67 ± 2.39 b	331.13 ± 129.36 a	80.94 ± 37.56 a	212.0 ± 82.95 a	624.08 ± 211.86 a
treatment 3 – GH + 1S (10.6%)	14.25 ± 3.89 a	288.28 ± 111.65 a	82.81 ± 39.62 a	125.26 ± 40.32 b	496.34 ± 177.77 b
treatment 4 – GH + 2S (4.8%)	13.36 ± 2.44 a	184.6 ± 64.10 b	52.97 ± 16.32 b	55.92 ± 15.10 d	293.49 ± 88.41 c

Variable response of ANOVA for each parameter was transformed to $\log_{10}$. For each parameter, mean followed by at least one equal letter are not statistically significant by Duncan's test (a = 0.05).

observed. RGR under radiation levels of 100% and 4.8% are the lowest of the experiment and close to each other (table 4).

High values of R:A ratio (root:aerial) and robustness index (RI) were obtained in seedlings grown in forest soil under 45% radiation (table 4). These results appear to be opposite to those of Kozlowski et al. (1991) where seedlings growing in unfertile soils allocate a higher proportion of photosynthates to the roots. Nevertheless, Godoy & Felippe (1992) reported that in some species of cerrado, higher allocation of photosynthates to the roots of seedlings occurs only after four months.

In general, the radiation of 45% appeared to be the best condition for seedling growth, very closely followed by that of 10.6%, because these conditions produced higher increase in total biomass with a higher investment in leaf mass (table 3), enlarging potentially the photosynthetic capacity of the seedling. Highest RGR were also found under these radiation levels in the two soil types (table 4). According to Paulilo et al. (1993), RGR varies from 0.003 to 0.086 $mg.mg^{-1}.d^{-1}$ in tropical forest tree species, and from 0.014 to 0.040 $mg.mg^{-1}.d^{-1}$ in cerrado tree species. Under the radiation levels of 45% and 10.6%, the RGR of *V. tucanorum* ranged respectively from 0.026 to 0.028 $mg.mg^{-1}.d^{-1}$ and from 0.024 to 0.027 $mg.mg^{-1}.d^{-1}$. These values are close to that found for *Q. grandiflora* (0.025 $mg.mg^{-1}.d^{-1}$), a tree species found in dense cerrados (Paulilo et al. 1993), but lower than that found for *Q. cordata* (0.038 $mg.mg^{-1}.d^{-1}$), a common tree species of cerrado (Godoy & Felippe 1992).

These results agree with the ecological characteristics of *V. tucanorum* in nature. This is a very frequent and widely distributed species, mostly in the cerrado domain, in environments with intermediate radiation levels, such as small forest gaps or edges or other places reached by the sunshine

Table 4. Root:aerial ratio, Robustness Index (RI) and Relative Growth Rate (RGR) of *V. tucanorum* seedlings under different treatments of radiation and soil. GH = glasshouse; S = screen.

Treatment (% solar radiation)	Soil	R : A	RI ($cm.mg^{-1}$)	RGR ($mg.mg^{-1}.d^{-1}$)
treatment 1 – full sun (100%)	forest	0.43 b	7.271 cb	0.021 d
	cerrado	0.48 b	6.692 b	0.019 d
treatment 2 – GH (45%)	forest	0.63 a	9.414 a	0.028 a
	cerrado	0.40 b	7.043 b	0.026 ba
treatment 3 – GH + 1S (10.6%)	forest	0.38 cb	5.651 cd	0.024 bc
	cerrado	0.31 dc	5.958 cb	0.027 a
treatment 4 – GH + 2S (4.8%	forest	0.29 d	3.737 e	0.019 d
	cerrado	0.20 e	4.171 ed	0.022 c

For each parameter, means followed by at least one equal letter are not statistically significant by Duncan's test (a = 0.05).

only part of the day (A.R. Barbosa, personal observation). These sites provide adequate conditions regarding the requirements for germination (highest or constant temperature around 25-30°C, light preference but not dependence) and seedling growth, since this species appeared to be well adapted to unfertile soils and is shade tolerant.

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