Psychotria hoffmansegiana (Willd ex Roem. & Schult.) Mull. Arg. and *Palicourea marcagravii* st. Hil. (Rubiaceae): potential for forming soil seed banks in a brazilian Cerrado

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(With 1 figure)

Abstract

The germinability of artificially buried *Psychotria hoffmansegiana* and *Palicourea marcagravii* seeds in Cerrado soil was tested, with the aim of evaluating whether dispersed seeds may be able to form a soil seed bank. The assays were carried out at a Cerrado Reserve in São Paulo State, Brazil. Seed samples were placed in nylon bags and buried at two different depths and in two different sites. Samples were periodically exhumed and germination tests were performed with both exhumed and dry stored seeds. In general, soil storage favoured seed survival and germination when compared to dry stored seeds. The seed germination was little affected by soil depth and by burial environment. Seeds of both species remained viable for at least 13 months, considering the time lapse between the collection and the end of the germination tests. It was suggested that both species can potentially form a persistent soil seed bank in Cerrado.

Key words: Psychotria hoffmansegiana, *Palicourea marcagravii*, soil seed bank, Cerrado, burial.

Psychotria hoffmansegiana (Willd ex Roem. & Schult.) Mull. Arg. and *Palicourea marcagravii* st. Hil. (Rubiaceae): potencial para formar bancos de semente em solo de Cerrado

Resumo

Observou-se a germinabilidade de sementes de *Psychotria hoffmansegiana* e *Palicourea marcagravii* enterradas em solo de Cerrado, buscando-se avaliar o potencial de formação de banco de sementes no solo. Ensaios foram realizados em uma Reserva de Cerrado, São Paulo, Brasil. Amostras de sementes foram colocadas em sacos de tela de nylon e enterradas em duas profundidades, e em dois ambientes. Amostras eram periodicamente desenterradas e submetidas a teste de germinação, juntamente com sementes armazenadas em laboratório. Em geral, o armazenamento no solo favoreceu a sobrevivência e a capacidade de germinação das sementes, em comparação com sementes armazenadas em laboratório. A germinação foi pouco afetada pela profundidade de enterramento e pelo ambiente. Sementes de ambas as espécies conservaram a viabilidade por 13 meses, considerando-se o período entre a coleta e o final dos testes de germinação. É sugerido que ambas as espécies são potencialmente capazes de formar banco de sementes persistente no solo do Cerrado.

Palavras-chave: Psychotria hoffmansegiana, *Palicourea marcagravii*, banco de sementes, Cerrado, enterramento.

1. Introduction

Cerrado is a Brazilian savannah vegetation and it encompasses Central Brazil, extending from the Amazonian forest in the north to Paraná state in the south. The Cerrado *strictu sensu* is varied in physiognomy, ranging from an open field with sparse covering of shrubs and small trees to a tall closed forest with a canopy height of 12-15 m. The diversity of herbs, subshrubs and small shrubs is greater than for taller plants. The ground layer encompasses a large number of plant families, particularly *Compositae, Graminae, Leguminosae* and *Rubiaceae* (Ratter et al., 1997).

The plant's life cycle and the regeneration of plant populations depends on its capacity to produce physiologically independent individuals (reproduction), which can be accomplished either by the production of seeds or through vegetative propagation (Fitter and Hay, 1981). Although in various communities such as savannahs and grasslands, regeneration occurs primarily by vegetative propagation (Bazzaz and Ackerly, 1992), it has been shown that sexual reproduction and seedling establishment are common features in Cerrado and involve adaptation mechanisms for that environment (Oliveira, 1998).

The regeneration of plant communities from seeds depends to a large extent on the capacity of the seed to germinate and establish seedlings under favourable conditions. In some species, the seeds germinate as soon as they are shed and water for imbibition is available, while in others, the seeds may survive for relatively long periods in the soil seed bank with intermittent germination of a fraction of the population (Murdoch and Ellis, 1992). Thompson and Grime (1979) defined two main soil seed bank types: transient and persistent. They consider a soil seed bank to be transient when the dispersed seeds remain viable in the soil up to 1 year, whereas in the case of a persistent seed bank a fraction of the seeds remains dormant in the soil for more than one year. It is widely assumed that seeds capable of forming persistent seed banks have dormancy mechanisms through which germination is arrested even when the environmental conditions seem to be suitable for embryo growth (Baskin and Baskin, 1998; Bewley and Black, 1994). On the other hand, Thompson et al. (2003) reported that there is no close relationship between seed dormancy and persistence in the soil, although non-dormant seeds exhibited a slight tendency to be less persistent.

The longevity of seeds in the soil is of great interest to basic and applied biology (Baskin and Baskin, 1998). The length of time that buried seeds remain viable and ungerminated in the soil increases (Howe and Chancellor, 1983), decreases (Lonsdale et al., 1988) or is not affected (Egley and Chandler, 1983) by seed burial. Germinability can also be affected by burial since in situ germination of *Avena fatua* seeds decreased with an increase in depth of burial due to induced seed dormancy (Zorner et al., 1984).

Psychotria hoffmansegiana and *Palicourea marcagravii (Rubiaceae)* are shrubs and sub-shrubs occurring in a residual area of Cerrado in the state of São Paulo, and are common in shaded sites. The objective of this work was to observe the effect of artificial burial in the Cerrado soil on seed viability from that two species, as well as to examine germination in situ of buried seeds at two different depths. It was also of interest to evaluate whether dispersed seeds can constitute part of a soil seed bank, and discuss seed germination as part of the strategies for the establishment of new plants in Cerrado.

2. Material and Methods

The Cerrado Reserve (22° 15' S and 47° 00' W) in Corumbataí, São Paulo State, has 38.7 ha of Cerrado with elevations ranging from 800 to 830 m. The area shows a high absolute density, and a very high diversity for a marginal area, with several species which normally occur in forest formations (Cesar et al., 1988). There has been no occurrence of fire in the Cerrado Reserve in the last fifty years.

This work was carried out with seeds of *Psychotria hoffmansegiana* (Willd ex Roem. & Schult.) Mull. Arg. and *Palicourea marcagravii* St. Hil. The fruits are two-seeded spherical drupes and were collected during the peak fruiting period of the species from individuals growing along a trail in the Cerrado Reserve in April-May, 2001. Several fruit collections were carried out during the fructification period. Seeds were manually removed, dried on filter paper sheets and stored under laboratory conditions in paper bags. The seeds were individually weighed to the nearest milligram using an analytical balance. Seed water content was calculated on a fresh weight basis, and dry weight was obtained after drying five samples (50 seeds per sample) at 105 °C for 24 hours.

For viability tests, seeds were submerged in a 3% tetrazolium chloride solution at 30 °C for 24 hours and the red stained seeds were counted (Piña-Rodrigues and Santos, 1988). Water imbibition of seeds of each species was tested for both intact and scarified seeds. Three samples of 50 seeds each one were soaked in distilled water at 25 °C, and daily readings of sample weight were taken up to six days, with the percentage of water uptake being calculated. When necessary, scarified seeds were obtained by friction of the seeds on sandpaper sheets.

The burial experiments were carried out along the trail where fruits were collected. Two distinct vegetation profiles along the trail were observed: one (referred to as "shaded site") with a higher canopy, and the other ("open site") where the canopy was lower and less dense. Irradiance measurements (Li-Cor LI 1000, PAR radiometer) were taken at 114 points along the trail, showing a mean (± confidence interval) irradiance of 337 ± 33 $\mu mol.m^{-2}.s^{-1}$ at the "open" site and 51 ± 13 $\mu mol.m^{-2}.s^{-1}$ at the "shaded" site. For each species seed samples (30 seeds per sample) were placed in 25 x 12 cm fine-mesh nylon envelopes and buried both in the "open" and in the "shaded" site, at 5 and 15 cm depths. The burial assay started on May 25th 2001 and was carried out in triplicate arranged as a randomised block design. Rainfall data were obtained from CEAPLA – IGCE – UNESP.

After 32, 66, 99, 130, 161, 192, 220, 247, 281 and 308 days from burial, seed samples were exhumed and submitted to germination tests. When a seed sample was recovered from the soil, laboratory stored samples were also removed from the paper envelopes and tested simultaneously for seed germination. The germination tests were conducted in a acclimatized room under continuous cool white fluorescent light (34.4 $\mu mol.s^{-1}.m^{-2}$) at 26 ± 2 °C, in 9 cm glass Petri dishes (three dishes per treatment) lined with three layers of filter paper moistened with distilled water. The radicle protrusion was checked for 90 days, and used as criterion for seed germination. Prior to the germination tests, the seeds were surface disinfected with a 10% commercial sodium hypo-chloride solution, and then washed in distilled water. When seeds were recovered from burial, the number of germinated seeds within envelopes was recorded (germination in situ).

The accumulated germination percentages (germinabilities) recorded at the end of the laboratory germi-

nation assays were compared using the Mann-Whitney U test (Santana and Ranal, 2004).

3. Results

Psichotria hoffmansegiana (from now on referred to as *Psychotria*) presented smaller and lighter seeds than *Palicourea marcagravii* (referred to as *Palicourea*), but both of them have similar water content (Table 1). Thus, the fresh seed weight difference between *Psychotria* and *Palicourea* comes from the dry mass higher in *Palicourea seeds*. Imbibition of intact and scarified seeds did not differ to each other, exhibiting similar patterns. The fresh mass of *Psychotria* seeds increased around 13% during the imbibition time (144 hours), whereas the mass of *Palicourea* seeds increased approximately by 16% (Table 2).

The results of the laboratory germination tests carried out with both dry stored seeds and exhumed seeds are presented in Table 3. Germinability (%) of soil stored *Psychotria* seeds exhibited a general decrease after 192 and 220 days of burial, whereas germination of 247, 281 and 308 day soil-stored seeds is in general similar to that obtained from both freshly collected and 32 day soil-stored seeds. The experimental conditions under which *Psychotria* seeds where stored in the Cerrado soil did not affect their germinabilities, with the exception of the seeds exhumed after 66 and 161 days, of which germination of seeds recovered from 15 cm depth at the "open" site was lower than germination of seeds from "shaded" sites.

The storage of the seed in the Cerrado soil affected favourably the germination capacity of *Psychotria* seeds, irrespective of the treatment (site and burial depth), as compared to dry-stored ones (Table 3). Such an influence could be observed from 161 days of storage, when the germination percentage of dry-stored seeds dropped to values near zero, and ceased after 281 days of storage.

The germinabilities of *Palicourea* seeds recovered after different burial times appear to "oscillate" (high, followed by lower percentages), although some differences are not significant statistically (due to their relatively high variances). By comparing the storage times of 32 and 308 days we could observe that germinabilities did not differ significantly, with the exception of the 5 cm depth / "open" site treatment. Few differences could be observed amongst laboratory germinabilities of soil-stored seeds under different conditions, which made it difficult to verify any effect of the burial conditions on the germination of *Palicourea* seeds. Otherwise, the burial in the Cerrado soil improved the germination capacity of *Palicourea* seeds as compared to laboratory-stored ones, since the germinabilities of exhumed seeds were in general significantly higher than dry-stored ones (Table 3).

The seeds that remained un-germinated by the end of the germination assays were submitted to tetrazolium test for the assessment of their viability. Viability percentages were obtained by dividing the number of viable seeds by the number of seeds that remained un-germinated in the Petri dishes. It was observed that a fraction of the *Psychotria* and *Palicourea* seeds were viable even after 308 days of storage and 90 days of imbibition in the Petri dishes, either among exhumed or dry stored seeds (Table 4). Thus, for example, at the

Table 1. Some characteristics of *Psychotria hoffmansegiana* and *Palicourea marcagravii* seeds. Data (mean ± SE) from individual seeds.

	Psychotria hoffmansegiana	***Palicourea marcagravii***
Fresh Weight (g)	0.0066 ± 0.00023	0.0272 ± 0.0008
Dry Weight (g)	0.0057 ± 0.00003	0.0234 ± 0.0001
Water content (%, FW basis)	13.7 ± 0.43	13.9 ± 0.19
Width (cm)	0.23 ± 0.008	0.33 ± 0.01
Length (cm)	0.29 ± 0.005	0.45 ± 0.013

Table 2 . Water uptake by intact and scarified seeds of *Psychotria hoffmansegiana* and *Palicourea marcagravii*. Data in % (±SE) referred as to non-imbibed seeds.

	Psychotria		***Palicourea***	
Imbibition time (hours)	**Intact**	**Scarified**	**Intact**	**Scarified**
8	3.4 ± 0.8	3.6 ± 0.6	4.2 ± 1.5	3.7 ± 0.2
24	6.1 ± 0.8	7.9 ± 0.6	9 ± 1.0	10 ± 1.8
48	12.9 ± 0.4	9.3 ± 0.5	13.2 ± 2.5	13 ± 0.1
72	12.9 ± 0.4	11.5 ± 1.7	14.6 ± 2.6	15.5 ± 1.0
96	12.9 ± 0.4	13 ± 3.1	16 ± 2.6	16.8 ± 0.3
120	12.9 ± 0.4	13 ± 3.1	16 ± 2.6	16.8 ± 0.3
144	12.9 ± 0.4	13 ± 3.1	16 ± 2.6	16.8 ± 0.3

Table 3. Germinability (%) of *Psichotria hoffmansegiana* and *Palicourea marcagravii* seeds stored in cerrado soil and in laboratory conditions for different periods (days). Germination was carried out at 25 °C, under white light, for 90 days.

Species	Time (days)	Storage conditions				
		Open[1]		Shaded		Dry
		5[2]	15	5	15	
Psichotria	32	57^{aA} [3]	33^{aAB}	53^{aA}	37^{aAB}	63^{aA}
	66	50^{abAB}	33^{bAB}	57^{abA}	67^{aA}	67^{aA}
	99	43^{aAB}	47^{aAB}	53^{aA}	67^{aA}	40^{aA}
	130	43^{aAB}	47^{aAB}	33^{aAB}	33^{aAB}	33^{aAB}
	161	20^{bcBC}	20^{bcB}	37^{abAB}	53^{aA}	3^{cC}
	192	20^{aBC}	17^{aB}	10^{aB}	7^{aC}	0^{bD}
	220	10^{aC}	23^{aB}	10^{aB}	20^{aBC}	7^{aBC}
	247	50^{aAB}	47^{aAB}	43^{aA}	40^{aAB}	3^{bC}
	281	40^{aAB}	57^{aA}	47^{aA}	37^{aAB}	0^{bD}
	308	30^{aBC}	33^{aAB}	53^{aA}	33^{aAB}	0^{bD}
Palicourea	32	77^{aAB}	67^{aAB}	77^{aA}	63^{aA}	17^{bA}
	66	83^{aA}	63^{abAB}	33^{bcB}	53^{abA}	17^{cA}
	99	34^{abCD}	40^{aC}	26^{abB}	50^{aA}	5^{bAB}
	130	33^{abCD}	20^{aC}	43^{abAB}	59^{bA}	0^{cB}
	161	40^{aBC}	67^{aAB}	53^{aAB}	47^{aA}	5^{bAB}
	192	27^{aCD}	34^{aBC}	30^{aB}	40^{aA}	0^{bB}
	220	8^{bD}	33^{abC}	40^{abB}	43^{aA}	0^{cB}
	247	27^{bCD}	73^{aA}	53^{abAB}	57^{abA}	0^{cB}
	281	53^{aABC}	33^{aC}	63^{aAB}	30^{aA}	0^{bB}
	308	15^{bCD}	60^{aAB}	47^{aAB}	27^{abA}	5^{bAB}

[1] Open – seeds stored in soil in "open" (lighter) site; shaded – seeds stored in soil in "shaded" site; dry – seeds stored in paper bags in laboratory conditions.
[2] 5 – Storage at 5 cm depth in the soil; 10 – storage at 15 cm depth.
[3] Means followed by the same letter are not significantly different (Mann-Whitney U-test, 0.05 level); small letters: horizontal comparisons; capital letters: vertical comparisons.

end of the germination assays, 55% of the *Psychotria* seeds previously dry-stored for 32 days were viable, whereas only 13% of the seeds were viable after assays performed with seeds stored for 308 days. As the germination assays lasted 90 days, the viable un-germinated seeds were considered as dormant. Since no statistical comparisons could be made between the treatments, the possible effects of the soil storage conditions (burial depth and environment) on the viability of un-germinated *Psychotria* and *Palicourea* seeds were not discussed.

At the time of the exhumations, it was observed that some seeds had germinated within the nylon envelopes, and such germination in situ occurred with seeds stored for 99 days and thereafter. The percentage of *Psychotria* seeds germinated in situ was highly variable, with two or more germination "peaks" distributed along the burial time (Figure 1). In general, the peaks from *Psychotria* seeds buried at 5 and 15 cm are not coincident either in the open site (Figure 1a) or in the shaded one (Figure 1b). In most of the assays, the germination of buried seeds of both species did not exceed 30% even when the rainfall was higher than 100 mm. High (>40%) germination percentages were achieved by *Palicourea* seeds buried at 15 cm depth and exhumed both from the open area after 281 days of storage (Figure 1c), and from the shaded area after 308 days of storage (Figure 1d). No clear correlation could be found between rainfall (Figure 1e) and germination of buried *Psychotria* and *Palicourea* seeds.

4. Discussion

The water content (nearly 14% on a fresh weight basis) of *Psychotria* and *Palicourea* seeds reported here was relatively low to a non-pioneer species, according to Garwood (1989). Otherwise, it was lower than typical values reported for recalcitrant seeds such as *Ocotea odorifera* (52%) (Davide et al., 2003), and close to values observed for some orthodox and intermediate seeds. The observed seed water percentages were higher than the optimum moisture content (5-6%) for maximum longevity, since seeds stored at moisture content above 14% begin to exhibit increased metabolism and fungal invasion that reduces seed viability (Copeland and McDonald, 1995).

The water uptake by *Psychotria* and *Palicourea* seeds soaked for 144h in distilled water was relatively low as

Table 4. Viability (%) of non-germinated *Psichotria hoffmansegiana* and *Palicourea marcagravii* seeds after the laboratory germination assays carried out with seeds stored in different conditions for different periods (days).

Species	Time (days)	Storage conditions				
		Open[1]		Shaded		Dry
		5[2]	15	5	15	
Psichotria	32	43 (14)[3]	30 (20)	36 (14)	32 (19)	55 (11)
	66	20 (15)	50 (20)	23 (13)	10 (10)	60 (10)
	99	15 (13)	31 (16)	22 (9)	30 (10)	56 (18)
	130	35 (17)	27 (15)	44 (18)	25 (20)	30 (20)
	161	26 (23)	40 (20)	28 (18)	53 (15)	62 (29)
	192	54 (24)	60 (20)	54 (26)	43 (21)	47 (30)
	220	22 (18)	26 (23)	18 (17)	30 (23)	21 (28)
	247	23 (13)	20 (10)	10 (10)	18 (17)	14 (29)
	281	22 (18)	36 (11)	60 (15)	21 (19)	17 (30)
	308	22 (18)	22 (9)	8 (12)	17 (12)	13 (30)
Palicourea	32	57 (7)	60 (10)	71 (7)	55 (11)	76 (25)
	66	80 (5)	80 (10)	80 (10)	86 (14)	96 (25)
	99	69 (16)	56 (18)	59 (17)	67 (15)	69 (29)
	130	56 (18)	50 (24)	29 (17)	42 (12)	63 (30)
	161	46 (13)	78 (9)	75 (12)	94 (17)	72 (29)
	192	58 (12)	72 (18)	60 (15)	71 (17)	77 (30)
	220	43 (23)	67 (18)	36 (14)	42 (12)	34 (29)
	247	36 (11)	50 (6)	25 (8)	63 (8)	43 (30)
	281	100 (6)	20 (5)	21 (19)	33 (12)	20 (30)
	308	10 (20)	8 (12)	23 (13)	100 (1)	21 (29)

[1] Open – seeds stored in soil in "open" (lighter) site; shaded – seeds stored in soil in "shaded" site; dry – seeds stored in paper bags in laboratory conditions.
[2] 5 – Storage at 5 cm depth in the soil; 10 – storage at 15 cm depth.
[3] Viability% (accessed by tetrazolium test) are followed by the amount of tested seed (in parenthesis).

compared to other seeds such *Vicia sativa* (112%), *Hyptis suaveolens* (50%) and *Sida cordifolia* (25%) (Mayer and Poljakoff-Mayber, 1975; Felippe et al., 1983; Cardoso, 1991). This was not caused by impermeability of seed coat to water, since scarification did not improve water uptake.

The germination of exhumed *Psychotria* seeds declined with increasing time of storage in soil, up to nearly seven months from burial. Sassaki et al (1999) stored fruits of *Psychotria barbiflora* in Cerrado soil for 1, 3 and 7 months and reported that germination of exhumed seeds decreased with the longer the period of storage. The authors also reported that storage for 1 month in soil, or at low temperature, causes a decrease both of seed viability and sensitivity to light. Furthermore, they observed that germination was reduced in seeds stored in the soil for 3 months when compared to storage at 4 °C. We reported that, in general, soil storage of *Psychotria* seeds appears to favour seed survival (accessed by both germination and tetrazolium tests) as compared to dry-stored seeds at room conditions. Unfortunately, the effect of cold storage was not evaluated in this work. Our results suggest that part of the seeds may be dormant, since many viable seeds did not germinate even after 90 days of imbibition in the Petri dishes.

The effect of the soil-storage was even higher in *Palicourea*, of which seeds germinated poorly when stored at room conditions. Given that part of the un-germinated *Palicourea* seeds were still viable after 90 days germination assays, such low germination percentages mean that a fraction of the seeds are dormant. Furthermore, the seeds may require an extended germination time (over 90 days), since the germination of several *Rubiaceae* was found to be slow as reported by Paz et al. (1999) in species of the genus *Psychotria*, of which total seedling emergence occurred only 3-5 months after seeds were sown. The authors also observed that after 7 months, none of the seeds that remained un-germinated were alive. This was not the case of *Palicourea* and *Psychotria* seeds, since a fraction of the seeds was still viable after approximately 400 days from seed collection. As suggested for *Palicourea rigida*, an evergreen woody species from the Venezuelan savannah, the seeds of which remained viable for a year in the soil (Garcia-Nunez et al., 2001), there must be dormancy mechanism(s) in these species, which would explain the failure of the seeds to germinate.

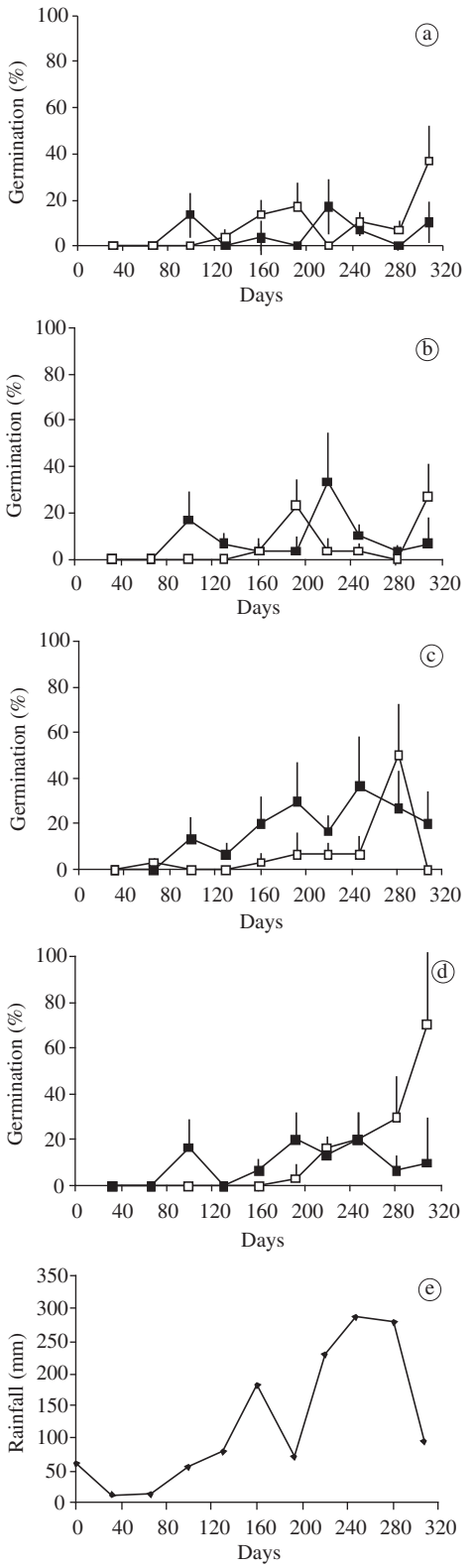

Figure 1. Germination in situ (mean ± SE) of *P. - hoffmansegiana* (a and b) and *P. marcagravii* (c and d) seeds buried in open (a and c) or shade (b and d) site, at 5 cm (■) and 15 cm (□) depth. Rainfall data for the period is displayed (e).

With exception of a few cases, no effect of the burial treatments on the germinability and viability of the seeds could be observed, either for *Psychotria* or *Palicourea*. Paz et al. (1999) reported that the seed behaviour of the tree species *Psychotria limonensis* and *P. simiarum* sowed in the field in a tropical rainforest was similar in gaps and shaded habitats.

In general, the germination assays with exhumed *Palicourea* and *Psychotria* seeds exhibited a relatively high variation, and for such variability, not only changes of the natural conditions can be responsible, but maybe also the size of the seed samples. It should be considered that germination assays were carried out on recovered seeds the number of which was determined by the proportion of germinated seeds while buried in the soil.

The high germination of exhumed seeds as compared to dry-stored ones was probably a consequence of their hydration in the Cerrado soil. The Cerrado soil where the seeds were buried has a sandy texture (60-80% sand) (Cesar et al., 1988) and more space exists between the larger soil particles. Thus, water can easily reach the buried seeds, which can imbibe and start the germination process if the seed does not exhibit physical dormancy (Sassaki et al., 1999). Those authors reported that the moisture content of *Psychotria barbiflora* seeds stored in Cerrado soil ranged from 11 to 17%, whereas the water content of seeds dry-stored at 4 °C was lower than 10%.

In the seed envelopes exhumed from July 2001, seedlings were present, indicating that *Palicourea* and *Psychotria* seeds could germinate while buried. As storage proceeded, the number of germinated seeds in the soil tended to be somewhat higher, accompanied by an increase of the rainfall. A study of the population of *Palicourea rigida* from a regularly burnt savannah in Venezuela showed that buried seeds remained un-germinated until 10 months after burial when all germinated synchronously at the beginning of the rains (Garcia-Nunez et al., 2001). Our results suggest that absence of light may not limit the germination of buried seeds. In this work, the photoblastic response of exhumed seeds was not checked due to the low availability of seeds, but it is probable that sensitivity to light changes with time of burial, as reported for *Psychotria barbiflora* seeds (Sassaki et al., 1999).

Although further experiments are needed for knowledge of seed behaviour of *Palicourea* and *Psychotria* in the field, our results suggest that soil-storage improves the germination capacity and longevity of the seeds as compared to dry-storage. Furthermore, one can conclude that both *Palicourea marcagravii* and *Psychotria hoffmansegiana* seeds may potentially constitute a type of persistent (Thompson and Grime, 1979) or "delayed-transient" (Garwood, 1989) soil seed bank in Cerrado, since viable seeds could be found even after approximately 13 months from seed collection, considering the time lapse between the collection and the end of the germination test. According to Garwood's description, a "delayed-transient" type has seeds which may

remain in the soil for 1-2 years and germinate with a delay and often asynchronously (Csontos and Tamás, 2003). *Palicourea* and *Psychotria* seeds dispersed in a given year may remain viable in the soil until the subsequent period of seed dispersal. Otherwise, most of the seeds can germinate at the beginning of the rainy season, allowing the seedlings to grow under favourable conditions before the next unfavourable period starts. Thus, if the seeds are dispersed from late summer to early/middle autumn, germination is delayed and the seeds last in the soil until the next rainy season (from October).

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