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## Soil preference and burrow structure of an endangered tarantula, *Brachypelma vagans* (Mygalomorphae: Theraphosidae)

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### Abstract

*Brachypelma vagans* is an endangered tarantula included in Appendix II of CITES because of its popularity as a pet. However, little is known about its ecology, in particular microhabitat choices. In this work we analyse the structure of the vegetation surrounding burrows of this tarantula, as well as soil preference for the burrow at different sites in relation to the density of the species. We also offer the first description of the burrow of this spider. *Brachypelma vagans* mostly uses open sites with low vegetation for establishing its burrow, rather than primary or secondary forest. The burrows are essentially built in sites with deep clay soils, whereas sandy soils or soils with a high density of roots and stones are avoided. The soil characteristics may be the key factor determining the presence of *B. vagans*. The burrow of *B. vagans* is deep and complex, exhibiting various chambers, even if only one seems to be used by the occupant. The structure of the burrow and soil characteristics are obviously related. These results could help determine the real distribution of *B. vagans* within its geographic range, and might be useful for a better management focused on protection and reintroduction.

**Keywords:** *Arachnida, Brachypelma vegans, burrow structures, conservation, Mexican Redrump Tarantula, microhabitat, soil characteristics, Yucatan*

### Introduction

Many species of Mexican tarantulas of the genus *Brachypelma* (Mygalomorphae: Theraphosidae) have populations with limited distribution on parts of the Pacific and Caribbean coasts (Yáñez and Floater 2000). The limited geographic distribution of this genus, the destruction of its habitat, the high mortality rates in juveniles, the age of sexual maturity (7–8 years for males, 9–10 years for females), and its high value in the pet trade, make all species of *Brachypelma* endangered (Baerg 1958; Loch et al. 1999).

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Consequently, the genus is listed in Appendix II of CITES. Even though these tarantulas are officially protected, few efforts have been made to increase knowledge of their ecology (Yáñez and Floater 2000; Machkour M'Rabet et al. 2005) and behaviour (Blein et al. 1996; Lochter et al. 1999; Reichling 2000), notwithstanding the usefulness of such data to protect them. In fact, most studies on *Brachypelma* tarantulas concern their geographic distributions (Valerio 1980; Smith 1986, 1994; Baxter 1993; Edwards and Hibbard 1999; Lochter et al. 1999) and their systematics (Coddington and Levi 1991; Pérez-Miles 1992; Pérez-Miles et al. 1996).

Natural history of the genus *Brachypelma* offers interesting clues to factors that might be significant for the persistence of the species, such as the functions of the burrow (Yáñez and Floater 2000). These spiders spend the day in burrows which have a sole entrance, slightly wider than the spider's body (Marshall 1996), and closed with silk to limit water loss (Baerg 1958). They are nocturnal predators feeding mainly on ground-dwelling arthropods, and possibly on small vertebrates (Marshall 1996). The predation site is usually the burrow itself, and the spiders spin silk around the entrance to transmit the vibrations of prey movement (Yáñez and Floater 2000). The burrow also serves as nesting site, where females make large silken egg sacs, 4–5 cm in diameter, containing around 300 young, and spiderlings stay with the mother for several weeks before they disperse (Moore 1994). Despite these important functions, the structure of *Brachypelma* burrows is poorly known, except for one species, *Brachypelma klaasi* (Schmidt and Krause, 1994) (Yáñez and Floater 2000).

Here we focus on one species of *Brachypelma*, *B. vagans* (Ausserer, 1875), commonly known as the Mexican Redrump Tarantula (Breene 1995). This species is reported from southern Mexico, Belize, El Salvador, Guatemala, Honduras, and northern Costa Rica (Valerio 1980), but it has also been recorded in the wild in Florida (Edwards and Hibbard 1999), where trade has promoted its dispersion out of its natural range. As for most tarantulas, the biology and ecology of *B. vagans* are poorly known (Carter 1997; Yáñez et al. 1999; Machkour M'Rabet et al. 2005), and no information on its habitat characteristics has been published.

The present study is part of a larger project aimed at gaining greater understanding of the ecology and biology of this endangered tarantula. Here we analyse the distribution of *B. vagans* in relation to one of its habitat characteristics, the soils where the spiders excavate their burrows. In addition, we describe for the first time the architecture of the burrow of this species.

## Methods

### *Study area*

The study took place in southern Mexico, next to the Calakmul Biosphere Reserve (CBR), in the state of Campeche (Mexico), in an area of approximately 70 km<sup>2</sup>. Natural vegetation in this area is dominated by semi-humid tropical forest, and typical soils are Leptosols. The climate is tropical semi-humid with a mean annual temperature around 26°C, and rainfall averaging 1300 mm annually. The rainy season starts in late May and finishes in October. This study was carried out in June 2004.

We collected soil samples and estimated tarantula densities in seven sites, two in forests, and five in four different villages (Figure 1). The forest sites were: (1) a natural mature forest (MF: 18°11'N, 89°45'W; 274 m) with no noticeable human activity, with a litter of approximately 3 cm thick covering the forest ground; (2) a secondary forest 10 years old (SF: 18°11'N, 89°46'W; 280 m), with a closed canopy and a mix of a thin litter (<2 cm)

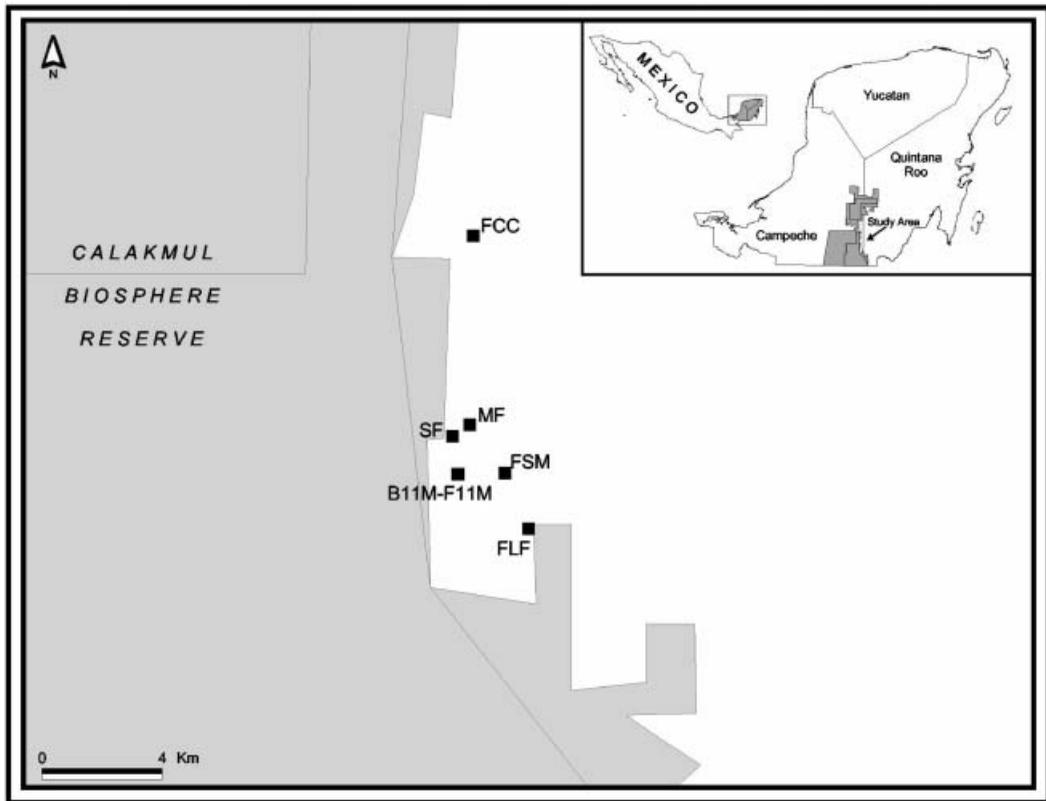


Figure 1. Study sites of *Brachypelma vagans* in the Greater Calakmul Region in southern Mexico. See “Methods” for codes.

and bare ground. The four study villages were surrounded by traditional agrosystems interspersed with forest remnants. In the centre of each village is the football field, surrounded by wood houses, each one with a backyard. In the village “11 de Mayo”, we established one plot in a backyard (B11M: 18°09'N, 89°45'W; 267 m) and another in the football field (F11M: 18°09'N, 89°46'W; 266 m). In the other three villages we established the plots in the football fields: village “Ley de Fomento Agrario” (FLF: 18°06'N, 89°41'W; 264 m), village “San Miguel” (FSM: 18°09'N, 89°43'W; 260 m), and village “Cristóbal Colón” (FCC: 18°22'N, 89°45'W; 248 m).

#### *Spider sampling and burrow description*

We sampled each site during daytime from 10:00 to 14:00 h on a single 400 m<sup>2</sup> area, looking for silk or food disposals at the burrows' entrances, which showed they were inhabited. We recorded the number of *B. vagans* spiders, to estimate spider density at each site.

We excavated 12 burrows (six occupied by females and six by spiderlings) on the B11M site to determine their structures (Figure 1). Before excavating, we removed the tarantula with a small stick and caught it carefully. We determined the orientation of the burrow and excavated parallel to it, starting at 10 cm from the entrance. We gradually removed the soil in the direction of the burrow to discover it, and clear a cross-section. For each burrow, we took the following measures: diameter of the entrance; length of the tunnel (from the

burrow entrance to the entrance of the ultimate chamber); depth of the burrow (from the surface to the deepest point of the burrow); height, length and width of the chamber(s). If found, we also collected moults and consumed prey, that were later determined.

### *Soil analysis*

To derive information on possible influence of soil properties on spider density and burrow characteristics, we analysed soil samples at the seven sites on the same 400 m<sup>2</sup> plots used for the evaluation of spider densities. At each site we determined from a soil profile the following soil characteristics using field methods described by Boden (1994): humidity, pF (pF=log Ψ (cm) with Ψ=tension of soil humidity; the higher pF, the drier the soil), depth, density of roots ( $D_{\text{roots}}$ ), percentage of stones (Stones), and vegetation cover (VC). Vegetation cover was the visually estimated percentage of shrub and tree cover in the 400 m<sup>2</sup> plot. From each soil profile, we collected soil samples of the A-horizons. From soil samples we determined the pH (KCl), texture and apparent density ( $D_{\text{app}}$ ), using standard methods described by Secretaría de Medio Ambiente y Recursos Naturales (2000). Furthermore, we characterized soil structure by the composition of different types of structures (G3: single grain structure <2 mm; G7: granular structure 2–10 mm; G8: sub-polyedric structure 10–20 mm; G12: clod structure 20–50 mm; G13: fragment structure >50 mm; Boden 1994).

### *Statistical analyses*

The densities of spiders were compared with a maximum likelihood ratio test. To investigate the relationship between tarantula density and soil characteristics, we ran a principal component analysis (PCA). We compared all measures of the single-chamber burrows occupied by females or juveniles using a Mann–Whitney *U* test. All analyses were performed with the software Statistica version 6.1 (StatSoft Inc., Tulsa, OK, USA).

## **Results**

### *Relationship between density of B. vagans and soil characteristics*

The density of tarantulas at each site varied from 0 in the forest sites (MF and SF) to 0.1 spiders per m<sup>2</sup> in F11M (Table I). Among the sites with tarantulas, the density varied significantly from FCC to F11M ( $G=64.27$ ; 4 df;  $P<0.0001$ ). As for soil variables, most of them varied strongly between samples (Table I), except apparent density and pH, which were excluded from the PCA.

The first three principal components of the PCA explained 86% of the variance, with the first contributing to 44%, the second to 28%, and the third to 14%, of total variance. The first principal component clearly separated the sites according to their spider density and soil texture (Figure 2). Sites without or with few spiders (MF, SF, and FCC) had sandy loam soils with very fine aggregates and many stones (eigenvalues for *B. vagans* density:  $-0.85$ , sand: 0.73, silt: 0.74, G3: 0.66, stones: 0.85). On the other side, sites with high tarantula density (B11M, F11M, FSM, and FLF) exhibited deep clayish soils with large aggregates (eigenvalues for depth:  $-0.73$ , clay:  $-0.84$ , G8:  $-0.75$ , G12:  $-0.65$ , G13:  $-0.63$ ). The second principal component revealed a humidity gradient coupled with a gradient of medium aggregates, with more humid sites showing higher percentages of G7 (eigenvalues for pF:  $-0.77$ , G7: 0.98). F11M and FCC were the driest sites, whereas the

Table I. Soil characteristics and densities of *Brachypelma vagans* in the seven sites sampled.

Variables measured	Sites						
	B11M	F11M	FLF	FSM	FCC	MF	SF
<i>B. vagans</i> density (individuals per ha)	600	1000	280	100	35	0	0
pH	6.8	6.8	6.8	7.0	6.8	6.9	6.9
$D_{app}$ (g cm <sup>-3</sup> )	0.68	0.68	0.68	0.71	0.68	0.69	0.69
Sand (%)	35.2	41.5	36.8	43.8	48.1	51.5	48.1
Clay (%)	52.2	48.3	46.3	46.1	5.2	37.8	5.2
Silt (%)	12.6	10.2	16.9	10.1	46.7	10.7	46.7
pF	3	4	3	3	5	4	3
Depth (cm)	45	41	12	42	8	22	25
Stones (%)	0	1	1	3	40	25	7
G3 (%)	0	0	0	0	100	0	0
G7 (%)	99	30	80	90	0	100	99
G8 (%)	1	40	20	8	0	0	1
G12 (%)	0	20	0	2	0	0	0
G13 (%)	0	10	0	0	0	0	0
$D_{Roots}$ (number per dm <sup>2</sup> )	4	8	4	8	8	50	15
VC (%)	40	0	0	0	0	100	100

See “Methods” for codes.

forests (MF and SF), the backyard (B11M), and two other football fields (FSM and FLF) were more humid (Figure 2). The third principal component was mainly a gradient of root density (eigenvalue for  $D_{root}$ : -0.81) that clearly separated the forest sites (MF and SF) from the others (B11M, F11M, FCC, FSM, and FLF).

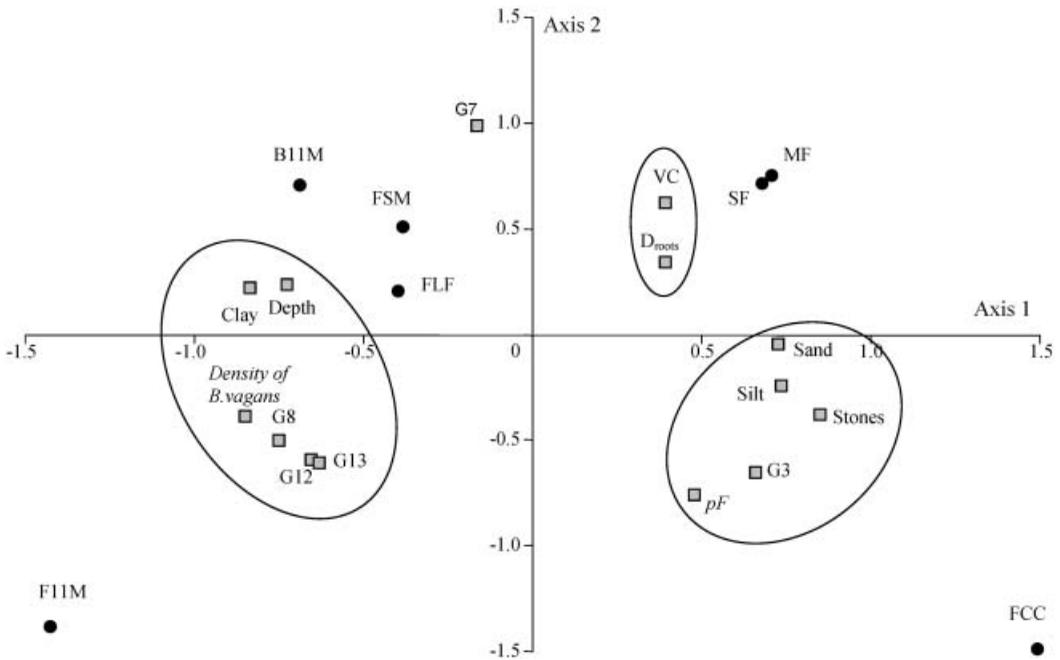


Figure 2. Principal components 1 and 2 extracted from the analysis of the tarantula densities and soil characteristics (squares) at seven sites (circles). See “Methods” for codes.

*Burrow description*

All burrows of females had at least one chamber (four had one chamber, one had two chambers, and one had four chambers), whereas only 33% of spiderlings' burrows had one chamber and the remaining had no chamber at all. The more common burrows (10 out of 12 excavated) consisted of a horizontal tunnel followed by a vertical tunnel with or without a chamber at its end (Figure 3C, D). The depth of these burrows was always around 20 cm, and the dimensions of the chambers were similar irrespective of spider age (entrance diameter:  $U_{1,10}=6$ ,  $P=0.20$ ; tunnel length:  $U_{1,10}=8$ ,  $P=0.39$ ; burrow depth:  $U_{1,10}=11$ ,  $P=0.83$ ; chamber height:  $U_{1,6}=3$ ,  $P=0.64$ ; chamber length:  $U_{1,6}=0$ ,  $P=0.06$ ; chamber width:  $U_{1,6}=3$ ,  $P=0.64$ ; Table II). The complex burrows (with more than one chamber) showed some differences in structure. They were significantly deeper ( $U_{1,12}=0$ ,  $P=0.03$ ) and generally with higher chambers ( $U_{1,12}=0.5$ ,  $P=0.008$ ).

Prey remains found in female burrows (in three out of six excavated) were all in the ultimate chamber along with moults. Only one spiderling burrow (out of six excavated) contained prey remains and a moult. This burrow had no chamber, and the remains were found at the entrance and in the bend of the tunnel, along with the moult. Overall, prey remains were from seven coleopterans (Passalidae), four hymenopterans (Formicidae), and one hemipteran (Belostomatidae).

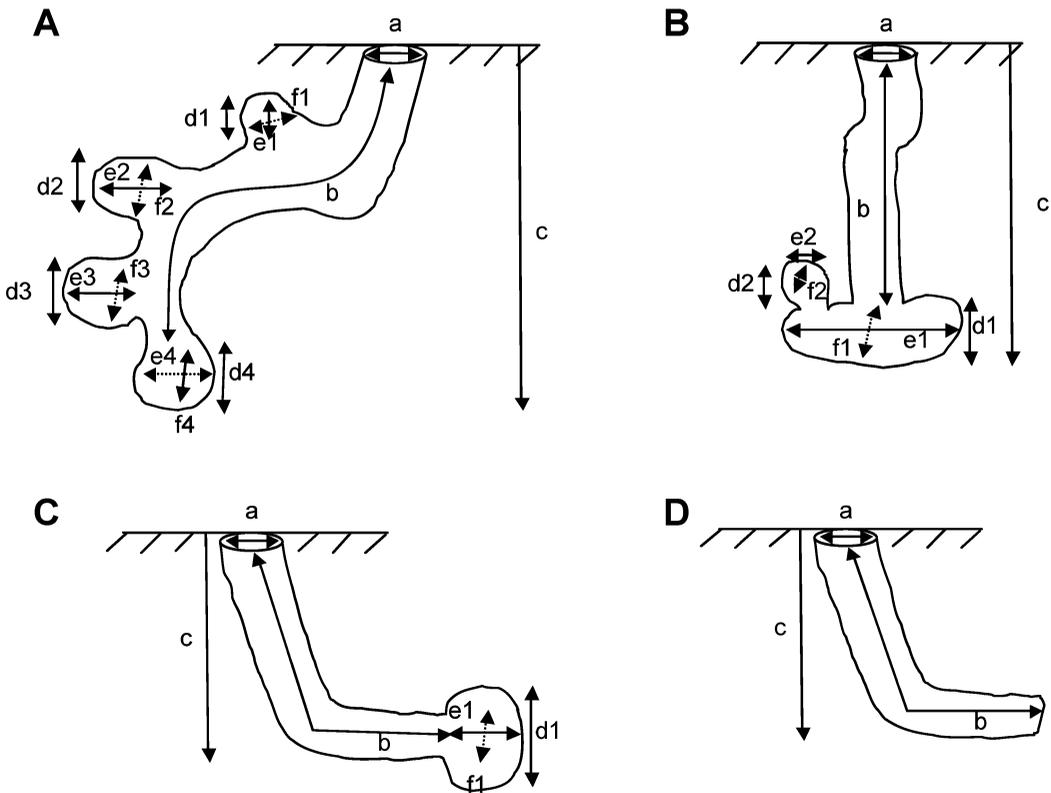


Figure 3. Structures of the burrows of *Brachypelma vagans*. (A) Burrow with four chambers; (B) burrow with two chambers; (C) prototype of single chamber burrow; (D) prototype of burrow without chamber. a, Entrance diameter of the burrow; b, length of the tunnel; c, depth of the burrow; d1–d4, length of chambers; e1–e4, width of chambers; f1–f4, height of chambers.

Table II. Characteristics of *Brachypelma vagans* burrows, according to their complexity, i.e. the number of chambers.

Measure (cm)	Burrow type				
	A	B	C		D
	Four-chamber burrow ( <i>n</i> =1 female)	Two-chamber burrow ( <i>n</i> =1 female)	One-chamber burrow ( <i>n</i> =4 females)	One-chamber burrow ( <i>n</i> =2 spiderlings)	Burrow with no chambers ( <i>n</i> =4 spiderlings)
a	4.2	3.8	4.8±0.9	3.1±0.6	3.7±0.5
b	62	32	32.0±6.7	15.3±1.3	29.7±5.5
c	38	40	20.0±1.4	16.5±2.5	22.5±3.8
d1	4	15	6.4±0.4	7.8±0.3	–
e1	4	15	6.0±0.9	6.5±1.5	–
f1	8	8	5.1±0.5	5.5±0.5	–
d2	13	5	–	–	–
e2	17	5	–	–	–
f2	7	4	–	–	–
d3	7	–	–	–	–
e3	9	–	–	–	–
f3	7	–	–	–	–
d4	15	–	–	–	–
e4	7	–	–	–	–
f4	6.5	–	–	–	–

See “Methods” for codes.

## Discussion

As previously, in the same area (Machkour M'Rabet et al. 2005), we did not find tarantulas in the primary and secondary forest plots. As suggested by the PCA, the high density of roots in the forests might complicate the excavation of burrows. Conversely, we always found *B. vagans* in plots without (or with scattered) shrubs and trees. In these plots, spider densities reflected differences among soils. Highest burrow densities were observed in deep, clayish soils with large aggregates. On the other hand, few spiders were found in sandy loam soil with a large quantity of stones. Gotelli (1993) showed that for antlion larvae (Neuroptera: Myrmeleontidae), also a sit-and-wait predator, micro-habitat selection was strongly influenced by soil characteristics. Factors other than soil characteristics influence microhabitat selection, such as fluctuation in daily temperature and humidity, as observed in *Brachypelma klaasi* (Yáñez and Floater 2000). However, considering the importance of the burrow for *B. vagans*, as a shelter and hunting site, soil properties are certainly a key factor determining the presence of this species.

The burrows of *B. vagans* were diverse in their structures, from very simple to relatively complex. The plasticity in burrow structure had not been described previously in tarantulas. Juveniles made simple burrows with just a tunnel or with only one chamber at its end. Females tended to make more complex burrows with one to four chambers. When various chambers were present, only one, the ultimate, contained prey remains and moult, suggesting that the occupant uses this chamber only. Yáñez and Floater (2000) reported that burrow length in *B. klaasi* varied from 0.5 to 2 m, depending on the site and the age of the spider. In *B. vagans*, burrows were shorter (from 0.15 to 0.62 m), but in juveniles the tunnel without a chamber was longer, which could compensate for the absence of the chamber.

Prey availability is an important factor governing the distribution of spiders in several species (Henschel and Lubin 1997). The sites exhibiting high tarantula densities were open

and with high human activity (Machkour M'Rabet et al. 2005), which does not favour a high abundance and diversity of prey (Dor and Weissenberger 2005). Conversely, although heterogeneous in their vegetation, the forest plots did not host any *B. vagans* burrows (Machkour M'Rabet et al. 2005). Thus, it seems that prey availability is less important than the quality of soil for *B. vagans*. Moreover, tarantulas can survive a long period (>2 months for *B. klaasi*) without food. Consequently, prey availability may be relatively unimportant for individual success (Yáñez and Floater 2000). We observed *B. vagans* catching prey such as lepidopterans or flying ants, which were also among the remains in the burrows. The strategy of these tarantulas does not appear to be catching prey all the time as do orb-weaving spiders (Champion de Crespigny et al. 2001), nor does the choice of hunting site depend on prey availability as in many spiders (Gillespie 1981; Morse and Fritz 1982; Morse 1999). Their hunting strategy seems rather related to the physical quality of the microhabitat, as observed by Robinson and Lubin (1979) for Araneidae spiders. In fact, we suspect that the abundance of adult females in the backyard reflected both (1) soil selection for burrowing, and (2) exclusive competition towards juveniles. In this plot, the soil was a clayey deep soil (thus favourable), and tree and shrub cover was high compared to football fields (where it was null), allowing buffering of microclimatic conditions (Yáñez and Floater 2000). Furthermore, competitive exclusion of young spiders by adult females is known to occur during the reproductive period, because females need to eat more (Smith 1994).

As suggested by Yáñez and Floater (2000) for *B. klaasi*, the understanding of ecological requirements of tarantulas may facilitate the re-introduction of captive-bred individuals. This study, by revealing soil and vegetation preferences for burrowing in *B. vagans*, as well as the spatial segregation of adults and juveniles, should help to localize the areas within its distribution range where reproductive populations of this species may be maintained.

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