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Abundance of arbuscular mycorrhizal fungi spores in different environments in a tropical rain forest, Veracruz, Mexico

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Abstract The aim of this study was to compare mycorrhizal abundance and diversity in sites with different regimes of disturbance in a tropical rain forest at Los Tuxtlas, Veracruz, Mexico. Arbuscular mycorrhizal spores were quantified at two sites: closed canopy and gaps in the forest. Data were recorded during dry, rainy, and windy ("nortes") seasons. Spores of eight *Glomus* species, sporocarps of three *Sclerocystis* species, three species of *Acaulospora* and two of *Gigaspora* were found. Significant differences in the number of species and spores were found among seasons. The highest numbers of species and spores were observed during the dry season, with a marked decrease during the rainy season. Our results show that disturbance does not but seasonality does affect abundance and richness of mycorrhizal spores in this tropical wet forest.

Key words Arbuscular mycorrhizae · Tropical rain forest · Gaps · Mexico

Introduction

The most important disturbance agents in tropical communities are tree falls that form gaps (Brokaw 1985). Such disturbance retards competitive interactions and diminishes dominance of species, maintaining richness and diversity (Connell 1978; Brokaw 1985). In the lowland tropical rain forest in Los Tuxtlas, Veracruz, Mexico, trees fall mainly during the rainy and "nortes" (high speed wind) seasons. Nutrients become available within gaps (Brokaw 1985), and there is probably a reduction in mycorrhizal inoculum (Allen 1991). However, remnant species in the gap after disturbance may be a source of mycorrhizal inoculum for renewing gap colonization (Janos 1980; Gange et al. 1993).

Spore quantification has been very useful for evaluating level and diversity of mycorrhizae, because spores are highly resistant to adverse conditions (Abbot and Robson 1991) and may reflect the previous history of a mycorrhizal symbiosis in the soil (Harley and Smith 1983). Changes in spore production may be due to drought (Nelsen 1987). In lowland humid tropics, spore abundance varies with the season, with highest abundance in the dry season (Janos et al. 1995; Sigüenza et al. 1996; Ramírez-Gerardo et al. 1997), and is related to low nutrient availability and plant phenology, among others factors.

Given the great importance of these endophytes in natural systems, it is important to identify and to study the distribution and abundance of mycorrhizal fungi. The aim of this present study was to quantify spore abundance and richness of arbuscular mycorrhizal (AM) fungi in two different environments in a tropical rain forest, closed canopy and gaps, where such disturbance might affect mycorrhizal performance within these different forest microenvironments.

Materials and methods

The study was carried out at the Tropical Biology Station of Los Tuxtlas, Universidad Nacional Autónoma de México. The station is located between 94°42' and 95°27' W and 18°10' and 18°45' N at an altitude of 150–530 m above sea level (Lot–Helgueras 1976). The soil is classified as an andosol with organic matter accumulating in the upper layers (García 1988). The climate is hot and humid with a total annual precipitation of 4700 mm. Precipitation distribution is uneven throughout the year: the dry season occurs from March to May (100 mm average per month), while the rainy season is from June to February (486 mm average per month). The region is seasonally affected by tropical hurricanes and "nortes", which are strong cold northerly winds from September to February (Lot–Helgueras 1976). Mean annual temperature is 27 °C, with a maximum in June (27.1 °C) and a minimum in January (21.1 °C).

The vegetation is a tropical lowland rain forest (Miranda and Hernández 1963). Ibarra-Manríquez and Sinaca (1995) reported

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940 species belonging to 129 Angiosperm families. The most important are: *Astrocaryum mexicanum* in the understory, *Nectandra ambigens*, *Pseudolmedia oxyphyllaria*, *Brosimum alicastrum* and *Guarea glabra* among others in the canopy (Bongers et al. 1988). The forest is characterized by a low density (2976 individuals with a DBH >1.0 cm per hectare) (Bongers et al. 1988).

Disturbance is high due to landslides and wind effects (Ibarra 1985). In the study area, the species observed in the gaps were *Eupatorium galeottii*, *Heliocarpus appendiculatus*, *Croton schiedeanus*, *Aphelandra aurantiaca*, *Pleuranthodendron lindenii*, *Rheedia edulis*, and in a peripheral location, *Stemmadenia donnell-smithii*, *Dussia mexicana*, *Pseudolmedia oxyphyllaria*, *Poulsenia armata* and *Nectandra ambigens*, among others.

Soil samples were collected in two different habitats (Hectárea and Vigía, the latter with a slope of 30°) in April (dry season), July (rainy season) and November ("nortes" season) in 1991: (a) closed canopy, with no evidence of disturbance and (b) gaps with a diameter larger than 10 m. We chose two sample areas at each site. The gaps were 2 years old and were formed by the fall of a single tree.

Under the closed canopy, we placed a 50-m long tape with a North-South orientation at each undisturbed site and randomly took five soil samples along the tape. Each soil sample was 200 g to a depth of 20 cm. We collected 20 samples for each season. The soil was placed in black plastic bags and stored in a refrigerator until analysis.

Spores from soil samples were isolated following the method of Gerdemann and Nicolson (1963) of wet sieving and decantation, as modified by Daniels and Skipper (1982). Samples were centrifuged on different density gradients (Daniels and Skipper 1982) and permanent slides prepared according to Schenck and Pérez (1990).

The total number of species was tabulated in a 4×3 contingency table (four sites by three seasons) and analysed by chi-square (Crawley 1993). Differences in the number of spores between sites and seasons were tested using a factorial ANOVA and the differences within the factor season were tested by Tukey's multiple comparison test. Logarithm transformation of number of spores was used to satisfy normal distribution and homogeneity of variance assumptions (Zar 1984).

Results

A total of 16 morpho–species of arbuscular mycorrhizae was found. Six of these were identified to species level. Eight of them corresponded to the genus *Glomus*, three to *Sclerocystis*, three to *Acaulospora* and two to *Gigaspora* (Table 1).

According to Schenck and Pérez (1990), *Glomus constrictum*, *Sclerocystis clavispora*, *Acaulospora scrobiculata* and *Acaulospora spinosa* have been recorded in Mexico from a tropical rain forest. *Sclerocystis sinuosa* was previously reported for Morelos state (central part of Mexico) (Varela and Vázquez 1989). This is the first time *Gigaspora rosea* has been reported in the Mexican tropics.

The highest number of species and spores of arbuscular mycorrhizae was found in the dry season and significantly decreased in the wet season (Fig. 1a, b). Statistic analysis showed significant differences in species between seasons ($n = 60$, chi-square = 6.286, $P < 0.05$), with the dry season being significantly different to the rainy and "nortes" seasons. There were differences in the numbers of spores between seasons ($n = 60$, $F = 21.443$, $P < 0.001$). Tukey's test showed significant differences between all seasons. There were no signifi-

Table 1 List of mean number of spores by species (±SE) in 100 g soil dry for each site (*CV* closed canopy, *GV* gap at the Vigía site, *CH* closed canopy, *GH* gap at the Hectárea site, *d* dry season, *r* rainy season, *n* "nortes" season

Species	CVd	GVd	CHd	GHd	CVr	GVr	CHr	GHr	CVn	GVn	CHn	GHn
GLOMACEAE												
Glomus constrictum Trappe	13± 5	139 ±120	13 ± 5	12 ± 4	2 ±1	19 ±94	3 ±1	0.1±0.1	36 ± 34	28±9	20 ±18	5 ±3
Glomus sp. 1	55±23	9 ± 5	66 ±34	43 ±26	4 ±3	–	9 ±5	5 ±1	15 ± 9	2±1	2 ± 2	8 ±2
Glomus sp. 2	80±26	23 ± 15	61 ±40	68 ±32	15 ±6	1 ± 0.4	9 ±4	14 ±4	190 ±173	8±8	16 ± 6	9 ±4.7
Glomus sp. 3	7± 5	0.6± 0.6	–	2 ± 2	0.5±0.4	–	–	–	–	1±0.6	–	1 ±0.3
Glomus sp. 4	–	2 ± 1	–	–	0.5±0.1	1 ± 0.6	–	1 ±0.4	0.3± 0.3	1±0.6	–	0.3±0.3
Glomus sp. 5	3± 2	18 ± 15	6 ± 6	0.4± 0.3	1 ±0.5	–	0.1±0.1	–	2 ± 1.5	–	0.3± 0.2	–
Glomus sp. 6	11± 9	23 ± 15	11 ± 8	22 ± 6	1 ±1	–	1 ±0.4	2 ±1	8 ± 4	2±1	17 ± 9	8 ±6
Glomus sp. 7	–	–	13 ±13	2 ± 2	–	–	0.2±0.2	0.4±0.4	–	1±0.7	–	–
Sclerocystis clavispora Trappe	2± 2	62 ± 62	10 ± 5	1 ± 0.5	–	–	–	–	–	–	1 ± 0.4	0.3±0.3
S. sinuosa Gerdemann & Bakshi	4± 4	–	0.7± 0.7	0.7± 0.7	–	–	–	–	–	–	–	–
Sclerocystis sp.	2± 1.5	1 ± 1	–	0.7± 0.7	–	0.1± 0.1	–	0.1±0.1	1 ± 1	–	–	2 ±1
ACAULOSPORA												
Acaulospora spinosa Walker & Trappe	7± 4	0.4± 0.4	14 ±12	24 ±21	0.4±0.4	1 ± 0.3	0.3±0.3	0.3±0.2	2 ± 1	1±0.6	–	2 ±1
A. scrobiculata Trappe	15±12	0.4± 0.4	7 ± 5	7 ± 2	5 ±2	–	0.4±0.3	1 ±0.4	1 ± 0.6	–	–	3 ±2
Acaulospora sp.	–	–	–	–	–	–	–	–	–	1±0.6	1 ± 0.6	–
GIGASPORACEAE												
Gigaspora rosea Nicolson & Shenck	–	–	14 ±14	–	–	–	1 ±1	–	–	–	6 ± 6	–
Gigaspora sp.	–	–	3 ± 3	–	–	–	–	2 ±1	–	–	–	–

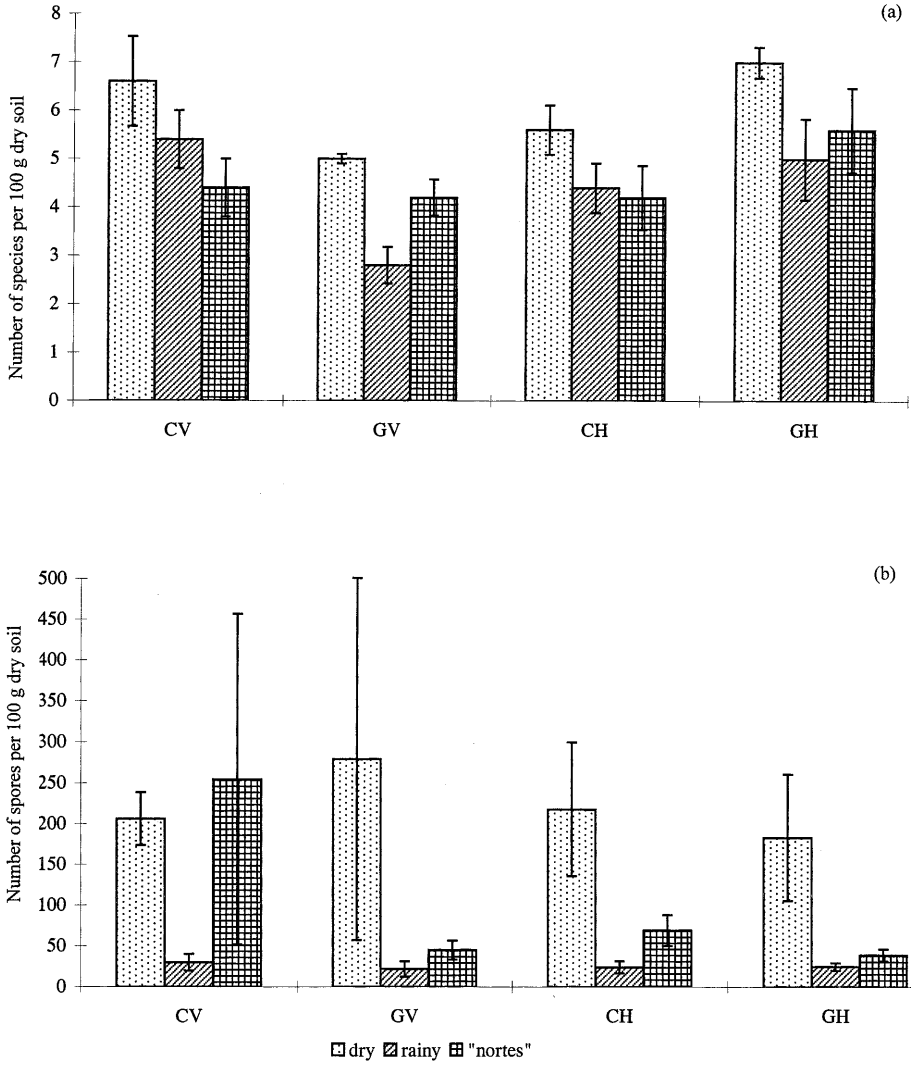

Fig. 1 Average number ± SE of mycorrhizal species (*a*) and spores (*b*) per 100 g of dry soil for each site and season (*CV* closed canopy, *GV* gap at the "Vigía" site, *CH* closed canopy, *GH* gap at the "Hectárea" site)

cant differences in species and spores number between sites.

Discussion

Seasonal fluctuations influence mycorrhizal dynamics. These organisms have a seasonal pattern of spore production closely related to plant phenology (Brundrett 1991). For example, in coastal dunes, Sigüenza et al. (1996) observed that phenology and seasonality were important factors for the production of spores and mycorrhizal colonization. Our results are similar to those of the latter study in that they also reveal the highest spore production during the dry season.

Root phenology and production can also influence spore quantity (Brundrett 1991). It has been observed that spore number increases while roots are decaying (Redhead 1975). Our results agree in that, during the dry season, spore abundance increased (more than 200 spores in 100 g dry soil) while fine root production decreased (from 0.1 g m^{-2} day^{-1} in the rainy season to 0.01 g m^{-2} day^{-1} in the dry season) (Sánchez-Gallén and Álvarez-Sánchez 1996). Some authors found that intra- and extramatricial mycelium increases during the rainy season, because spore germination is favoured and, as a result, mycorrhizal colonization increases and spore abundance decreases (Mason et al. 1992; Ragupathy and Mahadevan 1993).

Disturbance may also influence spore abundance and distribution (Jasper et al. 1991). Destruction of extraradical hyphae by disturbance agents diminishes mycorrhizal inocula (Evans and Miller 1990). However, spore abundance at gap sites and under closed canopy sites was not significantly different. In this case, size and age of gap may be important factors. It is likely that the microenvironment of a relatively small gap surrounded by forest species is not greatly affected, and that the roots from the bordering species invade the gap. Thus, there may be no significant difference between small gaps and closed canopy in spore abundance.

In conclusion, for this tropical rain forest in Mexico, the climatic seasons seem to be more influential on richness and abundance of mycorrhizal spores than is the formation of small tree-fall gaps.

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