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Changes in saprophytic fungal community structure in response to variations in moisture content

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ABSTRACT

This study examined community structure of fungal species on dead wood substrates of different moisture contents in Monteverde, Puntarenas, Costa Rica. Forty-five different samples of dead wood substrate were located in the cloud forest and sampled for abundance of fungi individuals and number of fungal morphospecies. Penetrability as a measure of moisture content, surface area, and percent of epiphytic and lichen cover were also recorded for each sample of dead wood substrate. A total of 42 morphospecies were found, with only three of them overlapping between hard and soft substrates. Significant negative correlations were found between penetrability and abundance of fungi individuals ($r^2 = .251$, $p = .0005$), as well as between penetrability and fungal diversity ($r^2 = .217$, $p = .0013$). The negative correlations suggest that there is a moisture barrier-a certain substrate saturation- beyond which fungal growth is restricted. The low rate of species overlap between hard and soft substrates indicates that there is a difference in community structure depending on moisture content.

RESUMEN

Esté experimento se centró el succesión de especies de hongos differentes en los árboles muertes en Monteverde, Puntarenas, Costa Rica. Se encontraron 45 muestras de árboles caídos en el bosque nuboso y estos se examinaron para encontrar la abundancia de hongos individuales, números de morfoespecies, y diversidad. También se anotó la penetrabilidad, el area superficial, el porcentaje de la cubierta epifítica y de liquenes para cada muestra de sustrato en los truncos caídos. Se encontró un total de 42 morfoespecies, con solomente tres de estas en traslape entre sustratos duros y sustratos suaves. Se usó regresiones simples para encontrar correlaciones negativas significativas entre penetrabilidad y la abundancia de hongos individuales, asi como entre penetrabilidad y diversidad de hongos en cada muestra de sustrato. Las correlaciones negativas sugieron que hay una barrera de humedad más alla de la cual el crecimiento del hongo especies entre sustratos duros y suaves indica que hay una diferencia en la estructura de la communidad dependiente del contenido de humedad.

INTRODUCTION

Fungi are an important, highly specialized but relatively little studied group of organisms (Mata 1999). Currently, there are approximately 100, 000 known species worldwide; however, this figure could increase to as much as 1.5 million (Mata 1999). Fungi aid in the decomposition of organic matter, nutrient transfer from soil to plants, and regulation of water uptake in plants. These organisms can be classified as saprophytic (decomposing dead organic matter), parasitic (absorbing nutrients from living organisms), or symbiotic (having a mutually beneficial relationship with another organism) (Mata *et al.* 2003).

Saprophytic fungi are especially important in ecosystem functions, as they decompose the remains of dead organisms that would otherwise accumulate in enormous deposits of non-decomposed organic matter (Mata *et al.* 2003). This decomposition contributes to the carbon cycle and also helps to recycle other elements such as nitrogen, phosphorus, and potassium (Mata 1999). Some species of saprophytic fungi require a specific substrate to grow on. Many, however, are versatile and can grow on a variety of substrates. A large percentage of fungi found in Monteverde grow on dead wood substrate and aid in its decomposition (Herz 2004). Although it is known that species succession occurs as one type of mushroom exhausts its nutrient supply (Arora 1986) and another type replaces it, not much is known about the succession in species found in Monteverde and their abundance as substrates decay.

This study examined the different species and abundance of fungi that colonize horizontal dead wood substrate at various levels of moisture content. It was hypothesized that the abundance of fungi individuals would positively correlate with the moisture content of the substrate, and also that the species of fungi would vary in relation to moisture content. Moisture content was hypothesized to correlate with epiphyte and lichen cover, and therefore with substrate age (stage of decomposition). Epiphyte and lichen cover was assumed to correlate with age because directly after a tree fall, many of the pre-fall epiphytes are still present. As the tree decomposes, it goes through various stages of lichen cover, and towards the final stages of decomposition there is little to no lichen growth (W. Zuchowski pers. comm.).

MATERIALS AND METHODS

This study was conducted in primary forest on the Pacific slope of the Tilaran Mountains near the Estación Biológica de Monteverde, Costa Rica. Samples were taken at elevations from 1505 m to 1645 m; this measurement was recorded using a Timex Helix altimeter. Forty-five random samples of horizontal dead wood substrate were located within this range. The number of fungi individuals and number of fungal morphospecies were recorded for total surface area of each sample and a photograph of each morphospecies was taken in the field using a Sony Cybershot digital camera.

The surface area, percent of shade cover, and percent of epiphytic and lichen cover were also recorded for each substrate. Percent of shade cover was estimated by standing directly next to log and looking up at a 90º angle through the viewfinder of the Sony Cybershot digital camera used to photograph the fungi. Epiphytic and lichen cover was measured by looking at all sides of the log and estimating the ratio of covered area to non-covered area.

The penetrability of each sample of dead wood substrate was also measured by holding a 78 cm long PVC pipe at a 90º angle to the substrate and dropping a sharp weighted blade (320 g) with a 10.3 cm tip through the top opening of the pipe. The blade was then removed from the substrate and the depth of penetration was measured and recorded. Three penetrability samples were taken for each substrate, and were then averaged together to find the mean penetrability for each sample of dead wood. The penetrability of each piece of substrate was categorized as hard (penetrability = 0 - 1.5 cm), medium (1.5 – 3 cm), or soft (> 3 cm).

Two simple regressions were performed comparing penetrability of the substrate versus abundance of fungi individuals and fungal diversity. Prior to running the regression, the data set for number of fungi individuals was normalized using the natural log transformation. Fungal diversity (H') was measured for each sample of substrate using the Shannon-Wiener Index. Another regression was run comparing surface area of the substrate versus fungal diversity. A one-way ANOVA was run to determine significant differences in epiphytic and lichen cover between each category of penetrability. The data set for percent epiphytic and lichen cover was normalized using the arcsine transformation. A Jaccard index of similarity was also calculated for morphospecies overlap between hard (penetrability $\leq$ 2 cm) and soft (penetrability >2 cm) substrates.

RESULTS

A total of 42 morphospecies and 2,114 fungi individuals were found on 45 different samples of dead wood substrate. A significant negative correlation was found between penetrability and fungal diversity on each sample of substrate ($r^2 = .217$, $p = .0013$) (Figure 1). Similarly, a negative correlation was found between penetrability and number of fungi individuals on each substrate sample ($r^2 = .251$, $p = .0005$)(Figure 2). A low species overlap was found, as only three species were found on both hard and soft substrates (Jaccard similarity index = .0952). No significant difference in epiphytic and lichen cover was found between hard, medium, and soft substrates.

DISCUSSION

It was predicted that the abundance of fungi individuals would positively correlate with the level of moisture content. The results showed a negative correlation between abundance of fungi individuals and moisture content as well as a negative correlation between fungal diversity and moisture content, dissimilar to the expectations. These results support past studies, which have suggested that in areas where the ground and other substrates are completely saturated, fungi are not present (Herz 2004). Herz's research also showed a moisture threshold of 85.4%, beyond which fungal growth was inhibited, so it is possible that the softer substrates in this study were past that threshold. It is also possible that after a certain stage of decomposition, macrofungi are replaced by microfungi, which then finish the decomposition process.

It was also expected that the species of fungi would vary in relation to moisture content, as one of the main factors that influence fungal growth is moisture (Alexopoulos *et al.* 1996). Also, Herz's research suggested that fungal growth might be related to wetter conditions and suitable substrates. This was found to be true, as the Jaccard index indicated very little overlap between hard and soft substrates.

Epiphytic and lichen cover was recorded in this study under the assumption that it directly correlates with age. A correlation was expected between penetrability and age of the substrate under the previously stated assumption regarding epiphytic and lichen cover. If this was true, as the substrate became more penetrable, epiphytic cover should have decreased. Since there was no significant difference in lichen cover between substrate categories, it appears that penetrability alone is not a solid indicator of age. In

future studies, it would be beneficial to hold the species of dead wood substrate constant, so that penetrability would more directly correlate to stage of decomposition. Also, more detailed fungal identification guides would be useful, as it was possible to identify only nine of the 42 morphospecies to genus.

This study has only begun to touch on the little studied process of fungal community structure by examining species composition differences between dead wood substrates of differing moisture contents. The negative correlations between penetrability and morphospecies diversity and between penetrability and number of fungi individuals, as well as the low amount of species overlap between hard and soft substrates suggest that there are definite differences in community composition on dead wood substrates, perhaps relating to the stage of decomposition (moisture level). In the face of increasing loss of biodiversity in neotropical cloud forests, it is imperative that further studies be conducted on the important role fungi play in decomposition and regulation of ecological processes before it is too late.

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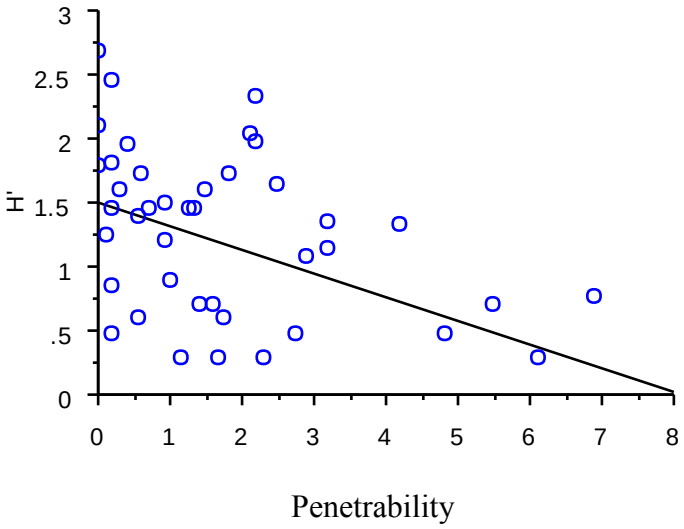

FIGURE 1. Penetrability vs. fungal diversity (H'). A significant negative correlation was found between penetrability and fungal diversity (r^2 = .217, p = .0013)(N = 45)(Y = 1.508 - .185*X).

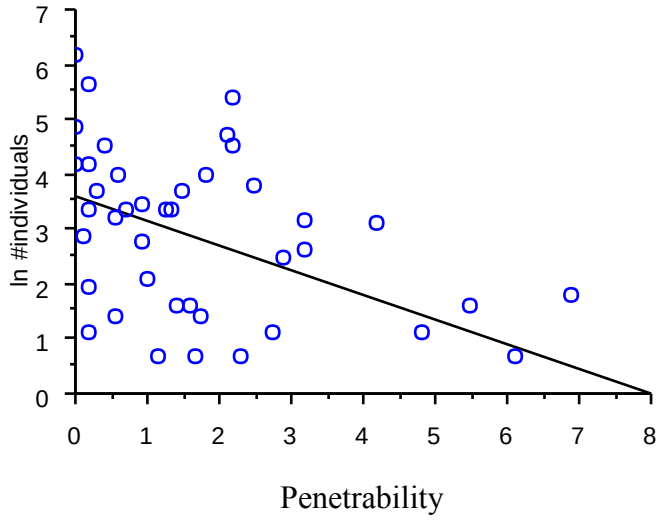

FIGURE 2. Penetrability vs. natural log number of individuals. A significant negative correlation was found between penetrability and number of fungi individuals (r^2 = .251, p = .0005)(N = 45)(Y = 3.581 - .446*X).

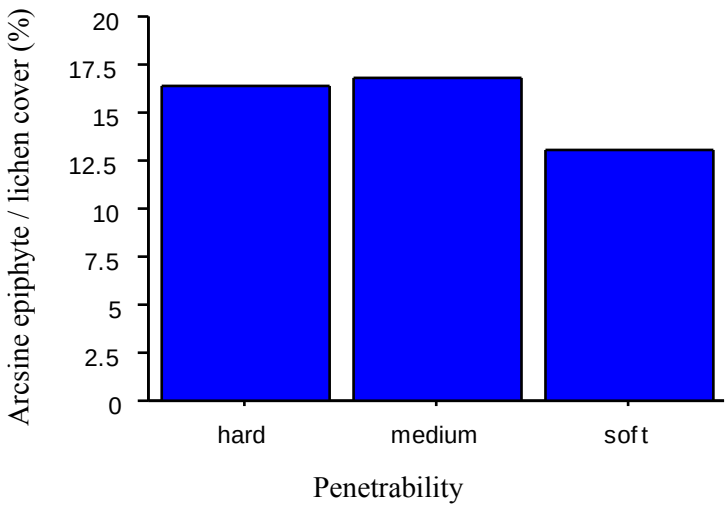

FIGURE 3. Average epiphyte and lichen cover for different substrate categories. No significant difference was found between the categories (p= .7907)