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Detection of arbuscular mycorrhizal fungal spores in the air across different biomes and ecoregions

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ABSTRACT

Aerial dispersal of fungal spores is common, but the role of wind and air movement in dispersal of spores of arbuscular mycorrhizal (AM) fungi is largely unknown. Several studies have examined the possibility of AM fungal spores being moved by wind vectors without observing spores taken from the air environment. For the first time this study observed the presence of AM fungal spores in the air. The frequency of AM fungal spores in the air was determined in six North American biomes composed of 18 ecoregions. Multiple samples were taken from both the air and the soil at each location. AM fungal spores were found in high abundance in the soil (hundreds of spores per gram of soil), however, they were rarely found in the air (most samples contained no AM fungal spores). Furthermore, only the *Glomus* morphotype was found in the air, whereas spores in the soil were taxomomically more diverse (*Glomus*, *Acaulospora*, *Gigaspora*, *Scutellospora* morphotypes were observed). The proportion of *Glomus* spores in the air relative to *Glomus* spores in the soil was highest in more arid systems, indicating that AM fungi may be more likely to be dispersed in the air in such systems. Nonetheless, the results indicate that the air is not likely a dominant mode of dispersal for AM fungi.

Introduction

Many fungi produce spore-bearing structures that extend from the substratum to the open atmosphere (e.g., *ascomata*, *basidiomata*, *conidiophores*, acervuli, sporangia) and can thus release their spores into the air (Kendrick, 2001). This allows these organisms to use air currents for dispersal (Aylor, 1986; Viljanen-Rollinson et al., 2007). Many other fungi do not have obvious structures associated with air dispersal, and are more likely dispersed by other means (e.g., hypogeous ascomata, such as truffles that depend on mycophagy and animal dispersal, and slimy spores that depend on water, rain or insect dispersal).

One important and cosmopolitan fungal group is the Phylum Glomeromycota (Oehl et al., 2003; Opik et al., 2008), whose members form symbiotic arbuscular mycorrhizal (AM) associations with plants. These fungi are hypogeous and produce hyphae and asexual chlamydospores in the soil. The spores are large, typically greater than 50 μm in diameter (up to 1 mm in some species). Dispersal of these

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fungi is mostly local, via invertebrates, such as collembola (Klironomos and Moutoglis, 1999) and earthworms (Gange, 1993). Over longer distances it has been shown that AM fungi are able to distribute their spores with the aid of mammal vectors (Vernes and Dunn, 2009) or sediment movement (Harner et al., 2009).

Aerial dispersal of spores is not considered to be significant, although studies have shown that AM fungal spores can be moved by wind (Tommerup, 1982; Allen, 1987; Allen et al., 1989), assuming these spores are carried into air currents from the surface of soil. AM fungi are found in all of the continents (Opik et al., 2013), and many species seem to be geographic generalists (Moora et al., 2011) with broad geographic distributions (Opik et al., 2010). Such patterns of distribution indicate that aerial transport may be a significant mode of dispersal for this group of fungi.

The objective of this study was to determine the frequency of occurrence of AM fungal spores in the air at several North American locations, across six different biomes: temperate broadleaf mixed forests, temperate grasslands/savannas/shrublands, Mediterranean forests/woodlands/shrublands, deserts and xeric shrublands, tropical and subtropical moist broadleaf forests, and tropical and subtropical dry broadleaf forests.

Materials and methods

Data collection

Air samples were taken from 18 North American ecoregions within six biomes (Table 1). Within each ecoregion 10 different locations were typically sampled at 4 times throughout the year (Apr./May 2010, Jul./Aug. 2010, Oct./Nov. 2010, Jan./Feb. 2011). Sampling locations were a minimum 1 km apart from each other (Table 1).

Table 1 – Number of air samples taken from each Ecoregion and grouped by Biome

Biome	Ecoregion	Geographic location	Number of sampling locations
Temperate broadleaf and mixed forests	Central US hardwood forests	Lower Missouri Ozarks, southern Missouri	4
		Shawanee Hills, southern Illinois	6
	Northern coastal forests	Cape May national wildlife refuge, southern New Jersey	6
		Great Bay wildlife refuge, southeastern New Hampshire	4
	Southeastern mixed forests	Uwharrie national forest, central North Carolina	3
		Bienville national forest, east central Mississippi	2
	Southern Great Lakes forests	Long Point provincial park, Ontario	3
		Rondeau provincial park, Ontario	3
		Point Pelee provincial park, Ontario	4
	Appalachian mixed mesophytic forests	Shawnee state forest, Ohio	5
		Monongahela national forest, West Virginia	5
Temperate grasslands, savannas, and shrublands	Central and southern mixed grasslands	Wichita mountains wildlife refuge, Oklahoma	5
		Great salt plains, Oklahoma	5
	Central tall grasslands	Loess hills, Iowa	10
	Western short grasslands	Pawnee, Colorado	5
		Commanche, Colorado	2
Temperate Mediterranean forests, woodlands, and scrub	California coastal sage	Sage scrub, southern California	10
	California montane chapparal and woodlands	Santa Lucia range, coastal California	10
Temperate deserts and xeric shrublands	Sonoran desert	Arizona uplands, Arizona	10
	Wyoming Basin shrub steppe	Central Wyoming	10
	Great Basin shrub steppe	Great Basin national park, Nevada	10
	Chihuahuan desert	Southern New Mexico	10
	Mojave desert	Mohave national park, California	10
Tropical and subtropical moist broadleaf forests	Great Antillean moist forest – Puerto Rico	Puerto Rican moist forest, Puerto Rico	5
Tropical and subtropical dry broadleaf forests	Jalisco dry forests – Pacific Mexico near Puerto Vallarta	Jalisco coast, Jalisco Mexico	5
	Sierra de la Laguna dry forest – Baja, Mexico	Southern Baja, California	6