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# Fungal Community-Plant Litter Decomposition Relationships Along a Climate Gradient

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## ABSTRACT

The decomposition of plant litter is a major process of equivalent status to primary production in ecosystem functioning. The spatiotemporal changes in the composition and dynamics of litter fungal community along a climate gradient ranging from arid desert to humid-Mediterranean regions in Israel was examined using wheat straw litter bags placed at four selected sites along the climate gradient, arid, semi-arid, Mediterranean, and humid-Mediterranean sites. Litter samples were collected over a two-year decomposition period to evaluate litter weight loss, moisture, C:N ratio, fungal composition, and isolate density. The litter decomposition rate was found to be the highest during the first year of the study at the Mediterranean and arid sites. Although the Shannon-Wiener index values of the fungal communities in the litter samples were the highest at the humid-Mediterranean site, the number of fungal species was not significantly different between the four study sites. Different fungal groups were found to be related to different study sites: Basidiomycota, Mucoromycotina, and teleomorphic Ascomycota were associated with the humid-Mediterranean site, while Coelomycetes were mostly affected by the arid site. Our results indicate that climate factors play an important role in determining the structure of saprotrophic fungal communities in the decomposing litter and in mediating plant litter decomposition processes.

*Key Words*: arid desert, community structure, fungal diversity, litter bag, Mediterranean region, saprotrophic fungi, Shannon-Wiener index

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## INTRODUCTION

The decomposition of plant litter is a major process of equivalent status to primary production in ecosystem functioning (Heal *et al.*, 1997), controlling storage and turnover of soil organic carbon (C) and thus the terrestrial net $CO_2$ flux (Hobbie, 1996). Fungi are the primary microorganisms responsible for organic-matter decomposition and nutrient cycling in most terrestrial ecosystems (Lodge, 1994; Dix and Webster, 1995). Three main phases of decomposition have been identified: early, mid, and late, in relation to the dominant organic compounds present (soluble sugars, cellulose-hemicellulose, and lignin, respectively) (McGuire and Treseder, 2010), with each succession being unique and dependent on substrate type and environment (Frankland, 1998). Fungi-degrading cellulose and other hydrolyzable plant polymers assume importance during the second stage, and lignin-degraders, especially among the basidomycetes, dominate the final stage (Gessner *et al.*, 2010). Gessner and Chauvet (1994) suggested that the initial lignin content of leaves controls litter breakdown rates through the kinetic limitation of C sources for saprotrophic microfungi. The decomposer activity of these organisms, in turn, would then govern litter breakdown rates. In doing this, fungi produce substantial amounts of both mycelial and conidial biomass that is potentially available to higher trophic levels of the food web.

In addition, decomposer (saprotrophic) fungi are sensitive to disturbances, pollution, and environmental changes (Frankland *et al.*, 1996), such as global warming and elevated carbon dioxide (Treseder, 2005). Impacts of environmental change on fungal diversity can influence ecosystem function *via* decomposition, so it is important to understand the dependence of decay rates on the number, frequency of occurrence, and function of the fungal species present (Deacon *et al.*, 2006). Osono (2011) claimed that understanding the distribution of fungi associated with litter decomposition in relation to climate patterns is crucial, as it will provide useful insights into future changes of biodiversity and functioning of ecosystems in response to global warming. However, much still remains unknown about species ri-

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chness patterns and fungal composition along regional climate gradients (Osono, 2011). Fukami and Wardle (2005) showed that natural gradients are useful in predicting long-term consequences of human-induced environmental changes. Gradients encompassing a wide range of spatially connected environmental conditions and communities, *e.g.*, geographic gradients, would be competent frameworks for exploring the effects of environmental dynamics, as well as potential climate changes, on soil microbial function (Oren and Steinberger, 2008).

Given the lack of information on fungal diversity for many regions, especially arid and semi-arid regions, there is a critical need to collect information on species richness at the ecosystem and landscape levels of organization (Hawksworth, 1997; Watling, 1997). Zak *et al.* (1995) summarized a series of on-going studies on fungi associated with different habitats at the Jornada and Sevilleta LTER sites in the northern Chihuahuan Desert in New Mexico. They elucidated that fungal species richness and functional diversity levels for fungal assemblages from plant roots and from decomposing wood are found to be higher than predicted, based on abiotic considerations. If the species richness and substrate specificity observed by Bills and Polishook (1994), Ramaley (1995, 1997) and Polishook *et al.* (1996) also apply to arid ecosystems, plant litter from arid environments should support very diverse and undescribed fungal taxa. Moreover, factors controlling fungal diversity (either taxonomic or functional) have a potentially important indirect effect on decomposition. However, evidence suggests that fungal diversity might also be determined by the variety of C input into a system (Robinson *et al.*, 1994). Thus, the influence of plant-community composition, temperature and moisture may have an indirect as well as a direct effect on fungal biodiversity across a landscape. Knorr *et al.* (2005) have elucidated the importance of the relationship between temperature and soil microorganisms in different ecosystem functions, *e.g.*, decomposition, nutrient cycling, *etc.*, and suggested that positive feedbacks from soil to climate might be even greater than is currently thought. After analyzing published studies across five continents, they claimed that organic C decomposition in soil is not sensitive to temperature (Giardina and Ryan, 2000). Oren and Steinberger (2008) studied the functional diversity (catabolic profiles) of soil fungal communities along a geographic climate gradient in Israel and found higher utilization rates of plant structural polymeric sugars (xylan and cellulose) in soils of the arid and semi-arid Negev as compared to Mediterranean soils. They associated this phenomenon with the fact that the arid soils, covered by sparse vegetation with a short period of plant growth, receive decreasing amounts of easily decomposed substrata, and their available substrate pools become increasingly polymeric, supporting fungal communities more capable of utilizing polymeric materials.

This study aimed to elucidate the effect of temperature and rainfall on litter fungal communities and their composition and dynamics on a temporal and spatial scale along a climate gradient. We hypothesize that: 1) the taxonomic diversity of litter saprotrophic fungi will decrease with aridity along the gradient; 2) litter decomposition will be significantly higher during the wet period, with no differences between the climate regions; and 3) the dry phase will be characterized by a large amount of fungal activity. This study would generate valuable qualitative as well as quantitative information that will enable us to understand the interplay between straw litter decomposition and alterations in saprotrophic fungal community composition on a temporal and spatial scale.

## MATERIALS AND METHODS

### *Study sites*

Four study sites under different environmental and climate conditions, humid-Mediterranean (HM), Mediterranean (M), semi-arid (SA), and arid (A), were selected along a 245-km stretch from the northern part of Israel toward the southern part, representing a climate gradient. The climate of all four sites is characterized by rainy winters (October–April) and prolonged, dry summers (June–August). The plant-growing season commences soon after the first rain, between October and December (Fleischer and Sternberg, 2006). Located at similar elevations, ranging between 470 and 620 m above sea level (a.s.l.), these sites are all on south-facing slopes, overlying calcareous bedrock with pH values in the alkaline range (7.5–7.9). The yearly rainfall at each of the four study sites was found to be significantly lower than the mean multiannual rainfall.

The HM site (33°0′ N, 35°14′ E, 500 m a.s.l.) is located in the northern Galilee Mountains. The average annual rainfall at this site amounts to 780 mm, and the mean annual temperature is 18.1 °C. Vegetation varies from dense, closed oak maquis to more open garigues dominated by shrubs. Herbaceous vegetation, mainly composed of annuals, coexists with shrubs. The soil of this site is a montmorillonitic terra rossa.

The M site (31°42′ N, 35°3′ E, 620 m a.s.l.) is lo-