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Influence of small scale conditions on the diversity of wood decay fungi in a temperate, mixed deciduous forest canopy

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ABSTRACT

Studies on fungal richness and ecology have been largely disregarded since the first intensive efforts to investigate organismal diversity in forest canopies. We used the Leipzig Canopy Crane research facility to sample wood-decaying fungi in a mixed deciduous forest canopy 10-30 m in height. The structural complexity of the canopy was analysed using different methods, including meteorological measurements. With respect to temperature and relative humidity, marked differences existed between forest floor and upper canopy layers that persisted on smaller scales. Of the 118 taxa found in 128 sample units, pyrenomycetes and corticioid fungi outnumbered other macrofungal groups. Fungal communities showed distinct variations both in species richness and composition with respect to substrate (tree species), height in the canopy, stage of decay, and branch diameter. Pyrenomycetes and their anamorphs dominated the mycobiota on thin, exposed twigs at great heights, indicating their ability to overcome extended periods of drought and high levels of solar irradiance. Other taxa of *Tremellales* (*Exidia* spp.), *Orbiliales* (*Hyalorbilia inflatula*, *Orbilia* spp.) or *Agaricales* (*Episphaeria fraxinicola*, *Cyphellopsis anomala*, *Lachnella* spp.) also exhibited features that enabled them to develop in lesser protected habitats within tree crowns.

Introduction

The life of wood-decay fungi in the canopy of a temperate, mixed deciduous forest 10-30 m in height is rarely considered. The upper canopy is widely composed of young twigs and exposed to high illumination levels, to strong winds, and heavy rainfall. Inner and lower canopy layers formed by a broad range of thin twigs and thick branches with a patchwork of sunny and shady places provide many different ecological niches for different organisms including fungi (Unterseher *et al.* 2005; Lodge & Cantrell 1995), arthropods (Basset *et al.* 2003; Novotny & Basset 2000; Corbet 1961) and various epiphytes, including lichenized fungi (Freiberg 2001; McCune *et al.* 2000).

There are many methods of assessing and defining the structural complexity of forest canopies, and many areas of uncertainty as to how it influences the occurrence and variation of organisms (Parker & Brown 2000). Parker & Brown mentioned that general predictions and averaging data should be omitted in favour of interpreting single measurements, and that information about variability (e.g. transition zones between the upper canopy and the understorey with great variability in light transmittance) should not be discarded. Instead such data should be used along with that on the ecology of the organisms. Differences in biotic and abiotic factors such as solar radiation (Anhuf & Rollenbeck 2001; Kuuluvainen & Pukkala 1989, 1987), quantity of available water (Bellot *et al.* 1999), diurnal and annual gradients in temperature, and the quality and amount of different substrates over time and space, most probably affect the richness and species composition of sessile organisms such as fungi (including lichens) on

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a vertical scale (e.g. Unterseher *et al.* 2005; McCune *et al.* 2000; Hallenberg & Parmasto 1998; Lodge & Cantrell 1995). Light is obviously a critical resource in the canopy, and in case of direct solar radiation, immediately influences the temperature on surfaces of branches (Théry 2001; Dirmhirn 1961; Haddow & Corbet 1961).

Despite more than 20 y of intensive canopy research (e.g. Ozanne *et al.* 2003; Morawetz 1998; Erwin 1982), studies on the diversity and ecological impacts of microorganisms, and especially of fungi, in forest canopies above 10 m in height are very rare (e.g. Unterseher *et al.* 2005; Keller *et al.* 2004; Keller 2004; McCune *et al.* 2000; Lodge & Cantrell 1995). In the recent edition of *Forest Canopies*, the current benchmark of canopy research (Lowman & Rinker 2004), nine pages, less than 2 % of the whole book, mention fungal activity (Fonte & Schowalter 2004).

Decayed wood desiccates faster in the canopy than at ground level, and may provide different niches for fungi than on the forest floor. Unterseher *et al.* (2005) presented a species list of wood-decay fungi from the canopy of a temperate mixed deciduous forest with 118 different taxa, but only three agaric species with a prominent stipe (*Mycena galericulata*, *Pleurotus cornucopiae*, and *Pluteus cervinus*). The few studies concerning fungi on dry, weathered wood have concentrated mostly on tropical forests, on the understorey or over short periods of time (e.g. Keller 2004; Lodge & Cantrell 1995; Hedger *et al.* 1993; Boddy 1992; Sherwood 1981). Apart from corticioid species of *Polyporales*, *Hymenochaetales* and *Russulales* (Tejera & Rodríguez-Armas 1999), pyrenomyceteous fungi frequently colonize decayed wood in arid habitats. Some are able to continue growth under dry weather conditions for some time if they possess large, immersed stromata and also to survive in desiccated conditions, if drought persists (e.g. Nuñez 1996; Munk 1957; Ingold 1954). Different groups of the *Auriculariales*, *Helotiales*, *Orbiliales* and *Tremellales*, also tolerate such conditions (Sherwood 1981, Baral, pers. comm.). In the 1980s, a series of studies was published by Boddy and co-workers focussing on the development and ecology of fungal communities on dead, attached branches in the understorey of temperate, deciduous tree species. Although dead, hanging branches occur naturally and are essential parts of nearly every tree crown (e.g. Boddy & Rayner 1983; Butin & Kowalski 1983), most of their studies were limited to single branches or to early stages of fungal succession (Boddy & Rayner 1984, 1983, 1982; Chapela & Boddy 1988a-c; Griffith & Boddy 1991a-c, 1989, 1988).

The aims of the present study were to: (1) expand knowledge of the diversity of wood-decay fungi in forest canopies; (2) extract fundamental climatic patterns that help; and (3) assess fungal ecology in this habitat. This paper shows a mycological approach to describing the forest canopy of a temperate, mixed deciduous forest in Central Europe, and presents new data on the diversity and ecology of corticolous and lignicolous fungi in a still widely unexplored ecosystem compartment.

Material and methods

Study site

The climate of the Leipzig city area (51°20′16″N, 12°22′26″E) is characterized as intermediate between maritime and continental (mean annual temperature 8.8 °C; mean annual precipitation 512 mm). The soils at the crane site are nutrient-rich loamy floodplain (alluvial) deposits. The investigation site is at the margin of a former oak and elm rich forest that is classified as typical floodplain forest of the upper alluvial zone (*Querco-Ulmetum minoris* Issler 1924, syn. *Fraxino-Ulmetum* (R.Tx.1952) Oberd. 1953). Due to river straightenings and canalization, as well as extensive brown coal mining since the early 20th century, the ground water level in the Leipzig floodplain forests dropped significantly. Thus, the forest suffered a gradual but notable change in species composition, favouring sycamore (*Acer pseudoplatanus*) which today represents the most frequent tree species. The forest stand at the crane site is characterized by a fairly diverse composition of woody species (17 tree species and five shrub species with 1 cm diam at breast height including four introduced tree species (Morawetz & Horchler 2004)). The actual canopy is mainly formed by oak (*Quercus robur*) trees (older than 250 y, 7 % canopy cover) and younger trees of ash (*Fraxinus excelsior*), sycamore, and lime (*Tilia cordata*) (younger than 130 y, 53 %, 17 % and 10 % canopy cover respectively). A peculiarity of the stand is the large amount of dead wood which provides an important habitat for several rare and endangered organisms.

Canopy access

With a construction tower crane (Liebherr 71 EC, height of tower 40 m, jib length 45 m, max. sampling height *ca* 33 m), mobile on a 120 m long railway track, 1.6 ha of forest can be explored (Unterseher *et al.* 2005). Many more information on canopy research and methods of access is given in Lowman & Rinker (2004), Basset *et al.* (2004) and Mitchell *et al.* (2002).

Sampling design and microhabitat descriptions

The new challenge to operate in a three-dimensional space with a construction crane forced us to apply new methods of sampling for mycological studies. Unterseher *et al.* (2005) give a detailed description of the methods applied in the field. Voucher specimens from the study are stored in the collections of the University of Leipzig (LZ).

Meteorological measurements

Meteorological measurements were performed on three scales. (1) On the 10 m scale three Hobo® devices (ONS-H08-032-08, www.synotech.de) measured temperature and relative humidity at 29 m, 19 m, and 6 m above ground in a least disturbed part of the investigation plot. (2) On the 1 m scale, temperature was measured at different locations in the canopy contrasting inner and outer canopy and sunlit and shaded areas. Four N-thermistors (ONS-27-9M1002-C3) were connected to a Hobo® data-logger (ONS-H08-008-04). The thermistors possessed black beads, 2 mm diam, simulating to some extent biological bodies. Air temperature and direct solar irradiation influenced the temperature measured by the thermistors. (3) On the 10 cm scale, temperature was measured at different aspects of branches (north, south, east, west) more than 25 m height above the ground. The thermistors were