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Influence of sand burial on cultivable micro-fungi inhabiting biological soil crusts

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ABSTRACT

We examined the influence of sand burial of 0.5-mm and 10-mm depths on micro-fungal communities inhabiting moss-dominated and mixed biocrusts in the vicinity of the Shapotou Research Station in the Tengger Desert, China. The buried communities were compared with those in unburied crusts, as well as with the sandy below-crust and topsoil communities. We isolated 65 fungal species belonging to 43 genera using the soil dilution plate method. Compared to the unburied communities, the buried crust communities were characterized by lower abundance of melanin containing species, especially those with large many-celled conidia, but higher abundance of species producing small light-colored and one-celled conidia, mainly mesophilic *Penicillium* spp. Sand deposition also caused reduction of isolate density that was more pronounced in the mixed crusts. Diversity characteristics of micro-fungal communities and isolate densities varied in the two crust types in response to the same level of sand burial. This difference between the mixed and moss-dominated crusts was less expressed when the communities had been subjected to the deep sand burial. Below-crust sandy communities showed a more significant decrease both in isolate density and species richness compared to buried crust communities, which was accompanied by the substitution of dominant species – the thermotolerant *Aspergillus fumigatus* in the subcrust sandy layers instead of melanized species with large multicellular conidia in the crusts. On the whole, the influence of sand burial on crust micro-fungal communities was likely associated with the shielding effect of sand layer which might protect the crust layer from evaporation and UV-radiation. Whereas sand deposition in the crusts partly changed the substrate quality and microclimatic conditions for soil micro-fungi, transition from the crust to the below-crust sandy layer much more substantially altered the environmental situation (mainly in nutrient status, from the comparatively rich organic crust layer to the poor mineral sandy layer) thus leading to the more significant changes in the micro-fungal communities.

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Introduction

In arid and semi-arid lands, sand burial is considered a noticeable environmental disturbance (e.g., Littmann, 1997; Bristow and Lancaster, 2004; Clemmensen and Murray, 2005; Rao et al., 2012). It affects soil temperature and moisture regime, as well as the availability of light, various nutrients, and oxygen (e.g., Harris and Davy, 1988; Maun, 1994, 2004; Williams and Eldridge, 2011). Sand burial is known to lower and slow the germination of seeds and seedling emergence (e.g., Ren et al., 2002). This kind of disturbance may be a source of severe stress for cyanobacterial crusts causing the reduction of chlorophyll content and biomass, including a decrease in total carbohydrate reserve, especially polysaccharides (Wang et al., 2007; Rao et al., 2012). Sand deposition may also influence the communities of soil microorganisms changing the ratio between aerobic and anaerobic microbes and reducing the amount of mycorrhizal fungi (Maun, 2004).

In the Shapotou revegetated region of the Tengger Desert, mobile sand dunes have been successfully transformed into stable, productive ecosystems, thereby displaying an example of human reversal of desertification in China (Li et al., 2004). Over the past 50 years, the structure and function of the stabilized and revegetated zone have changed considerably, and the development of biological soil crusts became an important factor in the restoration. The development of crust communities has substantially changed the physical and chemical soil properties, intercepting precipitation

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and modifying the vegetation dynamics of these ecosystems (Li et al., 2002, 2003; Duan et al., 2004).

Crust communities play an important role in the maintenance of the vegetation function, especially in areas where the sand binding role of previously planted shrubs has weakened with time (Li et al., 2004). However, these crusts every year are inevitably exposed to repeated sand or dust burial of various depths. This burial is caused by two different processes: by wind blowing, which mostly happens in spring when wind speed is usually the highest and precipitation is low; and by animal activity (burrows of ants, lizards, and rabbits) occurring mainly in summer and autumn when precipitation is relatively high. Sand burial has resulted in multiple organic horizons of 'fossilized crusts" in areas where they have survived this stress and barren spaces where they have not; both "fossilized crusts" and barren spaces weaken the protective function of the crusts. Hence, it is considered an important task to conserve these crusts in order to prevent or reduce the hazard associated with sandstorms and desertification in the region (Li et al., 2003).

To address this, the effect of sand burial of various depths under different water availability conditions on ecophysiological and morphological parameters of moss- and lichen-dominated crusts was studied in the revegetated area of the Tengger Desert (Jia et al., 2008). The study revealed a significant decrease in crust respiration rate and a significant increase of moss shoot elongation as a result of burial. Both of these responses might have acted as compensatory mechanisms that favored the recovery of crusts after sand burial.

Free-living micro-fungi are known to be an essential part of biological soil crusts. Together with heterotrophic bacteria, cyanobacteria, green algae, lichens, and mosses, they play a remarkable role in crust composition and functioning (e.g., States et al., 2001). In the revegetated area of the Tengger Desert, our pioneer mycological study revealed a diverse crust mycobiota composed of 134 species (Grishkan et al., 2015). In the present research, we examined the influence of sand burial on culturable micro-fungal communities inhabiting different crust types in the area. We hypothesized, based on our previous findings, that the composition and structure of these communities (reflected in the abundance of groupings with different life-history strategies), their diversity level, and the amount of micro-fungi would be affected by sand deposition. To test this hypothesis, the following characteristics of the communities were analyzed in the course of the study: species composition; contribution of the major taxonomic and ecological groupings to community structure; the dominant groups of species, density of isolates, and the diversity level (species richness, heterogeneity, and equitability).

Materials and methods

Site description

The study was conducted in the Shapotou research station (SRS) of the Cold and Arid Regions and Environmental and Engineering Research Institute, CAS, located in Zhongwei County in the Ningxia Hui Autonomous Region at the southeastern edge of the Tengger Desert (37°32′ N, 105°02′ E, elevation of 1340 m). It is an ecotone between steppified desert and desertified steppe, being also a transitional zone between sandy and re-vegetated deserts (Li et al., 1998). The mean, absolute minimum and maximum annual air temperatures reach 10.0 °C, −25.1 °C, and 38.1 °C, respectively. The mean, absolute maximum, and minimum annual precipitation is approximately 186, 304 and 88 mm, respectively, 80% of which falls between May and September (Jia et al., 2008). The temperature of the crust surface can reach 54 °C (the south-exposed cyanobacterial crusts at midday hours in July 2011). Moisture content of the crusts during dry periods is very low and does not exceed 2%. The vegetation in the region is dominated by psammophytes, such as *Hedysarum scoparium* Fisch., *Agriophyllum squarrosum* Moq., *Stilpnolepis centiflora* Krasch and *Pugionium calcaratum* Kom., etc., covering about one percent of the area (Li et al., 2004). The region consists of huge, dense and continuous reticulate barchan dunes with loose, impoverished, and mobile blown sand. The non-crusted dunes (Arenosols, according to the FAO-UNESCO system, 1974) consist of 99.7% of sand and only 0.3% of finer particles (silt and clay). However, the biological soil crusts (BSCs) contain up to 30–35% of finer particles (Li et al., 2006).

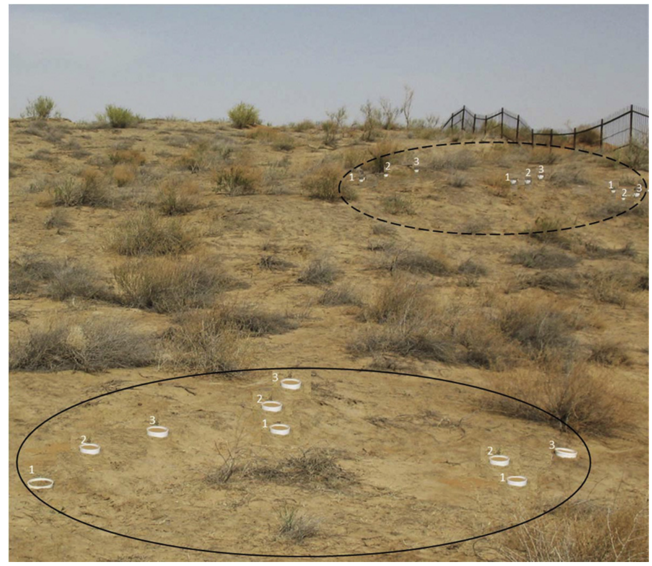

Fig. 1. Experimental plots covered by moss-dominated crusts (surrounded by solid line) and mixed crusts (surrounded by dashed line), with tubes for control (1) and for simulation of shallow (2) and deep (3) sand burial.

The non-irrigating vegetation system was initially established in 1956 to protect the Baotou–Lanzhou railway line from sand burial. This system was further expanded in 1964, 1981, and 1987. The stabilization method used included a combination of windbreaks, straw checkerboard barriers, and planted xerophytic shrubs (Duan et al., 2004). Following surface stabilization, biological (cyanobacterial) soil crusts began to colonize the dune surfaces. These crusts were then gradually converted to moss and lichen crusts (Li et al., 2003). Currently, the BSC cover more than 80% of the total revegetated desert sections.

Sampling design

Crust and below-crust samples were collected in September 2014, from two experimental plots covered by two crust types: moss-dominated (*Bryum argenteum* Hedw.) and mixed (lichens, green algae, cyanobacteria, and mosses in similar proportions). In these plots, located on the windward slope of the area with revegetation started at 1964, cylindrical polyvinyl chloride (PVC) tubes (104 mm diameter, 20 cm depth) were randomly placed into the soil in March 2013 (Fig. 1). Nine tubes were placed in each plot. Three tubes, with 6.5 g of air-dried drifting sand were gently and evenly distributed over a crust forming the 0.5-mm layer (hereafter – shallow sand burial). In another three tubes, 130 g of sand were distributed over a crust forming the 10-mm layer (hereafter – deep sand burial) and the remaining three tubes stayed intact and served as controls. The uppermost edges of the tubes were kept 0.5 cm above the lower flat surface to avoid the sand from blowing out of the tubes. In each tube, the below-crust sandy samples were also collected at depths of 0.5–1 cm (under the mixed crusts) and

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