frontiers | Frontiers in Forests and Global Change

EDITORIAL
published: 02 May 2022
doi: 10.3389/ffgc.2022.917430

Editorial: Fungi in a Changing World

Mark A. Anthony[1]*, *Adriana L. Romero-Olivares*[2] *and Camille Truong*[3]

[1] Department of Environmental System Sciences, ETH Zürich, Zurich, Switzerland, [2] Department of Biology, New Mexico State University, Las Cruces, NM, United States, [3] Royal Botanic Gardens Victoria, Melbourne, VIC, Australia

Keywords: fungi, global change, climate change, traits, mycorrhizal

Editorial on the Research Topic

Fungi in a Changing World

Fungi are critical members of forest microbiomes as decomposers, mutualists, and pathogens. As saprotrophs, fungi are the primary decomposers in forests (Schneider et al., 2012) and as mycorrhizal symbionts, they are widespread drivers of plant productivity (Read and Perez-Moreno, 2003). Increasing evidence suggest that fungi are sensitive to global changes and that this will have effects that ripple throughout ecosystems (Zhou et al., 2020). To better understand, conserve, and manage our ecosystems into the future, we therefore need to develop reliable knowledge for fungal responses to our changing world.

Greater attention has recently been paid to fungi in global change research, but is it enough? As a hyper-diverse kingdom with a myriad of life history strategies, it is the diversity and function of fungi that ultimately shape how ecosystems respond to global changes. For example, as key mediators of plant nitrogen up-take, ectomycorrhizal fungal diversity is reduced by increasing anthropogenic nitrogen deposition (Morrison et al., 2016), and this is accompanied by a concomitant shift toward the hydrolysis vs. oxidation of soil organic matter (Moore et al., 2021) and plant communities dominated by arbuscular mycorrhizal fungi (Jo et al., 2019). Because fungi form close relationships with living plants and their litter inputs, their diversity is also highly sensitive to non-native plant invasions (Lekberg et al., 2013; Phillips et al., 2019). These are well-characterized examples of the sensitivity of fungi to global changes, but we are only beginning to scratch the surface of our understanding.

In this Research Topic, we explore the sensitivity of fungi to a wide range of global changes and the implications of fungal life history traits for ecosystem functioning. Finestone et al. examined how projected future warming scenarios and their impacts on a shrinking snowpack influenced the ability of fungi to produce enzymes involved in nutrient cycling, with evidence that warming causes irreversible loss and gain of specific decomposition traits. By isolating fungal cultures from control, warming and snow-removal plots within the Climate Change Across Seasons Experiment at the Hubbard Brook Experimental forest, the authors demonstrated the importance of studying concurrent elements of global change. They show that fungal growth rates were reduced by concurrent warming and snow-removal, but not warming alone, and that fungal growth was positively linked to hydrolytic enzyme activity.

Lovero and Treseder measured the relationship between fungal maximum growth rates and genes involved in nutrient and carbon cycling. They showed that life history strategies associated with faster growth trade-off with some decomposition processes and competitive abilities. As demonstrated above by Finestone et al. fungal growth rates are highly sensitive to climate change.

OPEN ACCESS

Edited and reviewed by:
Frank Hagedorn,
Snow and Landscape Research (WSL), Switzerland

****Correspondence:***
Mark A. Anthony
mark.anthony@usys.ethz.ch

Specialty section:
This article was submitted to Forest Soils, a section of the journal Frontiers in Forests and Global Change

Received: *11 April 2022*
Accepted: *13 April 2022*
Published: *02 May 2022*

Citation:
Anthony MA, Romero-Olivares AL and Truong C (2022) Editorial: Fungi in a Changing World. Front. For. Glob. Change 5:917430. doi: 10.3389/ffgc.2022.917430

This work therefore helps us predict future fungal functions through the lens of life history traits. It also establishes that while trade-offs between traits may be generalizable across a wide range of fungi, there are equally common occurrences of "Blended life history" strategies characterized by unique combinations of decomposition, growth, and stress tolerance traits.

Romero et al. showed the importance of studying fossil records of fungi to better understand their response to climate change. Specifically, they assessed the fungal diversity and community composition recorded in the middle Miocene Climate Optimum, which has been the warmest interval of the last 23 million years and a good analog for proposed climate change scenarios. They found spores and other fungal remains in coal mines of Thailand and Slovakia, quantified fungal diversity, and reported over 200 morphotaxa. Their work reveals how fungal richness and community composition were affected by climatic conditions under rapid increases in temperature in the past, which may allow us to make inferences on how fungi may respond to climate change in the near future.

Cruz-Paredes et al. investigated the microbial community response to a soil pH gradient—by applying alkaline wood ash—in a plantation forest. Their overall goal was to compare fungal vs. bacterial responses to changes in soil pH and determine if the addition of wood ash is a good fertilization option. They reported that both, bacterial and fungal communities, showed directional changes correlated with shifts in soil pH. However, fungal responses were significantly less pronounced than bacteria. Specifically, the fungal community significantly changed only when exposed to higher doses of wood ash-induced increases in pH, whereas bacteria changed when exposed to lower doses. This study not only confirms that fungi are less sensitive to changes in soil pH compared to bacteria, but also, that using wood ash as fertilizer in plantation forests is a safe management option when viewed through the lens of microbial community changes and when used at standard dosages. Their contribution highlights how the microbial community may respond to changes in soil pH under global climate change.

Trautwig et al. explored how migrating plants from lower elevations can affect sub-alpine meadow species as a consequence of climate change. Using growth experiments, they demonstrated that growth, mortality, chlorophyll content and fine root endophytic fungal colonization of a dominant high elevation grass species, *Festuca thurberi*, were affected by leachate treatments from native and non-native mustards, but that the response of *F. thurberi* was highly variable between genotypes. This illustrates the need to consider not only the response of plant-microbial interactions at species level, but also for individual genotypes and their associated traits, to climate change.

Understanding the large-scale consequences of global changes for forests and other ecosystems requires a better understanding of fungi and their interactions with other organisms. This Research Topic provides a diverse glimpse into how future fungal communities may be structured and affect ecosystem functioning. Collectively, this work shows that many fungi inhabit an optimum environment that is becoming increasingly vulnerable to global changes.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.