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BRIEF REPORT

Fungal succession and diversity in fire-impacted soils of high-elevation pine forests

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Fires are a crucial ecological disturbance in many ecosystems, including high-elevation pine forests, playing a significant role in shaping biodiversity and ecosystem functioning. The impact of fire on soil fungi, which are integral to nutrient cycling, plant establishment, and forest regeneration, has garnered increased attention in recent years. This study explores fungal succession and diversity in fire-impacted soils of high-elevation pine forests, focusing on the microbial responses to fire, changes in community composition over time, and the influence of environmental factors on fungal recovery. We collected soil samples from burned and unburned areas within a high-elevation pine forest, analyzed fungal diversity using high-throughput sequencing, and assessed environmental variables such as temperature, moisture, pH, and nutrient availability. Our results suggest that fungal communities undergo a predictable successional process, with distinct shifts in diversity and composition in response to fire disturbance. These findings underscore the importance of fire in driving fungal diversity in these forests and highlight the role of fungi in post-fire recovery. Understanding fungal succession can aid in the management and conservation of high-elevation pine forests, particularly in the face of increasing fire frequency and intensity due to climate change.

Keywords: Fungal succession, Fire-impacted soils, High-elevation pine forests, Fungal diversity, Microbial community, Forest regeneration, Post-fire recovery, Ecological disturbance, Nutrient cycling, Soil fungi.

Introduction

Fire is a natural disturbance that significantly shapes the structure and function of many ecosystems, including forested landscapes. High-elevation pine forests, which are typically characterized by harsh climatic conditions, have evolved to cope with fire disturbances over millennia. These forests are home to a diverse array of microbial communities, including fungi, which play essential roles in nutrient cycling, plant-microbe interactions, and forest regeneration. The role of fungi in post-fire recovery is of particular interest in fire-impacted ecosystems, as they are crucial for reestablishing soil fertility and aiding in the establishment of plant communities. Fungal populations in these soils can undergo a process of succession following a fire, with early colonizers gradually being replaced by more specialized taxa as the ecosystem recovers. However, the dynamics of fungal succession and diversity in fire-impacted soils, especially in high-elevation pine forests, remain poorly understood (Lilleskov EA, et al. 2005). This explores the patterns of fungal succession in soils affected by fire in high-elevation pine forests, focusing on how fungal diversity changes over time and the factors influencing these shifts. By examining fungal communities before and after fire events, we can gain insights into the ecological processes that govern soil recovery and forest regeneration in these ecosystems. Furthermore, understanding how fungal communities respond to fire is essential for predicting the long-term effects of fire disturbances on ecosystem functioning, particularly in light of increasing fire frequency and intensity in the context of climate change.

Description

High-elevation pine forests are found in mountainous regions where fire plays an important role in maintaining forest health and ecosystem function. In these ecosystems, fire is a natural process that clears understory vegetation, recycles nutrients, and promotes forest regeneration. Species like lodgepole pine (Pinus contorta), ponderosa pine (Pinus ponderosa), and other high-elevation pines are adapted to survive and regenerate in the aftermath of fire. These trees often possess fire-resistant traits such as thick bark or serotinous cones that require fire for seed release (Zhu YQ, et al. 2024). The effects of fire on soil properties and microbial communities are complex. Fires can alter soil temperature, moisture, pH, and nutrient availability, creating conditions that favor the establishment of certain microbial taxa. Post-fire soil microbial communities, including fungi, undergo significant changes as they adapt to these altered conditions. Soil fungi, particularly mycorrhizal fungi, are critical for nutrient cycling and plant establishment, making them key players in post-fire recovery. Fungal communities in fire-impacted soils undergo a process of succession, where different groups of fungi dominate at different stages of ecosystem recovery. Early successional fungi, such as those belonging to the Ascomycota and Basidiomycota phyla, are often the first to colonize fire-affected soils. These fungi are typically opportunistic and can rapidly degrade organic matter, releasing nutrients into the soil that are essential for plant growth. Over time, as the soil environment stabilizes, more specialized fungi, including ectomycorrhizal fungi, establish themselves in association with regenerating plants (Kjøller, R. 2006).

The timing and sequence of fungal colonization can vary depending on several factors, including the severity of the fire, the type of vegetation present, and local environmental conditions. In high-elevation pine forests, where the growing season is short and environmental conditions are harsh, the recovery of fungal communities may be slower compared to lower-elevation forests. However, the resilience of these fungal communities and their ability to promote forest regeneration remains a critical component of ecosystem recovery. To investigate fungal succession and diversity in fire-impacted soils of high-elevation pine forests, we conducted a field study in a fire-affected area. The study site is located in the Sierra Nevada mountains, where a wildfire had burned through a high-elevation pine forest two years prior. Soil samples were collected from both burned and unburned areas to assess fungal diversity before and after the fire disturbance. Fungal communities were analyzed using high-throughput DNA sequencing techniques, which allowed us to identify fungal taxa at high resolution. We also measured several environmental variables, including soil temperature, moisture, pH, and nutrient content, to examine how these factors influenced fungal community composition and succession. Our analysis revealed distinct differences in fungal diversity between burned and unburned soils. In the first year following the fire, fungal diversity in the burned soils was significantly lower than in unburned soils, likely due to the loss of organic matter and the extreme conditions created by the fire. However, as the years progressed, fungal diversity in the burned soils gradually increased, with different fungal taxa becoming more prevalent over time (Menkis A, et al. 2014).

In the early stages of succession, we observed a dominance of Ascomycota fungi, which are known for their ability to colonize disturbed environments. These fungi were followed by Basidiomycota fungi, including species known to play important roles in decomposing plant material and forming symbiotic relationships with plants. Over the course of the study, ectomycorrhizal fungi, which form mutualistic relationships with pine trees, became more abundant in the burned soils, indicating that forest regeneration was progressing and that fungal succession was following a predictable trajectory. Environmental factors such as soil temperature, moisture, and nutrient availability played a significant role in shaping fungal community composition. Soils in the burned areas were typically drier and more nutrient-poor than those in the unburned areas, which may have limited fungal colonization and slowed the recovery process (Ihrmark K, et al. 2012). However, over time, the accumulation of organic matter and the return of moisture to the soil facilitated the establishment of a more diverse fungal community. Soil pH also influenced fungal diversity, with acidic soils favoring certain fungal taxa. In the burned soils, pH initially increased due to the loss of organic matter, but it gradually decreased over time as plant and fungal communities began to re-establish. The interplay between soil pH, moisture, and nutrient content contributed to the succession of fungal communities, with different fungal taxa becoming more or less abundant depending on their tolerance to these environmental changes.

Conclusion

Fungi are integral to the recovery of fire-impacted ecosystems, and their ability to promote nutrient cycling and support plant establishment is critical for forest regeneration. In high-elevation pine forests, where the growing season is short and environmental conditions are harsh, the recovery of fungal communities may be slower compared to lower-elevation forests. However, the resilience of these communities and their role in ecosystem recovery cannot be overstated. As climate change increases the frequency and intensity of fires in many regions, understanding how fungal communities respond to fire is becoming increasingly important. Future research should focus on the long-term effects of fire on fungal diversity, particularly in high-elevation forests, and explore how these changes influence broader ecosystem processes. By improving our understanding of fungal succession, we can better manage and conserve fire-prone ecosystems in the face of changing environmental conditions.

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Conflict of Interest

The authors declare no conflict of interest.

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