Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 11, No. 3, 2024

Mechanisms of Fire Disturbance Response to Forest Soils

Liheng Xia [1, 2, 3, 4, 5, *], Chenguang Ma [1, 2, 3, 4, 5]

[1] Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[2] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, Xi'an 710075, China
[4] Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China
[5] Land Engineering Technology Innovation Center, Ministry of Natural Resources, Xi'an 710075, China

*** Corresponding author:** Liheng Xia (Email: 18092729601@163.com)

Abstract: Forest soil microorganisms, as an indispensable component of soil ecosystems, play a key role in maintaining, regulating and promoting the process of material cycling, energy flow and natural succession in the whole forest ecosystem. Soil microorganisms are powerful promoters and participants in biogeochemical cycles, especially soil elemental cycles. Some fungi in soil can form a symbiosis-mycorrhiza with plant roots, which can help plants to absorb nutrients, resist diseases, and enable plants to stand in harsh environments such as barrenness, drought, or saline stress. At the same time, it can also decompose and utilize lignin, cellulose and macromolecules of organic matter in the soil that are difficult to decompose, providing nutrients for plants.

Keywords: Forest Soils; Fire Disturbance Response; Soil Microorganism.

1. Introduction

With the development of high-throughput sequencing technology, a large number of studies have focused mainly on the relationship between the community structure of forest soil microorganisms and soil environmental factors after fire disturbance. For example, in a study on the vertical distribution of forest soil bacteria in the Gongga Mountains, Kangding City, Ganzi Tibetan Autonomous Prefecture, Sichuan Province, it was found that the distribution pattern of soil bacterial community structure and diversity level was decreasing with elevation, and that environmental factors were the main influences in bacterial communities at lower elevations, whereas the expansion restriction was the main influence in high-elevation forests. Shen et al. conducted a study on the relationship between the study on the distribution of bacterial community composition and species diversity in forest soil in Changbai Mountain area of Jilin Province also found that the bacterial community had a vertical distribution pattern. Tripathi et al. used high-throughput sequencing technology to investigate the community structure and diversity of soil microorganisms in tropical rainforests in Malaysian region, which were affected by spatial distance and environmental factors, and showed that the environmental factors were the main factors influencing the community structure and diversity of soil microorganisms. The environmental factors were the most influential factors on soil microbial community structure and diversity, with soil pH being the most influential, followed by altitude and total nitrogen content in the soil [1].

2. Effects of Fire Interference

Fire disturbance can have a dramatic effect not only on the physicochemical properties of forest soils, but also on soil microorganisms, both directly and indirectly through high temperatures. These effects are moderated by many factors, such as the type of combustible material within the forest floor, fire duration, fire intensity level, local meteorological conditions and soil type. The overall increase in pH of forest soils after fire disturbance is due to the fact that fire disturbance causes soil organic matter to release large amounts of alkali metal ions at high temperatures, which leads to an increase in forest soil pH. The magnitude of the change in pH is related to the forest type, the type and amount of combustibles, and the amount of rainfall, among other factors. Studies have shown that changes in pH can significantly affect the composition and community structure characteristics of forest soil microorganisms [2].

2.1. Forest Fire

The incidence of forest fires greatly affects global climate change and contributes to environmental pollution. In particular, large-scale forest fires further exacerbate the process of global warming in the region. Fire disturbances further affect the soil carbon pool in forest ecosystems by affecting the microbial composition and community structure of forest soils, either directly or indirectly, through their action on forest plants. Forest fires act directly in the surface soil through high temperatures, changing the physicochemical properties of the soil and affecting the composition and structure of soil microorganisms. Previous studies have shown that the occurrence of heavy fire disturbances can lead to a severe loss of soil microorganisms, with a decrease in soil bacterial biodiversity of about 33.2% and soil fungal biodiversity of about 47.6% [3].

2.2. Forest Soil Organic Matter

The magnitude of the effect of fire disturbance on the organic matter of forest soils is related to the type of combustible material and the intensity of the fire, with a decrease of about 20-25% in soil organic matter after complete fire. On the contrary, the organic matter of forest soils that were not able to burn completely rose by about 20% [4]. From this result, it can be shown that mild fire disturbance

can significantly increase the content of organic matter and mineral nutrients in forest soils, improve soil fertility, and promote plant growth and development. Fire disturbance is a devastating damage to forest soil. In shrubland forests, if a forest fire removes two-thirds of the above-ground portion of a shrub, at the same time, about 50 percent of the surface combustible material will be burned, and about 20 percent of the soil humus will be lost in the 1-centimeter layer of the top soil. about 10 percent of the humus in the 2-centimeter layer of the soil will be lost. Light fire disturbances increase the organic matter content of the soil in the lower layers of the forest to some extent. Thus, there is a redistribution of soil organic matter in the different soil layers after the fire, rather than a simple decrease.

2.3. Microorganisms in Soil

The recovery of forest vegetation after fire cannot be separated from the role of microorganisms in the soil, soil bacteria are the most numerous and widely distributed microorganisms in the soil, while soil fungi are soil microorganisms that are second only to soil bacteria in terms of number. Soil fungi are a class of unicellular or multicellular heterotrophic microorganisms mountain of special mycelial structure. Fungi in forest soils mainly include fungi from the phylum Ascomycota and Stachybotrys, etc. More than 80% of nitrogen and phosphorus absorbed by plants in mountain woodlands are fixed by inter-root bacteria and mycorrhizae in the soil that are symbiotic with the plant root system. However, the growth and development of many plants with underdeveloped root systems depend on the presence of mycorrhizal fungal symbionts [5]. Shrubs are a particularly important component of post-fire forest succession, and their interactions with root fungi and bacteria are of great importance in the composition and community structure of soil microorganisms. Studies on the natural succession of degraded lands have shown a shift in soil bacterial community structure from barren-tolerant to fertile. Forest soil bacterial diversity did not coincide with surface vegetation, but soil nutrient content was significantly correlated with soil bacterial diversity [6]. Studies on natural succession processes in alpine ecosystems have found that soil microbial community structure is most influenced mainly by soil properties and surface vegetation cover, but less related to species richness of above-ground parts of vegetation. In contrast, inter-root soil bacteria and fungi were significantly correlated for plant communities, but not for non-root soil bacteria and fungi.

3. Conclusion

In summary, fire disturbance has different impacts on forest soil microbes in various aspects, and the feedback mechanisms of how such impacts synergize between above-ground vegetation growth and development and below-ground microbes to regulate vegetation recovery and soil health are poorly understood. The bottom-up feedback process in post-fire natural succession ecosystems is also an important direction of fire ecology research, and strengthening the research on the interactions between above-ground vegetation and below-ground soil microbial communities, especially on the linkage between above-ground and below-ground components and the interaction mechanism, will enable people to better understand the function of forest ecosystems and establish a more reasonable ecosystem natural restoration strategy.

Fire disturbance has a large impact on forest ecosystems, not only limited to the impact on the number of forest vegetation, but the impact of fire disturbance on the underground seed bank also determines the direction of the natural succession of the forest after the fire. In the process of fire disturbance, seed viability, changes in soil substrate, seedling transformation capacity and seedling growth, each of which is affected by fire disturbance. Therefore, the soil seed bank plays an important role in post-fire vegetation renewal and restoration, vegetation succession and growth and development. Seed germination is the first step in the natural regeneration of natural forest vegetation after fire. Increasing the number of seedlings, reducing the loss of seed germination, and improving the seed germination capacity are favorable measures to enhance the natural regeneration capacity of post-fire stands, and a basic criterion for evaluating the regeneration capacity of forests in the process of natural succession.

Acknowledgments

This research was funded by Shaanxi Provincial Land Engineering Construction Group fund (DJNY2024-26, DJNY 2024-36).

References

[1] S-R Holden, Gutierrez A, Treseder K-K. Changes in Soil Fungal Communities, Extracellular Enzyme Activities, and Litter Decomposition Across a Fire Chronosequence in Alaskan Boreal Forests[J]. ECOSYSTEMS, 2013, 16(1): 34-46.

[2] X-J Xiang, Shi Y, Yang J, et al. Rapid recovery of soil bacterial communities after wildfire in a Chinese boreal forest[J]. SCIENTIFIC REPORTS, 2014, 4.

[3] Butler, Elser J-J, Lewis T, et al. The phosphorus-rich signature of fire in the soil-plant system: a global meta-analysis[J]. ECOLOGY LETTERS, 2018, 21(3): 335-344.

[4] D-R Zak, Holmes W-E, White D-C, et al. Plant diversity, soil microbial communities, and ecosystem function: Are there any links? [J]. ECOLOGY, 2003, 84(8): 2042-2050.

[5] L Zifcakova, Vetrovsky T, Howe A, et al. Microbial activity in forest soil reflects the changes in ecosystem properties between summer and winter[J]. ENVIRONMENTAL MICROBIOLOGY, 2016, 18(1): 288-301.

[6] C-A Osborne, Zwart A-B, Broadhurst L-M, et al. The influence of sampling strategies and spatial variation on the detected soil bacterial communities under three different land-use types[J]. FEMS MICROBIOLOGY ECOLOGY, 2011, 78(1): 70-79.

[7] Johannes Rousk, Bååth Erland, Brookes Philip-C, et al. Soil bacterial and fungal communities across a pH gradient in an arable soil[J]. ISME JOURNAL, 2010, 4(10):1340-1351.