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Soil Biota: The Living Engine of Soil Health

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ABSTRACT

Microorganisms and soil animals fall within the scope of soil biota that are necessary to maintain not only soil health, but also ecosystem resilience. The biota effects in the soil functional significance include nutrient cycling, disintegration of organic matter, and establishment of soil structure, which are very important in the growth of plants and ecological imbalance. It also gives importance to the contribution of the different groups of biotics (microfauna, mesofauna and macrofauna) in addition to external contributions such as pH, temperature, moisture and compaction factors that influence distribution and activity. Recently, people have raised concerns about the potential risks to the health of soil that enter into the soil ecosystems as microplastics (MPs). To enhance agricultural sustainability and guarantee a stable environment, it is necessary to maintain soil diversity. Good and effective soil management methods are needed to ensure such ecological problems are addressed adequately.

Keywords: Soil biodiversity, Ecosystem, External factors, Soil Health, Agricultural sustainability

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Introduction

Soil biota is used to refer to the wide variety of living life in the ground, which includes microorganisms in the form of bacteria, fungi, and algae, soil animals including protozoans, nematodes, and earthworms. They have significant roles in enhancing the health and fertility of soil by breaking down the organic matter, nutrient recycling and maintenance of the structure of soil. Soils aid in the growth of higher plants by providing nutrients and water, as well as physical strength to hold plants in place. Soil organisms are a fundamental part of the soil and affect ecosystem processes that are responsible for providing an extensive range of essential ecosystem services [1]. MPs can also affect soil organism's growth, reproduction, gut microbiota, and mortality because of organ damage, nutritional imbalance, weak immune system, and metabolism. MPs consumption by earthworms can pass to the food chain, as it plays a vital role in the soil food web. Even earthworms can ingest, digest, and transport MPs downward from top soil to deep in the soil profile, possibly; they can reach groundwater [2]. In the presence of soil fauna mircrobial activity and biomass will increase, shrub litter and macrofauna support higher fungal abundance, whereas grass litter, along with micro- and mesofauna, promote higher microbial abundance overall. The rate of metabolism of soil fauna is generally known to be higher, resulting in a higher breakdown of litter.

A cylinder of 56 mm in diameter and 40 mm in depth had been used to collect mesofauna for inoculation from the floor of the forest at 30 distinct sites within a mixed forest in Central Europe [3,15]. Generally speaking, soil compaction reduces the macropore volume, which in turn alters the relative amounts of the soil's air and water contents. In addition to the structural characteristics of the soil, site-specific hydrological and climatic conditions also have an important impact on the effects of soil compaction on soil organisms. Soil compaction hinders the ability of burrowing species, including earthworms, which are mostly classified as macrofauna. Therefore, activity can be limited even if abundance stays the same [4]. The paper emphasizes the emerging threat of microplastics in soil ecosystems and advocates for proactive soil management to preserve biodiversity and ensure environmental sustainability. It is also evident that the role of soil biota in key processes like nutrient cycle, organic matter decomposition and ecological balance.

Soil biota and plant growth

In soil biota, a remarkable variety of creatures can be found. These biotas are crucial regulators for various ecosystem processes, and their overall impact depends on the interactions and abundance of several functional groups. Soils dominated by bacteria and bacteria feeders are inclined towards faster cycling rates and consequently more nutrients will be available to plants in the form of carbon fluxes and nutrient leaching. Other soil biota that affects plant communities, and thus ecosystem functioning, include mycorrhizal fungi, diseases, and root herbivores [5]. Diversity of plants influences the biota and other functions of the soil by providing microhabitat diversity and litter deposition as well as delivering nutrients that are derived by roots [6, 14]. Also, plant variety controls the biota found in soil and the processes of ecosystems associated with them. Soil microorganisms and invertebrates increase as increasingly varied and abundant plant inputs are added to the soil as plant communities. Through alteration of the structure of microbial community of the soil, the individual species would also influence relationships among plant diversity and microbial community structure via sampling effects [5].

Types of soil biota

Microfauna, mesofauna, macrofauna and microbiota are all included in the soil biota. The body size of mesofauna ranges from 100 µm to 2 mm, while that of macrofauna is greater than 2 mm. Abiotic and biotic variables, including soil features of plant communities, have an impact on the geographical distributions of soil macrofauna and mesofauna populations both above and below ground. Because of their shorter lifespans, mesofauna are likely able to react to environmental disturbances more quickly than macrofauna [7]. Microbiota includes microorganisms (bacteria, fungi, viruses, etc). Bacteria, being extremely small and inconspicuous, are the most numerous organisms on this planet, with typically more than 100 billion bacteria per teaspoon of agriculture soil. Fungi are actually more related to us than bacteria, but also play avital role in the ecology of the planet. Fungi are almost all terrestrial habitats, and form a large proportion. [8]

Factors affecting soil biota

Many factors influence soil biota, including soil pH, humidity, temperature and compaction. Soil pH is only important for the chemistry and fertility of soil. The functional significance of soil pH in soil biogeochemistry is being utilized for restoration of contaminated soils and regulation of pollutant translocation and modification in the environment [9]. To raise the soil pH, the use of high pH compounds (e.g., liming) has been a frequent practice, which impacts the soil microbial communities [10,13]. Extreme temperatures and water availability are thought to be main factors limiting desert output, organism activity and ecosystem activities. Recent research suggests that water content may not be as crucial as previously thought in regulating the activity of soil biota [11]. The soil pore system is where the biological activity, such as root growth, occurs. Studies have revealed that compacted soil can retain the overall biomass of roots, while uncompact soil has a larger percentage of deep roots. During wet growth seasons, compacted subsoils can cause anaerobic soil conditions. As a result, both instances of excess water and drought can negatively impact a compacted soil (poor rooting condition) [12].

Conclusion

Soil biota are the veiled but important engine that promotes soil health and green resilience. These organisms, comprising a variety of microbes and soil fauna, play significant parts in ecological procedures such as nutrient cycling, organic matter decomposition, soil structure maintenance, and the growth of plants. Their activities not only increase soil fertility and stability, but it curbs microbial diversity, and changes plant-soil feedbacks that are crucial in the life of an ecosystem. The health and diversity are inseparable in soil biota and the environment quality and survival of agriculture because they are the foundation of terrestrial ecosystems. In that way, maintenance and enhancement of soil biotic communities is critical

towards establishing resilient ecosystems and ensuring the continuity of food and ecological stability. On land, to sustain and develop ecosystems, the soil organisms, such as microfauna, mesofauna, and macrofauna are necessary. They may be influenced by a wide variety of external variables and physicochemical characteristics that specifically are soil pH, moisture, temperature, and tension. These conditions do not only influence the dynamics of microbes, but also the nitrogen metabolism, root growth and general soil structure. When land-use barriers and warming temperatures are taken into consideration, it is important that these variables are managed in order to have a healthy soil ecosystem. Soil conditions should be ameliorated to favor ideal conditions that increase the biological activity, build resilience, and be effective in agriculture in the long term.

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