Importance of Soil Bacteria In Agricultural Fields And Agronomic Regulation Pathways

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ABSTRACT

Soil bacteria are very important in biogeochemical cycles and have been used for crop production for decades. Plant–bacterial interactions in the rhizosphere are the determinants of plant health and soil fertility. Free-living soil bacteria beneficial to plant growth, usually referred to as plant growth promoting rhizobacteria (PGPR), are capable of promoting plant growth by colonizing the plant root. PGPR are also termed plant health promoting rhizobacteria (PHPR) or nodule promoting rhizobacteria (NPR). These are associated with the rhizosphere, which is an important soil ecological environment for plant–microbe interactions. Symbiotic nitrogen-fixing bacteria include the cyanobacteria of the genera Rhizobium, Bradyrhizobium, Azorhizobium, Allorhizobium, Sinorhizobium and Mesorhizobium. Free-living nitrogen-fixing bacteria or associative nitrogen fixers, for example bacteria belonging to the species Azospirillum, Enterobacter, Klebsiella and Pseudomonas, have been shown to attach to the root and efficiently colonize root surfaces.

PGPR have the potential to contribute to sustainable plant growth promotion.

KEY WORDS – Environmental, Agricultural land, Microorganisms, Biodiversity, Micro biome Interactions.

INTRODUCTION

For many years, soil microorganisms have been utilized in crop production. These bacteria's primary purposes are to supply nutrients to crops in order to promote plant growth—for example, by producing plant hormones—to control or inhibit plant pathogen activity in order to improve soil structure, and to bioaccumulate or leach inorganic matter through microbial means (Brierley 1985; Ehrlich 1990).

More recently, bacteria have also been used in soil for the mineralization of organic pollutants, i.e. bioremediation of polluted soils. In the era of sustainable crop production, the plant–microbe interactions in the rhizosphere play a pivotal role in transformation, mobilization, solubilization, etc. of nutrients from a limited nutrient pool, and subsequently uptake of essential nutrients by plants to realize their full genetic potential. At present, the use of biological approaches is becoming more popular as an additive to chemical fertilizers for improving crop yield in an integrated plant nutrient management system. In this regard, the use of PGPR has found a potential role in developing sustainable systems in crop production. A variety of symbiotic (Rhizobium sp.) and non-symbiotic bacteria (Azotobacter, Azospirillum, Bacillus, and Klebsiella sp., etc.) are now being used worldwide with the aim of enhancing plant productivity.

The pressure on agricultural land to provide the need for food, fuel, and raw materials rises as a result of the rapid growth in the human population. Farmers use chemical pesticides and fertilizers to meet regulations, but this deteriorates soil quality and reduces soil biodiversity. In the next 30 years, there will be a 70% increase in demand for agricultural produce. In a similar vein, people are now realizing that sustainable agricultural methods are necessary to meet the world's agricultural needs in the future. Because of differences in its chemical and physical makeup, soil can be found all over the world. Millions of microorganisms reside in soil, where they contribute to increased plant development and improved soil fertility. The amount and quality of organic matter in the soil, its pH, and its redox potential all affect the physical and chemical characteristics of the soil. Each of these has a major impact on soil functions as well as the dynamics and structure of the microscopic community.

MICROBIAL DIVERSITY AND ITS INTERACTION WITH PLANT-SOIL SYSTEM

Microorganisms, including bacteria, fungus, algae, protozoa, actinomycetes, and viruses, are the entities that comprise the vast array of microscopic diverse activities. These soil microorganisms have both beneficial and detrimental effects in addition to their many useful roles. The influence of soil biota is complex and varied throughout the soil profile since the same action might have different effects depending on where it is located. However, plants exhibit a distinct spectrum of interactions with these microorganisms that live in the soil, so expanding the range of biological possibilities (competitive, exploitative, neutral, commensal, and mutualistic). Nonetheless, given the state of affairs, more research is being done on the harmful impacts that are alleviating, such infection and herbivory.

Given that agronomic management practices and biological factors play a major role in the interactions between plants and microscopic communities in the current global revolution, it is important to take into account the impact of ecological stress factors when managing crop-microbiome interactions. More than hundreds of years of soil "evolution" produced the construction of highly fertile soil; given the intricate relationships between microbes and the plant-soil system, this conclusion is not surprising. The way that plants and bacteria interact in the soil system.

BACTERIA

Compared to most other microorganisms, bacteria have a higher nitrogen content (10–30% N, 3–10 C:N ratio). Soil bacteria can be classified into four primary functional groups: lithotrophs, mutualists, decomposers, and pathogens. Every type of useful bacteria has a part in recycling nutrients in soil. Bacteria have a higher nitrogen content (10–30% N, 3–10 C:N ratio) than the majority of other microorganisms. Every type of useful bacteria contributes to the recycling of soil nutrients.

AZOTOBACTER

Even though it can grow at low oxygen concentrations, Azotobacter is a necessary aerobe. According to Sumbul et al. (2020), this bacteria's ecological spread is dynamic and dependent on a variety of factors that determine whether the bacterium is present or missing in a particular soil.

ACTINOMYCETES

Gram-positive aerobic bacteria that are classified as members of the Actinomycetes order are distinguished by their ability to produce aerial mycelium and substrate. They associate with certain non-leguminous plants and fix nitrogen (N), making it available to the host and other nearby plants. They are essential to the cycling of organic matter and prevent a number of plant diseases from proliferating in the rhizosphere.

CYANOBACTERIA

Cyanobacteria are gram-negative, photoautotrophic bacteria that are abundant in a variety of soils and actively contribute to soil development and fertility maintenance. They have a significant effect on the quality of the soil and the ability of plants to withstand biotic and abiotic challenges, such as plant diseases. The biomass of the solubilized organic matter, which is processed by soil microorganisms into non-ribosomal peptides, isoprenoids, ribosomal peptides, alkaloids, and polyketides, is sourced sustainably from cyanobacteria and contributes to the growth of agricultural crops. In deficient semiarid soils, cyanobacteria may increase the population of microorganisms and N levels.

RHIZOBACTERIA

A Rhizosphere is the portion of the soil that is constricted and particularly impacted by soil microbiomes and root secretions. Lorenz Hiltner used the term "rhizosphere" to characterize the impact of plant root secretion on edaphon. Since they play a critical role in fostering plant growth, plant-111 microbe interactions have garnered a lot of attention. Additionally, rhizobacteria are important for improving soil structure, as well as for the growth and stability of other nutrients, soil aggregates, a-gluconase, dehydrogenase, and mineral phosphates.

Microorganisms	Number/g of soil	Biomass (g/m^2)
Fungi	10^5–10^6	100-1500
Bacteria	10^8-10^9	40-500
Algae	10^4–10^5	1-50
Nematodes	10^2–10^3	Varies
Protozoa	10^3–10^4	Varies
Actinomycetes	10^7-10^8	40-500

Table 2. Relative number and biomass of microbial species at 0-15 cm depth of soil

NITROGEN-FIXING BACTERIA

Nitrogen plays an important role in the production of food and promotes plant growth, it is also essential for the synthesis of cellular enzymes, chlorophyll, proteins, RNA and DNA. Nitrogen is provided through the fixation of symbiotic interaction of atmospheric N2 by nitrogenase in rhizobial bacteroids for the nodulating legumes. In agriculture currently, 65% of the nitrogen is utilized through the process of biological nitrogen fixation and will remain to be vital in upcoming sustainable systems of crop production. Favorable plant mutualistic symbionts comprise multifunctional arbuscular mycorrhizal (AM) fungi and the nitrogen-fixing bacteria. The diverse genera of bacteria collectively named "rhizobia" are capable to fix nitrogen in mutualistic symbiosis with plants legume.

Functions of Agricultural Soil Microorganisms

Crop Growth- Interactions between soil microorganisms and crops are essential for fostering crop growth, raising yield, and strengthening resistance to abiotic stress (Figure 1). Studies have shown that soil nitrogen-fixing bacteria can improve crop growth by fixing atmospheric nitrogen, interacting with legume crops through molecular communication and mutual recognition.

Nutrient Cycling in Agricultural Land- Microorganisms in the soil are essential to the cycling of nutrients in agricultural ecosystems. They influence this cycle by breaking down organic matter, releasing nutrients, helping plants absorb nutrients, and interacting with other organisms. Studies reveal a substantial correlation between the soil multinitrogen cycling index and the α- and β-diversity of bacteria in agricultural soils. Notably, saprophytic and tufted arbuscular mycorrhizal fungus accelerate the decomposition of apoplastic materials.
Stress Resistance- Crop growth is often impeded by harsh environments like high temperatures and drought, but beneficial microorganisms like mycorrhizal fungi can improve resilience. Drought increases the abundance of these fungi, which secrete growth regulators, produce polysaccharides, and enhance antioxidant enzymes, thereby enhancing crop stress resilience.
Climate Regulation- The dynamics of climate change may be influenced by soil greenhouse gas emissions, which are largely determined by soil microorganisms. The metabolism of soils is intimately linked to both carbon sequestration and greenhouse gas releases. Through respiration, they release the carbon dioxide they metabolize from the soil into the atmosphere.
Pollutant Degradations – Pesticides and other pollutants including chemical fertilizers, plastics, and heavy metals contaminating around 64% of the world's agricultural land, agricultural soil contamination is a major obstacle to sustainable agriculture [22, 39]. Because they are the main consumers and decomposers of pollutants, microorganisms are essential to soil remediation and pollutant degradation. Studies show that xenobiotics are metabolized by soil microbes and enzymes due to their broad-substrate characteristics, while naturally occurring contaminants go through microbial metabolism as part of the ecosystem cycle.

Roles of Agronomic Measures in Soil Microbial Regulation

Farmland ecosystems depend heavily on soil microorganisms because they control crop growth, make nutrient cycling easier, and promote crop health. Regional differences in soil microbes are typical, though. As a result, utilizing native soil microbial communities in the area to boost soil microorganisms through a combination of agronomic techniques has become an organic and sustainable approach.

Pathways of Agronomic Measures to Regulate Soil Microorganisms

The surroundings have an impact on soil microorganisms. Through techniques like soil tillage, planting schemes, and fertilizer and water management, human activities significantly modify the soil microenvironment in farmed ecosystems. The soil microorganisms in agricultural soils undergo adaptive changes as a result of these agronomic practices, either directly or indirectly. Consequently, examining human activity may present chances to improve the mix of agronomic practices to maximize the life conditions of soil microorganisms.

CONCLUSION

Microorganisms play a crucial role in soil cycling, soil production, and health. They break down organic matter into humus, releasing enzymes for plant growth. Controlling the relationship between microorganisms and plants promotes soil health and plant growth in an environmentally friendly setting. It follows that only soil bacteria have the ability to enhance crop productivity and soil health. Evolution of soil microorganisms: Investigating the development and succession of soil microorganisms can shed light on the formation of microbial community structures. Understanding how soil microorganisms evolve in farmland ecosystems and respond to agronomic measures is essential for optimizing agricultural measures. Interaction between soil microorganisms and crops: Soil, microorganisms, and crops form a cohesive unit, with microorganisms creating a conducive environment for crop growth and nutrient uptake. Exploring the interaction and co-evolution between soil microorganisms and crops reveals the microbial regulatory mechanisms affecting crop health, nutrient uptake, and pest resistance. Resource discovery and utilization of soil microorganisms: Soil harbors vast microbial resources with untapped potential. Identifying and harnessing new beneficial microbial resources and studying their applications in agriculture, energy, and healthcare offers promising avenues for sustainable development.

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