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A Short Review on the Significance of Microbiota in Soil

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Abstract

Soil offers the medium for root growth, and plants rely on the soil for all other nutrients and water, except for sources such as carbon, hydrogen, oxygen, and nitrogen. Soils grow through the disintegration of rocks and minerals, through the biotic activities of microbes and wildlife. The role of soil-biodiversity is well accepted in preserving fertility and the inter-dependence of physical and chemical activity. Biodiversity is the term that used to refer different living organisms (microorganisms, plants, animals, humans) from variable sources on earth which includes inter alia, land-dwelling, aquatic ecosystems, diversity within and between species of ecosystems. Biodiversity is very important for the establishment of mammoth ecological benefits that significantly promote the wellbeing of humans. Biodiversity is encompassed of different levels beginning with genes to individual genus, from species to communities of creatures and ultimately to whole ecosystems. Biodiversity of soil encompasses several kinds of organisms namely "bacteria, fungi, protozoa, nematodes, enchytraeids, earthworms, mites and springtails". The organisms can be distinguished depending on their preferred living environment such as aboveground and belowground. The soil's biological activity is "largely concentrated in topsoil".

Index Terms

Microbiota, Soil.

INTRODUCTION

Plant roots and soil organisms constitutes the living components of soil. It has been studied and reported that biological components occupy <0.5% of soil's total volume and <10% of whole soil organic matter. In temperate grasslands, earthworms represent around 50% of soil fauna biomass [1]. In temperate forest, they form a major part and represent about 60% of soil fauna biomass. Organisms living in soil interact in soil food web (degradation of roots and dead organic material) "where each tropical layer is food for next the next trophic layer and essential for biodiversity of soil organisms". Ecological function and stability are mainly reliant of the soil food web stability and the stability increases with increasing number of organisms' interactions. At the microbial scale, huge number of soil microorganisms are present and contribute to high levels of biodiversity. Microorganisms in soil majorly contribute (60-80%) to biological activity. This process is done by the decomposition of organic residues, soil food web interaction resulting in a flux of matter and regulating nutrient cycles effectively [2,3].

ROLE AND FUNCTIONS OF SOIL MICROORGANISMS

Recycling of organic material in soil is the primary function of soil biota. SOM referred as "soil organic matter" is a straightforward result of collective biological activity of microorganisms, plants, animals in addition to multitude of abiotic components. Soil microorganisms are vital for many soil functions such as aeration and fertility, soil organic matter production involving extracellular polysaccharides and cellular debris synthesis [4,5]. Furthermore, it improves the ability of soil to sustain its structure once it is formed. Fertilizer and sewage sludge; the exogenous organic matter very different from SOM, may contribute to its content only after processing by soil organisms. High concentration of organisms was found in such wastes and interfere with local soil organisms that might result in soil community shifts [6]. "Microorganisms present in soil accomplish broad spectrum of activities such as decomposition of organic matter, release of nutrients into plant available forms and degradation of toxic residues" [7]. Other range of functions include symbiotic associations with plant roots, act as pathogen antagonist, involvement in mineral solubilization and contribute to soil structure and aggregation effectively [8]. Vascular plants benefit with the association of arbuscular mycorrhizae fungi to extract nutrients particularly phosphorous from soil. Fungal species have a significant role in nutrient cycling, maintenance of soil structure and very importantly in plant community development [9].

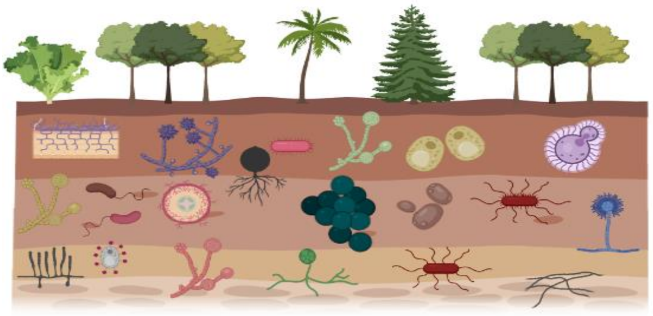

Figure-1: Microbial diversity in soil

RHIZOSPHERE

The importance of the rhizosphere in soil biodiversity has been stated in several studies. “The Rhizosphere is a biologically active region of soil around plant roots that contains soil-borne bacteria and fungi [10].” Microbial interactions with plant in the rhizosphere might benefit the microorganisms or the plant. Microbiologist and plant biologist often face with difficulties in studying the plant-microbe interactions [11]. The fact that many microorganisms in the rhizosphere region are difficult to cultivate and isolate in the laboratory is a major drawback in studying these interactions. Current advances in molecular biology techniques are very useful for researching microbial diversity in the rhizosphere [12].

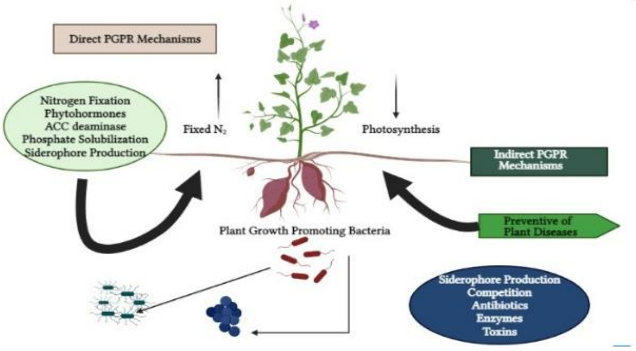

Figure-2: Schematic representation of significance of plant growth promoting bacteria in soil fertlity

The interactions between plants and soil microbes are important in understanding the intrinsic processes of "nutrient cycling, carbon sequestration, and ecosystem functioning" [13]. Positive interactions, pathogenic negative interactions, and neutral interactions are the three types of plant-microbe interactions [14]. In symbiosis, both the plant and the microbe benefit from the association; in associative interactions, one partner benefits from the association without damaging the other. The neutral interaction is the third form of classification, in which neither the plant nor the microbe benefits or is harmed because of the interaction. While studies of associative interactions are limited due to methodological approaches, symbiotic and pathogenic interactions have gained more scientific attention and have been extensively studied [15]. Many studies have recently been conducted on the role of rhizosphere interactions in plant diversity, nutrient cycling, and carbon sinks in high-CO2 environments. Recent discoveries and reports have sparked a lot of interest in plant-microbe interactions, which has sped up more advanced research in this area [16]. When it came to determining the function of microbes in the rhizosphere and natural environment, ecologists faced numerous challenges and difficulties. Molecular techniques open new avenues for research into the processes and structural diversity that occur in the rhizosphere [17].

Rhizodeposition

Rhizodeposition is the term for the method of demonstrating complete carbon transfer from plant roots to soil. This consists of "exudates containing small molecules such as sugars, amino acids, and organic acids, secretions such as enzymes, mucilage, and lysates from dead cells" [18]. Plants' net loss of carbon assimilation (rhizodeposition) ranges from 10% to 40%, with nutrient-stressed plants exuding up to 44% of their net carbon assimilation. Rhizodeposits play an important role in the regulation of symbiosis between plants and soil microorganisms in defensive associations. Several studies have shown that rhizodeposits play a role in controlling the microbial environment around roots, fostering defensive associations and symbioses [19]. The beneficial protective relationship would ensure the availability of vital nutrients while also enhancing the physical and chemical properties of the soil.

Nutrient cycling

"Root exudation" is a crucial process in the rhizosphere that involves carbon transfer to the soil. This carbon transfer mechanism can affect soil microbial communities to participate in nutrient cycling and organic matter decomposition [20]. While root exudation is a complicated procedure, it boosts the number of plant-soil microbial communities in the rhizosphere. Microorganisms present in soil is highly dependent on plant carbon. Soil microorganisms provide plants with nitrogen, potassium and phosphorous [21]. In addition to this, they also provide plants with other beneficial minerals via decomposition of soil organic matter. Many studies have reported that “Root production and turnover have immediate effects on biogeochemical cycling by providing carbon and energy to microorganisms present in soil and fauna microbial interactions play a significant role in carbon sequestration [22]”. More research is required to identify the interactions between “rhizodeposition, root turnover, and microbial activity [23]”. Accurate quantification of below-ground carbon distribution in ecosystems and net primary production is hampered by imprecise calculation. Several studies have demonstrated the role of various ammonia oxidising bacteria in the rhizosphere over the years. The role of nitrogen-fixing genes in the rhizosphere was also discussed in these studies. [24].

Other functions

Microbial interactions with the roots of plants are imperative in performing other ecosystem functions like “decomposition of organic matter, maintenance of soil structure and water relationships [25].” Several studies have recorded the importance of root-associated soil microorganisms in maintaining soil aggregate and stability. Microorganisms that generate glycoprotein and glomalin have been reported in well-structured field and native forest soils [7]. Glomalin is needed for soil aggregate stabilisation. Evidence suggests that biotic interactions below ground are important in "establishing plant diversity above ground through direct feedback on host growth and indirect effects on competing plants [26]."

Microorganisms are found throughout the environment and fulfil many important ecological functions. Important functions include microorganisms that are associated with processes such as nutrient cycling and maintaining ecosystem's health in soil. Several studies reported that the soil contains contain nearly hundred and nine prokaryotes. In addition, the soil contains approximately two thousand species of the genome "per gram of soil". The genome type is estimated to correspond to 0.05% of microbial population in soil [27]. Few years before, soil microbes could be studied (structure, characteristics, ecological importance) possibly by conventional methods on a small scale. Recent scientific advancements in molecular biology have remarkably successful in studying the soil microbial communities. The molecular approach in studying soil microbial diversity is primarily based on the analogy of nucleic acid sequences. The nucleic acid sequence information is imperative and provide cell information. Furthermore, sequence details are essential for classifying the microbial biota and in studying their ecological relationships. Molecular based approaches have been extremely effective in disclosing details of soil bacterial and fungal species. Microorganisms that are present in soil are vital for various functions (biogeochemical cycles). Both bacteria and fungi present in soil are responsible cycling organic compounds. In addition, they are vital for sustaining cycling of nutrients and for the sustainability of the surface environment [28,29].

Role of Endophytic Fungi

Endophytic fungi are important components of plant-micro ecosystems and have major impacts on the growth and development of host plants. Endophytic fungi extensively exist inside the living plants healthy tissue and establish relationship with one and another. This special relationship can significantly influence the formation of plethora of known secondary metabolic products in plants. Earlier studies revealed that like plants, endophytic fungal species are highly capable of producing bioactive secondary metabolites that can be an alternate source of bioactive secondary metabolites such as "antioxidant compound" [30]. The formation of secondary metabolites can be exploited and employed as essential medical resources. Endophytic fungi can bestow profound influences on their host plants such as growth enhancement and increase in fitness. In addition, endophytic fungi strengthen their host plant tolerances to abiotic and biotic stresses and promotes secondary metabolites accumulation. On the other hand, their distribution and population structure can be substantially influenced by factors such as age, genetic background, and their hosts environmental conditions. Endophytic fungi profound impacts on host plants are imperative to produce bioactive elements in their hosts [31]. These fungi belong to mitosporic and meiosporic ascomycetes that reside beneath the epidermal cell layer of the internal tissues of different plants asymptomatically by colonizing healthy and living tissues through latent infections. Several studies reported on the biological diversity of endophytic fungi taking place naturally in tropical rainforests and temperate regions. Furthermore, it has been reported that nearly three hundred thousand terrestrial host plant species are dispersed, and each plant species hosts one or more species of endophytic fungi.

These distinct polyphyletic groups of microorganism's flourishes in different living plants health tissue above or under the ground including roots, stems and leaves in an asymptomatic manner. Approximately one million endophytic fungal species are estimated to occur in nature, and they are categorized into three main groups namely mycorrhizal, pasture endophytic fungi (balansicaeous) and non-pasture endophytic fungi [32]. These fungi produce bioactive compounds solely for their host plants, that significantly increase the adaptability of both endophytic fungi and their host plants. In many instances, several bioactive compounds derived from plants are not essentially their own metabolic products rather produced by some microorganisms living inside healthy tissue of plants in a symbiotic fashion known as endophytes [33].

Plant growth promoting Rhizobacteria

Plant growth promoting Rhizobacteria are naturally occurring rhizosphere bacteria belonging to different kinds of bacteria, including *Pseudomonas* sp., and *Bacillus* sp [34]. These growth promoting organisms are isolated from a wide range of plant species, including Arabidopsis, barleycorn, beet, grain, maize, and beans. Rhizobacteria-fostering plant growth is employed as bio stimulants, biopesticides, bioinoculants, Phyto stimulation/rhizodegradation and biocontrol agents [35]. An improved growth and efficiency of plants is the overall outcome of rhizobacteria. Various mechanisms such as modulation of architecture of root systems and enhanced development of phytohormones such as auxins and cytokinin, can make their contribution [36]. Furthermore, indirect mechanisms are products like antibiotics and hydrogen cyanide, that stimulate plant growth through the inhibition of detrimental growth of organisms present in the rhizosphere. Rhizobacteria-promoting plant growth can lead to protection such as systemic acquired resistance and stimulated systemic resistance and minimise microbial phytotoxicity. Inducing systemic tolerance to abiotic stress can also be produced [37].

CONCLUSION

Ecological function and stability are mainly reliant of the soil food web stability and the stability increases with increasing number of organisms' interactions. At the microbial scale, huge number of soil microorganisms are present and contribute to high levels of biodiversity. The interactions between plants and soil microbes are important in understanding the intrinsic processes of "nutrient cycling, carbon sequestration, and ecosystem functioning. The microorganisms fuel plant growth: (1) controlling the hormonal signalling of plants; 2), preventing or outcompeting infective microbial species and (3) enhancing the bioaccumulation and utilization of the soil-borne nutrients.

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