A review of plant microbiome: Its functions and components

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Authors' contributions

This work was completed with the assistance of all authors. Author MHH wrote the first draft of the manuscript. As author GHN edited and reworked the work in line with the journal's style, author QA directed the literature searches. All authors have read and approved the final draft.

ABSTRACT

Microbes are living organisms that are lived everywhere in our environment. They occupy a place in, on, and around humans, plants, and animals. They have mutualistic, parasitic, and commensalism relationships with other organisms. The study of these microorganisms which live in a special habitat is called the microbiome. Plant microbiome function and their types have been discussed. Phyllosphere, endosphere, and rhizosphere microbiomes take important roles in plant growth by multiple mechanisms. It has been declared that Microbiome is important for us, animals, and as well as plants. Mutualistic microorganisms support animals' and plants' health and protect them from diseases and pests. The phyllosphere, endosphere, and rhizosphere are the components of the plant that live plenty of microbes there. They fix nitrogen, dissolve nutrients, decompose organic materials, and promote plant growth. To sum up, microbes clean up our environment, decompose wastes, help diet, support survival, and do many tasks in, on, and around organisms.

***Keywords*—** Microbiome, phyllosphere, endosphere, rhizosphere, endophyte

I. INTRODUCTION

Microbes are present everywhere in this environment. As well as in, on, and around our bodies, these microbes are widely distributed in water, soil, air, and food. By way of the wind, air microorganisms spread from one continent to another and start new colonies (Saleem, 2015). In nature, diverse activities are carried out by different microbes; some of them make the soil fertile, clean the environment, and sustain our bodies, but just a few of them cause sickness (Postgate, 2000). Our bodies contain more than ten thousand different types of microorganisms. Although very few of these microorganisms can cause illness and many of them are necessary for our survival, not all of them are dangerous (DeSalle& Perkins, 2015). Therefore, the human body is a significant reservoir of microbes, known as the human microbiome (Djikeng et al., 2011). Microbes have played the most principal role and enabled life on the earth. There is little information about these microbes and has not been well addressed, therefore further study requires their life cycle and functions (Berg et al., 2014).

In 2001, the microbiome term was coined by Joshua Lederberg (Ursell et al., 2012). He defined the total ecological diversity of microbes that live in certain habitats and ecosystems (Saleem, 2015). The human microbiome has approximately 100 trillion microbial cells. Thus, this amount is 10-fold more than human cells. A healthy intestine has beneficial microbiota, especially 500 - 1000 species of bacteria that live in the gut and prevent microbial pathogens that attack human bodies (Villa &Viñas, 2016). The human microbiome is significant for us, but the plant microbiome is necessary for plant health. The plant's major challenges are herbivores, pathogens, drought, salinity, pollutants, and some other abiotic stresses. The plant microbiome help plants to adapt to changing environments, remove obstacles and overcome these challenges (Doty, 2017).

The plant microbiome has a vital influence on plant health and productivity. Therefore, it reduces the incidence of plant diseases, chemical input, and emission of greenhouse gases (Turner et al, 2013). The plant-associated microbiome does not only affect plant growth but vitally takes part in human health. These microbes make better our health, prevent the activities of pathogens, and contribute to our diet (Berg et al., 2014).

2. The function of the plant microbiome

Microorganisms in the rhizosphere, phyllosphere and endosphere have an impact on the composition, structure, diversity, and productivity of natural plant communities both directly and indirectly (Anal et al., 2020). The plants have a specific microhabitat for microbes in each part of the plant, that are distinguished from each other. For instance, the rhizosphere (roots), the phyllosphere (leaves), the caulosphere (stem/bark), the anthosphere (flowers), the carposphere (fruits), calusphere (bud), spermosphere (seed), and endosphere (all inner parts) (Berg et al., 2015; Leveau, 2015). Plants and microbes have relationships with each other, this relationship can be parasitic, mutualistic, or commensalistic. Parasitic effects harm the plant, mutualistic effects promote plant growth and commensalistic effects are neutral and never affect plants' health (Lebeis, 2015). The microbiome influences the potential for plant health and development (Berendsen et al., 2012). Plant-associated microbes promote plant growth and suppress the progress of plant pathogens by producing plant growth hormones (Prieto et al., 2011). Microbes play a vital role in ecosystem processes, they decompose organic wastes, detoxify hazardous chemicals, recycle nutrients, and carbon sequestration (Taylor et al., 2009). All microbiota impact the global carbon and nitrogen cycles (Delmotte et al., 2009).

Generally, the microbes contribute to plant growth and development in three ways, (a) they take part in plant growth promotion, (b) protection, (c) and quality improvement. Microbes secrete nutrients and produce hormones and growth-promoting substances that influence plant growth promotion. The microbes protect plants from pests (bacteria, fungi, nematodes, etc.) damages, as well as help plants against abiotic stresses. The microbial community affects the quality of plant products that live in and around the plants (Krishnaraj et al., 2017). Microbiome is a major part of global biodiversity and plays a critical role in nutrient cycling. Plant microbiome take an important part in the phyllosphere, rhizosphere, and endosphere tissues of plants (Rossmann et al., 2017).

3. Type of plant Microbiome (phytobiome)

The words "phyto" (plants) and "biome," which refer to distinct ecological regions, are combined to form the term "phytobiome" (Trivedi et al., 2022), which refers to the microbiome that is connected to plants (Kumari et al., 2020). It covers the biology of how plants interact with both living and nonliving things in sound environments (Trivedi et al., 2022). The plant microbiota includes bacteria, fungi, protists, nematodes, and viruses that colonize all accessible plant tissues. The microbiome (microbiota and their genomes) inhabiting the soil, rhizosphere, roots, and other plant tissues establishes complex and dynamic interactions with the host plant. These interactions are highly influenced by the environment and can improve plant resilience to environmental stresses (Trivedi et al., 2022). We discuss in this article phyllosphere, endosphere, and rhizosphere such as the following:

3.1 Phyllosphere

The phyllosphere-aerial plant surface is the planet's biggest biological interface, providing vital life-sustaining global services including carbon dioxide fixation, molecular oxygen release, and primary biomass generation (Saleem et al., 2015). The aerial components (leaves, stems, buds, flowers, fruits) of a plant that supply the habitat of microorganisms are called phyllosphere (Whipps et al., 2008). There are lived different communities of microbes in the phyllosphere, including bacteria, filamentous fungi, yeasts, algae, and less frequently protozoa and nematodes (Lindow&Brandl, 2003). It is estimated that nearly 1 billion Km^2 in the world occupy leaf surfaces and have more than 1026 bacteria (Delmotte et al., 2009). Bacteria are the most prevalent and plentiful microorganisms in the phyllosphere ecosystem, while fungi are less prevalent (Anal et al., 2020). The most abundant community is the bacteria in the phyllosphere that present in numbers between 106 - 107 cells cm^{-2} of the leaf surface. The microbial communities that are found in the phyllosphere may take an important role in nitrogen fixation, protection from diseases, modification of metabolites, and biosynthesis of phytohormones (Rossmann et al., 2017). The phyllosphere niche is important in sustainable agriculture because it confirms interactions of phyllosphere microbial populations that affect the health of natural plants as well as the quality and yield of crops (Anal et al., 2020). Phyllosphere bacteria may promote plant health by enhancing plant tolerance to challenges such as frost-induced damage and drought stress. Moreover, phyllosphere bacteria can affect plant growth through some mechanisms, such as hormone generation for plants, control of plant metabolic pathways, and involvement in increasing nutrient availability (Verma & Kumar, 2019).

3.2 Endosphere

Endosphere is the inner plant tissues that are occupied by microorganisms. The host plants and microorganisms interact with each other. Internal root, shoot, and leaf tissues are components of the endosphere (Andreote et al., 2014). Endosphere microbiomes promote plant growth, increase resistance against several pathogens, and produce some antibacterial, metabolic, and biosynthesis compounds and so on (Figure 1) that support plant life, health, and development (Jeong et al., 2014; Verma & Kumar, 2019). There are produced metabolic materials that are essential for plant life, endophytes affect significant on the host plant and potentially impact its health, growth, and development (Rossmann et al., 2017).

The endophyte term is derived from the Greek language that means in the plant, such as its leaves, roots, stems, etc., without harming the host plant (Schulz & Boyle, 2005; Verma & Kumar, 2019). The word explains plant hosts and inhabitants. For example, some bacteria, fungi, algae, and insects live in the plant’s tissues. The plant and organism's relationship with each other may be mutualistic or parasitic (Schulz & Boyle, 2005). Endophytic microorganisms contribute to the plant microbiome, they live in the plant tissue and do not harm the plant, but they can be beneficial or commensal. These microbes stimulate plant growth and influence the health of the plant by different mechanisms (Velázquez et al., 2016). Endophytes are generally perceived to not be harmful (Verma & Kumar, 2019).

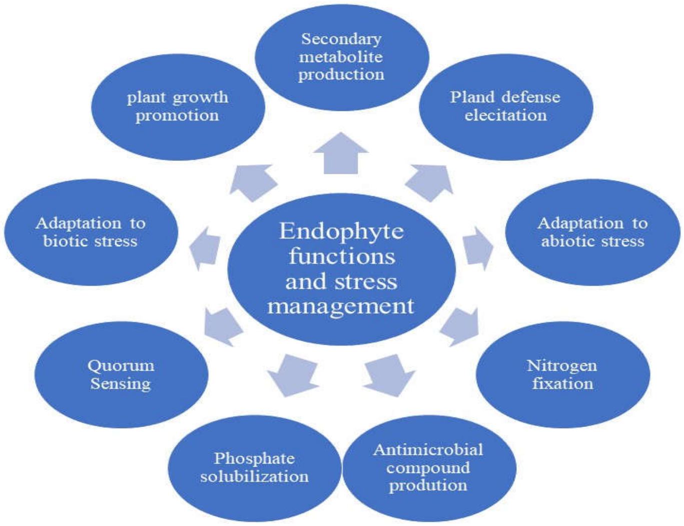

Figure 1: Endophytes' role in promoting plant growth and stress management (Singh et al., 2020).

3.3 Rhizosphere

Rhizosphere refers to the constrained area of soil that surrounds a plant's roots and is influenced by the roots, root hair, and exudates produced by the plant. The rhizosphere of a plant is said to have three separate interacting systems: the rhizoplane, the rhizosphere, and the root itself. The root surface, including the firmly adhering soil particles, is referred to as the rhizoplane (Hashimi, 2016; Subrahmanyam et al., 2020). The rhizosphere was first defined as the soil impacted by roots by the German scientist Hiltner in 1904. The soil area immediately adjacent to the roots is where a high level of microbial activity is maintained (Lugtenberg, 2015; Kumar, 2019). Because 6-21% of the carbon fixed by the plant is excreted by the root, the rhizosphere is more microbially diverse than the bulk soil in its immediate vicinity (Lugtenberg, 2015). The rhizosphere also includes the area of the soil where plant roots and specific root tissues have an impact on the physical, chemical, and biological characteristics of the soil (Kumar, 2019).

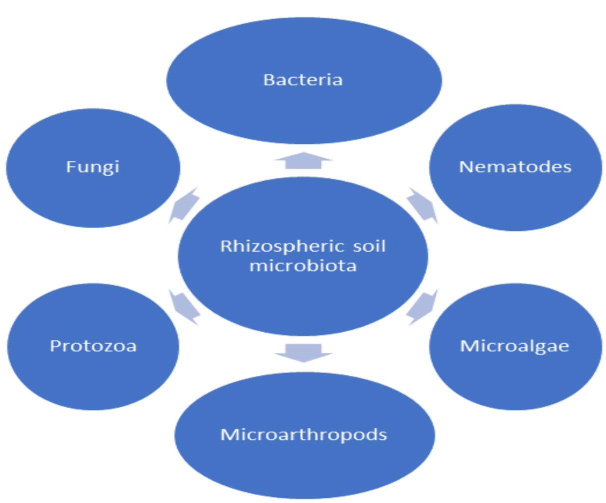

Figure 2: Rhizospheric soil microbiome categorization (Mokrani& El-Hafid, 2020).

Many microorganisms live in a variety of environments (Figure 2), including forests and agroecosystems. The rhizosphere of the soil is one of its richest regions. The kind of soil, the environment, the kind of plant, and the stage of plant development all have an impact on the organisms that live in a rhizosphere. Chemicals released by soil microbes interact with nearby microbes and plants. These substances are detected by plant roots, which in turn release plant exudates that can vary depending on the species, ecotype, and root type of the plant. Besides other things, root exudates contain sugars, amino acids, and fatty acids. These substances can attract both advantageous and harmful organisms into the rhizosphere (Nadarajah, 2019). The accumulation of microbes is increased in this zone more than in other parts of the soil because the roots secrete bio-available, low-molecular-weight carbon compounds (Toal et al., 2000). The density of bacteria in the rhizosphere is up to 100-fold higher than in bulk soil, various bacteria cover or occupy more than 15 % root surface by their microcolonies (Van Loon, 2007). Due to the abundance of nutrients actively released by the plant root and mucilage, bacteria are plentiful in the highly competitive environment known as the rhizosphere of plants. Plant growth-promoting rhizobacteria (PGPR) are a general term for certain of these bacteria that are present in or near plant roots and aid in plant growth. In many situations, the plant growth-promoting activity is associated with their ability to reduce soil-borne plant diseases (bacteria and micro-fungi), existing in the competing microflora (Borriss, 2020). Microorganisms in the soil are essential for sustaining plant health and productivity, controlling soil fertility, and cycling nutrients. The microbial communities in soil are extremely complex and composed of a variety of organisms (Subrahmanyam et al., 2020).

Rhizosphere microbes take part in many processes in the soil, they increase soil productivity, preserve soil structure, contribute to nutrients recycling, control plant diseases, and degrade pollutants (Hashimi, 2016; Lareen et al., 2016), as well as the Soil microbiota can change plant traits, for example, the flowering time (Panke-Buisse et al., 2015). Agricultural practices influence negatively soil microbes, these microbes reduce soil organic matter and cause groundwater pollution (Lareen et al., 2016). The interaction among soil, microbe, and plant is complex and dynamic. Soil provides nutrients and a place to grow the plant, microbes take part in nutrient cycling, help with plant growth and plant conserve soil, improve physical and chemical properties of soil and microbes feed on plant residues (Taylor et al., 2009).

Plant roots affect the soil and organisms, because, some compounds are secreted by roots into the soil, and the accumulation of organisms in the root zone is increased. Microbes have positive or negative effects on plant growth (Hashimi, 2016; Laksmanan et al., 2014). Plant roots release different compounds (carbohydrates, amino acids, organic acids) into the soil (Bais, 2006). These compound change soil chemical properties and supply nutrients for microbes (Miransari, 2013). Rhizospheric microbes produce siderophores that increase the solubility of iron, therefore enhancing iron absorption by plants (Carvalhais et al., 2013). Plant roots release strigolactones compound into the soil to attract mycorrhiza, these microbes improve nitrogen and phosphate supply to the host plants (Akiyama et al., 2005). Legumes roots secrete flavonoid compounds and rhizobia bacteria attract and establish symbiotic life together. These bacteria fix nitrogen in the soil and plant use it (Hassan &Mathesius, 2012). Furthermore, these rhizosphere microbes improve soil and plant productivity in general by (a) secreting hormones and other growth-regulating chemicals, (b) acquiring and making essential nutrients bioavailable, (c) inhibiting pathogens through the production of biocontrol agents, and (d) tolerating abiotic stress

(Saha et al., 2020).

Finally, the rhizosphere microorganisms have beneficial or harmful effects on plant growth (Philippot et al., 2013). These are positive aspects of microbes that mycorrhizal fungi and rhizobia bacteria provide phosphorus and nitrogen for the plant, some bacteria produce siderophores that support iron availability to plants, and some other bacteria promote plant growth with different mechanisms (Sugiyama et al., 2014). These are the negative aspect of microbes that some of them live in the rhizosphere and have pathogenic properties, such as nematodes, fungi, and oomycetes causing diseases and reducing the yields of food, feed, fiber, and fuel crops (Mendes et al., 2013).

4. Conclusion

The microbiome is a microbial component of the plant, because it supports plant growth and development, and protects and resists biotic and abiotic stresses. Plant growth is affected by various factors the microbiome produces some substances to help it on removing external or internal pressure.Therefore, these material support plant life, improve production, and give stability and adaptability to the plant. Microbiome is the community of microbes that live in, on, and around the plant. This community of microbes impacts plant growth, development, and life span. They decompose organic matter and release nutrients to the soil, fix nitrogen in the soil, increase the solubility of some elements as well as detoxify toxic chemicals to harm the ecosystem.

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