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Role of Microorganisms in Agriculture

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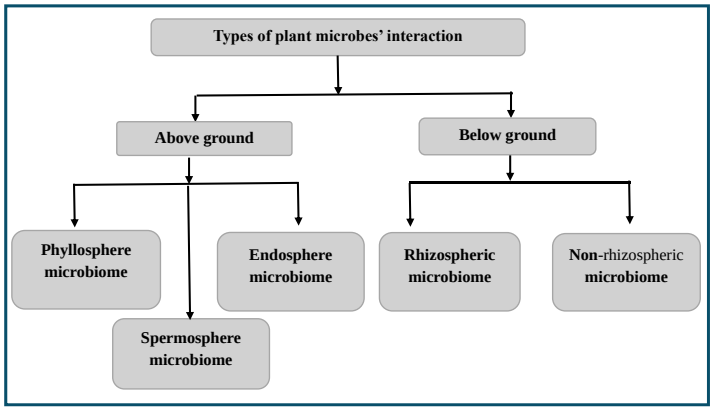
Microbiology has a unique significance in agriculture whether in maintaining the fertility and health of the soil or it is essential for the growth, development and production of plants. Microbiology is a key component of designing sustainable agriculture. The application of microbes in agricultural techniques has garnered substantial attention in the past few decades, owing to their potential to stimulate plant growth and effectively manage plant pests and diseases by biological means (Araujo et al., 2021). The accumulation of microbial diversity in soils over long periods of evolution is vital for crop production sustainability as it enriches the soil and reduces the effects of biotic and abiotic stresses. (Jat S. et al.,2021). Several distinct soil microorganisms play a role in these processes, some have promising biocontrol properties against pests, crop diseases and weeds, for instance, Certain bacteria such as those found in the genera *Streptomyces, Burkholderia, Bacillus, Pseudomonas, Enterobacter, Pantoea* and *Paraburkholderia, Paenibacillus* have the ability to protect plants from pathogens (Santos L. F., & Olivares F. L. 2021), whereas mycorrhizal and rhizobacteria species play key roles in long-term fertility management for example *Rhizophagus intraradices* is a well-known Arbuscular Mycorrhizal Fungi species (Nanjundappa A. et al., 2019). A few commonly used beneficial microbes in agriculture are *Azospirillum, Bacillus, Mycorrhizae, Pseudomonas, Trichoderma, Rhizobia, Streptomyces species* etc. (Singh S. et al., 2017). For a variety of crops, microorganisms are currently being utilized in place of synthetic fertilizers and pesticides. The agro-ecosystems depend on diversity, which is being destroyed by the continuous disturbance of the soil and the applications of agrochemicals. As a result, cropping system efficiency has been declining, which has been made worse by an increase in abiotic stressors brought on by alterations in weather patterns (Mohamed H. et al., 2021). Abiotic factors that are affected by climate change include temperature, rates of precipitation, drought intervals, intensity of light and the evaporation. These factors influence the physical and chemical properties of soil & cause stresses that can directly and indirectly hinder plant growth and productivity.

A sustainable crop production approach may involve an understanding of the microbiota that lives in the phyllosphere, endosphere, spermosphere, rhizosphere, non-rhizosphere and making use of it (Jat S. et al., 2021). Microorganisms found in rhizosphere which perform functions such as supplying nutrients and fertilizer, altering the chemical and physical composition of soil, and regulating signaling of hormones, are closely associated with plant physiology. The single-celled eukaryotes known as protozoa, which feed on bacteria and other microorganisms, are essential for controlling populations of microbes and nutrient cycling in the rhizosphere (Thepbandit W. and Athinuwat D. 2024). Relationship of microbes with plant system, such as rhizospheric, endophytic and epiphytic ones, are

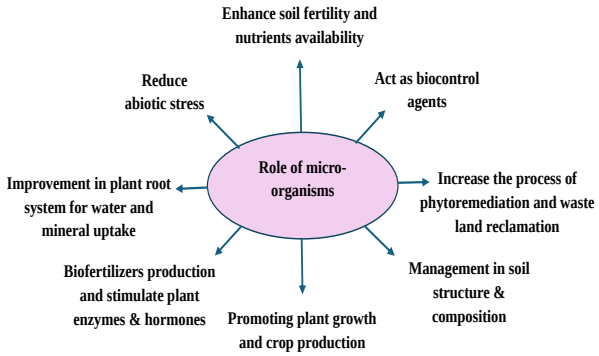


referred to as plant-microbe interactions (Berendsen R. et al., 2012). (Fig. 1)

Fig. 1 Types of interaction between plants and micro-organisms

Benefits of microbiomes for agriculture are considered that includes, microbe that promote plant development and optimize resource utilization, also it is widely accepted that a large number of symbiotic and free-living microorganisms promote the accessible amount of nutrients for plants (Lyu D. et al., 2021). For example, Algae and Cyanobacteria act as a biocontrol agent against plant pathogens like fungal and bacterial, biofertilizers production, improvement in fertility of soil (Mohamed H. et al., 2021). The physiological mechanisms of plant growth-promoting

rhizobacteria (PGPR) aid in the process of adaptation and promotion of plant species to resist abiotic stresses brought on by edaphoclimatic changes, PGPR is also play crucial role in degradation of soil pollution, in the production of hormone, antibiotics and siderophore, nitrogen fixation, improvement in root system of plant for better water uptake (Mohanty P. et al., 2021). Another example is Seaweeds that live in maritime environments are subject to a variety of abiotic challenges, like rising temperatures, intense light, ultraviolet radiation, or hazardous metals. Eventually, repeated cycles of dehydration and rehydration in



seashore species can have a detrimental effect on the development and growth of seaweeds (Begum M. et al., 2018). (Fig. 2)

Fig. 2 Role of micro-organisms in agriculture

Conclusions

In the upcoming decades, the main goal will be to use beneficial microbial communities associated with plants and soil to create a clean and green environment. Global agriculture is changing significantly as a result of human activities and climate change. Microbiota are essential for both improving agricultural output and enabling plants to adapt to these stressful environments. Consequently, a thorough grasp of their roles in the interaction between microbes and plants, as well as their communities, processes, and other prerequisites, is required. By boosting soil fertility, disease resistance, plant yield and nutrition as well as offering the possibility of repairing degraded lands, this knowledge will offer long-term answers for sustainable agriculture. This enormous microbial ecosystem provides solutions that support the development of novel biocontrol mechanisms and their uses, so greatly aiding in the preservation of plant as well as human life on our planet.

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