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PLANT-MICROBE INTERACTION FOR INCREASED PLANT PRODUCTIVITY

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Abstract

The microbial-based interaction with the plants serves as an alternative and sustainable trend in the field of agriculture. The chemical-based pesticides and fertilizers had led soil pollution and problematic health issues among the humans due to which the plant productivity has been compromised and various diseases have prevailed over the few decades. The use of PGPR (plant growth-promoting rhizobacteria) as a symbiotic association with plants in which proper inoculant numbers can be beneficial to increase plant productivity. The underlying mechanism such as the production of biomolecules and certain enzymes which help the plant to assimilate nutrients from the soil, protection against the nematodes or pathogenic microbes. The interaction has also a positive impact on higher plant productivity even in different abiotic stress. The research needs to be the focus on the large and long term effect of such microbial communities for an alternative yet sustainable agricultural practices and also the need to publicize the awareness to adopt such practices to enhance the plant and crop productivity among the farmers and agriculturalist.
***Keywords*:** Plant growth-promoting rhizobacteria, symbiosis, tolerance, abiotic stress, nematodes.

Introduction

Many recent developments have been revolved in the field of agriculture from the use of the biological-based fertilizers to the development of the transgenic plants to increase plant productivity. It has been noted that the use of chemical fertilizer, pest control for reduced the growth of the nematodes and improved irrigation facilities have been enhanced over the last 50 years in the agriculture sector (Ramakrishna *et al.*, 2019). The use of chemical pesticides and fertilizer also brings cons such as contamination of the groundwater, decreases the fertility of the soil which leads to the destruction of the biodiversity (Diaz and Rosenberg, 2008; Naik *et al.*, 2019). Many health issues have been recorded due to the contamination of the crops. The consumption of such crops by humans leads to the accumulation of such chemicals by the process of bio-magnification and disturbs the food web and ecological pyramid (Naik *et al.*, 2019). The groundwater which is being polluted by the chemical fertilizers or pesticides also affects the human in many ways such as hypertension, congenital, testicular cancer, stomach cancer, goiter, respiratory diseases, and sensitivity towards the pathogenicity of various diseases like malaria, cholera and West Nile disease (Divya and Belagali, 2012; Hazra, 2016). By the use of such indiscriminate chemical fertilizer or pesticides has led agricultural practices towards safer practices such as organic farming and various approaches for enhancing the soil microflora to increase the plant productivity as the soil microbiota most likely plant growth-promoting rhizobacteria and microbes (PGPR or PGPM) are necessary for the nutrient recycling in the soil (Fitzsimons and Miller, 2010).

The plant growth-promoting rhizobacteria or the soil microbiota are the beneficial microbes which are found as free-living or the rhizobacteria which colonize the root rhizospheres (Souza *et al.*, 2015) and such microbes have improved the agronomical status over the past decade through the improvement of soil fertility and increase the crop production (Ramakrishna *et al*, 2019). The PGPM or PGPR enact through fixation of the nitrogen, solubilization of the phosphate and potassium, biocontrol activity, siderophore secretion, plant growth promoter secretion, immobilization of the soil nutrients like calcium, iron, minerals, maintenance of the plant nutrients, organic matter decomposition and providing resistance in plants against the various phytopathogens (Souza *et al.*, 2015; Dakora *et al.*, 2015; Spence and Bais, 2015). The following literature is been reviewed for many approaches used for promoting plant productivity through the interaction between plants and microbes.

The microenvironment of the soil relevance to agriculture

The soil environment has been exploited as an alternative yet sustainable source for enhancing plant growth. In such an environment, there are many different types of microbial communities associated which are present throughout the soil environment and promises to promote plant growth through their interaction with different plant species (Wani *et al.*, 2017). Such soil microbial communities help in balancing both biotic and abiotic elements in the soil such as the resistance power in plants is biotic and nutrient recycling is abiotic. But there are some of the microbial communities which are stringently present in the plant rhizosphere which provides defense mechanism to the roots of the plants against the phytopathogens (Mendes *et al.*, 2014). These beneficial microbes first react to root exudate before colonizing by chemotaxis, biofilm formation, degradation, and secondary metabolism but once they are used to such root exudate and later may function as environmental cues to attract other microbial species to form rhizosphere around the roots and carry out their interaction (Balsanelli *et al.*, 2016) (Zhang *et al.*, 2015; Singh *et al.*, 2019; Singh *et al.*, 2017; Singh *et al.*, 2016). The main types of species that are associated with promoting the plants are PGPB and fungal association with plants commonly known as mycorrhiza. Among the PGPB group, the common bacterial species found belong to the group of Proteobacterium and Firmicutes (Rojas-Tapias *et al.*, 2012). The proteobacterium includes the class of gamma proteobacterium with genera such as *Pseudomonas*, *Serratia*, *Acinetobacter*, *Enterobacter*, and many more which form a mutualistic association with the plant and confers nutrient assimilation for higher biomass productivity in plants (Sharma *et al*., 2015). Such association also confer tolerance which mitigates against the abiotic stress conditions (Mirshad and Puthur, 2017; Vurukonda *et al*., 2016). The soil microbes also play an important role in the chelation of the trace elements like mangnase, magnesium, iron, zinc, and make them available to the plants (Kumar *et al*., 2015; Kumar and Singh, 2020). The plants, as well as crops, make an association with the soil microbes that can be positive/beneficial or negative through certain interactions such as mutualism, commensalism, cooperation, parasitism, amensalism. However, for the increased plant productivity mutualistic or symbiotic interaction must be needed between the plants and the soil microbial groups (Mishra *et al*., 2016; Pandey *et al*., 2017; Pierre *et al*., 2014). There are certain AMFs (Arbuscular Mycorrhizal Fungi) that enhance the photosynthetic activity in the plants and protect against the different abiotic stress to increase the productivity of the plants (Mugabo and Bhople 2015; Kumar and Kumar 2018).

Mechanism of plant-microbe interaction

The soil rhizosphere has the major diversity of the microbial communities and their role with the plants that can be a positive or negative impact. The microbial communities interact with the plants for increasing plant productivity in several ways. The production of antioxidants and exopolysaccharides by the microbes, through solubilization of the phosphate and potassium, through the release of biocontrol agents like antibiotics, siderophores, hydrogen cyanide, antifungal agents. The microbes also enhance the release of phytohormones, fixation of nitrogen, and also chelates trace elements like nickel, iron, manganese, magnesium, and many more.

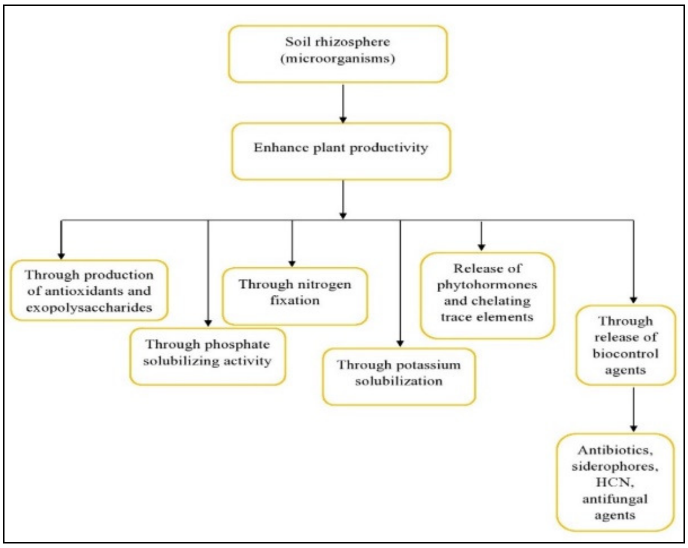

Fig. 1: Mechanism used by microbe while interaction with a plant to increase plant productivity (Kaur *et al*., 2018)

Growth promoting microbes

There are many groups of fungi and bacterial species that promote plant growth with the help of certain mechanisms (Karnwal 2017; Karnwal 2020; Karnwal 2019). The *Bacillus* species and *Pseudomonas* species along with *Aspergillus* and *Pencillium* species which are commonly found in the soil rhizosphere enhance the growth of the plant by phosphate solubilization (Sharma *et al*., 2013). The symbiotic association between *Pseudomonas fluorescens*, *Bacillus subtilis*, *Pseudomonas putida* with the plant shows beneficial activity in the plant growth (del Rosario Cappellari *et al*., 2017). The Arbuscular Mycorrhizal Fungi (AMF) and the bacterial species like Pseudomonas enhance the tomato plant growth in terms of sugar and vitamin production and sweetness content and such microbial group that inhabitant the soil forms a symbiotic association with the root of plant (Bona *et al*., 2017). Certain groups of AMF like *Glomus fasciculatum*, *Glomus mossae*, *Gigaspora margarita*, Acaulospora *laevis* that form a symbiotic association with the plant enhance the phosphatase activity that helps in the effective accumulation of the phosphorus in the plants (Usharani *et al*., 2014). *Pseudomonas reactans*, *Chryseobacterium humi*, and *Rhizophagus irregularis* help in the fixation of the nitrogen through a symbiotic association with the plants that are found in the soil rhizosphere around the roots of the plants (Moreira *et al*., 2016). There are certain PGPB which manage to tolerate and through bioremediation of the heavy metals provide benefits to the soil and the plants through the synthesis of siderophores, phytohormones and ACC deaminase that delays the early ripening (Ma *et al*., 2010; Santoyo *et al*., 2016; Yahaghi *et al*., 2019; Bansal *et al*., 2016). The work of Franchi *et al*. (2017) showed that certain *Acinetomycetes*, *Proteobacterium*, and *Bacilli* species that were isolated from the soil and phytoremediation of arsenic as well as mercuric metals were achieved through the growth-promoting molecules like indole acetic acid (auxin), siderophore (carrier of iron), protease production, ability to solubilize the metals and secretion of exopolysaccharides and just enhance the overall growth of the plants. The microbial species *Kocuria flava* and *Bacillus vietnamensis* that were isolated from the mangrove rhizosphere showed a decrease in the arsenic uptake through the synthesis of siderophores, IAA and exopolysaccharides (Mallick *et al*., 2018). *Chitiniphilus* sp. MTN22 (KF699070) and *Streptomyces* sp. MTN14 (KF699062) which were isolated from a medicinal plant *Bacopa monnieri* showed stress tolerance against nematodes through the production of the phenolic compounds and antioxidants production and just enhancing the plant productivity (Gupta and Kumar, 2017; Gupta *et al*., 2019; Goutam *et al*., 2015). There was improved and increased in the plant height with enhanced resistance power and reduced disease incidence of a host plant *Nicotiana tabacum* through the interaction with *Trichoderma harzianum*, *Glomus mosseae* (Havugimana and Bhople 2015; Yuan *et al*., 2016). The interaction between the plant of foxtail millet (*Setaria italica*) and microbial communities of *Arthrobacter siccitolerans* 4J27, *Pseudomonas fluorescens* DR11, *Enterobacter hormaechei* DR16, and *Pseudomonas migulae* DR35 stimulated seed germination and seedling growth of the plant (Havugimana *et al*., 2016; Niu *et al*., 2017).

Conclusion

The interaction between plants and microbes has a beneficial impact on plant growth and productivity. These soil microbes provide a wide range of positive impacts to the plants in terms of nutrient availability, resistance power against the abiotic stress and to some extent resistance to nematodes. However, there is still a need for research of plant-microbe interaction to provide protection as well as enhance the plant growth in case of nematode stress. The soil rhizosphere has now led to the decreased use of chemical pesticides as well as fertilizers and more use of biological-based fertilizers and pesticides which are eco-friendly for the environment and to the humans. There will more relatable use of such sustainable and alternative sources in the field of agriculture in the near future. There is and will be more use of microbial inoculants in the near future. Further research should be done for the advances in the instrumentation for the identification of the soil microbial communities and their characterization may lead to the novel use for enhancing plant productivity.

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Competing Interest's Statement

The author(s) declare(s) that there is no conflict of interest.

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