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Agriculturally Important Microbiomes: Biodiversity and Multifarious PGP Attributes for Amelioration of Diverse Abiotic Stresses in Crops for Sustainable Agriculture

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Abbreviations: ACC: 1-aminocyclopropane-1-carboxylate; BNF: Biological Nitrogen Fixation; PGP: plant growth promoting

Introduction

The Microbiomes from plant and different extreme environments have been reported and characterized for genotypic and multifarious functional attributes. The plant Microbiomes (phyllospheric, endophytic and rhizospheric) and microbiomes of extreme habitat (acidophilic, alkaliphilic, halophilic, psychrophilic, thermophilic and xerophilic) are natural bioresearches, which may play critical roles in the maintenance of global nutrient balance and ecosystem functions. The crops microbiomes and extreme habitat microbiomes with plant growth promoting (PGP) attributes have emerged as an important and promising tool to enhance plant growth, crop yield and soil fertility. The microbes possesses PGP attributes such as solubilization of phosphorus, potassium and zinc; ACC deaminase; biological nitrogen fixation and production of auxin, gibberellic acids, cytokinin, Fe-chelating compounds, ammonia, HCN, hydrolytic enzymes and secondary metabolites. These PGP microbes could be applied as biofertilizers [An eco-friendly agriculturally important bioinoculants] to replace the chemicals fertilizes and for amelioration of different abiotic stresses in crops inclining, salinity, temperature, drought and pH. The agriculturally important microbes may play important role in plant growth, development, and soil health for sustainable agriculture.

Plant microbiomes and its interaction with plant is a key for plant growth and development. In general, there are three kinds of plant-microbes interactions are considered i.e. epiphytic, endophytic and rhizospheric. The rhizosphere is the zone of soil influenced by roots through the release of substrates that affect microbial activity [1,2]. The phyllosphere is a common niche for synergism between microbes and areal parts of plant [3,4]. The phyllospheric microbes may performs an effective function in controlling the air borne pathogens inciting plant disease. The endophytic microbes are referred to those microorganisms, which colonizes in the interior of the plant parts viz: root, stem or seeds without causing any harmful effect on host plant. The biodiversity of plant microbiomes revealed that the representative microbes from archaea (Euryarchaeota); bacteria (Acidobacteria, Actinobacteria, Bacteroidetes, Deinococcus-Thermus, Firmicutes and Proteobacteria) and fungi (Ascomycota and Basidiomycota) have been characterized genotypically and phenotypically for its beneficial attributes for human welfare.

On the basis of different research, it may be suggested that the distribution of microbes although varied in all bacterial phyla, but proteobacteria were most dominant and ubiquitous followed by actinobacteria. Least number of microbes have been was reported from phylum Deinococcus-Thermus and Acidobacteria followed by Bacteroidetes [5-11]. There are very few reports of halophilic archaea as plant growth promoting including rhizospheric as well as endophytic [12,13]. A number of microbial species belonging to different genera such as *Alcaligenes, Arthrobacter, Azospirillum, Bacillus, Burkholderia, Enterobacter, Flavobacterium, Haloarcula, Halobacterium, Halococcus, Methylobacterium, Paenibacillus, Penicillium, Piriformospora, Pseudomonas, Rhizobium* and *Serratia* have been sortout from rhizosphere of different crops and characterized for different PGP attributes [14-21]. Many microbes such as *Achromobacter, Beijerinckia, Brevibacterium, Diplococcus, Flexibacterium, Methylobacterium, Micrococcus, Micromomospora, Nocardioides, Pantoea, Penicillium, Pseudomonas* and *Streptomyces* have been reported as phyllospheric microbes with beneficial attributes for crops under the diverse abiotic stress conditions [22-28]. There are large numbers of endophytic microbiomes including

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Azoarcus, Burkholderia, Curtobacterium, Gluconoacetobacter, Herbaspirillum, Klebsiella, Micromomospora, Nocardioides, Pantoea, Pseudomonas, Streptomyces and *Thermomonospora* have been identified from different host plants [23,28-31].

The plant microbiomes have been shown to be beneficial for different crops by promoting plant growth either directly, e.g. by biological N_2-fixation, solubilization of phosphorus (P), potassium (K) and zinc (Zn); production of Fe-chelating compounds, cytokinins, auxins and gibberellins or indirectly, via production of antagonistic substances by inducing resistance against plant pathogens. Biological nitrogen fixation (BNF) is one of the possible biological alternatives to N-fertilizers and could lead to more productive and sustainable agriculture without harming the environment. Plant-associated microbes typically produce plant growth hormones such as auxins and gibberellins. The gibberellins production is most typical for the root-associated microbes and auxin production is common to all plant-associated microbes. Auxins can promote the growth of roots and stems quickly or slowly [32-34].

Phosphorus (P) is major essential macronutrient for biological growth and development. Microbes offer a biological rescue system capable of solubilizing the insoluble inorganic P of soil and make it available to the plants. P-solubilization is a common trait among microbes associated with different crops. For instance, the majority of microbial populations from wheat, rice, maize, and legumes were able to solubilize mineral phosphates, and a vast number of PGP microbes with P-solubilizing property have been reported which include members belonging to *Burkholderia, Enterobacter, Halolamina, Pantoea, Pseudomonas, Citrobacter* and *Azotobacter* [35-41]. Ethylene is a stress-induced plant hormone that can inhibit plant growth. Some microbes can lower the level of ethylene in the plant by cleaving the plant-produced ethylene precursor 1-aminocyclopropane-1-carboxylate (ACC). Ethylene is a key regulator of the colonization of plant tissue by bacteria which in turn suggests that the ethylene inhibiting effects of ACC-deaminase may be a microbial colonization strategy. Generally, ethylene is an essential metabolite for the normal growth and development of plants [42-45]. Microbial strains exhibiting ACC deaminase activity have been identified in a wide range of genera such as *Achromobacter, Azospirillum, Bacillus, Burkholderia, Enterobacter, Pseudomonas, Serratia and Rhizobium* [46-49]. The indirect mechanism of plant growth occurs when microbes lessen or prevent the detrimental effects of pathogens on plants by production of inhibitory substances or by increasing the natural resistance of the host. Phytopathogenic microbes can control by releasing siderophores, chitinases, antibiotics, fluorescent pigment or by cyanide production [50,51]. Biocontrol systems are eco-friendly, cost-efficient and involved in improving the soil consistency and maintenance of natural soil flora [52-54]. The microbes with zinc solubilizing and Fe-chelating compounds production attributes may be used for bio-fortification of Fe and Zn for different cereal crops.

Conclusion and Future Vision

The microbes are capable of colonizing the rhizosphere, phyllosphere as well as living inside the plant tissues as endophytes. The agriculturally important microbes plays important role in plant growth, development, and soil health for sustainable agriculture. The plant microbiomes (phyllospheric, endophytic and rhizospheric) and microbiomes of extreme habitat (acidophilic, alkaliphilic, halophilic, psychrophilic, thermophilic and xerophilic) are natural bioresources. Due to the diverse range of activities as well as the number of microbes in varying habitats around the world, these are important bioresources towards rationalized use of chemicals fertilizers in agriculture. The microbes having multifarious PGP attributes could be applied as biofertilizers to replace the chemicals fertilizes and for amelioration of abiotic stress under normal and stressed conditions.

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