# The Role Of Microbes In Climate Change Mitigation

Microbes are smallest forms of life on earth having largest uncultivated pool of biodiversity. Microbes are the driving force for many functions of the ecosystem and thus could play crucial role in maintaining agriculture and energy security. Furthermore, microorganisms play a vital role in every spectrum of life and microbial ecology thus becomes the frontier in present world facing several problems. The role of microorganisms in context of plant growth and promotion under various stresses is well established and their role as biological control agent cannot be denied. The traits possessed by PGPR such as P solubilisation, nitrogen fixation, production of siderophores, ACC deaminase, exopolysaccharides, phytohormones, etc. facilitate plants to grow efficiently under all circumstances. Rhizobacteria from genus Pseudomonas, Bacillus, Rhizobium, Azotobacter, Paenibacillus, etc. are involved in growth promotion. Some of these are efficient biocontrol agent for fungal pathogens in crops. The role of fungi belonging to genus Trichoderma as a biocontrol agent and nutrient acquisition cannot be denied.

During plant microbe interactions, plant root exudates acts as signals to attract microorganisms which sense chemical messages and activate complex cascade to initiate several responses in plant. Though microbes contribute in natural emission of gases like CO2, CH4 and N2O but their roles in the utilization of greenhouse gases is also elaborated and that's why their role in climate change mitigation cannot be neglected. A change in climate induces changes not only in plants but also in microorganisms and affects plant–microbe relations. Use of microbial inoculants becomes important because of their ability to adapt to various agro climatic conditions and over wide range of temperature, pH and salt concentration. Soil microbes are involved in biogeochemical cycling of elements like C, N, etc. Additionally, increase in productivity as a result of microbial inoculation influence GHG budget by limiting emission per unit productivity of GHGs. Therefore, accrued benefits from above mentioned traits of microorganisms can be regarded as their prominent role in mitigation of climate change. Figure 2 shows how climate change affects food and energy security and how microbes can be beneficial in this context.

Beneficial microorganisms enhance resistance capacity of plants protecting the crops against several biotic and abiotic factors like drought, heat, insects, pests and pathogens which are the consequence of changing climate. A group of rhizosphere inhabiting bacteria which are known as plant growth promting rhizobacteria (PGPR), for eg., Pseudomonas sps., A. chroococcum, A. basilensis, Bacillus sps., Paenibacillus sps., Rhizobium sps. etc., possess various plant growth promoting traits like phosphate solubilisation, siderophore production, biological nitrogen fixation, formation of volatile compounds and antibiotics, etc; helps in the growth of plants. The use of beneficial microorganisms should be promoted in reclamation of barren land to increase cultivable land for agriculture. The use of specific mycorrhizal fungi can assist in growth of C4 plants under elevated levels of CO2. The Rhizobia species of Medicago sativa can function in diverse stresses associated with extremes of temperature, pH and organic matter). Thus, microbes are unexplored reservoir of tremendous opportunity that can be exploited for enormous purposes associated with agriculture under both normal and adverse conditions.

Climate change has not only enhanced emergence of pests and pathogens in agriculture but has affected soil quality negatively. In this scenario, to overcome adverse conditions a large pile of fossil fuel is used for generating energy, to derive synthesis of chemicals needed in agriculture in the form of fertilizers and pesticides. Moreover, advancement in technology has lead to mechanization of agriculture which consumes a large part of energy. Use of plant probiotics can though reduce use of chemical fertilizers and pesticides and thereby reducing energy input which is used in the synthesis of chemicals. Various bio-control agents are known which can be used efficiently for controlling pests and pathogens in field such as N. Fresenii, B. thuringiensis, Trichoderma, etc. N. fresenii is reported to control cotton pest A. gossypii, and rust fungus M. cryptostegiae where as B. thuringiensis kills lepidoptera and diptera larvae. Trichoderma is a well established bio-control agent against several pathogens in variety of crops. Though, it is completely an impossible task to replenish exhausting fossil fuel reserve as it takes hundreds of million years to produce fossil fuels. Progressing advances in science has made microbial biofuels closer to economic reality and an alternative to fossil fuels. One benefit of using microbes for producing biofuels is they can be cultivated and replenished easily. Overall, due to multifaceted ability as well as effortlessness associated with microbes, they might be a promising approach to substitute a quantity of our fossil fuel usage. Certainly, employing sun’s energy in solar power, photovoltaics, etc helps to congregate human demand, but use of energy stored in waste biomass and water can undeniably contribute in energy security. However, there is a drawback associated with microbial factories i.e., they sometimes evolve in an unexpected way, so it becomes challenging to figure out how to get maximum output.

Microbial activities are crucial for sustainability of life on earth. Whether, it is degradation of organic matter, bioremediation or plant growth promotion, microbes are very essential. Hence, conservation of microbial diversity becomes necessary. In present time, population in increasing rapidly and climate change problems have surged, plant-microbe interaction and microbial communities are also affected severely. Higher concentrations of $CO_2$ in atmosphere limit nutrients like nitrogen acquisition rate and, thereby increase fertilizer input and consequently energy. Exploitation and management of plants probiotics to be used as biofertilizer and bio-control agent can contribute to both climate change adaptation and mitigation. Recent advancement in science and technology has made microbial genome sequence easily available and, thus, genomic approaches can be powerful tools for food and energy sustainability. Further, novel genes related with tolerance for several harsh conditions can be identified using above mentioned techniques. The research should be focussed more on to exploit diverse microbial communities and efficient strains that can help in combating climate shift in future.

Rapidly increasing population, disproportionate usage of chemicals, decreasing cultivable land and water resources have affected food and energy security profoundly. Problems due extremities in climate like drought, cyclone, floods, etc., have made the condition even worse. Rising concern of food and energy insecurity has attracted researchers and public minds to propel investigation for alternative eco-friendly approaches for sustainable development. Diverse microbes have diverse role in ecosystem functioning and maintenance; and thus, can be exploited more for amelioration of stress induced by climate change. Beneficial microbes have already been documented as an appropriate choice for plant growth and development under various biotic and biotic stresses, and therefore, offers an innovative crop protection tool for climate change. Smart sustainable development needs a better understanding of interaction between plants, microbes and global climate change that will help to fight against climate change.