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Editorial

Agriculturally Important Microorganisms for Improvement of Crop Health Status

Soil is a dynamic, living matrix that is an essential part of the terrestrial ecosystem and it is considered a storehouse of microbial activity. Soil microorganisms play an important role in soil processes that determine plant productivity and form a vital component of the ecosystem. Diverse microorganisms are essential to a sustainable biosphere and the role of rhizosphere microbial populations for maintenance of root health, nutrient uptake and tolerance of environmental stress is now recognized. The current inventory of the world's biodiversity is very incomplete and that of viruses, microorganisms and invertebrates is especially deficient. Scientists have identified about 1.7 million living species on our planet. Studies indicate that 5,000 identified species of prokaryotes represent only 1 to 10% of all microbial species and therefore we have only a small idea of our true microbial diversity. Microorganisms in soil are critical to the maintenance of soil function in both natural and managed agricultural soils because of their involvement in such key processes as soil structure formation, decomposition of organic matter, toxin removal and the cycling of carbon, nitrogen, phosphorus and sulphur. In addition, microorganisms play key roles in supporting soil borne plant diseases, in promoting plant growth and changes in vegetation. In this connection, agriculturally important microorganisms are used in a variety of agroecosystems both under natural conditions and artificial inoculation for diverse application such as nutrient supply, biocontrol, bioremediation and rehabilitation of degraded lands. Soil bacteria and fungi play a pivotal roles in various biochemical cycles and are responsible for the cycling of organic compounds.

The use of biological fertilizers in recent times, is receiving attention mainly on account of increased global preference for natural 'organic' products. Isolation of microorganisms, screening for desirable characters, selection of efficient strains, production of inoculum and preparation of carrier-based formulation are important steps in the use of this microbe-based environment friendly and sustainable technology. A microbial inoculant containing many kinds of naturally occurring beneficial microbes called 'effective microorganisms' are being used widely in nature and organic farming. Studies have shown that effective microorganisms may have a number of applications, incuding agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algal control and household uses. When these cultures are introduced into the natural environment, their individual beneficial effects are greatly magnified in a synergistic fashion.

Integration of beneficial microorganisms into production systems can somewhat shift the balance of the microbial communities towards a population structure more conducive for increased plant health and productivity. Such beneficial rhizosphere organisms are generally termed as agriculturally important microorganisms (AIMs). Best on their most wellknown beneficial effect on the plant they are classified into two broad groups viz. (a) plant growth promoting microorganisms (PGPM) with direct effects on plant growth promotion and (b) biological control agents (BCA) that indirectly assist with plant productivity through the control of plant pathogens.

Plants are not simply passive recipients of nutrients, but information from the environment affects their belowground allocations such as root proliferation, formation of symbiotic relationships e.g. mycorrhizal fungi or N_2-fixing bacteria, alteration in exudation rates, interactions with free-living bacteria or production of secondary defence compounds against herbivores. Phosphorus (P) is a major growth-limiting nutrient, and unlike the case for nitrogen, there is no large atmospheric source that can be made biologically available. Root development, stalk and stem strength, flower and seed formation, crop maturity and production, N-fixation in legumes, crop quality and resistance to plant diseases are the attributes associated with phosphorus nutrition. Soil P dynamics is characterized by physicochemical (sorption-desorption) and biological (immobilization-mineralizaion) processes. Large amount of P applied as fertilizer enters into the immobile pools through precipitation reaction with highly reactive Al^{3+} and Fe^{3+} in acidic, and Ca^{2+} in calcareous or normal soils. Inorganic forms of P are solubilized by a group of heterotrophic microorganisms excreting organic acids that dissolve phosphate minerals and/or chelate cation patterns of the P ions directly and release P into solution. Among the whole microbial population in soil, phosphate solubilizing bacteria (PSB) constitute 1 to 50%,while phosphate solubilizing fungi (PSF) are only 0.1 to 0.5% in P solubilizing potential. Microorganisms involved in phosphorus acquisition include mycorrhizal fungi, *Penicillium, Aspergillus*, *Pseudomonas, Bacillus, Rhizobium, Enterobacter* and they directly affect the ability of plants to acquire P from soil through a number of structural or process-mediated mechanisms. These include (i) an increase in the surface area of roots by either an extension of existing root systems (eg. mycorrhizal associations) or by enhancement of root branching and root hair development, (ii) by displacement of sorption equilibria that results in increased net transfer of phosphate ions into soil solutions or an increase in the mobility of organic forms of P and (iii) through stimulation of metabolic processes that are effective in directly solubilizing and mineralizing P from poorly available forms of inorganic and organic P.

Beneficial soil-borne microorganisms, such as plant growth promoting rhizobacteria (*Bacillus megaterium, B. pumilus*, *B. altitudinus*, *Pseudomonas fluorescens*, *Ochrobacterium anthropi*) mycorrhizal fungi (*Glomus* mosseae,*G. fasciculatum*, *G. intraradices*, *Gigaspora margarita*) as well as biocontrol agents (*Trichoderma harzianum*,*T. asperellum*, *T. hamatum*)can improve plant performance by inducing systemic resistance that confer broad-spectrum resistance to plant pathogens and even insect herbivores. Different beneficial microbe-associated molecular patterns (MAMPs) are recognized by the plant, which results in a mild, but effective activation of the plant immune responses. Screening strategies for selecting the best strains of agriculturally important microorganisms will require more comprehensive knowledge of the traits required for rhizosphere competence and studies on the ecology of introduced beneficial microbial species in the plant rhizosphere. However, biopriming seeds or foliar applications are now viewed as a mean to enhance plant growth, the effects of various management practices using beneficial microorganisms still needs location specific field testing to fully understand the underlying mechanisms involved in a healthy plant microbe interaction. The use of bioinoculants in agriculture offers many opportunities to improve plant nutrition, crop yields and disease management, while improving sustainability by reducing the need for chemical inputs. Root colonization with *Trichoderma asperellum* that lead to massive changes in the plant genome and metabolism for induce accumulation of antimicrobial compounds has been documented. Besides, based on our current knowledge, mechanisms of how plant-rhizobacteria, plant-*Trichoderma* as well as plant-mycorrhiza interaction help in alleviating abiotic stress conditions in different crop systems are also evident. Several genes have been reported to be up- or down regulated in response to different biotic and abiotic stresses following application of bioinoculants. These genes might generate products that play a role in stress regulation. Further metabolomic-genomic study for elucidating the role of numerous gene products of bioinoculants for the discovery of many antimicrobial compounds which can be used for resilient agriculture.

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