**POTENTIAL OF SOIL MICROBES IN SUSTAINABLE AGRICULTURE: A REVIEW**

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**Abstract**

Mostly the Indian soil is deficient in NPK. In recent decades due to addition of chemical fertilizers to the soil the overall fertility and natural composition of soil is distorted to a great extent and the load of pollutants in soil and ground water is also increased. To minimize and gradually remove the chemical fertilizer from soil it is more appropriate to move our farming practice from chemical to organic fertilizers which can be enriched by adding specific kind of microbe according to the need of soil. For example Rhizobium fixes the atmospheric nitrogen into an organic form also improving soil quality and nutrient content, Azotobacter provides certain antibiotics and growth substances to plant along with nitrogen, Pseudomonas sp. (Phosphate Solubilising Microorganism) produces growth regulating compounds such as auxin and enzymes capable of working in P-organic mineralization. There has been report of increase in yield of crop upon adding rhizobium inoculants by 56%, Phosphate solubilising microorganisms (PSM) improved sugarcane yield by 12.6%, wheat yield up to 30% with Azotobacter inoculation and up to 43% with Bacillus inoculants. It would be of ultimate benefit to our mother earth to reduce the load of chemical fertilizers and enriching it with natural biota that is bio-inoculation which not only will increase the yield of our crops but also helps in managing our ecosystem.

**Keywords: NPK, PSM, Soil fertility, Organic fertilizers, Bio-inoculation**.

**INTRODUCTION**

Soil microorganisms play an important role in determining plant productivity. These microbial bio inoculants determine the soil health and strong efforts are made to explore soil microbial diversity of primitive community, their distribution and behaviour in soil habitats (Hill *et al*., 2000). A fertile soil should possess all the micro and macro nutrients as these minerals promote plant growth (Sneha *et al*., 2018). To meet the food demands of a growing human population, Conventional agriculture plays a significant role leads to an increase in dependence on chemical fertilizers and pesticides (Santos *et al*., 2012). Chemical fertilizers are industrially synthesized substances that are composed of known quantities of nitrogen, phosphorus and potassium, and their exploitation causes air and ground water pollution by eutrophication of water bodies. Regarding to this, recent efforts have been channelized more towards the production of ‘nutrient rich high quality food’ in sustainable comportment to ensure bio-safety. Alternative to agro-chemicals, biological based organic fertilizers are in exclusive demand (Raja, 2013).

**SOIL FERTILITY**

Soil is an essential part of earth on which plants grow, consisting of three layers namely top soil, sub soil and parent material. For the growth of plants top soil plays an important role that contains minerals, air, water, living organisms and inorganic and organic matter. These components should be in a particular ratio with medium pH level so as to constitute a fertile soil (Itelima *et al*., 2018). A good quality soil is a combination of minerals(45%), water(25%), air(25%) and organic living matter(5%) (Purves *et al*., 2000). Essential nutrients consist of macronutrients and micronutrients. A fertile soil should possess all the macro and micronutrients as these minerals promote plant nutrition (Itelima *et al*., 2018).

**NITROGEN FIXATION**

Nitrogen, an essential element for all forms of life, It is the most common nutrients required for plant growth and productivity as it forms an integral part of proteins, nucleic acids and other essential biomolecules (Bockman, 1997; Gupta *et al*., 2015). Approximately more than 78% of nitrogen is present in the atmosphere, but it is unavailable to plants. It needs to be converted into ammonia, which is available to plants and other eukaryotes. Atmospheric nitrogen is converted into the form that is utilized by plants by three different processes:

 **a)** Conversion of atmospheric nitrogen into its oxides in the atmosphere.+ut

 **b)** Industrial nitrogen fixation uses catalysts and high temperature (300-500 ºC) to convert nitrogen to ammonia.

**C)** Biological nitrogen fixation (BNF) involves the conversion of nitrogen to ammonia by microorganisms using a complex enzyme

**SOLUBILIZATION OF PHOSPHORUS**

Phosphorus is the second important plant growth-limiting nutrient after nitrogen, and is abundantly available in soils in both organic and inorganic form (Khan *et al*., 2009). Phosphorus has an major role in several essential processes of plant growth and development like cell division, photosynthesis, break-down of sugar and transferring energy and nutrient in crop plant . Decomposition of organic compounds and making phosphorus available to plants is performed by Rhizobacteria by the action of minerals and acids released by it. *Pseudomonas, Bacillus* and *Rhizobium* are the most powerful phosphate solubilizers in cropping system (Rodriguez and Fraga, 1999)**.** Though, PSB are commonly found in most soils; their establishment and performances are severely affected by environmental factors especially under stress conditions (Ahemad and Khan, 2010a,b; (Ahemad and Khan, 2012). However, the beneficial effects of the inoculation with PSB used alone (Chen *et* *al*., 2008; Poonguzhali *et al*., 2008; Ahemad and Khan, 2010d; Ahemad and Khan, 2011k; Ahemad and Khan, 2012e) or in combination with other rhizospheric microbes have been reported (Zaidi and Khan, 2005).

**SEQUESTERING OF IRON BY PRODUCTION OF SIDEROPHORES**

Iron is an important nutrient for plant growth and development. Naturally iron in soil is present as ferric ion (Fe3+), which is too low that it is difficult to promote and facilitate soil microbial growth so some bacteria. The ability to assimilate unavailable iron in order to overcome iron stress by producing ferric-specific ligands is referred as **siderophores**. Soil microorganisms, especially rhizobacteria, are in great use for siderophore production. (Neilands 1995).

**PGPR**

PGPR may promote plant growth directly, e.g. by fixation of atmospheric nitrogen (Soares *et al*., 2006), hydrogen cyanide (HCN), ammonia production, nitrogenase activity (Khan, 2005; Glick, 2012), mineral solubilization such as phosphorus, zinc, potassium (Basak and Biswas, 2009; Ahemad and Khan, 2012), production of siderophores that solubilize and sequester iron (Tian *et al*., 2009), or production of plant growth regulators i.e. phytohormones (Tank and Saraf, 2010, Ahemad and Khan, 2012) and lowering plant ethylene levels using ACC deaminase that accumulate during biotic and abiotic stresses (Glick, 1995; Glick *et al*., 1999). On the other hand some rhizobacteria support plant growth indirectly, by improving growth restricting conditions either via producing antagonistic substances or by inducing resistance against plant pathogens as biological control of phytopathogens and insects, pesticide degradation/tolerance (Ahemad and Khan *et al.*, 2012a,b), salinity tolerance( Tank and Saraf, 2010) and heavy metal detoxifying potentials (Wani and Khan, 2010). Essential Phytohormones for plant growth are produced by PGPR and indole-3-acetic is the most common phytohormone produced by PGPR, which participates in root growth and increases root surface area, and also enabling plants to absorb more nutrients from soil. Plant Growth Promoting Rhizobacteria (PGPR), which enhances plant growth and increase crop yield via secretion of various plant growth promoting substances as well as biofertilizers. PGPR exhibit antagonistic effects to soil-borne pathogens or induce the systemic resistance against pathogens in the entire plant lifespan (Prashantkumar *et al*., 2019). Some worker studied that PGPR inoculants in Triticum varities.(Pagnani *etal*.,2020)

**Biofertilizer**

Biofertilizers are the preparation from living cells or efficient microorganism which helps to uptake the nutrients for the growth of plants.Biofertilizers improves the soil fertility and enhances the plant growth. Certain microbial processes are accelerated in the soil, which augment the extent of availability of nutrients in a form plants can easily assimilate. The term Biofertilizer implies eco-friendly to environment and farmers. Biofertilizers are the preparations containing cells of microorganisms which may be nitrogen fixers, phosphorus solubilizers, Potassium mobilizing micro-organism (*Frateuria aurentia*), sulphur oxidizers or organic matter decomposers. In short, to improve growth and yield these bioinoculants are supplied to plants.The biological waste don’t contain toxic materials, hence the living microorganism present in the soil are able to enrich the fertility of the land.Thus Biofertilizers increases the production and improve the quality of the soil. Continued use and overuse of petrochemical based fertilizers and toxic pesticides have caused a detrimental effect to the soils, water supplies, foods, animals and even people**.** In the past century, the farmers were eager in the usage of chemical fertilizer as it yielded great number of crops. But eventually, they realized that chemical fertilizer affects the soil fertility and kills the beneficial microbes which enhance the growth of crops. The major issue they faced using chemical fertilizers were affecting not only the soil but also human beings who eat these farm products. , Biofertilizer came as the solution to overcome the problems faced by farmers using chemical fertilizer. The Biofertilizer and biological waste are used to replace the usage of chemical fertilizers as it does not contain any toxic substance and makes the soil enriched. Using natural product biofertilizers in crop cultivation will help in safeguarding the soil health and also the quality of crop production.Organic fertilizers (manure, compost, vermicompost) are also considered as Biofertilizers, which are rendered in available forms due to the interactions of microorganisms or their association with plants. Since the farm products do not contain traces of hazardous and poisonous materials**.** Thus these nature based products are accepted globally as Organic ones. Hence the use of biofertilizers or bio-inoculants is mandatory for organic farming.

**Significance of Biofertilizer**

To increase the number and biological activity of useful microorganisms, application of Biofertilizers to seed, soil or compost pit is used to accelerate certain microbial processes to augment the extent of availability of nutrients to plants in the form which can be easily assimilated is the main object behind the whole process. Due to two reasons the use of Biofertilizers has arisen primarily i.e. though chemical fertilizers increase soil fertility, crop productivity and production, but increased / intensive use of chemical fertilizers has caused serious concern for soil texture, soil fertility and other environmental problems, whereas using Biofertilizers benefits economically as well as results in environment friendly. Therefore, applying both chemical fertilizers and Biofertilizers may prove as a best way of integrated nutrient supply in agriculture. Biofertilizers increases the nutrients of host plants when applied to their seeds, plant surface or soil by colonizing the rhizosphere of the plant. Biofertilizers are really cost-effective as compared to chemical fertilizers (Paul 2014). The microorganisms in biofertilizers restore soil’s natural nutrient cycle and build soil organic matter. Biofertilizer do not contain any chemical that are harmful to living being. It provides protection against drought and some soil borne diseases. Biofertilizers are cost effective as compared to chemicals. It not only prevents damaging the natural source but also helps to some extent to cleanse the plant from precipitated chemical fertilizer.

Some important roles of biofertilizers are:

\*Makes availability of nutrients

\*Make the root rhizosphere more nutritive

\*Growth Promoting Substances are produced

\*More root proliferation

\*Better germination

\*Improve quality and quantity of products

\*Improve fertilizer use efficiency

\*More biotic and abiotic stress tolerance

\*Improve soil health

\*Residual Effect

\*Make the system more sustainable

**CONCLUSION**

Uncontrolled over-application of chemical fertilizers by farmers during intensive agricultural practices has led to excess nutrients accumulation in soils, which, as a result, makes the soil dead. That is why nowadays the production of efficient and sustainable biofertilizers for crop plants, wherein inorganic fertilizer application can be induced significantly to avoid further pollution problems, represents major research interest. The demand for bio-based soil treatments due to the increasing environmental concern is also expected to stimulate the demand for biofertilizers over the next few years. Phosphate-solubilizing bacteria are expected to show the fastest growth over the next few years because of their potential use in agriculture, namely in developing cost-effective and eco-friendly multifunctional biocontrol agents and biofertilizers. Biofertilizers are profitable to farmers; they offer higher nutrient use efficiency, benefit–cost ratio, reduced requirements for chemical fertilizers and environmental benefits. As long as the cost of inorganic fertilizers is quite high and less profitable, biofertilizers will play a significant role when well-understood and correctly applied. Good practices of profitability of biofertilizers in various countries where they have been successfully applied may be useful to support policy and farmers’ decisions related to incorporation of biofertilizers into their agricultural systems.

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