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Policy Article

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Bio-fertilizers: A alternative approach for nutrient management and soil productivity

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Bio-fertilizers are microorganisms that have the capability of increasing the fertility of soil by fixing atmospheric nitrogen and through phosphate solubilization. Bio-fertilizers have biological nitrogen fixing organism which help them in promoting the growth of plants and trees by increasing the supply of essential nutrients, enhance biomass production and grain yields. Biofertilizers comprises living organisms viz: *Rhizobium, Azotobacter, Azospirillum,* PSB and *Pseudomonas,* phosphorus solublizing bacteria*,* mycorrhizal fungi, blue-green algae, and bacteria etc. have been found to be very effective tools of soil fertility management and biological nutrient mobilization. Recently customized consortia of such bio-fertilizer organisms, better adapted to local climatic conditions have also been developed and are available commercially. Efficiency of such microbial formulations is much higher under no-chemical use situations, therefore application of such inputs need to be ensured under all cropping situations. There are some important and widely used bio-fertilizers.

Symbiotic nitrogen-fixation:

Rhizobium, Frankia and *Anabaena azollae* bacteria in association with legumes, fixes atmospheric nitrogen in root nodules of leguminous. The legumes and their symbiotic association with the rhizobium bacterium result in the formation of root nodules that fix atmospheric nitrogen. These are widely used bio-fertilizer which can fix around 100-300 kg nitrogen ha^{-1} in one crop season.

Asymbiotic/ Associative symbiotic nitrogen-fixation:

Blue Green Algae, *Azolla, Azotobacter, Azospirillium, Beijerinkia, Clostridium, Klebsiella, Anabaena* and *Nostoc,* grow on decomposing soil organic matter and fixes atmospheric nitrogen in suitable soil medium. *Azotobactor* has beneficial effect on vegetables, millets, cereals, sugarcane and cotton. Organism is capable of producing nitrogen as well as antifungal, antibacterial compounds, siderophores and harmones. *Azospirillium* has beneficial effect on oats, barley, maize, sorghum, forage crop and pearl millet. It fixes nitrogen by colonising root zones.

Phosphorus solubilizing bacteria (PSB):

Phosphorus solubilizing bacteria are commonly used plant probiotics that promote plant development by converting insoluble Phosphorus into soluble phosphorus that is easily absorbed plant by roots. *Bacillus megaterium* var. *phosphaticum, Bacillus subtilis, Bacillus circulans* and *Pseudomonas striata,* are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. Phosphorus solubilization ability of rhizosphere microorganisms is considered to be one of the most important in plant phosphate nutrition.

Phosphorus solubilizing fungi (PSF):

The group of beneficial microorganisms capable of hydrolyzing organic and inorganic insoluble phosphorus compounds to soluble phosphorus form that can easily be assimilated by plants.
phosphorus solubilizing activity of fungal microorganisms such as *Penicillium, Aspergillus*, and *Trichoderma* strains can be used to solubilize phosphorus bearing materials in fermentation systems and substitute for chemical processing. *Penicillium sp, Aspergillus awamori* and *Fusarium* play a noteworthy role in increasing the bioavailability of soil phosphates for plant nutrition.

Phosphorus solubilizing microorganisms (PSM):

Soil microorganisms are capable of solubilizing/mineralizing insoluble soil phosphate to release soluble phosphorus and making it available to plants. These microorganisms improve the growth

and yield of a wide variety of crops. Arbuscular mycorrhiza-Glomus sp.,Gigasporasp., Acaulospora sp., Scutellospora sp. and Sclerocystis sp.; Ericoid mycorrhizae-Pezizellaericae; Ectomycorrhiza-Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp. and Orchid mycorrhiza-Rhizoctonia solani. phosphate solubilizing microorganisms (PSM) could play an important role in phosphorus nutrition in many natural and agro-ecosystems.

Potassium solubilizing bacteria (KSB):

Potassium soluble bacteria is a bio-fertilizer that plays an important role in the formation of mono acids and proteins, these are produced by ammonium ions, which are then absorbed by the root from the soil. It also helps plants to take up other elements that activate several enzymes. It helps in raising potash in all soil types and increases the crop yield by 15-20% and increases crop resistance against different weather conditions. This biofertilizer also helps in photosynthesis properly and improves fruit and grain size and quality of crops. Potassium solubilization is carried out by a large number of bacteria such as ***Bacillus*** mucilaginosus, ***Bacillus megaterium, Bacillus*** edaphicus, ***Bacillus*** circulans, *Pseudomonas, Burkholderia, Acidithiobacillus ferrooxidans,* and *Paenibacillus spp*. The Potassium Releasing Microorganisms (KRMs) present in the soil are capable of converting the fixed form of potassium into an available form of K for the plants to uptake. Potassium solubilizing microbes also produce hormones that help plants withstand both biotic and abiotic stresses.

Bio-fertilizers for micro nutrients:

Bio-fertilizers help in maintaining the micronutrients in soil and making them available to plants. Micronutrients like boron, iron, manganese, zinc, and copper, although required in small quantities, are essential for plant health and growth to plants. Silicate and zinc solubilizers-*Bacillus* sp. micro nutrient and bio-fertilizers along with recommended dose of major nutrients increases the availability of the essential nutrients in the rhizosphere zone. Several zinc-solubilizing bacteria, such as *Bacillus amyloliquefaciens, Bacillus endoradicis, Bacillus oryzicola*, *Chitinophaga oryziterrae* sp.,*Pseudomonas protegens, Bacillus megaterium*, and *Bacillus altitudinis* have been recognized as plant growth-promoting bacteria due to the production of plant hormones and growth factors. *Pseudomonas, Bacillus, Leptothrix, Citrobacter, Acidobacteria, Firmicutes, Nitrospira, Chromobacterium, Actinomyces, Azotobacter* and *Azospirillum* are widely known for molybdanum solubilization and enhancing plant availability.

Plant growth promoting Rhizobacteria:

Plant growth-promoting rhizobacteria are microbes associated with plant roots that promote plant growth are referred to as promoting rhizobacteria are the soil bacteria inhabiting around/on the root surface and secretion of various regulatory chemicals in the vicinity of rhizosphere. Generally, plant growth promoting rhizobacteria facilitate the plant growth directly by either assisting in resource acquisition (nitrogen, phosphorus and essential minerals) or modulating plant hormone levels, or indirectly by decreasing the inhibitory effects of various pathogens on plant growth and development in the forms of biocontrol agents. Pseudomonas-*Pseudomonas fluorescens* are known to enhance plant growth promotion and reduce severity of various diseases. The efficacy of bacterial antagonists in controlling fungal diseases was often better as alone, and sometimes in combination with fungicides.

Blue green algae (BGA):

Blue-green algae reduce soil alkalinity and it is good for rice cultivation and bio-reclamation of land. Blue-Green Algae are a type of photosynthetic bacteria consisting either of single cells or colonies which is also known as the Cyanobacteria. Cyanobacteria contain only one type of chlorophyll, Chlorophyll a, a green pigment. In addition, they also contain pigments such as carotenoids, phycobilin proteins, chlorophyll, xanthophylls along with c-phycoerythrin and c-phycocyanin. Some of the blue green algae can fix nitrogen as it contains nitrogenase – an oxygen-sensitive enzyme. When they fix carbon from carbon dioxide, some blue green algae fix dinitrogen from the atmosphere. They are called nitrogen-fixing blue green algae and are inclusive of symbiotic and free living forms.

Azolla:

Azolla is a heterosporous aquatic ferns that are green in colour in the family Salviniaceae. They are extremely reduced in form and specialized, looking nothing like other typical ferns but more resembling duckweed or some mosses, freely floating on the water surface. It can be used in animal and poultry feed as a protein source. Small floating fern, *Azolla harbours, blue-green algae, anabaena,* commonly seen in shallow fresh water bodies and in low land fields. They fix nitrogen in association.

Mycorrhizae:

Mycorrhizae is symbiotic association of fungi with roots of vascular plants. The fungi which commonly form mycorrhizal relationships with plants are ubiquitous in the soil. Certain plants require an association with mycorrhizae. For example, mycorrhizae are necessary for the germination and establishment of *Pinus* seeds. When two organisms form a mycorrhizal relationship, the fungus colonises the host plant's root tissues either intra cellularly like in arbuscular mycorrhizal fungi (AMF or AM), or extracellularly like in ectomycorrhizal fungi. Mycorrhizae may associate parasitically with host plants depending on the species or the environment. This helps in increasing phosphorous uptake and improves the growth of plants.

N.P.K.Consortia:

Bio-fertilizer is a blend of microbes capable of fixing nitrogen, solubilizing phosphate, and mobilizing potash to provide well-balanced nutrition to crops. It significantly reduces the need for chemical nutrient additives, resulting in healthy plants, abundant crops, and lower input costs. NPK Bio-Fertilizer is a consortium of *Rhizobium, Azotobacter* and *Acetobacter, Phospho* Bacteria-*Psuedomonus* and Potassium Solution-Baciles bacteria which are atmospheric nitrogen and phosphorus fixing organisms. NPK consortia has higher efficiency in Nitrogen, Phosphorous, and potassium fixing and has the ability to drive atmospheric Nitrogen and provide it to plants. It converts complex nutrients present in non-available forms into simple forms absorbed by crops. Improves soil organic carbon, soil useful bacteria population, biomass carbon, biomass nitrogen, and soil respiration. Consortia is a unique microbial formulation of multiple bacteria which are able to synthesize macro nutrients - atmospheric nitrogen, solubilize phosphorus and mobilize potassium into available form, thereby supplementing balanced nutrition to the crops. It helps to increase the crop yield and improves the soil health and increases plant drought tolerance under stress condition. NPK bio fertilizer increases the availability of micronutrients (such as Mn, Mg, Fe, Mo, B, Zn, and Cu) from the soil to the plant, resulting in faster root growth, and nutrients uptake, and increased resistance/tolerance to diseases/drought. It is boosts nitrogen uptake while also producing plant growth hormones and vitamins. These aids the crop's germination, early emergence, and root development.

Application of Bio-fertilizers:

These are some of the most important Bio-fertilizers types that are widely used in crops. So Bio fertilizers are the need of the hour. They are stable reliable and environment-friendly also. **Soil Treatment:** Bio-fertilizers can be used to treat soil since they restore the soil's original fertility. For soil treatment, we mixed bio fertilizers with compost fertiliser and, we kept mixture for a night. Then we spread this mixture into soil where seed is to be sown. **Seed Treatment:** We can also use organic fertilizers to treat the seeds. For seed treatment process, seeds are soaked in a mixture of nitrogen and phosphorus fertilizers. After that, the seeds dry out and harden as quickly as possible.

Recommended liquid Bio-fertilizers:

Crops	Recommended Bio-fertilizer	Application method	Quantity to be used
Field crops **Pulses :** Chickpea, pea, groundnut, soybean, beans, lentil, lucern, berseem, green gram, black gram, cowpea and pigeon pea.	*Rhizobium*	Seed treatment	200ml/acre
Cereals: Wheat, oat, barley, rice, maize, sorghum.	*Azotobacter/ Azospirillum*	Seed treatment	200ml/acre
Oil seeds: Mustard, seasum, linseeds, sunflower, castor.	*Azotobacter*	Seed treatment	200ml/acre
Millets : Pearl millets, finger millets, kodo millet	*Azotobacter*	Seed treatment	200ml/acre
Forage crops and Grasses : Bermuda grass, sudan grass, napier grass , paragrass, star grass etc.	*Azotobacter*	Seed treatment	200ml/acre
Other Misc. Plantation Crops, Tobacco.	*Azotobacter*	Seedling treatment	500ml/acre
Tea, Coffee	*Azotobacter*	Soil treatment	400ml/acre
Rubber, Coconuts	*Azotobacter*	Soil treatment	2-3 ml/plant
Agro-Forestry/Fruit Plants : All fruit/agro-forestry (herb,shrubs, annuals and perennial)	*Azotobacter*	Soil treatment	2-3 ml/plant at nursery

plants for fuel wood fodder, fruits, gum, spice, leaves,flowers,nuts and seeds puppose			
Leguminous plants/ trees	*Rhizobium*	Soil treatment	1-2 ml/plant

Recommended Bio-fertilizers:

Crops	Recommended Bio-fertilizer	Recommended / Doses
Field Crops **Pulses :** Chickpea, pea, groundnut, soybean, beans, lentil, lucern, berseem, green gram, black gram, cowpea and pigeon pea.	*Rhizobium*	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated
All Crops	Phosphate Solubilizing Bacteria (PSB)	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field. **3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted.
All Cereals, Oilseeds, Vegetables and Cash crops	*Azotobactor*	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field. **3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted.
All Cereals, Oilseeds, Vegetables and Cash crops	*Azospirillum*	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field. **3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted.
All Crops	Potassium Mobilizing Bacteria(KMB)	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field. **3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted.
All Crops	NPK Consortia	**1.** Seed treatment- @10 g inoculation per kg of seed coated with 5% sugar solution or Gum Arabic as sticker **2.** Soil application- 750 g inoculation mixed with 50 kg of well rotted FYM and 7 days incubated then apply for one acre field. **3.** Root dipping- @ 10 g inoculation mixed with per liter of water. The root portion of seedlings is dipped in the mixture for 5 to 10 minutes and then transplanted.
Rice	Blue Green Algae	4 kg BGA Culture apply for 1 acre area after 1 week of transplanting or biasi.