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# AGROMICROBES POTENTIAL TO ENHANCE SOILS FERTILITY AND YIELD

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Microorganisms are very important components of the ecosystem; played central roles in Earth's climatic, geochemical, geological, and biological evolution (Xu, 2006). They are regulating various biotic activities in the forest, water, as well as soil ecosystem, making it dynamic for nutrient turn over and sustainable for plant growth and crop development. But soil nutrient levels can reduce over time when crop plants are harvested, as nutrients do not come back to the soil. Soil ecosystem diversity is also decreased due to extensive use of the chemical fertilizer, pesticide and herbicides use in the extensive commercial agriculture system. Microorganisms are essential for the majority of soil ecosystem functions and services. In agriculture, the role of microorganism is very important for maintaining the fertility of soils. They play a central and essential role in the biogeochemical cycling of nutrients in soils health.

Agricultural production primarily depends on the health of soils, which is a measure of a complex set of biological, chemical and physical interactions driven by microorganisms. Living microorganisms are an important tool for efficient utilization of solar energy, biogeochemical cycling of nutrients in soils and recycling of organic molecules. Microorganisms are used to promote plants growth and the increasing availability of primary nutrients to the host plant.

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Bioherbicide is another way of controlling weeds without environmental exposure caused by artificial herb killing chemical agent or synthetic herbicides. Bioherbicides are preparing by microorganisms (i.e. viruses, bacteria, fungi) and certain insects like painted lady butterfly and parasitic wasps, which can target particular weeds. The microbes have power over invasive genes that can attack the resistance genes of the weeds, thereby killing it (https://isaaa.org/).

Biopesticides are certain types of pesticides derived from such natural materials such as bacteria, animals, plants, and certain minerals. Microbial pesticides consist of a microorganism, i.e., virus, bacteria, fungi and protozoa, as the active constituent. Microbial pesticides can manage numerous classes of pests, although each separate active ingredient is comparatively specific for its target pest[s]. The most commonly used microbial pesticides are subspecies and strains of *Bacillus thuringiensis*, or Bt. April 2016, there are 299 registered active ingredients of biopesticide and 1401 active biopesticide product registrations (www.epa.gov/).

Agricultural microbiology is concerned with the association between microbes and crops with an emphasis on improving yields and fight against plant diseases. Microorganisms are responsible for maintenance of soil structures, and sustainability of soil quality for efficient plant growth these microorganisms are known as friendly microorganisms or effective microorganism. A concept of "Friendly microorganisms" was proposed by Professor Teruo Higa in 1982 from the University of Ryukyus in Okinawa, Japan. The Dominance principle is classifying the three groups of Effective Microorganism i)—positive microorganisms (regeneration) ii). Negative microorganisms (degeneration) and iii). Opportunist microorganisms" (regeneration or degeneration). Micro-organisms are played a very important role to the processes of regeneration and decomposition required for phosphorus cycle, nitrogen cycle and other elements in the natural environment. Some living microorganism or latent cells are mixed with inert substance as used as the biofertilizers. It increases the nutrients of host plants when applied to their seeds, plant surface or soils by colonizing the rhizosphere of the plant.

## Role of microorganisms in soil

Microbial ecology examines the diversity of microorganisms and how micro-organisms interact with each other and with their environment to generate and to maintain

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such diversities. There are five different types of soil microbes such as bacteria, actinomycetes, fungi, Algae and protozoa (Table 1). Each of these microbe types has a different job to boost soil as well as plant health.

**Table 1**: Microbial diversity present in per gram of soils in natural environments.

| S.N. | Microorganism in fertile soils | Number (Millions $g^{-1}$ of soils) |
|---|---|---|
| 1. | Bacteria | 1-100 |
| 2. | Actinomycetes | 0.1-1.0 |
| 3. | Fungi | 0.1-1.0 |
| 4. | Algae | 0.01-0.1 |
| 5. | Protozoa | 0.01-0.1 |

## Bacteria

Bacteria are microscopic prokaryotes; ubiquitous, single-celled organism, live in soils, wastewater, the ocean as well as the human gut. Bacteria are classified on shape-based of cells such as Round bacteria called cocci, cylindrical, Capsule shaped known as bacilli and spirilla etc. Food and Agriculture Organization (FAO) once said: "Bacteria may well be the most valuable of life forms in the soil." Agriculture has a complex relationship with bacteria and another microorganism (Table 2).

**Table 2:** Microbial activities influencing plant growth and health

| Characteristics | Microorganism |
|---|---|
| Ammonifying bacteria | Bacillus subtilis, B. mycoides, B. ramosus |
| Nitrifying bacteria | Nitrosomonas, Nitrosococcus, Nitrobacter Nitrococcus. |
| Nitrogen-fixing bacteria | Azotobacter, Clostridium, Rhizobium spp. Azospirillum, Blue-green algae (cyanobacteria) |
| Biopesticides | Bacillus thuringiensis, Agrobacterium radiobacter, Bacillus subtilis var. amyloliquefaciens, Pseudomonas chlororaphis, Hirsutella thompsonii |
| Bioherbicides | Streptomyces anulatus Xanthomonas and Pseudomonas |

## Actinomycetes

Actinomycetes are gram-positive microorganism intermediate in form and function between bacteria and fungi. However, some actinomycetes typically form branched

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filamentous network and are capable of decomposing recalcitrant compounds such as cellulose, hemicelluloses and other chemical compounds. Streptomyces is actinomycetes produce antibiotic streptomycin and aureomycin for predators and damage the unwanted plant.

## Fungi

Some specialized fungi colonize plant roots and extend far into the soil to acquire resources beyond the nutrient depletion zone that plants cannot access alone. Mycorrhizal fungal filaments in the soil are truly living extensions of plants root systems and are more effective in nutrient and water absorption than the roots themselves. They are u**b**iquitous, occurring in natural ecosystems in most climatic zones throughout the world. *Mycorrhizae* are as follows*:* Vesicular-arbuscular mycorrhizae (VAM), Ectomycorrhizae, Ectendomycorrhizae, Arbutoid, Monotropoid, Ericoid and Orchidioid.

Like bacteria, fungi also live in the root zone and helps make nutrients available to plants. For example, *Mycorrhizae* is a fungus that facilitate water and nutrient like Phosphorus uptake by the roots and plants to provide sugars, amino acids and other nutrients.

**Table 3:** Role of fungi in nutrient production and pest control

| Property | Microorganism |
|---|---|
| Biofertilizers | Mycorrhizal fungi (ectomycorrhiza e.g. *Pisolithus tinctonus,* Arbuscular mycorrhizae e.g. *Glomus intraradices* |
| Bioherbicides | *Colletotrichum gloeosporioides f.sp. aeschynomene*, *Phoma herbarum, Sclerotinia minor, Puccinia thlaspes, Alternaria destruens and Phytophthora palmivora* |
| Biopesticides | *Beauveria bassiana, Trichoderma, Fusarium oxysporum and Metarrhizium spp.* |

## Protozoa

Protozoa are single-celled eukaryotes either free-living or parasitic larger microbes that love to consume organic matter, either bacteria or fungi or organic tissue and debris.

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Over 250 species of entomophilic protozoa are also known, out of which several show promise for insect pest control: *Malamaba lacustae* was observed to be effective against grasshoppers, and *Lambornella* sp. can control the mosquitoes population (Table 4). Some protozoa have played an important role in the decomposing cycle and plant growth, and are valuable bioindicators for natural and anthropogenic influences.

**Table 4:** Protozoa are important bioagents with their target

| Protozoa | Target |
|---|---|
| *Malameba locustae* | Grasshoppers |
| *Mattesia* spp. | Lepidoptera, coleopteran |
| *Nosema* spp. | Grasshoppers, *Anapheles* |
| *Octosporea muscaedomesticae* | Muscoid flies |

## Beneficial Microbes in Agricultural crop production

The other dominant form of soil degradation is erosion and salinity, where the causative factors for former type include improper agricultural practices, deforestation and overgrazing. These practices degrade 38% of the world agricultural land, 21% permanent pasture and 18% forests and woodlands.

**Tables 5:** Important agromicrobes used to enhance soil and plant health the fix with primary nutrient

| Group of microorganism | Type of association | Example |
|---|---|---|
| **Nitrogen Fixing Microorganism** | | |
| Free-Living | No direct association | *Azotobactor, Clostridium, Nostoc* |
| Associative symbiotic | Loosely associated with root system | *Azospirillum,* |
| Symbiotic | Nodule Forming | *Rhizobium Sp., Casuarina alder, Frankia* |
| | Non-Nodule Forming | *Anabaena azolloe* |

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| | | |
|---|---|---|
| **P Solubilizing Biofertilizers** | | |
| Bacteria | No direct association | *Bacillus megaterium var phosphaticum Bacillis circulans, Pseudomonas striata* |
| Fungi | No direct association | *Penicillium sp., Aspergillus awamori* |
| **P Mobilizing Biofertilizers** | | |
| Symbiotic | Ectomycorrhiza | *Laccaria sp., Pisolithus sp., Boletus sp. and Amanita sp.* |
| Symbiotic | Arbuscular mycorrhiza | *Glomus sp., Gigaspora sp., Acaulospora sp., Scutellospora sp. and Sclerocystis sp.* |
| Symbiotic | Orchid mycorrhiza | *Rhizoctonia solani* |
| **Mocronutrient solubilizers Biofertilizers** | | |
| Bacteria | Silicate and Zinc solubilizers | *Bacillus sp.* |
| **Plant Growth Promoting Rhizobacteria** | | |
| Pseudomonas | | *Pseudomonas fluorescens* |

Nitrogen-fixing and phosphate solubilizing bacteria may be considered to be PGPR including *Azotobacter, Azospirillum, Rhizobium* sp. (Fig. 1) other bacterial genera e.g. *Arthrobacter, Bacillus, Burkholderia, Enterobacter, Klebsiella, Pseudomonas* etc. also reported as PGPR (Badoni, *et al*., 2017). Chandra *et al.,* 2005 evaluate field trials, *Frateuria aurentia* also to be considered as PGPR.

## Microbes used as Biofertilizers

Rhizospheric microorganisms contribute significantly to fixation of atmospheric nitrogen and solubilization of phosphorous, potassium, iron, as well as zinc from insoluble forms to plant-available forms, in the free-living state or in symbiosis association with plants. Apart from their nutrient-solubilizing abilities, rhizospheric microorganisms have the ability to produce plant growth hormones, ammonia, and siderophores. *Rhizobium* inoculants are used for leguminous crops. *Azatobacter* can be used with crops like wheat, maize, mustard, cotton, potato and other vegetable crops. *Azospirillum* inoculants are recommended mainly for sorghum, millets, maize, rice, sugarcane and wheat.

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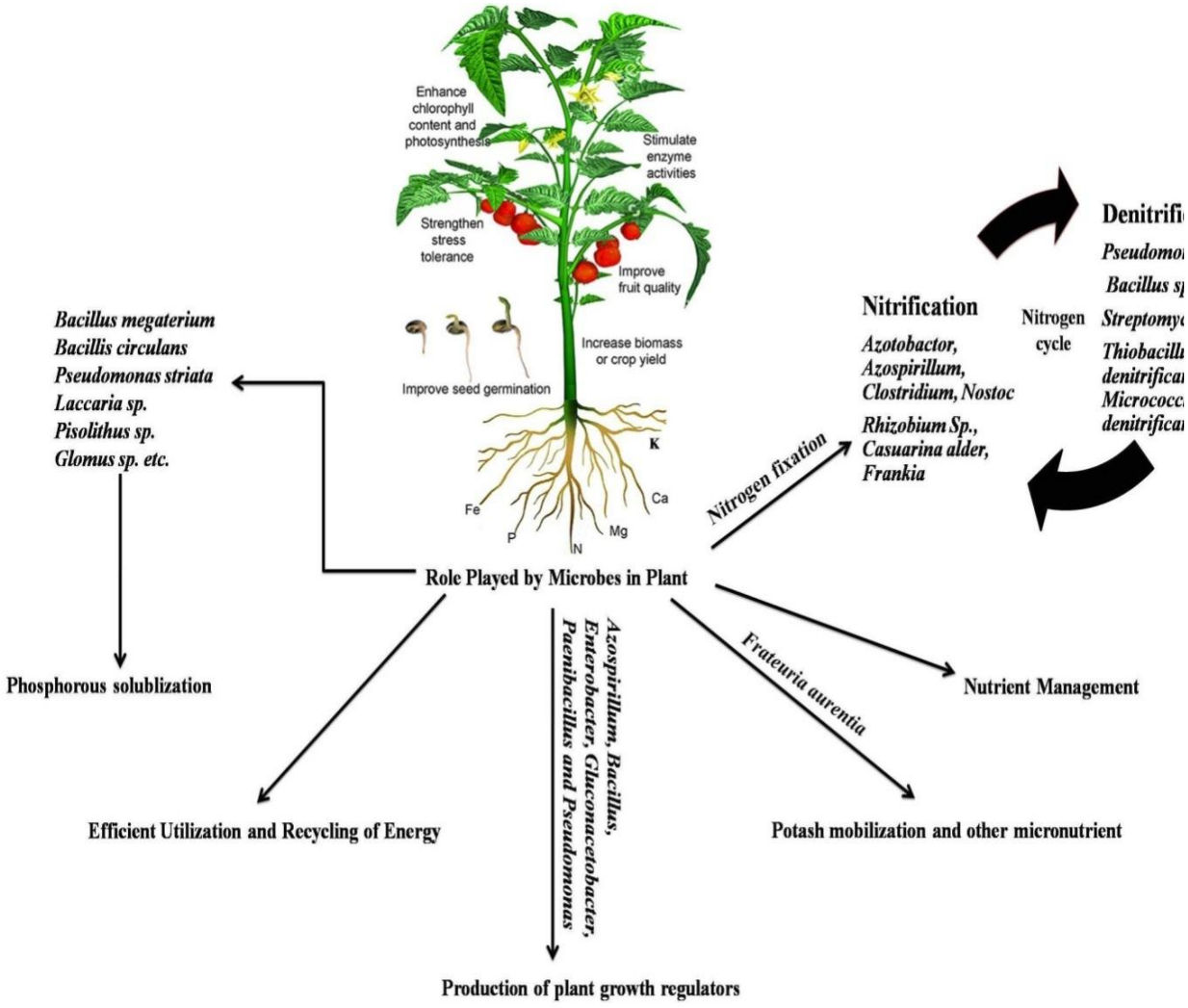


**Fig. 1-** Role of microorganism in the proper development of the plant. The different function performed such as minerals mobilization, essential elemental cycle regulating, and plant growth regulators for proper development of plant they all activity conducted by the microorganism**.**

## Plant growth regulators produced by microbes

PGPB are mostly isolated from natural plant habitats, produced natural phytohormonal substances to promote plant growth. However, the efficacy of the action of plant growth-promoting bacteria depends on plant species, conditions of their growth and other factors (Marulanda *et al.*, 2009), increasing the workload of their testing and developing recommendations for their application.

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| Plant Growth Regulators | Microorganism | Reference |
|---|---|---|
| **Auxins** | *Azospirillum, Pseudomonas* | Spaepen *et al.* 2007 |
| **Cytokinins** | *Azotobacter vinelandii* | Azcon and Barea 1975 |
| | *Pantoea agglomerans* | Omer *et al.* 2004 |
| | *Bacillus subtilis* | Arkhipova *et al.* 2007 |
| **Gibberellins** | *Proteus mirabilis* | Karadeniz *et al.* 2006 |
| | *P. vulgaris* | |
| | *Klebsiella pneumonia* | |
| **Abscisic acid (ABA)** | *Azospirillum brasilense* | Cohen *et al*. 2009 |
| **Jasmonic acid** | *Bacillus pumilus* | Forchetti *et al.* 2007 |
| | *Achromobacter xylosoxidans* (endophytic bacteria of sunflower) | |
| **Salicylic acid** | *Pseudomonas aeruginosa* | De Meyer *et al*. 1999 |

## Advantages of microorganism in agriculture field

1. Application of effective microorganism in the form of biofertilizers are cost-effective relative to chemical fertilizers; they have lower manufacturing cost, especially nitrogen and phosphorous use.

2. Microorganisms have improved the physical and chemical properties of soil and capacity to maintain soil fertility.

3. Use of microorganism as biofertilizers increases the crop yield by 10 – 20 % because it enhances the root proliferation of plants due to the release of growth-promoting hormones and provides against biotic stresses.

4. Biofertilizers are made by easily available natural sources viz. rice husk, leftover vegetables and organic matter, hence they are environment friendly.

5. Microorganism increases the organic matter content of the soil, therefore improving the water holding capacity, cation exchange capacity, soil aggregation and buffering capacity of soil against soil acidity, salinity, alkalinity, pesticides and toxic heavy chemicals.

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6. Biofertilizers supply food and encourage the growth of beneficial microorganism and earthworms.

## Conclusion

Agromicrobes are a vital component for sustainable agriculture and the ever-green revolution. Agricultural microorganisms are improved the soil fertility and deliberating the plant nutrition for crop production as well as crop protection. The health of soil has been an indicator of agriculture as well as environmental sustainability. Phytohormones produced by microorganisms may exert beneficial effects on plants by influencing their growth, ability for the uptake of water and mineral nutrients, and by increasing their pathogen tolerance and resistance to abiotic stresses. However, further study of the effect of hormone production by microorganisms and their effect on plants is necessary to enable a stable and reproducible effect that may be used in agriculture for increasing crop yield.

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