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A review on effect of biofertilizers on paddy

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Abstract
Biofertilizers are natural fertilizers which are microbial inoculants of bacteria, algae, fungi alone, or in combination. They augment the availability of nutrients to the plant and help in maintaining soil fertility. The biofertilizers use living microorganisms that establish a symbiotic relationship with the plants and promote plant growth by increasing the primary nutrient supply to the host plant. The role of biofertilizers in agriculture assumes special significance, particularly in the present context of the increased cost of chemical fertilizers and their hazardous effects on soil health. Blue-green algae (BGA) which act as a biofertilizer are known to contribute up to 80 kg N/ha/season. The application of biofertilizer with beneficial microbes improve the leaf chlorophyll, plant nutrients, and grain protein content in paddy. Hence, the application of biofertilizers helps reduce the use of chemical fertilizers by 50%. Application of biofertilizers (yeast extract, Azolla, BGA, and rhizobium) with 107 kg N/ha in saline soils results in a slight increase in the paddy yield. Higher content (%) in grain and straw were found in PA-6444 with 125% RDF + Biofertilizer treatment. Biofertilizers also reduce the intensity of diseases in paddy. Consortia of biofertilizers-*Trichoderma spp.* combined with composted straw reduce the intensity of rice diseases i.e. brown spot, narrow brown spot, sheath rice blight, and bacterial leaf blight diseases. Therefore, biofertilizers can be used in combination with inorganic fertilizers to increase the yield of paddy on a sustainable basis.

Keywords: biofertilizer, blue-green algae, chemical fertilizer, nitrogen-fixation, nutrients, soil health

Introduction

Agriculture plays an important role in the growth and survival of a nation and healthy soil is the soul of agriculture. Therefore, it is very important to maintain soil quality for sustainable food production. Over the years, agriculture has undergone various scientific innovations to make it more efficient (Ajmal *et al*., 2018) [2]. In the past decades, the use of chemical fertilizers and pesticides has increased at an unprecedented pace to produce more crop yield for achieving higher net returns. Continuous application of these fertilizers has adversely affected the soil quality and fertility and ultimately human health. Dependence on chemical fertilizers for agricultural growth results in a further loss in soil quality and an undue burden on the agricultural system (Rajasekaran *et al*., 2012) [17]. Hence, new fertilization strategies with lower cost, more efficiency, and eco-friendly properties are required. Therefore; to fulfill the goal of sustainable agricultural production, emphasis must be put on the use of organic fertilizers which improve soil fertility. In this sequence, the biofertilizers are an excellent alternative to the chemical fertilizers. They can potentially participate in sustainable agriculture and maintain better environmental quality. Biofertilizers are eco-friendly, cost-effective agricultural inputs that keep the environment safe (Mohammadi and Sohrabi, 2012; Panhwar *et al*., 2011) [13, 16]. In India, a systematic study on biofertilizers was started by N.V. Joshi in 1920. Incorporation of biofertilizers in regular agriculture practices reduces the requirement of inorganic Fertilizers, improves soil health, and will enhance farmers' profit by reducing fertilizer input under integrated nutrient management (Soumare *et al*., 2020) [21].

2. Biofertilizer

Biofertilizer is a substance that contains living microorganisms which when applied to the soil, seeds, and plant surfaces provides available essential nutrients to the plants (Vessey, 2003) [24]. They contain living cells of efficient strains of microorganisms and by their biological activity and formulations, improve the soil properties by increasing the availability of nutrients. Microorganisms require organic matter for their growth and activity in the soil and provide primary available nutrients to the plants through the processes of nitrogen fixation, phosphorus solubilization, and by promoting plant growth-promoting substances in the soil. They are eco-friendly, cost-effective, and environment friendly. Their effect on the crops is relatively slow in comparison to chemical fertilizers. Special care like storage, mixing with the powders must be done carefully to maintain the long term effectiveness of microbial inoculants. Short shelf life, susceptibility to high temperature, lack of suitable carrier materials, storage, and transportation are some drawbacks that need to be solved to get the best effects (Mohammadi and Sohrabi, 2012) [13].

3. Types and Characteristic of Biofertilizers

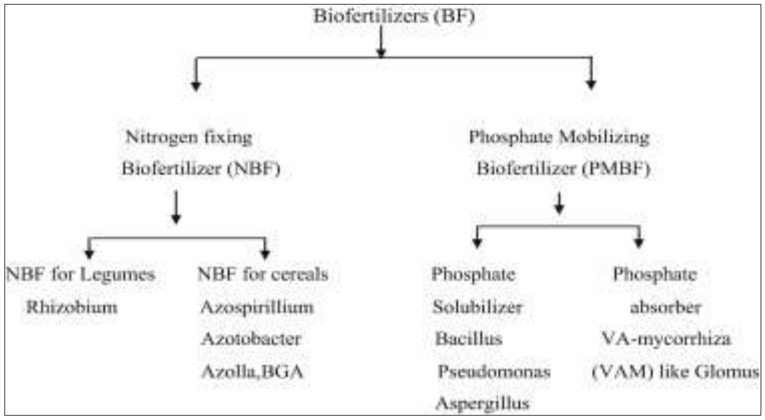

Fig 1: Biofertilizer types (Ayman, 2018) [3]

3.1 Rhizobium

Rhizobium belongs to the family Rhizobiaceae. These inoculants are generally known for their ability to fix the atmospheric nitrogen in association with plants forming nodules in roots. There are several species of rhizobium including *Rhizobium leguminosarum, R. lantis, R. japonicum, R. trifolii, R. phaseolii, R. alamii, and R. smilacinae.* Rhizobium is a symbiotic bacteria and fixes 50-100 kg/ha nitrogen with legumes only. It is useful for pulse legumes like green gram, red gram, chickpea, lentil, etc. Also, the population of the rhizobium depends upon the legume crops grown in the field and decreases drastically with the absence of legumes (Bhattacharjee and Dey, 2014) [4].

3.2 Azospirillum

Azospirillum belongs to the family Spirilaceae and is considered to be the most effective plant growth-promoting rhizobacteria (PGPR). It fixes the atmospheric nitrogen and benefits the plants. It also promotes plant growth by tolerance mechanisms for both biotic and abiotic stresses. Azospirillum also synthesizes phytohormones and plant growth-promoting substances including auxins, cytokinins, gibberellins, ethylene, and abscisic acid. Some azospirillum strains solubilize inorganic phosphorus and make it available to the plants resulting in higher yield (Fukami *et al*., 2018) [9]. *A. brasilense* and *A. lipoferum* are the most widely distributed and beneficial species of this genus. Other species are *A. amazonense, A. halopraeferens* (Mahdi *et al*., 2010) [11]. In non-leguminous plants such as wheat, rice, maize, millets, grasses, sorghum, etc., azospirillum also fixes about 20-40 kg N/ha in the rhizosphere.

3.3 Azotobacter

Azotobacter is a free-living nitrogen-fixing bacterium which promotes the growth of plants. It belongs to the family Azotobacteriaceae. It is aerobic and heterotrophic and helps in the modification of nutrient uptake by the plants in the presence of root exudates. It also can synthesize and secrete several biologically active compounds such as vitamin B, nicotinic acid, heteroauxins, gibberellins which enhances the root growth of the plants (Sivasakthi *et al*., 2017) [20]. This bacterium is present in alkaline or neutral soils and is recommended for non-leguminous crops like paddy, wheat, millets, cotton, tomato, etc. The population of azotobacter is generally low in the rhizosphere of the crop plants and uncultivated soils (Mahdi *et al*., 2010) [11].

3.4 Azolla

Azolla is an aquatic fern found in the temperate climate and is mostly suitable for paddy cultivation. It fixes atmospheric nitrogen and increases soil fertility. Generally, nitrogen is fixed by the symbiotic relationship between the fern and BGA, *Anabaena azollae*. The fern doubles its biomass in 2-5 days under ideal environmental conditions (Bhuvaneshwari and Singh, 2015). It contains 4-5% N on a dry basis and 0.2-0.4% on a wet basis (Mahdi *et al*., 2010) [11].

3.5 Blue-green algae (BGA)

Blue-green algae, also known as cyanobacteria, are a group of aquatic prokaryotic organisms. They are present in freshwater as well as marine ecosystems and have the potential to fix the atmospheric nitrogen. These are used as biofertilizers in rice and beans cultivation. On decomposition, it helps in increasing soil structure and fertility (Chittora *et al*., 2020) [6].

3.6 Phosphate solubilizing bacteria (PSB)

Phosphate solubilizing bacteria convert inorganic phosphorus to a plant-available form. The use of PSB as inoculants increases the plant phosphorus uptake. They provide essential macro-nutrients to the plants thus reduce chemical fertilizer usage. Some major phosphorus solubilizing bacteria present in the soil are *Pseudomonas spp., Bacillus spp., Aspergillus spp.* and *Fusarium spp.* (Malboobi *et al*., 2009) [12].

3.7 Vesicular arbuscular mycorrhiza (VAM)

VAM is a symbiotic association between phycomycetous fungi and angiosperm roots. They are intercellular and are active only near the plant roots. It comprises of two special structures i.e. vesicles and arbuscules. Plant roots provide shelter to the fungi and the fungi transmit nutrients and water to the plant roots (Swami, 2020) [22]. Mycorrhiza mobilizes the phosphorus, iron, zinc, and other trace elements. These fungi not only increase nutrient availability but also increase their mobility. It improves crop growth due to the uptake of phosphorus and hence increases the crop yield (Mohapatra *et al*., 2013) [14].

4. Biofertilizers Application to Crops

Biofertilizer application increases the yield of crops by about 25% and reduces the application of nitrogenous fertilizers by 25-30% and about 25% for phosphorus fertilizer (Aggani, 2013; Ghany *et al*., 2013) [1, 10]. The Following are the main methods for inoculation of biofertilizers:

- **Seed treatment:** The nitrogen and phosphorus biofertilizers are mixed in the water and then seeds are dipped in the mixture. After that, seeds are shade dry and immediately sown in the field before they get damaged by the harmful microorganisms.
- **Seedling root dip:** This method is mainly applied to the rice crop. Water mixed with biofertilizers is filled in a sunken bed. Paddy seedlings are kept in that sunken bed for 8-10 hours and then transplanted in the field.
- **Soil treatment:** Biofertilizers are mixed with the compost and kept for one night. After that, the mixture is broadcasted in the field where the seeds have to be sown (Youssef and Eissa, 2014) [25].

5. Role of Nitrogen-Fixing and Phosphate Solubilizing Biofertilizers in Increasing Paddy Productivity

Rice is the staple food of more than half of the world population. Its production requires a large amount of chemical fertilizer especially urea. Paddy requires two most important nutrients i.e. nitrogen and phosphorus. Biofertilizers are applied to the paddy field in different treatments like seed treatment, seedling root dip, and soil treatment (Naher *et al*., 2015) [15]. Generally, nitrogen-fixing bacteria present in biofertilizers like azospirillum, blue-green algae, and azolla provide nitrogen to the crops. Azospirillum biofertilizer is usually applied in paddy as a seed treatment, soil treatment, and seedling root dip. For seed treatment and seedling root dip, the slurry is prepared and seeds and seedlings are soaked for some time and then planted and transplanted in the field respectively. For soil treatment, azospirillum inoculants are mixed with FYM are broadcasted in the main field. By this application, 30% of inorganic fertilizer consumption can be reduced. Blue-green algae also fix the atmospheric nitrogen and promote plant growth in the paddy field. BGA occurs naturally but it can be cultured artificially. Artificially cultured algae are formed in the form of flakes that are applied in the field in the required quantity. Also, these flakes can be powdered, mixed with soil and FYM, and can be broadcasted. Azolla also fixes the atmospheric nitrogen and is the most important biofertilizer for paddy, because it can be applied as green manure or can be grown as a dual crop with paddy.

Phosphobacteria biofertilizers generally provide phosphorus. It can be applied for lowland and upland rice. The application doses are similar to that of azospirillum. VAM generally mobilizes the phosphorus and also applied in lowland and upland rice.

El-Hawary and El-Kholy (2019) [7] studied the effect of biofertilizer's application on the yield components of rice in saline soils. They observed that the application of biofertilizers (yeast extract, Azolla, BGA, and rhizobium) with 107 kg N/ha resulted in a slight increase in yield. Application of 107 kg N/ha + biofertilizers in paddy can reduce the 25% of nitrogen fertilizer requirements and maintain productivity.

Another experiment was conducted by Tejaswini *et al*., (2017) [23] at the research farm of the ICAR-Indian Institute of Rice Research (IRRI), Hyderabad, Telangana state. In this experiment, biofertilizers i.e. azospirillum, phosphorus solubilizing bacteria, and potassium solubilizer were applied @ 5 kg/ha. Maximum N (2.16%), P (0.44%) and K (0.58%) content in grain was recorded in PA-6444 and minimum in DRR Dhan-44 (1.79%, 0.27% and 0.54%, respectively). The maximum nitrogen (0.61%), phosphorus (0.15%) and potassium (1.85%) content in straw was recorded in PA-6444. Among the nutrient levels, 125% RDF + Biofertilizers treatment recorded higher nitrogen (2.27%), phosphorus (0.39%) and potassium (0.64%) content in grain and higher nitrogen (0.60%), phosphorus (0.17%) and potassium (2.13%) content in straw in par with treatment 125% RDF. The lower N, P, and K content in grain were recorded in 75% RDF treatment (1.73%, 0.3%, and 0.5% resp.). The maximum phosphorus content in treatment 125% RDF+Biofertilizers treated plot was due to the solubilization of P in the soil by PSB which is made available to the crop (Chittora *et al*., 2020) [6]. NPK content (%) in grain and straw was found to be higher in PA-6444 with treatment 125% RDF + Biofertilizer as compared with the rest of treatments (Tejaswini *et al.*, 2017) [23].

6. Role of Biofertilizers in Reducing the Disease Intensity in Paddy

Biofertilizers also provide protection against drought and some soil-borne diseases (Ellafi *et al*., 2010; Singh and Purohit, 2011) [8, 19]. The application of composted straw (CS) and consortia of biofertilizer (CB) improves soil health and reduces the intensity of rice diseases by promoting induced systemic resistance (ISR) and increases the efficiency of fertilizers (Simarmata *et al*., 2017) [18]. Simarmata *et al*., (2017) [18] studied the effect of composted straw, consortia of biofertilizers, and combination of consortia of biofertilizers with *Trichoderma* species on the intensity of brown spot (*Helminthosporium oryzae)*, narrow brown spot (*Cercospora janseana*), sheath rice blight *(Rhizoctonia solani*), and bacterial leaf blight diseases (*Xanthomonas oryzae*) of rice at 7 weeks after transplanting. Application of consortia of biofertilizers-*Trichoderma spp.* combined with a composted straw reduces the intensity of rice diseases. Application of 400 g per ha of consortia of biofertilizers- *Trichoderma sp.* (CB-T) with 2.5-7.5 ton per ha composted straw reduces the intensity of brown spot diseases from 16.7% to 3.3-8.0%, narrow brown spot diseases from 20% to 4-10%, sheath rice blight disease from 24% to 2.7-4.7% and bacterial leaf blight diseases from 20.7% to 8.0-14.0% at 7 weeks after transplanting (Simarmata *et al*., 2017) [18].

7. Conclusion

Overdependence on chemical fertilizers and pesticides disturb the ecological balance. The practice of these chemical fertilizers results in air and groundwater pollution. Depletion of biodiversity, soil erosion, waterlogging, deterioration of soil fertility, etc. are some of the other environmental hazards which occur due to the excessive use of chemical fertilizers. It is very important to know about the beneficial effects of biofertilizers and their implementation in modern agricultural practices. Generally, biofertilizers activate microorganisms effectively found in soil, providing nutrients in the available form to the plants and can help in the maintenance of soil fertility over a long period, but they cannot replace the chemical fertilizers. Biofertilizers also provide resistance against biotic and abiotic stress. Biofertilizer comes out as the most natural and chemical-free alternative source for promoting paddy productivity. Biofertilizers are important components of the Integrated Nutrient Management system and organic farming for sustaining agricultural productivity and a healthy environment. Therefore, it is very much essential to develop a strong, workable, and compatible package of nutrient management through organic and inorganic sources for rice-based cropping systems.

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