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Biofertilizers, Impact on Soil Fertility and Crop Productivity under Sustainable Agriculture

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Abstract Biofertilizers, a sustainable eco-friendly agricultural approach to crop improvement are used to supplement chemical fertilizers mainly to maintain soil fertility. Continuous application of expensive chemical fertilizers causes reduction of organic matter content in soil and also microbial activity drastically. Biofertilizers are organic, bio-degradable. They contain micro-organisms, provide nutrients viz., N, P, K and other nutrients, antibiotics, hormones like auxins, cytokinins, vitamins which enrich root rhizosphere. The present article highlights biofertilizer mediated crop functional such as plant growth and productivity, nutrient profile, plant protection and there by crop improvement. The knowledge gained from the literature appraised here in will help us to understand the physiological bases of biofertilizers towards sustainable agriculture in reducing problems associated with the use of chemicals fertilizers.

Keywords Biofertilizer, Crop improvement, Soil fertility, Crop production, Sustainable agriculture.

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Introduction

Biofertilizers the gift of modern agricultural sciences retards the nitrification for sufficiently longer time and increases the soil fertility. Biofertilizers are important components of integrated nutrient management. They play key role in productivity and sustainability of soil while protecting environment, being cost effective, eco-friendly and renewable source of plant nutrients to supplement chemical fertilizers in sustainable agricultural system. Unlike inorganic fertilizers, bio-fertilizers do not supply nutrients directly to plants. These are the microbial inoculants containing the living or latent cells of efficient strains used for application to seeds , soil or composting areas with the purpose to accelerate the microbial process to augment the availability of nutrients that can easily be assimilated by plants, colonize the rhizosphere or the interior of the plant and promotes growth by converting nutritionally important elements to available form through biological process such as nitrogen fixation and solubilization of rock phosphate. Beneficial microorganisms in biofertilizers improve the plant growth and protect the plants from pest and diseases. Biofertilizers are promoted to harvest the naturally available, biological system of nutrient mobilization. Biofertilizers are microbial inoculants or carrier based preparations containing living or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing and cellulose decomposing microorganisms intended for seed or soil application and designed to improve soil fertility and plant growth by increasing the number and biological activity of beneficial microorganisms in the soil.

The objects behind the application of biofertilizers / microbial inoculants to seed, soil or compost pit is to increase the number and biological / metabolic activity of useful microorganisms that accelerate certain microbial processes to augment the extent of availability of nutrients in the available forms which can be easily assimilated by plants. The need for the use of biofertilizers has arisen primarily due to two reasons i.e. though chemical fertilizers increase soil fertility, crop productivity and productiion, but increased/ intensive use of chemical fertilizers has caused serious concern of soil texture, soil fertility and other environmental problems, use of biofertilizers is both economical as well as environment friendly. Therefore, an integrated approach of applying both chemical fertilizers and biofertilizers is the best way of integrated nutrient supply in agriculture.

Development of a nation is directly proportional to the amount of food or nutrient available to the population. Growth of the human population creates demand for more food grains. To supply food grains according to the demand, fertilizers are used. A fertilizer is any substance that is used for increasing the productivity of the soil. It promotes soil fertility by adding nutrients in the soil , which helps in plant growth. Fertilizers which are composed of raw chemicals in solid or liquid form manufactured in factories targeting the nutritional requirement of the plants are by definition called a chemical fertilizer. Nitrogen, phosphorus, potassium together called NPK are normally present in these chemical fertilizers along with other nutrients (Youssef et al. 2014).

Advantages of biofertilizers are as follows : (1) Reduce the use of chemical fertilizers, (2) Reduce environmental pollution, (3) Increase the validity of nutrients and easily absorbed, (4) Excretion of doping substances for growth, (5) Improve the physical, chemical and biological properties of the soil, (6) Excretion of some antibiotics that is resistant to some plant diseases, (7) Biofertilizers are not costly and even poor farmers can make use them, (8) Microorganisms convert complex organic material in simple compound, so that plant can easilytake up, (9) Enhance root proliferation due to release of growth promoting hormones, (10) Environmentally friendly, cleanse the plant from precipitated chemical fertilizers.

Limitations are as follows : (1) Biofertilizers act slowly than chemical fertilizer, (2) It is very tough to store biofertilizers mainly because of their high sensitivity to temperature and humidity changes, (3) In rural and remote areas, often it's hard to find a retailer selling biofertilizers, (4) Biofertilizers can't replace other fertilizers completely, they only can complement them, (5) Shortages of particular strains of microorganisms or of the best growing medium reduce the availability of some biofertilizers.

Role of *Azospirillum* in cereal crop production

Azospirillum is a gram negative motile bacteria belonging to the order Rhodospirillales, associated with roots of monocots, including important crops, such as wheat, corn and rice. *Azospirillum* is the primary commercial phyto-stimulator inoculant for cereals worldwide. *Azospirillum* can establish an associative symbiosis with cereals but unlink mutualistic symbiosis, the association is not accompanied by the formation of new organs. *Azospirillum* benefits the plant directly, via associative nitrogen fixation, synthesis of phyto-hormones (notably indole-3-acetic acid, IAA), and modulation of plant hormonal balance by deamination of the ethylene precursor. It is an associative type of microorganism capable of colonizing the root surface of the plants. By establishing a symbiotic association ship, it helps the plants in getting the nutrient nitrogen from the atmosphere (Essam and Lattief 2016).

Inoculation of wheat with *Azospirillum* sp. increased root dry weight and 1000-kernel weight (Jagnow 1990), raised number of spikes per plant, number of grains per spike and grain and straw yield in wheat (Bhattarai and Hess 1993). Inoculation with *Azospirillum* produced significantly higher grain yield by 29% and the grains contain more N (22.8%), P (59.5%) and K (34%) compared to the control plants (Askary et al. 2009). A strong increase in total plant and grain dry weight was obtained when maize plants were inoculated with *Azospirillum brasilense*, seropedicae in individual experiments, in comparison to plants grown in soils without nitrogen (Riggs et al. 2001). Swedrzynska, and Sawicka (2000) found that inoculation of maize crops with an active strain of *Azospirillum braselene* has a beneficial effect on maize vigor and yield. Increase in different plant parameters such as height, tiller number, dry matter yield and N uptake of rice plants that inoculated with *Azospirillum lipoferum* was observed by Nayak (1986). Inoculation of *Azospirillum* sp. to wetland rice under acidic condition improved shoot growth , straw yield and N uptake (Govindan and Bagyaraj 1995). *Azospirillum* inoculation could significantly increase the growth in terms of height; number of leaf/plant; length and breadth of leaf; and fresh and dry weight/ plant of rice plant (Hossain et al. 2015). Inoculation of rice plants with *Azospirillum* has been found to cause significant increases in growth and yield which is equivalent to that is attainable by application of 15-20 kg N/ha (Rodrigues 2008). Inoculation by *Azospirillum* increased total dry matter and seed yield in sorghum up to 10-30% compared with control (Kapulnic et al. 1981). Effect of different N fertilizer levels and biofertilizers on forage sorghum indicated that using of 75 kg/ha N (urea), 25 kg/ha N (castor residuum) and inoculation by *Azospirillum* increased the raw protein and quality of forage (Yadav et al. 2007). Seed inoculation with *A. brasilense* increased the mean grain yield of pearl millet under different agro-climatic conditions in India. Also, the root biomass increased with *Azospirillum* spp. inoculation at 10 and 20 kg N/ha than their correspnding un-inoculated controls (Tilak and Subba Rao 1987). Abdullahi et al. (2014) found that bio-fertilizer (*Arbuscular mycorrhizal* fungi and *Azospirillum brasilense)* + poultry manure recorded highest plant performance viz. plant height, number of tillers/plant, shoots and root dry biomass of pearl millet. Results also showed that bio-fertilizer tended to reduce by half the application rates of organic manure.

The beneficial aspects of biofertilizers in sustainable agriculture

The rhizosphere, the narrow zone of soil surrounding plant roots, can comprise up to 10 microbial cells per gram of root and above 30,000 prokaryotic species general, improve plant productivity. The collective genome of rhizosphere microbial community enveloping plant roots is larger compared to that of plants and is referred as microbiome whose interactions determine crop health in natural agro-ecosystem by providing numerous services to crop plants viz., organic matter decomposition, nutrient acquisition, water absorption, nutrient recycling, and weed control. Rhizosphere microbial communities an alternative for chemical fertilizers has become a subject of great interest in sustainable agriculture and bio-safety program. A major focus in the coming decades would be on safe and eco-friendly methods by exploiting the beneficial microorganisms in sustainable crop production. Such microorganisms, in general, consist of diverse naturally occurring microbes whose inoculation to the soil ecosystem advances soil physico-chemical properties, soil microbial biodiversity, soil health, plant growth, development and crop productivity. The agriculturally useful microbial populations cover plant growth promoting rhizobacteria, N fixing cyanobacteria, mycorrhiza, plant disease suppressive beneficial bacteria, stress tolerance endophytes and biodegrading microbes. Biofertilizers are a supplementary component to soil and crop management traditions viz., crop rotation, organic adjustments, tillage maintenance, recycling of crop residue, soil fertility renovation and the biocontrol of pathogens and insect pests, whose operation can significantly be useful in maintaining the sustainability of various crop productions. *Azotobacter, Azospirillum, Rhizobium,* cyanobacteria, phosphorus, and potassium solubilizing micro-organisms and mycorrhizae are some of those were found to increase in the soil under no-tillage.

Yield impact of biofertilizers by climate

Averaged across all biofertilizer categories, yield was increased the most in dry climates (+20.0 ±1.7%), followed by tropical climates (+14.9 ± 1.2%), oceanic climates (+ 10.0 ± 3.7%), and continental climates (+ 8.5 ±2.4%). For interpretation, it is important to keep in mind that 45% of the comparisons in dry climate were conducted in the presence of irrigation. In a separate analysis of the data from dry climates, Scientists found a significant difference in the yield increase under irrigated conditions with + 15.9 ±2.0% (316 comparisons, 39 studies) and under rainfed conditions with + 21.0 ± 3.1% (274 comparisons, 20 studies). In dry climates soils had the highest pH and the lowest soil organic matter (OM) content; where, the highest amount of N fertilization was used. However, in all climates, the variation of fertilizer application levels within the trials was high.

Role of biofertilizers in crop production

The incorporation of bio-fetilizers in soil play major role in improving soil fertility, yield attributing characters and thereby final yield. Bio-fertilizers enhance the nutrient availability to crop plants and impart better health to plants and soil, hence enhancing crop yields in a moderate way. *Azolla* biofertilizer is used for rice cultivation because of its quick decomposition in soil and efficient availability of its nitrogen to rice plants. *Azolla* application brought an impressive increase in rice yield by 0.5-2t/ ha^{-1}. An increase in grain yield by 29.2% was achieved through the application of *Azolla microphylla* @ 15 t ha 33. *Azotobacter* , a free living and heterotrophic bacteria fixes nearly 20 to 40 kg nitrogen ha^{-1} and increases yield up to 50%. However, their effectiveness is found to vary greatly,depending largely on soil condition, temperature and farming practices. However they don't produce any visible nodules or out growth on root tissue and fixes about 20-40 kg nitrogen ha^{-1} and 15-30% improvement in crop yield. *Azospirillum lipoferum* produces plant growth promoting substances like pantothenic acid, thiamine and niacin in large quantities that improve plant growth and yield. *Azospirillum* mineralizes nutrients from soil, sequesters Fe, survives in harsh environmental conditions and favors beneficial mycorrhiza plant associations.

Under temperate conditions, inoculation of *Rhizobium* improved number of pods $plant^{-1}$, number of seed pod^{-1} and 1000 seed weight (g) and thereby yield over the control. In rice under low land conditions, the application of BGA + *Azospirillum* proved significantly beneficial in improving LAI and all yield attributing aspects. It is an established fact that the efficiency of phosphate fertilizers is very low (15-20%) due to its fixation in acidic and alkaline soils and unfortunately both soil types are predominating in India accounting more than 34% acidity affected and more than seven million hectares of productive land salinity/alkaline affected. Therefore, the inoculations with PSB and other useful microbial inoculants in these soils become mandatory to restore and maintain the effective microbial populations for solubilization of chemically fixed phosphorus and availability of other macro and micro nutrients to harvest good sustainable yield of various crops (Mishra et al. 2013).

Need for other nutrient sources other than chemical fertilizers

Inoculation with *Azospirillum* helps in improving water status of plants thus prove favorable to protect crops in arid soils. *A. brasilense* can synthesize phenyl acetic acid (PAA), an auxin like molecule with antimicrobial activity, which prevents the proliferation of other non-pathogenic rhizosphere bacteria due to production of bacteriocins and siderophores. Biofertilizers made from *Azospirillum* is suitable for C_4 crops such as sugarcane, maize, bajra, sorghum and other cereals like rice, wheat, barley, ragi. In this context, practices and potentialities still have a wider gap and a lot can be done in sustaining cereal production. Micro-organisms with phosphate solubilizing potential increases the availability of soluble phosphate and enhances the plant growth by improving biological nitrogen fixation. Under temperate conditions *Rhizobium* improved the number of pods $plant^{-1}$, seeds pod^{-1}, test weight (1000-seed) and there by yield over control.

Major inoculation groups with inoculant and host plants.

Cross inoculation group	*Rhizobium* species	Host legume
Pea group	*R. leguminosorum*	Pea, sweet pea
Alfalfa group	*R. meliloti*	Sweet clover
Clover group	*R. trifoli*	Clover / berseem
Bean group	*R. Phaseoli*	All beans
Soybean group	*R. Japoniuim*	Lupins
Cowpea group	*R.* species	Cowpea, grain, arhar, urd

Conclusion

In conclusion, it can be said that there is an urgent need to improve the awareness and use of biofertilizer. It is crucial to play in ensuring biofertilizers technology is fully adopted as the first choice in our quest to address soil fertility challenges. Inoculation with *Azospirillum* helps in improving water status of plants thus prove favorable to protect crops in arid soils also. So, integrated application of biofertilizers along with chemical fertilizers in a sustained way can meet the nutrient need of plant besides maintaining the soil health and environmental safety.

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