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Biofertilizers an Approach to Sustainability in Agriculture: A Review

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ABSTRACT

The green revolution brought impressive gains in food production but with insufficient concern for sustainability. With the increasing demand in agriculture it has become important for us to increase the productivity by using various chemical fertilizers. But with the continued use of these products the soil has been affected badly because of the depletion in the essential minerals of the soil, decreasing soil fertility and rapidly declining production levels. Dependence on chemical fertilizers for future agricultural growth would mean further loss in soil quality, possibilities of water contamination and destruction of soil biota. So to overcome this problem it has become important for all of us to use a different remedy. In nature, there are a number of useful soil microorganisms which can help plants to absorb nutrients known as bio-fertilizers. Their utility can be enhanced with human intervention by selecting efficient organisms, culturing them and adding them to soils directly or through seeds.

Key words: *Bio-fertilizer, Chemical Fertilizer, Productivity.*

INTRODUCTION

Nutrients are required for growth of all living organisms. The conventional knowledge indicates farms manuered regularly yield better. India having attained self sufficiency in food production for 17% population of the world with nearly 2% of the worlds land resources[27]. By the year 2025, the country will face an uphill task of producing 325 Mt food grain to meet national food and nutritional security for projected population of 1.4 billion[15]. To meet the food demand of the increasing population soils have been rendered barren with indiscriminate use of fertilizers, hence the concern for its continued health and sustainability. The introduction of high yielding varieties, chemical fertilizers undoughtly increased the production level for feeding the burgeoning population, but in this quest of more food production health of soils has gone uncared. The organic carbon content of Indian soils declined further during the post green revolution era from 1.2% to 0.6% [25]. For optimum plant growth, nutrients must be available in sufficient and balanced quantity[3]. The most important constraint limiting the crop yield is soil fertility thus warrants the improvement in soil fertility through different approaches viz., biological nitrogen fixation(BNF) and increased efficiency of inputs .

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Efficient 'Nitrogen' utilization is an essential goal in crop management. Biofertilizers the gift of modern agricultural sciences retards the nitrification for sufficiently longer time and increases the soil fertility[11]. Bio fertilizers are important components of integrated nutrient management. Thus would 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 solubilisation of rock phosphate[26]. Beneficial micro organisms in biofertilizers improve the plant growth and protect the plants from pest and diseases[8]. Biofertilizers are promoted to harvest the naturally available, biological system of nutrient mobilization. Based on nature and function bio fertilizers can be grouped as following.

S. No.	Groups	Bio-agent
N2 fixing Bio-fertilizers		
1.	Free-living	*Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc,*
2.	Symbiotic	*Rhizobium, Frankia, Anabaena azollae*
3.	Associative Symbiotic	*Azospirillum*
P Solubilising Bio-fertilizers		
1.	Bacteria	*Bacillus megaterium* var. *phosphaticum, Bacillus subtilis* *Bacillus circulans, Pseudomonas striata*
2.	Fungi	*Penicillium sp, Aspergillus awamori*
P Mobilizing Bio-fertilizers		
1.	Arbuscular mycorrhiza	*Glomus sp.,Gigaspora sp.,Acaulospora sp., Scutellospora sp.* & *Sclerocystis sp.*
2.	Ectomycorrhiza	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
3.	Ericoid mycorrhizae	*Pezizella ericae*
4.	Orchid mycorrhiza	*Rhizoctonia solani*
Bio-fertilizers for Micro nutrients		
1.	Silicate and Zinc solubilizers	*Bacillus* sp.
Plant Growth Promoting Rhizobacteria (PGR)		
1.	Pseudomonas	*Pseudomonas fluorescens*

Types of bio-fertilizers:

Rhizobia: *Rhizobia* are symbiotic bacteria which colonizes the legume roots and fixes the atmospheric nitrogen symbiotically. In symbiotic relationship, bacteria receive the products of photosynthesis as energy source and in turn they fix nitrogen from the air for their host. The morphology and physiology of *Rhizobium* will vary from free-living condition to the bacteroid of nodules. They are the most efficient biofertilizer as per the quantity of nitrogen fixed is concerned. For harnessing the better results crop specific strain should be used when inoculated with specific Rhizobium strain (Table 1) these crops may help farmers to harvest maximum benefits. The amount of nitrogen so fixed depends on crop and environmental condition. To harvest maximum returns crop specific bio-inoculants should be used e.g. *Rhizobium trifolli* for berseem, *R. Melilotii* for lucerne, *R. phaseoli* for green gram and black gram, *R. Japoniccum* for soybean, *R. Leguminosarum* for pea and lentil and *R. lupni* for chickpea and the appropirate strain can increase yield up to 10-35% [30]. 1t is reported that rhizobium can fix 50-200 kg N ha^{-1} which is able to meet up to 80 to 90% nitrogen need of the crop. Because of the nitrogen fixing capacity of the legumes as compared to their counterpart non legumes, they are less reliant on inorganic nitrogen fertilizer and can provide additional advantage of maintaining soil fertility and benefit the following crop.

Azotobacters and Azospirillum

These are free living bacteria that fix atmospheric nitrogen in cereals without symbiosis. *Azobacter* besides fixing atmospheric nitrogen (15-20 kg ha^{-1}) per year can also produce antifungal compounds to fight against plant pathogens and can also aid in vigour and germination leading to improved crop stands.

Phospate solubilising bacteria

Under acidic or calcareous soils phosphorus gets fixed in soil resulting in plant sufferings for the need of phosphorous. Phosphobacteria can make the unavailable phosphorus available to the plants through release of various organic acids (oxalic acid, succnic acid, citric acid, glutamic cid, malic acid and fumaric acid) which brings about the release of bound forms of phosphate. PSB can be used for all crops including rice millets, oilseeds, pulses and vegetables through seed treatment, soil application or seedling dip.

Potash solublising bacteria

Potash solublising bacteria like *Fracteuria aurentia* are capable of mobilising elementary or mixture of potassium into usable form and can be applied to all crops with other bio fertilizers without showing any antagonistic effect.

Vesicular arbuscular mycorrhiza (VAM)

VAM fungi are intercellular and obligate endosymbionts and probably the most abundant fungi in agricultural soils. They account for 5–50% of the biomass of soil microbes[21]. Approximately 10–100 m mycorrhizal mycelium can be found per cm root[17]. Many of the graminaceous and leguminous plants harbour VAM. These plants posses special structures, which help in transfer of nutrients from soil to root system. The plant roots transmit substances (some supplied by exudation) to the fungi, and the fungi aid in transmitting nutrients and water to the plant roots. The fungal hyphae may extend the root lengths 100-fold thus providing greater opportunity to access wetter soil areas and help plants absorb many nutrients, particularly the less available mineral nutrients such as phosphorus, zinc, molybdenum and copper. Some VAM fungi give cottony appearance around the root a type of protective cover which increase seedling tolerance to drought (high temperature) thus inculcating to better uptake of water by plants to infection by disease fungi and even to extreme soil acidity[16].

Plant growth promoting rhizobacteria (PGPR)

The root colonising bacteria (Rhizobacteria) that exert beneficial effects on plant development via direct (by fixation of atmospheric nitrogen, solublisation of phosphate production of siderophores that solubilise sequester iron or PGRs that enhance plant growth) or indirect (by improving growth restricting conditions) mechanism are known as PGPR also referred as bio fertilizers but not all PGRs can be considered as bio fertilizers. PGPR can be applied as soil applications, seed coating and foliar sprays to improve the effectiveness which not only depends on effectiveness of the strain but also on suitable method of application.

Harmful effects of chemical fertilizers

The growth in agricultural production during the last three decades has been accompanied by a sharp increase in the use of chemical fertilisers, causing serious concern. Foremost among these concerns is the effect of excessive fertiliser (especially nitrogenous fertilisers) on the quality of soil and ground water. Among the inorganic fertilizers, nitrogen fertilizer increases denitrification, resulting in elevated emission of nitrous oxide (N_2O) to the atmosphere which contributes to global warming.

Crop produced with chemical fertilizers is not good for health and contains heavy metals which are harmful for good health. Use of chemical fertilizers also causes several disease (Table 2) due to excess of NO_2, NO_3 and pollutes the environment[2]. Excess and indiscriminate use of inorganic fertilizers has deteriorated soil badly with deficiency of macronutrients. It has also been reported that application of nitrogen fertilizers may deplete soil organic carbon in the long run[14].

Benefits of biofertilizers:

Since a bio-fertilizer is technically living, it can symbiotically associate with plant roots. Involved microorganisms could readily and safely convert complex organic material in simple compounds, so that nutrients are easily taken up. Microorganism function is in long duration, causing improvement of the soil fertility, prevent the depletion of the soil organic matter[13] and maintains the natural habitat of the soil. It increases crop yield by 20-30%, replaces chemical nitrogen and phosphorus by 25%, and stimulates plant growth. Application of biofertilizers increases yield and reduce environmental pollution[18].

1. It can also provide protection against drought and some soil-borne diseases.
2. Bio-fertilizers are cost-effective relative to chemical fertilizers. They have lower manufacturing costs, especially regarding nitrogen and phosphorus use.
3. Biofertilizers provide beneficial support to soil by fortifying soil eg. Aquatic cyanobacteria bestows natural growth hormone , protein, vitamins and minerals to soil. Azotobacter is known to infuse the soil with antibiotics thus replenishes the soils fertile capacity and can also strengthen the soil against drought and inhibit the spread of soil born diseases.

Need for other nutrient sources other than chemical fertilizers

Indiscriminate use of chemicals fertilizers disturbs natural soil ecosystem, deteriorates soil health, pollutes the water basins, destroys micro organisms, friendly insects rendering crop prone to diseases and ultimately kills the soil. Thus necessitating the alternate source of nutrients to overcome the ill effects of chemicals and at the same time improving the yield to meet the needs of food production for increasing population.

Role of biofertilizers in crop production

The incorporation of bio fertilizers 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* bio fertilizer is used for rice cultivation because of its quick decomposiotion in soil and efficient availability of its nitrogen to rice plants. *Azolla* application brought an impressive increase in rice yield by 0.5 -2 t ha^{-1} [10]. An increase in grain yield by 29.2% through the application of *Azolla microphylla* @ 15 t/ha [33]. *Azobacter*, a free living and heterotrophic bacteria fixes nearly 20 to 40 kg nitrogen ha^{-1} and increases yield up to 50% [30]. However, their effectiveness is found to vary greatly, depending largely on soil condition, temperature and farming practices (Table 3) shows the effect of *azatobacter* on yield. *Azospirullum* an associative symbiotic bacteria are found in cortical cells and protoxylem vessel in some cereals like maize, sorghum, wheat, barley etc. 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[30]. *Azospirillum lipoferum* produces plant growth promoting substances like pantothenic acid, thiamine and niacin in large quantities that improve the plant growth and yield. *Azospirillum* mineralizes nutrients from soil, sequesters Fe, survives in harsh environmental conditions, and favours beneficial mycorrhiza-plant associations[1]. Use of Azospirillum has been found enhance the maize crop yield in the range similar to 60 kg urea N ha^{-1} [9].

positive effects of *Azospirillum* inoculation to minimise the negative effects of NaCl on plant growth parameters in wheat(*Triticum aestivum* cv. 'Buck Ombu') seeds[4]. Inoculation with *Azospirillum* helps in improving water status of plants thus prove favourable to protect crops in arid soils. *A. brasilense* can synthesize phenylacetic acid (PAA), an auxin-like molecule with antimicrobial activity[31]. which prevents the proliferation of other non pathogenic rhizosphere bacteria due to production of bacteriocins and siderophores[28]. Biofertilizers made from *Azospirillum* is suitable for C4 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. Microorganisms with phosphate solubilizing potential increases the availability of soluble phosphate and enhance the plant growth by improving biological nitrogen fixation [24].Under temperate conditions *Rhizobium* improved the number of pods plant^{-1}, seeds pod^{-1}, test weight (1000-seed) and thereby yield over control[19]. *B. subtilis, Thiobacillus thioxidan*s and *saccharomyces sp.* can be used as bio-fertilizers for solubilisation of fixed micro nutrients like Zn.

Application of biofertilizers in combination has been found to increase the available phosphorus and potassium in the soils which could be attributed to improvement in release of inorganic and organic anions such as oxalate which can replace phosphorus sorbed at metal hydroxide through ligand exchange reactions and dissolve metal oxide surfaces that sorb phosphorus. Combined application of biofertilizers caused considerable increase in plant height and tillering and accordingly, the highest grain yield in wheat when the crop received combined bio-fertilizers[29]. Bio-fertilizers in combination with inorganic fertilizers resulted in significantly higher yield in comparison to lone application of inorganic fertilizers in field pea[12]. In rice under low land conditions, application of BGA + Azospirillum proved beneficial in improving LAI and all yield attributes[19]. Higher grain and straw yields with combined use of Rhizobium and PSB in *Pisum sativum* L[35] and increase in grain yield and nutrient uptake in gram by Rhizobium and PSM co-incolution [7]. PSM inoculation alone resulted in increase in grain yield of gram[34]. Seed bacterization with Rhizobium and organic amendments in acid soils significantly enhanced plant growth, nodulation and grain yield in green gram and black gram[20]. Seed inoculation with Rhizobium or PSB and combined inoculation resulted in conspicuous increase in nodulation, nitrogenase activity, growth, yield and nutrient uptake by crop over no inoculation[32]. Maximum values for growth and yield parameters in Pigeon pea fertilized with RDF 50% along with compost 5 t ha^{-1} in combination with dual inoculation of Rhizobium and PSB over uninocolulated treatments[22]. Potash solubilising bacteria applied to soil @ 2.5 kg ha^{-1} after mixing it with 200-500 kg FYM resulted in increase in crop yield by 25% in paddy crop[30].

Table 1: Major inoculation groups with inoculant and host plants [24].

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, moong and groundnut

Table 2: Adverse effect of nitrogenous fertilizers on human health and environment[2]

Effect	Causative agent
Human health	ExcessNO_3 and NO_2 in water and food
Methemoglobineemia cancer	Nitrosomine illness from NO_2, secondary amines, Peroxyacyl nitrate.
Environmental health Environment	Excess NO_3 in feed and water.
Eutrophication	Inorganic and organic water in surface water
Materials and ecosystem damage	HNO_3 and aerosols in rainfall.

Table 3: Effect of *azotobacter* on crop yield[7]

Crop	Increase in yield over yields obtained with chemical fertilizers(%)	Crop	Increase in yield over yields obtained with chemical fertilizers(%)
Wheat	8-10	Potato	16
Rice	5	Carrot	40
Maize	15-20	Cauliflower	2-24
Sorghum	15-20	Tomato	7-27
Other	13	Cotton	9-24

CONCLUSION

Keeping in view the illeffects of indiscrimate use of inorganic fertilizers, enrgy crisis and rapid depletion of non renewable energy sources, bio-fertilizers have become an important and efficient means in agriculture by exploiting beneficial microorganisms for sustainable crop production. These help in reducing fertilizer demand and provide an eco-friendly way of maintaining productivity and soil health.

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