

The Role and Future Potential of Bio-fertilizers in Indian Agriculture

Abstract

Only imports and subsidies have been able to guarantee the accessibility and affordability of chemical fertilizers based on fossil fuels at the farm level in India. Today, because they are non-toxic, easy to use, eco-friendly, and affordable, biofertilizers have become a very powerful substitute for chemical fertilizers. Additionally, they serve as a complement to agrochemicals by rendering nutrients that are naturally plentiful in soil or the environment useful for plants. Additionally, if producers and farmers have appropriate access to knowledge through experience and communication, this product has the potential to be economically promising in the long term. The Indian government has been attempting to use more advanced agrochemicals in conjunction with biofertilizers. In order to enhance the potential for sustainable agriculture development, this paper highlights the success and failure issues in the Indian context. It also highlights the need for high levels of innovation and active participation in scientific research and development, public awareness campaigns, and encouraging private organizations and policy makers to take an interest in this field.

Key words: *Rhizobium, Biofertilizers, Nitrogen, Bacteria, Phosphorous*

Introduction

In order to add, preserve, and mobilize crop nutrients in the soil, biofertilizers are best described as biologically active products or microbial inoculants, i.e., formulations containing one or more beneficial bacteria or fungal strains in affordable and user-friendly carrier materials. Stated differently, biofertilizer is a material containing living microorganisms that, when added to soil, plant surfaces, or seeds, colonize the plant's interior or rhizosphere and stimulate growth by making more primary nutrients available to the host plant (Mazid et al., 2011a). Organic fertilizers contain organic substances that improve soil fertility either directly or indirectly through degradation. Similarly, the words "biofertilizers," "green manure," "manure intercrop," and "organic supplemented chemical fertilizer" should not be used interchangeably. One of the current difficulties of the new millennium is to boost agricultural food production from decreasing amounts of arable land per person. The long-term environmental effects of biofertilizers are significant and counterbalance the negative consequences of chemicals. At the farm level, the benefits of more technology use can spread to other farms and industries since it pollutes water less than chemical fertilizers and, to some extent, even creates organic manures. Unlike chemical fertilizers, which show immediate returns, the benefits of the new method in stopping soil deterioration could not be seen right away. Liquid bio-fertilizers are distinctive liquid formulations that contain the targeted microorganisms and their nutrients together with additional chemicals or cell protectants that encourage the production of dormant spores or cysts for extended shelf life and resistance to harsh environments. The farmer must also assume a significant initial risk, trial and error, and skill learning costs. Investment is discouraged by the producer businesses' severe uncertainty over the product's capacity to be sold or in demand, especially if it is irreversible (Ghosh, 2004). Important information is communicated to others and ultimately to society through the successes or failures of early entrants who take the initiative or those who engage in research for a superior product. Furthermore, intentionally replicated cultures of certain soil organisms are known as biofertilizers, or microbial inoculants, and they can increase crop yield and soil fertility. While legumes have long been recognized for their ability to improve soil fertility and for their part in biological N-fixation, which was identified over a century ago, the commercial exploitation of these biological processes is the focus of most attention and activity. In order to increase the number of these microorganisms and speed up the microbial processes that increase the availability of nutrients that are easily assimilated by plants, latent cells of effective strains of nitrogen fixing, phosphate solubilizing, or cellulolytic microorganisms are applied to seed, soil, or composting areas (Mazid et al., 2011b). Not all PGR serves as a biofertilizer. While not only biofertilizers, several other

bacterias function as bio-pesticides by controlling undesirable microbes to stimulate plant development. Similar to this, bacteria are regarded as bio enhancers rather than biofertilizers since they may promote plant development by generating phytohormones (Mazid et al., 2011c). By fixing atmospheric N in conjunction with plant roots and independently, biofertilizers significantly improve soil fertility by producing plant growth chemicals in the soil, solubilizing insoluble soil phosphates, and solubilizing insoluble N. Biofertilizers are mixtures of microorganisms that include cells; these microorganisms can be decomposers of organic materials, P solubilizers, N fixers, or S oxidizers. To put it briefly, they are known as bio inoculants, and when applied to plants, they increase their yield and rate of growth (Khan et al., 2011a). Not every PGR qualifies as a biofertilizer. While not biofertilizers, several bacteria operate as bio-pesticides by controlling harmful organisms to stimulate plant development. Similar to this, bacteria are considered bio enhancers rather than biofertilizers since they may promote plant development by generating phytohormones (Mazid et al., 2011c). By fixing atmospheric N in conjunction with plant roots and independently, biofertilizers significantly increase soil fertility by producing plant growth chemicals in the soil, solubilizing insoluble soil phosphates, and solubilizing insoluble N. Biofertilizers are mixtures of microorganisms that include cells; these microorganisms can be decomposers of organic materials, P solubilizers, N fixers, or S oxidizers. In short, they are called as bio inoculants which on supply to plants improve their growth and yield (Khan et al., 2011a). In present times a need has arisen for organic fertilizers including biofertilizers to minimise our dependence on fertilizer N. Studies on biofertilizers carried out in India and outside have shown that, given the right environmental circumstances, legumes such as beans, soybeans, chickpeas, and pigeon peas may fix 50–500 kg of atmospheric nitrogen per hectare. Because of this, biofertilizers provide a safe way to use renewable resources to increase soil fertility by combining biological wastes with the helpful microorganisms that provide organic nutrients to farm products. Biofertilizers are becoming more and more popular as environmentally friendly additions to fertilizers for healthy plant development. They have huge potential to minimize the need for synthetic fertilizers while maintaining the supply of nutrients plants needed. These bio-inputs, also referred to as bio-inoculants, are products that contain live cells of various microorganisms and can mobilize nutritionally important elements from non-usable form through biological stress. When applied to plants, they improve their growth and yield (Khan and Naeem, 2011; Mazid et al., 2012a). Due to the widespread use of toxic pesticides and chemical fertilizers on crops, contemporary agriculture has become more unsustainable, increasing cultivation costs, stagnating farmer income, and posing serious challenges to food security and safety. Indiscriminate and imbalanced use of chemical fertilizers, especially urea, along with chemical pesticides and unavailability of organic manures has led to considerable reduction in soil health.

Production and Demand

The production of biofertilizers is always driven by demand, and one of the most crucial tasks in promoting biofertilizers is to create demand among farmers. The nation now produces more biofertilizers than it needs because of the government's and research institutions' outstanding programs in biofertilizer production and widespread use (Parr et al., 1994). For instance, plant responses to *Azotobacter* inoculation in irrigated wheat were shown to be significant in 342 cases and varied from 34 to 247 kg/ha in a sample of 411 field experiments conducted across districts.

If biofertilizers produce certain long-term and societal benefits that private people would not be prepared to pay for, at least not until the benefits are "visible," then there is a case to be made for splitting the cost among a greater number of recipients or the general public. However, incorrect and haphazard applications of chemical fertilizers negatively impact the microbial ecology, the

surrounding environment, and the natural balance of soil agricultural ecosystems, leading to a general drop in crop output (Bohlool et al., 1992). As a result, we need to reduce our reliance on chemicals and hunt for ecologically friendly yet affordable technologies. The market for biofertilizers is therefore trending significantly. In the past century, several families have lived in India. India is already self-sufficient in food production thanks to the Green Revolution, but there is still no space for complacency. In addition, Sharma and Upadhyay (2007) provided an overview of the current state of supply and demand, marketing plans, networks, and government initiatives pertaining to biofertilizer pricing in India.

Although the green revolution significantly increased food supply, sustainability was not given enough thought. Dependence on chemical fertilizers for future agricultural expansion would entail additional loss in soil quality, potential of water pollution and unsustainable weight on the fiscal system. In line with the current situation, the government wants to support private initiative and the financial feasibility of production in addition to encouraging their usage in agriculture. In India the availability and affordability of fossil fuel based chemical fertilizers at the farm level have been ensured only through imports and subsidies. The Government of India has been trying to promote an improved practice involving use of bio-fertilizers along with fertilizers. These inputs have multiple beneficial impacts on the soil and can be relatively cheaper and convenient to use. Failure of a market to build up the need for public intervention when the expected social gains from a relatively new product outweigh the costs, whereas the private gains do not and uncertainty about the product performance coupled with long periods of learning involved can lead to poor demand from end users who are farmers. Field studies have demonstrated them to be effective and cheap inputs, free from environmentally adverse implications that chemicals have.

Moreover, Biofertilizers can act as a renewable supplement to chemical fertilizers and organic manures. They have the capacity to produce natural resistance in plants against pests and soilborne diseases, because antibodies are produced and beneficial micro-organisms participate in the soil to increase fertility (Board, 2004). For soil treatment, 500-800g of biofertilizers is mixed homogeneously with 10-15 kg of FYM and the mixture is added to soil at the time of sowing because Biofertilizers require organic manure after being added to soil for their growth and development, as well as for their activity in soil. But consistency in gains again eludes the trials conducted by All India Coordinated Pulse Improvement Project Transportation because distribution is a major problem in rural areas (Khan and Mazid, 2011). There is an on-going attempt to promote Biofertilizers in Indian agriculture through public intervention, and in keeping with the spirit of the times, these policies motivate private sector and the profit motivation will help propel the new technology. Government of India and various State Governments have been promoting the nascent biofertilizer market both at the

level of the user-farmer and the producer-investor through the following measures:

- (i) farm level extension and promotion programmes,
- (ii) financial assistance to investors in setting up units,
- (iii) subsidies on sales and
- (iv) direct production in public sector and cooperative organizations and in universities and research institutions.

The present expiry period is limited to 6 months which is related to carrier (lignite/charcoal). High moisture content attributes contamination of microorganisms that either compete with Biofertilizers or have antagonistic interaction. Retail shops do not sell Biofertilizers because of short shelf-life, limited demand and lack of storage facilities. The reasons responsible for it are:

- lack of marketing infrastructure and distributing network;
- ignorance of farmers about Biofertilizers;
- absence of public support and lack of assurance of higher benefits for retailers.

Because there is inadequate control over the quality of production, biofertilizers are sold. Only a few biofertilizers now have ISI criteria in place, and strains unique to a certain area still need to be created. There are few facilities and laws pertaining to the testing of biofertilizers, and long-lasting carrier material is unavailable. Dry land agriculture is characterized by low production, erratic weather patterns, and low chemical fertilizer dosages. The microorganisms utilized as biofertilizers are members of the fungal, BGA, and bacterial groups. The carriers of rhizobia and other biofertilizers

that are kept in storage for an extended amount of time are sterilized using ionizing radiation (Tittabutr, 2012).

N-fixing Biofertilizers (NBF):

Rhizobium (Family: Rhizobiaceae) Biofertilizers, particularly Rhizobium, could be a bridge between removals and additions to soil nutrients where farmers can scarcely afford costly inputs and that too in a risky environment. N fixation on land amounts to 135 million metric tons per annum average. In recent years use of Rhizobium culture has been routinely recommended as an input in pulse cultivation. In India about 30 million hectares of land is under pulse cultivation. They belong to family Rhizobiaceae, symbiotic in nature, fix nitrogen 50-100 kg/ha with legumes only. It is useful for pulse legumes like chickpea, red gram, pea, lentil, black gram, etc., oil-seed legumes like soybean and groundnut and forage legumes like berseem and lucerne. It colonizes the roots of specific legumes to form tumour like growths called root nodules, which act as factories of ammonia production. Rhizobium has the ability to fix atmospheric N- in symbiotic association with legumes and certain non legumes like, Parasponia (Saikia and Jain, 2007)

Biological N fixation (BNF) occurs in the free living states, in association or in symbiosis with plants. From an ecological point of view, the most important N fixing systems are the symbiotic associations. Rhizobium-a symbiotic Biofertilizer can be used for legumes crop and trees (e.g., leucerna) and is a crop specific inoculant, for example, *Rhizobium trifoli* for berseem; *Rhizobium meliloti* for leucerna, *Rhizobium phaseoli* for green gram, black gram, *Rhizobium japonicum* for soybean; *Rhizobium leguminosorum* for pea, lentil; *Rhizobium lupini* for chickpea. These inoculants are known for their ability to fix atmospheric N- in symbiotic association with plants forming nodules in roots (stem nodules in *Sesbania mrostrata*). Rhizobium is however limited by their specificity and only certain legumes are benefited by this symbiosis. N fixation by leguminous and other crops is reported to be 44 million metric tons per annum. Crop responses to *Rhizobium* inoculation under field conditions have been quite variable depending upon field conditions, type of crop, inoculant used and soil conditions. In terrestrial habitats the symbiotic fixation of N by rhizobia counts for the largest combustion of combined N (Philippot and Germon 2005). Moreover, seed and straw yield of green gram increased significantly up to single inoculation with Rhizobium under 20kg N + 45 kg P₂O₅ ha⁻¹ fertility level. Field trials carried out in different locations have demonstrated that under certain environmental and soil conditions inoculation with azotobacteria has beneficial effects on plant yields (Mazid et al., 2011d). The appropriate strain can increase the crop yield up to 10-35% since N is fixed at 40-200kg/ha which is able to meet up to 80-90% of N need of the crop. Also, residual N is beneficial for the next crops grown in the same field. 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. The number of pods plant⁻¹, number of seed pod⁻¹ and 1000-seed weight (g) recorded were 25.5, 17.1 and 4.7 percent more over the control, respectively which was statistically significant.

Azotobacter (Family: Azotobacteriaceae)

The Azotobacter colonizing the roots not only remains on the root surface but also a sizable proportion of it penetrates into the root tissues and lives in harmony with the plants, belongs to family Azotobacteriaceae, aerobic, free living, and heterotrophic in nature. Azotobacters are present in neutral or alkaline soils and *A. chroococcum* is the most commonly occurring species in arable soils.

A. vinelandii, *A. beijerinckii*, *A. insignis* and *A. macrocytogenes* are other reported species. The occurrence of this organism has been reported from the rhizosphere of a number of crop plants such as rice (*Oryza sativa* L.), maize (*Zea mays* L.), sugarcane (*Saccharum officinarum* L.), bajra (*Pennisetum glaucum* L.), vegetables and plantation crops (Mazid et al., 2011e). They do not, however, produce any visible nodules or out growth on root tissue. These are non-symbiotic free living aerobic bacteria possessing highest respiratory rate and can fix N up to 25 kg/ha under optimum conditions and increase yield up to 50%. Alkaline phosphatase activity in the peach roots was highest with *Azotobacter chroococcum* + P fertilizer. This has been found beneficial to a wide array of crops covering cereals, millets, vegetables, cotton and sugarcane. The effect of *Azotobacter chroococcum* on vegetative growth and yields of maize as well as the effect of inoculation with this bacterium on wheat has been studied by numerous authors. It is free living and non-symbiotic N fixing organism that also produces certain substances good for the growth of plants and antibodies that suppress many root pathogens. They improve seed germination and plant growth by producing B-vitamins, NAA, GA and other chemicals (plant hormones) that are inhibitory to certain root pathogens (Mazid et al.,

2011f). Moreover, increase in yield due to Azotobacter inoculation could be obtained in crops like rice, wheat, sorghum, maize, pearl millet, cotton, sesame and vegetables. These fertilizers have been successfully used in wheat (*Triticum aestivum* L.), maize, cotton (*Gossypium arboreum* L.), pearl millet (*Pennisetum glaucum* L.) and paddy, though their response depends upon the amount of organic matter available in the soil. For sugarcane, *Azotobacter indicum* is suitable in acidic soils in which it forms *rhizo bacteriocoenotic* association with roots and application in soil is economical but a large amount of organic C- and Mo is needed for stimulating nitrogenase enzyme activity during N fixation (Mazid et al., 2012b; Khan et al., 2012a).

Azospirillum (Family: Spirillaceae)

It is also *Bacillus polymixa*. When applied to rhizosphere it fixes atmospheric N (free living state) and makes it available to crop plants. This is also N-fixing microorganism, beneficial for non-leguminous plants, belongs to family Spirillaceae, heterotrophic and associative in nature. In addition to their N fixing ability of about 20-40 kg/ha, they also produce growth regulating substances. Although there are many species under this genus like, *A. amazonense*, *A. halopraeferens*, *A. brasilense*, worldwide distribution and benefits of inoculation have been proved mainly with the *A. lipoferum* and *A. brasilense*. Azospirillum proved significantly beneficial in improving leaf area index and all yield attributing aspects. Grain yield and harvest index (HI) also exhibit a discernable increase with use of biofertilizers. Besides this, the Azospirillum forms associative symbiosis with many plants particularly with those having the C4-dicarboxylic acid pathway of photosynthesis, because they grow and fix N on salts of organic acids such as malic, aspartic acid. Thus it is mainly recommended for maize, sugarcane, sorghum (*Sorghum bicolor* L.), pearl millet etc. Like Azospirillum, the benefits transcend N-enrichment through production of growth promoting substances. Dipping the roots of rice seedlings in 2% suspension of Azospirillum inoculant increased the yield by 100 kg/ha (Kennedy et al., 2004).

Herb spirillum

It is an association symbiont that is responsible for fixation of atmospheric N on the roots of sugarcane. Enhancing the availability of N, promoting the uptake of nitrate, K, phosphate and production of growth promoting hormones (kinetin, gibberellic acid and auxin) are its subsequently beneficial effects (Khan et al., 2011b).

Acetobacter

It is best adopted endo-phytically in sugarcane ecosystem and can tolerate high sucrose concentration. This bacterium can fix N- up to 15 kg/ha/year as plant secretes the growth promoting hormones IAA that enhance germination and root development and ultimately helps in absorption of plant nutrients. There are also changes in shares by types with moderate success in Azotobacters and by far the best performance is given by PSB. The decline in Rhizobium indicates that success in groundnut and pulses was below expectation and annual capacity of units deflated by the number of units. A measure of capacity utilized is obtained relating actual distribution (as opposed to production) to capacity. Inoculation with Azotobacter + Rhizobium + VAM gave the highest increase in straw and grain yield of wheat plants with rock phosphate as a P fertilizer.

Azolla Family: Azollaceae

Azolla can be used as green manure or as dual crop. For green manuring, Azolla is sown in the field or in a separate shallow pond. It is a free floating symbiotic fern found on water surface, individually in low land field and water bodies. Water is drained off the field and Azolla is incorporated into the soil before transplanting of paddy. Dried inoculum of Azolla is also pre-soaked in 50 ppm of superphosphate solution for 12 h and inoculated in the paddy field (Kannaiyan, 2002). One kg of it fixes 40-55 kg N/ha, 15-20 P/ha and 20-25 kg K/ha in a month, thus increasing yield of flooded paddy by 10-20%.

Blue Green Algae (BGA) / Cyanobacteria, Chlorococcales, Mastigociadaceae, Nostocaceae, Oscillatoriaceae, Oscillatoriaceae, Rivulariaceae, Scytonematoceae, Stigonemataceae

These phototropic prokaryotic bacteria are effective only in submerged paddy in presence of bright sunlight by forming a bluish-green algae on standing water and by converting the insoluble P into soluble forms fixing N to the tune of 2-30 kg/ha thereby raising the crop yield by 10-15% when applied at 10 kg/ha. BGA biomass decomposes in soil and organic compounds are liberated and plant growth is regulated. These belong to eight different families, phototrophic in nature and produce Auxin, Indole acetic acid (auxin) and Gibberellic acid, fix 20-30 kg N/ha in submerged rice fields as they are abundant

in paddy, so are also referred as 'paddy organisms'. N is the key input required in large quantities for low land rice production. Soil N and BNF by associated organisms are major sources of N for low land rice. The 50-60% N requirement is met through the combination of mineralization of soil organic N and BNF by free living and rice plant associated bacteria (Rahman et al., 2009). BGA are photosynthetic N-fixers and are free living. They are found in abundance in India. They too add growth-promoting substances including vitamin B₁₂, improve the soil's aeration and water holding capacity and add to biomass when decomposed after life cycle. Most N fixing BGA are filamentous, consisting of chain of vegetative cells including specialized cells called heterocyst which function as micro nodule for synthesis and N fixing machinery. BGA forms symbiotic association capable of fixing N- with fungi, liverworts, ferns and flowering plants, but the most common symbiotic association has been found between a free floating aquatic fern, the Azolla and Anabaena azollae (BGA).

Azolla is an aquatic fern found in small and shallow water bodies and in rice fields. The most common species occurring in India is *A. Pinnata* and the same can be propagated on commercial scale by vegetative means. The important factor in using Azolla as biofertilizers for rice crop is its quick decomposition in the soil and efficient availability of its nitrogen to rice plants. It has symbiotic relation with BGA and can help rice or other crops through dual cropping or green manuring of soil (Ghosh, 2004).

Phosphate Solubilizing Microorganisms and Mycorrhizae

Most of the Indian soils are low to medium in P status and the efficiency of phosphate fertilizers is also allowed due to fixation of large fraction of applied P into sparingly soluble inorganic phosphates.

Some times PSM produce plant growth hormones (IAA, GA etc.). Such soluble phosphorus is taken up easily by plants resulting in 10-20% increase in the yield of almost all the crops. Results of a greenhouse pot experiments with onion (*Allium cepa* L.) showed that application of *G. fasciculatum* + *A. chroococcum* + 50% of the recommended P rate resulted in the greatest root length, plant height, bulb girth, bulb fresh weight, root colonization and P uptake. Also the rates of chemical phosphatic fertilizers can be brought down (Carter, 1967). Several reports have examined the ability of different bacterial species to solubilize insoluble inorganic phosphate compounds, such as tri-calcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate. Among the bacterial genera with this capacity are *Pseudomonas*, *Bacillus*, *Rhizobium*, *Burkholderia*, *Achromobacter*, *Agrobacterium*, *Micrococcus*, *Aerobacter*, *Flavobacterium* and *Erwinia*. P, is both native in soil and when applied in inorganic fertilizers, becomes mostly unavailable to crops because of its low levels of mobility and solubility and its tendency to become fixed in soil. The PSB are life forms that can help in improving phosphate uptake of plants in different ways. The soil bacteria belonging to the genera *Pseudomonas* and *Bacillus* and Fungi are more common. The major microbiological means by which insoluble-P compounds are mobilized is by the production of organic acids, accompanied by acidification of the medium. The PSB also has the potential to make utilization of India's abundant deposits of rock phosphates possible, much of which is not enriched. Through symbiotic association between certain fungi (glomus) and plant roots the uptake of nutrients is facilitated and such symbiosis is called Mycorrhizae (Karandashov and Bucher, 2005). This is of two types, the ectomycorrhizae, is found in trees and is beneficial for forest trees whereas, the second one is endomycorrhizae which is common in crop plants. Transplant seedlings become hard survivors and growth of the soil borne pathogens causing root disease is inhibited.

K-Solubilizing Bacteria

Bacteria such as *Frateruria aurantia* are capable of mobilizing mixture of K into a usable form to the plants known as K solubilizing bacteria, applied to all crops in association with other Biofertilizers without any antagonistic effect. However, while positive responses have been observed in a wider range of field trials, there is remarkable inconsistency in responses across crops, regions and other conditions (Ghosh, 2004). Even for a given crop the range of response is quite high. *Rhizobium*, *Azospirillum*, *Azotobacter*, BGA and Phosphate solubilizing bacteria like *B. magisterium*, *Pseudomonas striata*, and phosphate mobilizing Mycorrhiza have been widely accepted as biofertilizers. However, these supply only major nutrients but a host of microorganism that can transform micronutrients are there in soil that can be used as biofertilizers to supply micronutrients like zinc, iron, copper etc., zinc being of utmost importance is found in the earth's crust to the tune of 0.008 per cent but more than 50 percent of Indian soils exhibit deficiency of zinc with content mostly below the critical level of 1.5 ppm of available zinc. Zinc can be solubilized by microorganism's viz., *B. subtilis*,

Thiobacillus thiooxidans and *Saccharomyces* sp. These microorganisms can be used as Bio-fertilizers for solubilisation of fixed micronutrients like zinc. The results have shown that a *Bacillus* sp. can be used as Bio-fertilizer for zinc or in soils where native zinc is higher or in conjunction with insoluble cheaper zinc compounds like zinc oxide (Samoon et al., 2010).

Biofertilizers Required

The commercial history of biofertilizers began with the launch of 'Nitragin' by Nobbe and Hiltner, a laboratory culture of *Rhizobia* in 1895, followed by the discovery of *Azotobacter* and then the blue green algae (BGA) and a host of other micro-organisms. *Azospirillum* and Vesicular-Arbuscular Micorrhizae (VAM) are fairly new discoveries. In India the first study on legume *Rhizobium* symbiosis was conducted by N. V. Joshi and the first commercial production started as early as 1956. However the Ministry of Agriculture under the Ninth Plan initiated the real effort to popularize and promote the input with the setting up of the National Project on Development and Use of Biofertilizers (NPDB). Although biofertilizers have been promoted as supplement or complement of chemical fertilizers, in reality they are two alternative means of accessing plant nutrients. The strength of complementarity as against substitution between the two inputs is open to empirical verification, but there is no denying that farmers and producers do perceive the substitutability relation and believe that to an extent Biofertilizers have various benefits. Besides accessing nutrients, for current intake as well as residual, different biofertilizers also provide growth-promoting factors to plants and some have been successfully facilitating composting and effective recycling of solid wastes. By controlling soil borne diseases and improving the soil health and soil properties these organisms help not only in saving, but also in effectively utilising chemical fertilizers and result in higher yield rates (Bot and Benites, 2005). To attain production targets, the Govt. of India implemented a central sector scheme called National Project on Development and use of Biofertilizers (NPDB) during the Ninth Plan for the production, distribution and promotion of biofertilizers. A National Biofertilizers Development Centre was established at Ghaziabad as a subordinate office of the Department of Agriculture and Cooperation with six regional centres. The coexistence of smaller new units with the larger ones of higher vintage has increased the variety in industry as measured by the coefficient of variation (Ghosh, 2004). The share in distribution, however, has been relatively more stable despite showing a slight declining trend in the last five years reportedly, however, this is only partially valid as units with large distribution networks do distribute over larger areas. Public sector fertilizer giant IFFCO is located in Phulpur in Uttar Pradesh, IFFCO's MLN Farmers' Training Institute produces all strains of Biofertilizers and have distributed it in states other than the home state.

More than 70% of the large units are of long vintage reiterating that new entry has been mostly in small units. About 70% of the small units came into being after March 1995. The small units show some tendency to specialize in either nitrogen fixers or phosphate solubilizers while all the large units produce both kinds. Eastern states like Bihar and Orissa are also served though the share has gone down notably for West Bengal where distributions came down to nil in 2000-02. The distribution does not follow that of chemical fertilizers they supplement, where north is the largest claimant. However, the eastern region comes last in share in both chemical and biofertilizer though the share in the latter case is even more diminutive (Ghosh, 2004). The comparison, however, is not complete without bringing in the cropped area in the regions. In the case of biofertilizers, the initiatives taken by the public sector along with numerous universities and research units, that are also state funded, must, with time, lead to commercial success once the technology is transmitted to the field to draw private enterprise since the market is open for entry.

Our all modern agricultural practices widely carry on a very different heavy range of agrochemicals including different types of organic and inorganic fertilizers (Brodt, 2002). They washed off from lands along with water through irrigation rainfall drainage etc. reaching into the rivers, lakes and streams and so on. Where they turn fully to our natural ecosystem then effect human life indirect/indirect ways such as:

1. Consumption of vegetables grown in NO₃-rich soil may lead to diseases (methaemoglobinemia); then leads to various ailments as damage to respiratory and vascular system, blue coloration of skin and even cancer.
2. Chemical fertilizers use imbalance of whole mineral pattern of plant body. For example, excessive K- treatment decreased valuable nutrients in foods such as ascorbic acid and carotene.

3. Depleting soil fertility due to widening gap between nutrient removal and supplies.
4. NO_3 fertilizers increase the total crop yield but at the expense of protein. Since, most of Indians are vegetarians, consumption of low qualities of protein leads to malnutrition.
5. Increasing concern about environmental hazards.
6. It is estimated that by 2020, to achieve the targeted production of 321 million tonnes of food grain, the requirement of nutrient will be 28.8 million tonnes, while their availability will be only 21.6 million tonnes being a deficit of about 7.2 million tonnes.

Other problems are associated with compatibility with host genotypes, improper handling facility, inoculants techniques and improper dose. Therefore, viable effects of Biofertilizers application are not generally observed in traditional agriculture (Rivera and Fernandez, 2006). The potential demand of Biofertilizers is quite large and far exceeds the present production levels. It has been computed at 348 thousand tons with the assumption of Biofertilizers application in 50% of the gross cropped area under different crops (Wiesman, 2009). The average distribution also declined in the first two years possibly signalling the need for a down size but picked up subsequently. The average capacity utilization has been poor but the downsizing may have arrested the declining trend. Depending on the source of funding, Biofertilizers production units located in different states can be categorized in two groups;

1. Units financed by Government of India (GOI)
2. Units financed by other sources

So far, 64 biofertilizers production units have been established with the GOI support. They have over 900 tonnes of total installed production capacity and over 6000 tons of the total Biofertilizers production. Remaining 38 biofertilizers production units with total installed production capacity is still very low compared to potential demand of 235 thousand tons for bacterial Biofertilizers (Choonawala, 2007).

Procedure

Biofertilizers are made up of two compounds, the microorganisms and a carrier material. Apart from the microorganisms itself, carrier plays the most significant role in any formulation. It involves several steps. Apart from environmental factors, deficiencies in handling procedure are a major cause of under performance in real life application. The high sensitivity to temperature and other external conditions of these 'living' inputs, calls for enormous caution at the stage of manufacture/culture, transportation/distribution and application. This involves investment and time in research, packaging, storage and use of suitable carrier materials; mass multiplication of selected competent strain of organisms in the broth media and mixing of quality tested broth cultures of the microorganisms in the homologous carrier. Inoculants are used to gain maximum number of spores. It is a good practice to promote biofertilizers as an input conjunctive to other forms of fertilizers, but keeping in view the protection given to chemicals, there is some ground for subsidizing the former to encourage their use (Sundar, 2002). However, there is a need to work out a systematic and uniform way to give out subsidies so that they do not distort inter unit prices and help some units at the cost of others. The States should be strongly guided on this norm. The main purpose of the subsidies would, however, be to induce farmers to try out the input at affordable and acceptable prices rather than to support certain producers directly. Production and distribution of different biofertilizers were also undertaken but subsequently discontinued as the centres redefined their role towards R&D and HRD related activities. Capacity creation and production was, however, encouraged through one time grant for new units. Numerous studies on technological evolution emphasized the developmental role of a firm, and the strength of its sales network, creating market and drawing market feedback, for its success. In general, firms with larger production facilities are expected to invest more in networks to understand and access the market but it is not uncommon for firms with larger distribution networks to act as marketing agents for smaller units who are lacking and in few rare cases like that of NAFED the distribution even exceeds capacity. The sales networking would be stronger also for concerns that are in some way already in the business of selling agricultural inputs (Ghosh, 2004). Since, the exact scope and nature of the units or possibly their parent companies is not clear from the data, past experience in selling biofertilizers may be considered as an indicator of their marketing capabilities (Singh, 2007). The curing period depends upon the growth rate of the microorganisms to be used. After curing, the Biofertilizers is packed generally in polythene bags made of 50-70 mm thick and low density sheets. Each packet should be marked legibly to give information about the name of the product,

crop for which intended, date of manufacture, expiry date, net quality meant for 0.4 hectare storage instructions and directions for the use of biofertilizers. Each packet duly tested should be marked with ISI certified mark.

Eligibility Criteria

It may be noted, that only 30% of India's total cultivable area is covered with fertilizers where irrigation facilities are available and on the remaining 70% of the arable land, which is mainly rain fed, very negligible amount of fertilizers are being used. It is a very critical task because an efficient strain of the N-fixing/P-solubilizing microorganisms is as important in Biofertilizers production as seed is in crop cultivation (Saravanakumar and Gandhi, 2009).

The main criteria for selecting an efficient N fixer are its ability to

- (a) Fix N over a range of environmental conditions
- (b) Competition with other strain
- (c) Multiplying in broth and survival in the carrier etc.

Crude calculations of bulk and cost in terms of N on the basis of reported N equivalence indicates that biofertilizers are cheap and convenient compared to chemical and farm organic fertilizers and therefore have considerable promise for crops like cereals, oilseeds, vegetables. Nevertheless, a crude

estimation is attempted for indication of the potential without attaching significance to the magnitudes as such. The FAI reports (1996, 1998, and 2001) give information of annual distribution levels of various inoculants and their sale prices for consecutive years by firms. In addition the annual capacity as of March is provided for the three years 1995, 1997 and 1999. Two approaches viz, single and multi-strain inoculating has been recommended and both practices are in use. *Rhizobium* inoculum is produced in shake-flasks/fermenters using appropriate growth medium. In addition,

Azolla is vegetative mass-cultured in small field nurseries (20m x 2m) containing 10 cm standing water and irrigation channels (Rao, 1982). Each nursery is supplied with 10 g super phosphate and inoculated with 8 kg fresh *Azolla* to yield 40-50 kg fresh *Azolla* per plot in 15 days.

Environmental Limitations for Application of Bio-fertilizer

1. Unavailability of suitable carrier Resource constraint
2. Market level constraints and lack of awareness of farmers
3. Lack of quality assurance and limited resource generation for Biofertilizers production
4. Seasonal and unassured requirement
5. Soil and climatic factors and inadequate experienced staff
6. Native microbial population, faulty inoculation techniques and mutation during fermentation

Indian Market for Biofertilizers

Around 170 organizations in 24 countries are engaged in commercial production of Biofertilizers. NifTAL (U.S.A) has played a major role in the popularization of *Rhizobium* inoculants. In such circumstances, the price of Biofertilizers along with the risk and responses will be weighed with those of chemical fertilizers, and promotion of technology for environmental reasons would call for some degree of protection to minimize the inter-fertilizer price distortion. Australia has taken the lead role in the quality control of different commercial products. Philippines implemented the National *Azolla* Programme (NAAP) in 1982 to develop farm-based technology for the use of *Azolla* fertilizer for rice. The current global market for organically raised agricultural products is valued at around US\$ 30 billion with a growth rate of around 8%. Nearly 22 million hectares of land is now cultivated organically (Sheng et al., 2009). The organic cultivation represents less than 1% of the world's conventional agricultural production and about 9 percent of the total agricultural area. This only highlights the tremendous potential in the growth of biofertilizers. Now, there are 60 production units producing 10-115 tons per unit per year. Different State governments also provide subsidies sometimes up to 50% of the sales realization but the manner of subsidization is rather unsystematic. In many cases, the discrimination and manipulation in subsidizing lead to a lot of intra industry variation in prices. One of the main barriers faced by the producers and investors is inadequate demand and the inconsistent and seasonal nature of the existing demand. It may be recalled that the technology is as yet nascent and evolving. The rice dominated eastern region remains a non-starter and the wheat rice growing north has not shown much interest (Luft and Korin, 2009). Research on developing efficient, temperature tolerant and hardy strains is a vital step to the actual success of the technology.

In particular, there can be some focus on the potential of the technology in rice and cereals in general although its significance for crop diversification is of equal concern (Mahmud et al., 1994). The government also plays a dominant part in marketing Biofertilizers in three possible channels:

- (a) State government via District level Officers and Village level workers to farmers,
- (b) State Marketing federation via cooperative bodies to farmers and
- (c) State Agro-industries

Corporations via Agro service Centre to farmers. The producers are, however, free to sell through their own sales network or through market. Over the period of four years the number of units went up by 53% from 62 to 95 and further to 122 in 2002. The total capacity expanded by 12% going by the information on units reporting their capacities. New private units joined the industry improving their numeric share while the public sector, after the initial burst slowed its pace. However, a deeper look would be more illuminative. The distribution of Biofertilizers, and its adoption rate has not consistently grown over time and has slowed down in the late nineties. Starting from a small base one would have expected a faster and possibly accelerating growth performance as the input finds greater acceptance. Secondly, although there have been more and more new entries in the market, the average capacity came down characterizing the industry by a large number of small units. While size adjustment in infant industry is normal, it must be borne in mind that distribution of an agro-input also calls for substantial sales networking and a deep understanding of the field reality in agriculture (Ghosh, 2004). Whether the smaller units will have the necessary expertise and incentive for meeting farm demands or synergistic associations with bigger producers or simply distribution agents or local bodies would be the desired institution is a matter of review. There has practically been no diffusion of the technology despite the central government's interventions and the distribution among units has tended towards greater concentration especially in Maharashtra and other states of the west and south. Govt. of India and the different State Governments have been promoting use of Biofertilizers through grants, extension and subsidies on sales with varying degrees of emphasis (Alam, 2000). With time farmers to learn about the technology forming their perception on the basis of agronomic realities of their regions, the knowledge gained from experiences of farmers around them and including themselves and the information provided by different disseminating agents and form their own decisions of adoption (Khan et al., 2011c). GOI has provided the National Biofertilizers Development Centre at Ghaziabad with six regional centres at Bangalore, Bhubaneswar, Jabalpur, Hisar, Imphal and Nagpur. In the absence of reported information on farm level use of the inputs, this can help in understanding the progress of the technology and its adoption in India.

Conclusion

The new techniques of applications particularly use of methylcellulose for seed coating and pellets for direct soil application should be encouraged. The responses usually depend on several environmental

factors. (1) The type of soil as measured by its water holding capacity, its levels of other nitrates, phosphate and even calcium and molybdenum that help in protein synthesis in Rhizobia and the alkalinity, salinity and acidity of soil, all affect the response (Naeem et al., 2011; Khan et al., 2011d;

Khan et al., 2012b). Higher dose of mineral N- as starter suppresses nodulation, reducing response of Rhizobium but phosphate deficiency can be an inhibitor also. (2) The inadequacy of organic matter especially common in dry-land and agriculture is a deterrent more for the nonsymbiotic strains, which essentially depend on soil organic matter for energy. Phosphobactrin response was found to be positive only in soils with high organic content and low available phosphorus. (3) Soil water deficit and high temperature (hyper-thermia) are prominent abiotic factors that affect N- fixation in dry land agriculture (Mazid et al., 2011g; Khan et al., 2012c). (4) Native microbial population opposes the inoculants. In general, predatory organisms, often already present in the soil are more adapted to the environment and out compete the inoculated population. Microbial sensing and response mechanisms in the form of cell to cell communications through use of small signalling molecules have been reported. In case of iron deficient soil, *Pseudomonas* species colonize crop roots that results in improvements in plant growth (Khan et al., 2011e). These aspects are important in dry soil affecting bacterial population in rhizosphere. Pelleting of seed with lime for acidic soil and with gypsum for saline soil is beneficial. Chemical fixation in soil limits the use of Biofertilizers therefore different strains of phosphorus solubilising bacteria mixed with rock phosphate and single super phosphate may

be needed. Farmers should be advised to mix Biofertilizers to get benefits of the synergistic effect on plant growth and ultimately on yield, but multi strains biofertilizers may be avoided (Khan et al., 2011f). If chemical fertilizers are to be applied to soil, there should be a gap of 15-20 days for better N-fixation. Moreover, cold storage facility should be provided at districts level to facilitate timely availability to farmers at the village level, as majority of farmers use Biofertilizers as and when needed and even after expiry date. Over time as the industry emerges from infancy with public guidance, the following observations will be expected due to following reasons, (a) increasing sales volumes and diffusion across the country, (b) greater role of profit motivated private enterprise. Since, information on farm level usage of biofertilizers or profitability of units are not reported till date, one way to get about is by following the secondary indicators as incorporated in (a) and (b).

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