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 Indiathe availability and affordability of fossil fuelbased chemical fertilizers at the farm level havebeen ensured only through imports and subsidies.The Government of India has been trying topromote an improved practice involving use ofbio- fertilizers along with fertilizers. These inputshave multiple beneficial impacts on the soil andcan be relatively cheaper and convenient to use.Failure of a market to build up the need for publicintervention when the expected social gains from arelatively new product outweigh the costs, whereasthe private gains do not and uncertainty about theproduct performance coupled with long periods oflearning involved can lead to poor demand fromend users who are farmers. Field studies havedemonstrated them to be effective and cheapinputs, free from environmentally adverse implicationsthat chemicals have.

Moreover, Biofertilizers can act as a renewablesupplement to chemical fertilizers and organicmanures. They have the capacity to producenatural resistance in plants against pests and soilborne diseases, because antibodies are producedand beneficial micro-organisms participate in thesoil to increase fertility (Board, 2004). For soiltreatment, 500-800g of biofertilizers is mixedhomogenously with 10-15 kg of FYM and themixture is added to soil at the time of sowingbecause Biofertilizers require organic manuresafter being added to soil for their growth anddevelopment, as well as for their activity in soil.But consistency in gains again eludes the trialsconducted by All India Coordinated Pulse ImprovementProject Transportation because distributionis a major problem in rural areas (Khan andMazid, 2011). There is an on-going attempt topromote Biofertilizers in Indian agriculturethrough public intervention, and in keeping withthe spirit of the times, these policies motivateprivate sector and the profit motivation will helppropel the new technology. Government of Indiaand various State Governments have been promotingthe nascent biofertilizer market both at the
level of the user-farmer and the producer-investorthrough the following measures:

(i) farm levelextension and promotion programmes,
(ii) financial assistance to investors in setting up units,
(iii) subsidies on sales and
(iv) direct production inpublic sector and cooperative organizations and inuniversities and research institutions.

The presentexpiry period is limited to 6 months which isrelated to carrier (lignite/charcoal). High moisturecontent attributes contamination of microorganismsthat either compete with Biofertilizers or haveantagonistic interaction. Retail shops do not sellBiofertilizers because of short shelf-life, limited demand and lack of storage facilities. The reasonsresponsible for it are:

- lack of marketing infrastructureand distributing network;
- ignorance offarmers about Biofertilizers;
- absence of publicsupport and lack of assurance of higher benefits forretailers.

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 abridge between removals and additions to soilnutrients where farmers can scarcely afford costlyinputs and that too in a risky environment. Nfixation on land amounts to 135 million metric tonsper annum average. In recent years use ofRhizobium culture has been routinely recommendedas an input in pulse cultivation. In Indiaabout 30 million hectares of land is under pulsescultivation. They belong to family Rhizobiaceae,symbiotic in nature, fix nitrogen 50-100 kg/ hawith legumes only. It is useful for pulse legumeslike chickpea, red-gram, pea, lentil, black gram,etc., oil-seed legumes like soybean and groundnutand forage legumes like berseem and lucerne. Itcolonizes the roots of specific legumes to formtumour like growths called root nodules, which actas factories of ammonia production. Rhizobiumhas the ability to fix atmospheric N- in symbioticassociation with legumes and certain non legumeslike, Parasponia (Saikia and Jain, 2007)

Biological N fixation (BNF) occurs in the freeliving states, in association or in symbiosis withplants. From an ecological point of view, the mostimportant N fixing systems are the symbioticassociations. Rhizobium-a symbiotic Biofertilizerscan be used for legumes crop and trees (e.g.,leucerna) and is a crop specific inoculant, forexample, *Rhizobium trifoli*for berseem; *Rhizobiummelilotti*for leucerne, *Rhizobium phaseoli* forgreen gram, black gram, *Rhizobium japonicum* forsoyabean; *Rhizobium leguminoserum*for pea,lentil; *Rhizobium lupini*for chickpea. Theseinoculants are known for their ability to fixatmospheric N- in symbiotic association withplants forming nodules in roots (stem nodules in*sesabaniamrostrata*). Rhizobium is however limitedby their specificity and only certain legumes arebenefited by this symbiosis.N fixation by leguminous and other crops isreported to be 44 million metric tons per annum.Crop responses to *Rhizobium* inoculation underfield conditions have been quite variabledepending upon field conditions, type of crop,inoculant used and soil conditions. In terrestrialhabitats the symbiotic fixation of N by rhizobiacounts for the largest combustion of combined N(Philippot and Germon 2005). Moreover, seed andstraw yield of green gram increased significantlyup to single inoculation with Rhizobium under 20kg N + 45 kg P_2O_5 ha-1 fertility level. Field trialscarried out in different locations have demonstratedthat under certain environmental and soilconditions inoculation with azotobacteria hasbeneficial effects on plant yields (Mazid et al.,2011d). The appropriate strain can increase thecrop yield up to 10-35% since N is fixed at 40-200kg/ha which is able to meet up to 80-90% of Nneed of the crop. Also, residual N is beneficial forthe next crops grown in the same field. Inoculationof 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 ofpods plant-1, number of seed pod-1 and 1000-seedweight (g) recorded were 25.5, 17.1 and 4.7 perent more over the control, respectively which wasstatistically significant.

Azotobacter (Family: Azotobacteriaceae)

The Azotobacter colonizing the roots not onlyremains on the root surface but also a sizableproportion of it penetrates into the root tissues andlives in harmony with the plants, belongs to family

Azotobacteriaceae, aerobic, free living, andheterotrophic in nature. Azotobacters are present inneutral or alkaline soils and *A. chroococcum*is themost commonly occurring species in arable soils.

A. vinelandii, *A. beijerinckii*, *A. insignis* and *A.macrocytogenes*are other reported species. Theoccurrence of this organism has been reportedfrom the rhizosphere of a number of crop plantssuch as rice (*Oryza sativa* L.), maize (*Zea mays*L.), sugarcane (*Saccharum officinarum* L.), bajra(*Pennisetum glaucum* L.), vegetables andplantation crops (Mazid et al., 2011e). They do not,however, produce any visible nodules or out growth on root tissue. These are non-symbioticfree living aerobic bacteria possessing highestrespiratory rate and can fix N up to 25 kg/ha underoptimum conditions and increase yield up to 50%.Alkaline phosphatase activity in the peach rootswas highest with *Azotobacter chroococcum*+ Pfertilizer. This has been found beneficial to a widearray of crops covering cereals, millets, vegetables,cotton and sugarcane. The effect of *Azotobacterchroococcum*on vegetative growth and yields ofmaize as well as the effect of inoculation with thisbacterium on wheat has been studied by numerousauthors. It is free living and non-symbiotic Nfixingorganism that also produces certainsubstances good for the growth of plants andantibodies that suppress many root pathogens.They improve seed germination and plant growthby producing B-vitamins, NAA, GA and otherchemicals (plant hormones) that are inhibitory tocertain root pathogens (Mazid et al., 2011f).Moreover, increase in yield due to Azotobacteriainoculation 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 arboretum* L.), pearlmillet (*Pennisetum glaucum* L.) and paddy, thoughtheir response depends upon the amount of organicmatter available in the soil. For sugarcane, *Azotobaacterindicum*is suitable in acidic sols in which itforms *rhizobacteriocoenotic*association with rootsand application in soil is economical but a largeamount of organic C- and Mo is needed forstimulating nitrogenase enzyme activity during Nfixation(Mazid et al., 2012b; Khan et al., 2012a).

Azospirillium (Family: Spirillaceae)

It is also *Bacillus polymixa*. When applied torhizosphere it fixes atmospheric N (free livingstate) and makes it available to crop plants. This isalso N-fixing microorganism, beneficial for nonleguminous plants, belongs to family Spirilaceae,heterotrophic and associative in nature. In additionto their N fixing ability of about 20-40 kg/ha, theyalso produce growth regulating substances.Although there are many species under this genuslike, *A. amazonense*, *A. halopraeferens*, *A.brasilense*, worldwide distribution and benefits ofinoculation have been proved mainly with the *A.lipoferum and A. brasilense*. Azospirillum provedsignificantly beneficial in improving leaf areaindex and all yield attributing aspects. Grain yieldand harvest index (HI) also exhibit a discernableincrease with use of biofertilizers. Besides this, theAzospirillum form associative symbiosis withmany plants particularly with those having the C4-dicarboxyliac path way of photosynthesis, becausethey grow and fix N on salts of organic acids suchas malic, aspartic acid. Thus it is mainly recommendedfor maize, sugarcane, sorghum (*Sorghumbicolor*L.), pearl millet etc. Like Azospirillium,the benefits transcend N-enrichment throughproduction of growth promoting substances.Dipping the roots of rice seedlings in 2%suspension of Azospirillum inoculant increased theield by 100 kg/ha (Kennedy et al., 2004).

Herbspirillum

It is an association symbiont that is responsible forfixation at atmospheric N on the roots ofsugarcane. Enhancing the availability of N, promotingthe uptake of nitrate, K, phosphate andproduction of growth promoting hormones(kinetin, gibberellic acid and auxin) are itssubsequently beneficial effects (Khan et al.,2011b).

Acetobacter

It is best adopted endo-phytically in sugarcaneecosystem and can tolerant high sucroseconcentration. This bacterium can fix N- up to 15kg/ha/year as plant secretes the growth promotinghormones IAA that enhance germination and rootdevelopment and ultimately helps in absorption ofplant nutrients. There are also changes in shares bytypes with moderate success in Azotobacters andby far the best performance is given by PSB. Thedecline in Rhizobium indicates that success ingroundnut and pulses was below expectation andannual capacity of units deflated by the number ofunits. A measure of capacity utilized is obtainedrelating actual distribution (as opposed toproduction) to capacity. Inoculation with Azotobacter+ Rhizobium + VAM gave the highestincrease in straw and grain yield of wheat plantswith rock phosphate as a P fertilizer.

Azolla Family: Azollaceae

Azolla can be used as green manure or as dualcrop. For green manuring, Azolla is sown in thefield or in a separate shallow pond. It is a freefloatingsymbiotic fern found on water surface,individually in low land field and water bodies.Water is drained off the field and Azolla isincorporated into the soil before transplanting ofpaddy. Dried inoculum of Azolla is also pre-soaked in 50 ppm of superphosphate solution for12 h and inoculated in the paddy filed (Kannaiyan,2002). One kg of it fixes 40-55 kg N/ha, 15-20P/ha and 20-25 kg K/ ha in a month, thusincreasing yield of flooded paddy by 10-20%.

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

These phototropic prokaryotic bacteria areeffective only in submerged paddy in presence ofbright sunlight by forming a bluish-green algae onstanding water and by converting the insoluble Pinto soluble forms fixing N to the tune of 2-30kg/ha thereby raising the crop yield by 10-15%when applied at 10kg/ha/BGA biomass decomposein soil and organic compounds are liberated andplant growth in regulated. These belong to eightdifferent families, phototrophic in nature andproduce Auxin, Indole acetic acid (auxin) andGibberllic acid, fix 20-30 kg N/ha in submergedrice fields as they are abundant in paddy, so arealso referred as 'paddy organisms'. N is the keyinput required in large quantities for low land riceproduction. Soil N and BNF by associatedorganisms are major sources of N for low land rice.The 50-60% N requirement is met through thecombination of mineralization of soil organic Nand BNF by free living and rice plant associatedbacteria (Rahman et al., 2009).BGA are photosynthetic N-fixers and are freeliving. They are found in abundance in India. Theytoo add growth-promoting substances includingvitamin B_{12}, improve the soil's aeration and waterholding capacity and add to bio mass whendecomposed after life cycle. Most N fixing BGAare filamentous, consisting of chain of vegetativecells including specialized cells called heterocystwhich function as micro nodule for synthesis andN fixing machinery. BGA forms symbioticassociation capable of fixing N- with fungi,liverworts, ferns and flowering plants, but the mostcommon symbiotic association has been foundbetween a free floating aquatic fern, the Azolla andAnabaena azollae (BGA).

Azolla is an aquatic fern found in small andshallow water bodies and in rice fields. The mostcommon species occurring in India is *A. Pinnata*and the same can be propagated on commercialscale by vegetative means. The important factor inusing Azolla as biofertilizers for rice crop is itsquick decomposition in the soil and efficientavailability of its nitrogen to rice plants. It hassymbiotic relation with BGA and can help rice orother crops through dual cropping or greenmanuring of soil (Ghosh, 2004).

Phosphate Solubilizing Microorganisms andMycorrhizae

Most of the Indian soils are low to medium in Pstatusand the efficiency of phosphate fertilizers isalso allowed due to fixation of large fraction ofapplied P into sparingly soluble inorganic phosphates.

Some times PSM produce plant growthhormones (IAA, GA etc.). Such soluble phosphorusis taken up easily by plants resulting in 10-20% increase in the yield of almost all the crops.Results of a greenhouse pot experiments withonion (*Allium cepa* L.) showed that application of*G. fasciculatum* + *A. chrooccocum*+ 50% of therecommended P rate resulted in the greatest rootlength, plant height, bulb girth, bulb fresh weight,root colonization and P uptake. Also the rates ofchemical phosphatic fertilizers can be broughtdown (Carter, 1967). Several reports haveexamined the ability of different bacterial speciesto solubilize insoluble inorganic phosphatecompounds, such as tri-calcium phosphate, dicalciumphosphate, hydroxyapatite, and rock phosphate.Among the bacterial genera with thiscapacity are pseudomonas, Bacillus, Rhizobium,Burkholderia, Achromobacter, Agrobacterium,Micrococcus, Aereobacter, Flavobacterium andErwinia. P, is both native in soil and when appliedin inorganic fertilizers, becomes mostly unavailableto crops because of its low levels of mobilityand solubility and its tendency to become fixed insoil. The PSB are life forms that can help inimproving phosphate uptake of plants in differentways. The soil bacteria belonging to the genera

Pseudomonas and Bacillus and Fungi are morecommon. The major microbiological means bywhich insoluble-P compounds are mobilized is bythe production of organic acids, accompanied byacidification of the medium.The PSB also has the potential to make utilizationof India's abundant deposits of rock phosphatespossible, much of which is not enriched. Through symbiotic association between certain fungi(glomus) and plant roots the uptake of nutrients isfacilitated and such symbiosis is called Mycorrhizae(Karandashov and Bucher, 2005). This is oftwo types, the ectomycorrihae, is found in treesand is beneficial for forest tress whereas, thesecond one is endomycoorhizae which is commonin crop plants. Transplant seedlings become hardsurvivors and growth of the soil borne pathogenscausing root disease is inhibited.

K-Solubilizing Bacteria

Bacteria such as *Frateuria aurantia* are capable ofmobilizing mixture of K into a usable form to the

plants known as K solubilizing bacteria, applied toall crops in association with other Biofertilizerswithout any antagonistic effect. However, whilepositive responses have been observed in a widerange of field trials, there is remarkable inconsistencyin responses across crops, regions andother conditions (Ghosh, 2004). Even for a givencrop the range of response is quite high. Rhizobium,Azospirillum, Azotobacter, BGA andPhosphate solubilizing bacteria like *B.magaterium, Pseudomonas striata*, and phosphatemobilizing Mycorrhiza have been widely acceptedas bio-fertilizers. However, these supply onlymajor nutrients but a host of microorganism thatcan transform micronutrients are there in soil thatcan be used as biofertilizers to supply micronutrientslike zinc, iron, copper etc., zinc being ofutmost importance is found in the earth's crust tothe tune of 0.008 per cent but more than 50 percent of Indian soils exhibit deficiency of zinc withcontent mostly below the critical level of 1.5 ppmof available zinc. Zinc can be solubilized bymicroorganism's viz., *B. subtilis,* *Thiobacillusthioxidans*and Saccharomyces sp. Thesemicroorganisms can be used as Bio-fertilizers forsolubilisation of fixed micronutrients like zinc. Theresults have shown that a *Bacillus sp.* can be usedas Bio-fertilizer for zinc or in soils where nativezinc is higher or in conjunction with insoluble cheaper zinc compounds like zinc oxide (Samoonet al., 2010).

Biofertilizers Required

The commercial history of biofertilizers beganwith the launch of 'Nitragin' by Nobbe andHiltner, a laboratory culture of Rhizobia in 1895,followed by the discovery of Azotobacter and thenthe blue green algae (BGA) and a host of othermicro-organisms. Azospirillum and Vesicular-Arbuscular Micorrhizae (VAM) are fairly newdiscoveries. In India the first study on legumeRhizobium symbiosis was conducted by N. V.Joshi and the first commercial production startedas early as 1956. However the Ministry ofAgriculture under the Ninth Plan initiated the realeffort to popularize and promote the input with thesetting up of the National Project on Developmentand Use of Biofertilizers (NPDB). Althoughbiofertilizers have been promoted as supplement orcomplement of chemical fertilizers, in reality theyare two alternative means of accessing plantnutrients. The strength of complementarity asagainst substitution between the two inputs is opento empirical verification, but there is no denyingthat farmers and producers do perceive thesubstitutability relation and believe that to anextent Biofertilizers have various benefits. Besidesaccessing nutrients, for current intake as well asresidual, different biofertilizers also providegrowth-promoting factors to plants and some havebeen successfully facilitating composting andeffective recycling of solid wastes. By controlling soil borne diseases and improving the soil healthand soil properties these organisms help not only in saving, but also in effectively utilising chemicalfertilizers and result in higher yield rates (Bot and Benites, 2005).To attain production targets, the Govt. of Indiaimplemented a central sector scheme calledNational Project on Development and use ofBiofertilizers (NPDB) during the Ninth Plan for the production, distribution and promotion ofbiofertilizers. A National Biofertilizers Development Centre was established at Ghaziabad as asubordinate office of the Department of Agricultureand Cooperation with six regional centres.The coexistence of smaller new units with thelarger ones of higher vintage has increased thevariety in industry as measured by the coefficientof variation (Ghosh, 2004). The share indistribution, however, has been relatively morestable despite showing a slight declining trend inthe last five years reportedly, however, this is onlypartially valid as units with large distributionnetworks do distribute over larger areas. Publicsector fertilizer giant IFFCO is located in Phulpurin Uttar Pradesh, IFFCO's MLN Farmers' Training Institute produces all strains of Biofertilizers andhave distributed it in states other than the homestate.

More than 70% of the large units are of longervintage reiterating that new entry has been mostlyin small units. About 70% of the small units cameinto being after March 1995. The small units showsome tendency to specialize in either nitrogenfixers or phosphate solubilizers while all the largeunits produce both kinds. Eastern states like Biharand Orissa are also served though the share hasgone down notably for West Bengal where distributionscame down to nil in 2000-02. Thedistribution does not follow that of chemicalfertilizers they supplement, where north is thelargest claimant. However, the eastern regioncomes last in share in both chemical and biofertilizersthough the share in the latter case is evenmore diminutive (Ghosh, 2004). The comparison,however, is not complete without bringing in thecropped area in the regions. In the case ofbiofertilizers, the initiatives taken by the publicsector along with numerous universities andresearch units, that are also state funded, must,

with time, lead to commercial success once thetechnology is transmitted to the field to drawprivate enterprise since the market is open forentry.

Our all modern agricultural practices widely carryon a very different heavy range of agrochemicalsincluding different types of organic and inorganicfertilizers (Brodt, 2002). They washed off fromlands along with water through irrigation rainfalldrainage etc. reaching into the rivers, lakes andstreams and so on. Where they turn fully to ournatural ecosystem then effect human life indirect/indirect ways such as:

1. Consumptions of vegetables grown in NO_3rich soil may lead to diseases (methaemoglobinaemia); then leads to variousailments as damage to respiratory and vascularsystem, blue coloration of skin and evencancer.

2. Chemical fertilizers use imbalance of wholemineral pattern of plant body. For example,excessive K- treatment decreased valuablenutrients in foods such as ascorbic acid andcarotene.

3. Depleting soil fertility due to widening gapbetween nutrient removal and supplies.
4. NO_3 fertilizers increase the total crop yield butat the expense of protein. Since, most ofIndians are vegetarians, consumption of lowqualities of protein leads to malnutrition.
5. Increasing concern about environmental hazards.
6. It is estimated that by 2020, to achieve thetargeted production of 321 million tonnes offood grain, the requirement of nutrient will be28.8 million tonnes, while their availabilitywill be only 21.6 million tonnes being a deficitof about 7.2 million tonnes.
Other problems are associated with compatibilitywith host genotypes, improper handling facility,inoculants techniques and improper dose. Therefore,viable effects of Biofertilizers application arenot generally observed in traditional agriculture(Rivera and Fernandez, 2006). The potentialdemand of Biofertilizers is quite large and farexceeds the present production levels. It has beencomputed at 348 thousand tons with the assumptionof Biofertilizers application in 50% of thegross cropped area under different crops(Wiesman, 2009). The average distribution alsodeclined in the first two years possibly signallingthe need for a down size but picked upsubsequently. The average capacity utilization hasbeen poor but the downsizing may have arrestedthe declining trend. Depending on the source offunding, Biofertilizers production units located indifferent 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 beenestablished with the GOI support. They have over900 tonnes of total installed production capacityand over 6000 tons of the total Biofertilizersproduction. Remaining 38 biofertilizers productionunits with total installed production capacity is stillvery low compared to potential demand of 235thousand tons for bacterial Biofertilizers (Choonawala,2007).

Procedure

Biofertilizers are made up of two compounds, themicroorganisms and a carrier material. Apart from the microorganisms itself, carrier plays the mostsignificant role in any formulation. It involvesseveral steps. Apart from environmental factors,deficiencies in handling procedure are a majorcause of under performance in real life application.The high sensitivity to temperature and otherexternal conditions of these 'living' inputs, callsfor 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 carriermaterials; mass multiplication of selected competentstrain of organisms in the broth media andmixing of quality tested broth cultures of themicroorganisms in the homologous carrier. Inoculantsare used to gain maximum number of spores.It is a good practice to promote biofertilizers as aninput conjunctive to other forms of fertilizers, butkeeping in view the protection given to chemicals,there is some ground for subsidizing the former toencourage their use (Sundar, 2002). However,there is a need to work out a systematic anduniform way to give out subsidies so that they donot distort inter unit prices and help some units atthe cost of others. The States should be stronglyguided on this norm. The main purpose of thesubsidies would, however, be to induce farmers totry out the input at affordable and acceptable pricesrather than to support certain producers directly.Production and distribution of different biofertilizerswere also undertaken but subsequentlydiscontinued as the centres redefined their roletowards R&D and HRD related activities. Capacitycreation and production was, however, encouragedthrough one time grant for new units. Numerousstudies on technological evolution emphasized thedevelopmental role of a firm, and the strength of itssales network, creating market and drawing marketfeedback, for its success. In general, firms withlarger production facilities are expected to investmore in networks to understand and access themarket but it is not uncommon for firms withlarger distribution networks to act as marketingagents for smaller units who are lacking and in fewrare cases like that of NAFED the distribution evenexceeds capacity. The sales networking would bestronger also for concerns that are in some wayalready in the business of selling agriculturalinputs (Ghosh, 2004). Since, the exact scope andnature of the units or possibly their parentcompanies is not clear from the data, pastexperience in selling biofertilizers may beconsidered as an indicator of their marketingcapabilities (Singh, 2007). The curing perioddepends upon the growth rate of themicroorganisms to be used. After curing, theBiofertilizers is packed generally in polythene bagsmade of 50-70 mm thick and low density sheets.Each packet should be marked legibly to giveinformation about the name of the product, cropfor which intended, date of manufacture, expirydate, net quality meant for 0.4 hectarestorageinstructions and directions for the use ofbiofertilizers. Each packet duly tested should bemarked with ISI certified mark.

Eligibility Criteria

It may be noted, that only 30% of India's totalcultivable area is covered with fertilizers whereirrigation facilities are available and on theremaining 70% of the arable land, which is mainlyrain fed, very negligible amount of fertilizers arebeing used. It is a very critical task because anefficient strain of the N-fixing/P-solubilizingmicroorganisms is as important in Biofertilizersproduction as seed is in crop cultivation (Saravanakumarand Gandhi, 2009).

The main criteriafor selecting an efficient N fixer are its ability to

(a) Fix N over a range of environmental conditions

(b) Competition with other strain

(c) Multiplyingin broth and survival in the carrier etc.

Crudecalculations of bulk and cost in terms of N on thebasis of reported N equivalence indicates thatbiofertilizers are cheap and convenient comparedto chemical and farm organic fertilizers andtherefore have considerable promise for crops likecereals, oilseeds, vegetables. Nevertheless, a crude

estimation is attempted for indication of thepotential without attaching significance to themagnitudes as such. The FAI reports (1996, 1998,and 2001) give information of annual distributionlevels of various inoculants and their sale prices forconsecutive years by firms. In addition the annualcapacity as of March is provided for the three years1995, 1997 and 1999. Two approaches viz, singleand multi-strain inoculating has been recommendedand both practices are in use *Rhizobium* inoculum is produced in shake-flasks/fermentsusing appropriate growth medium. In addition,

Azolla is vegetative mass-cultured in small fieldnurseries (20m x 2m) containing 10 cm standingwater and irrigation channels (Rao, 1982). Eachnursery is supplied with 10 g super phosphate andinoculated with 8 kg fresh Azolla to yield 40-50 kgfresh Azolla per plot in 15 days.

Environmental Limitations for Applicationof Bio-fertilizer

1. Unavailability of suitable carrier Resourceconstraint
2. Market level constraints and lack of awarenessof farmers
3. Lack of quality assurance and limited resourcegeneration for Biofertilizers production
4. Seasonal and un assured requirement
5. Soil and climatic factors and inadequateexperienced staff
6. Native microbial population, faulty inoculationtechniques and mutation during fermentation

Indian Market for Biofertilizers

Around 170 organizations in 24 countries areengaged in commercial production of Biofertilizers.NifTAL (U.S.A) has played a major role inthe popularization of *Rhizobium* inoculants. Insuch circumstances, the price of Biofertilizersalong with the risk and responses will be weighedwith those of chemical fertilizers, and promotion oftechnology for environmental reasons would callfor some degree of protection to minimize theinter-fertilizer price distortion. Australia has takenthe lead role in the quality control of differentcommercial products. Philippines implemented theNational Azolla Programme (NAAP) in 1982 todevelop farm-based technology for the use ofAzolla fertilizer for rice. The current global marketfor organically raised agricultural products isvalued at around US$ 30 billion with a growth rateof around 8%. Nearly 22 million hectares of land isnow cultivated organically (Sheng et al., 2009).The organic cultivation represents less than 1% ofthe world's conventional agricultural productionand about 9 percent of the total agricultural area.This only highlights the tremendous potential inthe growth of biofertilizers. Now, there are 60production units producing 10-115 tons per unitper year. Different State governments also providesubsidies sometimes up to 50% of the salesrealization but the manner of subsidization is ratherunsystematic. In many cases, the discriminationand manipulation in subsidizing lead to a lot ofintra industry variation in prices.One of the main barriers faced by the producersand investors is inadequate demand and the inconsistent and seasonal nature of the existingdemand. It may be recalled that the technology isas yet nascent and evolving. The rice dominatedeastern region remains a non-starter and the wheatrice growing north has not shown much interest(Luft and Korin, 2009). Research on developingefficient, temperature tolerant and hardy strains is avital step to the actual success of the technology.

Inparticular, there can be some focus on the potentialsof the technology in rice and cereals ingeneral although its significance for cropdiversification is of equal concern (Mahmud et al.,1994). The government also plays a dominant partin marketing Biofertilizers in three possiblechannels:

(a) State government via District levelOfficers and Village level workers to farmers,

(b)State Marketing federation via cooperative bodiesto farmers and

(c) State Agro-industries

Corporations via Agro service Centre to farmers.The producers are, however, free to sell throughtheir own sales network or through market. Overthe period of four years the number of units went up by 53% from 62 to 95 and further to 122 in2002. The total capacity expanded by 12% goingby the information on units reporting theircapacities. New private units joined the industryimproving their numeric share while the publicsector, after the initial burst slowed its pace.However, a deeper look would be more illuminative.The distribution of Biofertilizers, and its adoptionrate has not consistently grown over time and hasslowed down in the late nineties. Starting from asmall base one would have expected a faster andpossibly accelerating growth performance as theinput finds greater acceptance. Secondly, althoughthere have been more and more new entries in themarket, the average capacity came downcharacterizing the industry by a large number of small units. While size adjustment in infantindustry is normal, it must be borne in mind thatdistribution of an agro-input also calls forsubstantial sales networking and a deep understandingof the field reality in agriculture (Ghosh,2004). Whether the smaller units will have thenecessary expertise and incentive for meeting farmdemands or synergistic associations with biggerproducers or simply distribution agents or local bodies would be the desired institution is a matterof review. There has practically been no diffusion of the technology despite the central government'sinterventions and the distribution among units has tended towards greater concentration especially inMaharashtra and other states of the west and south. Govt. of India and the different State Governmentshave been promoting use of Biofertilizers through grants, extension and subsidies on sales withvarying degrees of emphasis (Alam, 2000). Withtime farmers to learn about the technology formingtheir perception on the basis of agronomic realitiesof their regions, the knowledge gained fromexperiences of farmers around them and includingthemselves and the information provided bydifferent disseminating agents and form their owndecisions of adoption (Khan et al., 2011c). GOIhas providing the National Biofertilizers DevelopmentCentre act Ghaziabad with six regionalcentres at Bangalore, Bhubaneswar, Jabalpur, Hisar, Imphal and Nagpur. In the absence ofreported information on farm level use of theinputs, this can help in understanding the progressof the technology and its adoption in India.

Conclusion

The new techniques of applications particularly useof methylcellulose for seed coating and pellets fordirect soil application should be encouraged. Theresponses usually depend on several environmental factors. (1) The type of soil as measured by itswater holding capacity, its levels of other nitrates,phosphate and even calcium and molybdenum thathelp in protein synthesis in Rhyzobia and thealkalinity, salinity and acidity of soil, all affect theresponse (Naeem et al., 2011; Khan et al., 2011d; Khan et al., 2012b). Higher dose of mineral N- asstarter suppresses nodulation, reducing response of Rhyzobium but phosphate deficiency can be aninhibitor also. (2) The inadequacy of organicmatter especially common in dry-land andagriculture is a deterrent more for the nonsymbioticstrains, which essentially depend on soilorganic matter for energy. Phosphobactrin responsewas found to be positive only in soils withhigh organic content and low available phosphorous.(3) Soil water deficit and hightemperature (hyper-thermia) are prominent abioticfactors that affect N- fixation in dry land agriculture (Mazid et al., 2011g; Khan et al.,2012c). (4) Native microbial population opposesthe inoculants. In general, predatory organisms,often already present in the soil are more adaptedto the environment and out compete the inoculatedpopulation.Microbial sensing and response mechanisms in theform of cell to cell communications through theuse of small signalling molecules have been reported. In case of iron deficient soil,*Pseudomonas* species colonize crop roots thatresults in improvements in plant growth (Khan etal., 2011e). These aspects are important in dry soilaffecting bacterial population in rhizosphere.Pelleting of seed with lime for acidic soil and withgypsum for saline soil is beneficial. Chemicalfixation in soil limits the use of Biofertilizerstherefore different strains of phosphorus solubilising bacteria mixed with rock phosphate andsingle super phosphate may be needed. Farmersshould be advised to mix Biofertilizers to getbenefits of the synergistic effect on plant growthand ultimately on yield, but multistrains biofertilizersmay be avoided (Khan et al., 2011f). Ifchemical fertilizers are to be applied to soil, thereshould be a gap of 15-20 days for better N-fixation.Moreover, cold storage facility should be providedat districts level to facilitate timely availability toformers at the village level, as majority of farmersuse Biofertilizers as and when needed and evenafter expiry date.Over time as the industry emerges from infancywith public guidance, the following observationswill be expected due to following reasons, (a)increasing sales volumes and diffusion across thecountry, (b) greater role of profit motivated privateenterprise. Since, information on farm level usageof biofertilizers or profitability of units are notreported till date, one way to get about is byfollowing the secondary indicators as incorporatedin (a) and (b).

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