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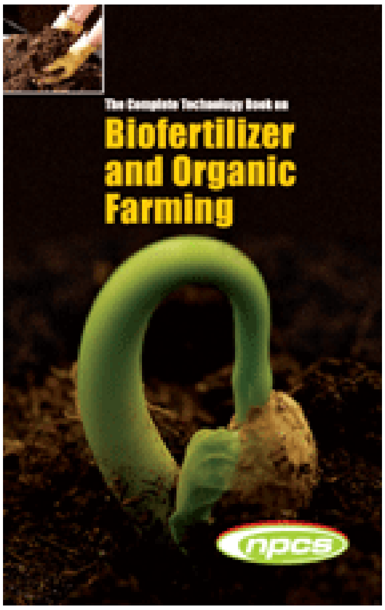
The Complete Technology Book on Biofertilizer and Organic Farming (2nd Revised Edition)



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Biofertilizers are seen as an important alternative technology, since the negative externalities of chemical fertilizers have become well known. The use of the latter has led to considerable environmental cost. Biofertilizers do not pollute the soil and do not disrupt the ecological balance, and hence are environment friendly. An increasing number of farmers are using biofertilizers, and the numbers of biofertilizer manufacturing units have also grown considerably. Organic farming system in India is not new and is being followed from ancient time. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (biofertilizers) to release nutrients to crops for increased sustainable production in an eco friendly pollution free environment. Organic farming has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals.
Going organic may be a clear way of getting back to basics and getting away from the havoc chemicals can wreak on our health and our environment but the basics themselves may not be so clear. This book provides the view of immense potential of biofertilizers as a supplementary nutrient source for the crops and covers all major types of bacterial fertilizers.

The major contents of this book is crop response to biofertilizers, nitrogen fixation, phosphate solubilising microorganisms, application and evaluation techniques, Bio Gas production, pest and disease management system in agriculture, production, promotion, quality control, marketing, future research planning, photographs and details of machineries, list of manufacturers and suppliers of biofertilizers and organic farming in directory section.

This book will be of use and interest to consultants, researchers, libraries, entrepreneurs, manufacturers of biofertilizer and for those who wants to venture in to this field.

Content:

Sample Chapter:

INTRODUCTION TO BIOFERTILIZERS

According to an estimate 240 million tonnes of food grains will be required to feed about one billion expected population by 2000 AD in India and to achieve this milestone, a sizable quantity of mineral fertilizers will be required. The total fertilizer requirements of our country would be 23 million tonnes as against the present consumption level of 13 million tonnes per annum. The problem is so acute that it is beyond any single type of nutrient source to accept the challenge of appropriate nutrient supply. Integrated use of all the sources such as mineral fertilizers, organic manures, biofertilizers, etc. is the only alternate for improving soil fertility. The use of organic manures and mineral fertilizers is in practice but use of biofertilizer in agriculture is not very popular. Hence, there is a need to make its use popular. The increased cost of fertilizer production coupled with progressively increasing use of chemical fertilizers particularly needed by HYV (High Yielding Varieties) are adding to the cost of cultivation of crops and causing nutritional enhancement in Indian agriculture. Recent energy crisis, rapid depletion of non renewable energy sources like eneptha, natural gas, sulphur, etc. their production also releases pollutants, nutrient potential from all organic sources in India is over 19 million tonne/year which is adequate requirement to meet 70 per cent of the projected nutrient requirement for the decade ending 2000 A.D. But this potential is made up of more by contribution from bovine excreta and crop residues than from any other source which alone contributes about 14.8 million tonne/yr.

It has been estimated that almost 87 per cent of cooking energy in India is derived from firewood, cow dung and agricultural waste and only rest 13 per cent is from commercial sources. Unless the firewood sources are expanded and a situation is created for facilitating social and economic access of the rural poor to the developed sources, the organic potential of the country would not become fully available for the crop production.

Legume effect has been successfully utilised in green manuring. The amount of nitrogen fixed by ordinary green manure crop like Dhaincha, Sunhamp, etc. may average about 60 kg/ha. However, the amount of nitrogen accumulated by green manure crop is not likely to be able to provide to the level of nitrogen accumulated by green manure crop is not likely to be able to provide to the level of nitrogen currently needed by high yielding varieties. Therefore, integrated use of both chemical fertilizer and green manuring is best solution. Thus, green manuring with Dhaincha (Sesbania aculetai) incorporated @ 12.5 t/ha before transplanting of paddy in Haryana gave higher yield as compared to these from NPK alone. Succeeding wheat also yielded higher on green-manured plots, confirming carry over effects of green manuring.

It has now become possible to meet a large part of our total nitrogen demand through proper husbandry of BNF (Biological Nitrogen Fixation) by micro-organism (bio-fertilizers) in crop production systems. Bio-fertilizers are capable of providing an economically viable level for achieving the ultimate goal of enhanced productivity. The crop microbial soil ecosystem can, therefore, be energised in sustainable agriculture.

Promotion of agro-forestry and tree planting in waste lands and community holdings is most appropriate strategy to accomplish the twin objectives of having sufficient firewood and rejuviniate the degraded land.

Therefore, both the research and extension have to take note of the increasing importance of IPNM in maintenance of soil fertility and of plant nutrient supply to an optimum level for sustaining desired crop productivity through optimisation of benefits from all possible sources of plant nutrients in an integrated manner. The cropping system rather than an individual crop, and the whole farm rather than an individual field should be the focus of attention.

CONCEPT OF IPNM

The basic concept underlying the IPNM is the maintenance of adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimisation of the benefits from all possible sources of plant nutrients in an integrated manner. The appropriate combination of mineral fertilizers, organic manures, crop residues, compost of N-fixing crops varies according to the system of land use and ecological, social and economic conditions and decreases in subsidy on fertilizers by Government have become the cause of concern to the government, fertilizer industry and farmers. Import of fertilizers to meet the growing demand has imposed a heavy foreign exchange burden on the country. In this context, it was considered necessary for an alternative renewable source of nutrient supply to the crops and as such emphasis has been given to the fertilizers of the biological origin. The biofertilizers and green manures are used in agriculture to combat the ill effects of chemical fertilizers. It is necessary to adopt an integrated nutrient supply system by means of judicious combination of fertilizers, organic manures and biofertilizers.

INTEGRATED PLANT NUTRIENT MANAGEMENT (IPNM)

Sustainable agriculture requires the management of resources in a way to fulfill changing human needs without damaging order deteriorating the quality of environment and conserving vital natural resources. For the country, the compulsion of increasing crop yields per hectare is simply a matter of necessity to achieve production target of atleast 225 million tonnes by the turn of century to feed over 1 billion people in the ever deteriorating land: man ratio. India is fourth largent user of chemical fertilizers (12.5 million tonnes of NPK nutrients) in the world, its soils are still being depleted of their inherent nutrients reserve as a result of wide gap between additions (12.5 million tonnes) and removal (18.5 million tonnes). One tone produce removes on average 32 kg nitrogen: 12 kg phosphorus and 58 potash.

The strategy for sustaining satisfactory yield levels envisages nutrients balances and efficient nutrient cycling. This can be successfully achieved through integrated plant nutrients supply system. Integrated nutrients management involves tapping of all the major sources of plant nutrients be it soil nutrient reserve, mineral fertilizers, bulky organic manures, compost, green manures, biological inoculants etc.; in a judicious way and to ensure their efficient use. One important feature of this approach is that the fertilizer recommendation should take into account the cropping system as a whole rather than individual crops in a system.

The nutrient supply from soil can be enhanced by adopting appropriate soil management and conservation practices to reduce losses of nutrient through leaching, erosion and run off. Amelioration of problem soils and improving soil physical conditions insure maximum possible efficiency of applied nutrients.

There is great need to use available fertilizers most efficiently. This will ensure not only clean environment but also higher return by using a somewhat lower fertilizer doses. Fertilizer use efficiency is of high order when nutrients are applied in needed quantities in a balanced proportion at appropriate time in a proper form with suitable method in right way to a crop. Besides, soil moisture, weed control also has a considerable impact on response of fertilizers and efficient use of added plant nutrients. At present, the nutrient use in India is much less compared to that of other countries. Against world average consumption of 95 kg/ha we are using 74 kg/ha with national productivity level of merely 1.1 metric ton per hectare.

Under the emerging situation of the global energy crisis and escalating high cost of inorganic fertilizers dependence on chemical fertilizers alone as a source of plant nutrients has to be supplemented by some other sources. India has a great potential for the production and use of organic manures in cropping systems. Organic manures are valuable not only as supplier of nutrient elements such as N, P and K but even more so for their ability to mobilize native soil phosphorus and render it available to crops. They even enhance fertilizer use efficiency when applied in conjunction with mineral fertilizers. Organic residues however are bulky and have low nutrient contents. The estimated Contrary to the Low External Input (LEI) and Organic Farming, the IPNM involves a low to medium external input approach taking into holistic view of soil fertility and plant nutrient management for a targeted yield based not only on cropping and farming systems but also distinct geographical areas or villages as dynamic system.

With almost twice the quantity of plant nutrients being removed from soil than what is added through fertilizers, the growing nutrient imbalance poses a major threat to sustain soil health and crop productivity. The recent fall in fertilizer consumption due to unprecedented hike in the prices of P and K fertilizers has further aggravated the problem and has underlined the need for adoption of Integrated Nutrient Supply System (INSS) which involves the combined use of different nutrient sources such as chemical fertilizers, organic manures and biofertilizers etc.

Biofertilizers (BF) (microbial nutrients) are the products containing living cells of different types of microorganisms which have an ability to mobilise nutritionally important elements from non usable to usable form through biological process. Although the advent of the phenomena is as old as a century, the need of its commercial exploitation was not felt in traditional agriculture. In recent years, biofertilizers have emerged as an important component of INSS and hold a promise to improve the crop yields and nutrient supplies.

Food production of a country is closely associated with its population. Increased production from a unit area brings abundant pressure on land. This leads to denudation of forests and grassland cover and increase of soil erosion. Energy resources are necessary for intensive agriculture and investments are not only involved in highly mechanised form operations but also in the production of fertilizers, herbicides, pesticides and other materials commonly used in modern agricultural practices. Energy and fertilizer constitute a serious problem and farming does not remain economically feasible. Moreover, increased use of fertilizers may lead to health hazards apart from soil erosion. Increasing population has therefore compelled many nations to take necessary steps to increase food production by alternative means.

The most important of the biological processes existing on earth are photosynthesis and nitrogen fixation. Biological Nitrogen Fixation (BNF) is second to photosynthesis. Nitrogen as one of the two abundant elements in biosphere help in soil fertility. It is one of the major limiting factors responsible for primary production in agro-ecosystems. The process of photosynthesis involves the fixation of carbon and nitrogen through BNF. The atmosphere contains about 350 ppm of carbondioxide and 79% nitrogen. However, nitrogen gas is not available in the form of that most plants or animals can use. They require nitrogenous components such as nitrate or ammonium and are usually supplied to them as fertilizers. The required forms of nitrogen are rather expensive and beyond the reach of most of the poor farmers.

Biological Nitrogen Fixation can in many instances help to alleviate heavy fertilizer demand which could be better used in various parts of the world. A global inventory of the process of N2 for agriculture crop production indicates that BNF is predominant. Approximately 175 million metric tonnes of N2 are fixed annually. Approximately 90 million metric tonnes are fixed biologically in agriculture soils, 35 million tonnes coming from legumes crop and 10 million tonnes from non-legumes with 45 million coming from pastures and grasslands. The global value of BNF runs in several dollars. Nitrogen economy is different. In the recent years the fact is well illustrated by quoting two estimates varying by approximately 100%. The estimates of Dr. Dahwiche of Germany suggested that about 100 million metric tonnes of N2 is turned over on the earth each year whereas, Dr. Burns and Hardy of USA in 1975 suggest that the figure is closer to 200 million tonnes annually. These does appear to be agreement that perhaps two third of the N2 cycling annually on the earth comes from biological rather than chemical N2 fixation. There are various food crops existing on the earth of which 95% of the world's food supply come directly or indirectly from plants. Sixty per cent of the calories and 50 per cent of the proteins consumed by people comes from the cereal grains, while 20 per cent of the protein is provided by the seed legumes. This protein comes directly or indirectly from either biologically or chemically fixed nitrogen.

BIOFERTILIZER DEVELOPMENT

At present India produces about 117 million metric tonnes of food grains for its growing population of more than 800 million people. During the recent plan the target to produce is additional 30 million food grains and

5 million tonnes of pulses and oil seeds. In order to meet the food requirment of ever increasing population, the nitrogen fertilizer requirement for crop production by 2000 AD is estimated to be about 11.4 Ã- 106 tonnes as against 3.9 Ã- 106 tonnes. At present the waste gap cannot be filled up merely through the production of synthetic nitrogenous fertilizers due to scarcity of high cost of raw materials such as fossil fuels. Biological nitrogen fixation is the key to sustain agricultural productivity application of biofertilizers in the field is the viable alternative. Biofertilizer as a living fertilizer composed of microbial inoculants or groups of microorganisms which are able to fix atmospheric nitrogen, the microorganisms are known as biological nitrogen fixers. They are grouped into free-living bacteria (Azotobacter and Azospirillium) and the blue green algae and symbionts such as Rhizobium, and Frankia and Azolla.

In fertilizer manufacturing factories, nitrogen is fixed industrially, by means of the Haber Bosch process requiring H2 gas, very high temperature and enormous energy. Industrially fixed nitrogen has been used precipituously. It was produced 4.0 lakh metric tonnes in 1905. This was increased to 3.5 million tonnes of nitrogen fertilizer was produced industrially. Meanwhile the contribution of biologically fixed nitrogen has not changed. The estimate of chemically fixed nitrogen for 1976 is 42 million metric tonnes. It is projected that by 2000, if we continue to rely entirely on increased use of chemical fertilizers to achieve the food production level more demand for fertilizer nitrogen to results and around 100-200 million metric tonnes would be needed to produce at an average cost of rupees.

MATERIALS OF BIOLOGICAL ORIGIN

Indian soils are usually poor in organic matter as well as in nitrogen. The materials of biological origin which are commonly used to maintain and improve soil fertility may be grouped into two main categories - (a) biofertilizers and (b) green manures (Discussed in Organic manures).

BIOFERTILIZERS

The term biofertilizers or which can be more appropriately called 'microbial inoculants' can be generally defined as a preparation containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilising or cellulytic microorganisms used for application of seed, soil or composting areas with the objective of increasing the numbers of such microorganisms and accelerate certain microbial process to augument the extent of the availability of nutrients in a form which can be easily assimilated by plant. In large sense, the term may be used to include all organic resources (manure) for plant growth which are rendered in an available form for plant absorption through microorganisms or plant associations or interactions.

CLASSIFICATION

Biofertilizers can be broadly classified into three categories:

POTENTIAL OF BIOFERTILIZERS IN CROP PRODUCTION IN INDIAN AGRICULTURE

Soil harbours a range of microorganisms which bring about a number of biochemical reactions in soil. The soil organisms are classified into two broad groups i.e., soil flora and soil fauna; these are again subdivided, depending upon their size such as micro and macro flora. Soil microflora includes bacteria, fungi, actinomycetes, algae, etc. Of these groups, bacteria are the most abundant followed by actinomycetes, and fungi; algae are found under specific situations. The biomass and population of these microorganisms in soil are found under specific situations. The biomass and population of these microorganisms in soil have been given in the table 2 below:

TABLE-2 : IMPORTANT SOIL MICROORGANISMS, THEIR NUMBER AND BIOMASS

Microorganisms	Average number(in lakhs) per g of soil	Average biomass(in Kg per ha)

Bacteria	1000	500
Fungi	10	1000
Actinomycetes	100	750
Algae	0.01	150

The presence of these microorganisms make the soil a living and active system. These microorganisms play a significant role in the life cycle of plants and animals through a number of processes such as decomposition, solubilization, nutrient fixation and supply of plants.
Biofertilizer means using living organisms as fertilizer, either to fix atmospheric nitrogen or to solubilize mineral nutrients like phosphorus. The microbial inoculants have attained special significance in modern agriculture. Keeping in view the increasing cost of chemical fertilizers and poor purchasing capacity of Indian farmers several microorganisms which can be used in agriculture are being listed in table-4.
TABLE-4: IMPORTANT MICRO ORGANISMS CONSTITUTING BIOFERTILIZERS

Microorganism	Nutrient fixed(Kg/ha/year)
Actinorrhizae(Frankia sp.)	150 kg nitrogen/ha
Algae	25 kg N2/ha
Azolla	900 kg N2/ha
Azospirillum	10-20 kg N2/ha
Rhizobium	50 to 300 kg N2 / ha
Azotobacter	0.026 to 20 kg N2 / ha
Mycorrhizae	Solubilize food phosphorus (60%)
Phosphate solubilizing bacteria and fungi	Solubilize about 50-60% of them fixed phosphorus in the soil

CHEMICALLY FIXED NITROGEN VERSUS BIOLOGICALLY FIXED NITROGEN

With the fast depletion of fossil fuel and exorbitant cost of chemical fertilizers, efforts should be made for augmenting biological nitrogen fixation by microorganisms. On an average, one acre of grain legumes (like soybean, bean or pea) provide sufficient protein for 1000-2000 days for one person, whereas an average acre of plant materials converted to animal protein like beef and poultry provides it only for 75-250 days. India being one of the less affluent nations, where the per capita income is low and consequently, the intake of vegetable protein is more in comparison to animal protein. Accurate estimates of annual turnover of nitrogen in the biosphere vary from 100 to 200 million tonnes. The amount of nitrogen fixed by various legumes irrespective of soil and other conditions has been given in the table-5.
Above every hectare of land, there are 78,000 tonnes of inert nitrogen gas (N_2). Nitrogen is the most limiting nutrient for increasing crop productivity. Only a few procaryotic organisms are able to fix nitrogen directly through a biological process. Annual biological nitrogen fixation (BNF) is estimated to be around 175 million tones of which close to 79% is accounted for by terrestrial fixation.
TABLE-5: ESTIMATES OF NITROGEN FIXED BY SOME LEGUMES

Crop	Nitrogen fixed (kg per hectare)
Alfalfa	100-300
Berseem	120-150
Chickpea	26-63
Clusterbean	37-196
Clover	100-150
Cowpea	53-85
Blackgram	38-50
Greengram	50-55
Groundnut	112-152
Lentil	35-100
Peas	59-80
Pigeonpea	60-200
Soybean	49-130
Sesbania	69-90

SYNERGISTIC INTERACTION BETWEEN BIOFERTILIZING AGENTS

Biofertilsing agents such as Rhizobia, mycorrhizae, Azotobacter, Azospirillum, etc. are member of soil-biota or soil biosphere; they live together since the introduction of life in the universe. Hence they have developed a sort of natural relationship with each other and they maintain it unless disturbed by human beings by growing crops, application of fertilizers or pesticides. Crop growth in the soil releases several organic substances which may selectively eliminate certain microorganisms or reduce their activities or even augment the activities of the soilbiota. Since various biofertilizing agents are selective, such as Rhizobia fix N2 from atmosphere in the root zone of the legumes or phosphate solubilizing bacteria (PSB) or fungi (PSF) solubilize phosphate in the soil; this results in the simultaneous application of rhizobia and PSF or mycorrhizae. The question is always raised whether the simultaneous application may not jeopardize the activity of the individuals. Experiments were conducted on the simultaneous application or blending application of biofertilizing agents and it is generally concluded that the application has, by and large synergistic action.

Biofertilizers are apparently environment and farmers friendly renewable source of non-bulky, low cost organic agro-input. While Rhizobium, Blue Green Algae (BGA) and Azolla are crop specific, bio-inoculants like Azotobacter, Azospirillum, Phosphorus Solubilizing Bacteria (PSB), Vesicular Arbuscular Mycorrhiza (VAM) etc. could be regarded as broad spectrum biofertilizers. Their use has so far not received desired attention. This is mainly because of inadequate awareness both among the extention workers and farmers regarding their utility, their short shelf life, lack of ready availability in time and in desirable quality, and inconsistency in results with their use. However, proper education of the extension workers, dealers and

farmers about their significance and economic feasibility of their application both by seed treatment or to soil, could go a long way in prompting their adoption. These could effectively supplement the nutrient requirement of crops through chemical fertilizers, to meet the soaring demand for food, fibre and fuel.
A biofertilizer is an organic product containing a specific micro-organism (microbial inoculant) in concentrated form (107 to 109 per gram) which is derived either from the nodules of plant roots or from the soil of root zone (rhizosphere). They possess unique ability to fix atmospheric nitrogen either by living symbiotically with the roots of leguminous plants or non-symbiotically (free living) or to transform native soil nutrients such as phosphorus, zinc, copper, iron, sulphur etc. from the non usable (fixed) to usable form through biological processes. Biofertilizers are apparently environmental friendly, low cost, non-bulky agricultural input which could play a significant role in plant nutrition as a supplementary and complimentary factor to mineral nutrition.

BIOFERTILIZING AGENTS AND PLANT DISEASE CONTROL:

Biofertilizing agents control the plant pathogenic fungi directly as well as indirectly. Directly they parasitize the pathogens; application of rhizobium culture on the legume seeds control seed borne fungi such as Colletotrichum, Ascochyta, Helminthosporium, etc. The rhizobia produce a toxic substance when they multiply on the seed and rhizosphere. Phosphate solubilizing fungi such as Aspergillus niger and other Penicilla produce antibiotic substances and thus kill the pathogenic fungi. Indirect killing of the plant pathogens is achieved by producing healthy seedlings and phytoalexins. Application of mycorrhizae produce better root systems which overcome the attack of root rotting and soil borne pathogens. Numerous reports are available that applications of biofertilizers in the soil stimulate and augment the activity of saprophytic microorganisms.
Biofertilizers and Insect Control - Legume inoculation indirectly protect plants from the attack of insects.

BRIEF ACCOUNT OF BENEFICIAL MICROORGANISMS

Rhizobium

Symbiotic N2 fixation by Rhizobium in legumes contribute substancially to total biological nitrogen fixation. Rhizobium inoculation is well known agronomic practice to ensure an adequate nitrogen of legumes in lieu of N-fertilizer. Different species of rhizobium are classified into two groups viz. (i) slow growing rhizobia (under the genus Bradyrhizobium) and (ii) the fast growing groups (under the genus Rhizobium).
Why inoculation? Although, native rhizobia are present in the soil but all of them are not capable of forming nodules. Some of the strains are highly effective in this respect while others are partially or completely effective. It is also reported that native flora gradually lose their efficiency. Hence, the artificial inoculation with tested effective strains, should be taken up as a comparatively means, cheap insurance for obtaining optimum yield.
Carrier-based inoculants are usually coated for the introduction of bacterial strains into soil. However, alternative inoculation methods are necessary where seed treatment with fungicides and insecticides is needed or where seeds like groundnut and soyabean can be damaged when the inoculants is used with an adhesive. Direct contact with the acidic fertilizer can also be harmful for rhizobium.
Apart from application with seeds, the normal carrier-based inocula can also be separately applied. While all methods of application were successful under favourable conditions, "Liquid" and "Granular" methods were superior to seed inoculation under adverse conditions.

AZOTOBACTER AND AZOSPIRILLUM

Many genera and species of N2 fixing bacteria have been isolated from the rhizosphere of various cereals. Thus mainly belong to Azotobacter and Azospirillum genera.
These are free-living bacteria and fix atmospheric nitrogen in cereal crops without any symbiosis. They fix 15-20 kg/ha nitrogen per year. Azotobacter sp. also has ability to produce antifungal compounds against

many plant pathogens. They also increase germination and vigour in young plants leading to an improve stand in crops. There is evidence in the literature that Azotobacter biologically control the nematode diseases of plants.

PHOSPHATE SOLUBILIZING MICROORGANISMS

Phosphorus is also one of the major elements required for plant growth and higher yields. This element is necessary for the nodulation by Rhizobium and even to nitrogen fixers, Azolla and BGA. The phospho-microorganism mainly bacteria and fungi make available insoluble phosphorus to the plants. The root fungus association or mycorrhiza has high potential in accumulating phosphorus in the plants. Mixture of charcoal and soil is satisfactory material for these microorganisms in order to prepare commercial inoculants. It is reported that microphos cultures increase yield upto 200-500 Kg/hectare and thus 30 to 50 kg superphosphate can be saved.

Next to nitrogen, phosphorus is the vital nutrient for plants and microorganisms. Superphosphate is one of the common forms of phosphate fertilizers. These fertilizers are prone to be fixed in the soil.

Rock phosphate is one of the basic raw materials for phosphatic fertilizers. Direct application of rock phosphate is limited to acidic soil, while in other types of soil the applied phosphate becomes insoluble within a short time. Monocalcium phosphate are converted to dicalcium phosphate which is slowly available to plants. Under such conditions large amount of phosphorus is fixed in the soil which is unavailable to the plants.

Several soil bacteria and a few species of fungi posses the ability to bring insoluble phosphate in soil into soluble forms by secreting organic acids. These acids lower the soil pH and bring about the dissolution of bound forms of phosphate.

VESICULAR ARBUSCULAR MYCORRHIZAE (VAM)

The symbiotic association between plant roots and fungal mycelia is termed as mycorrhiza (Fungal roots). These fungi are found associated with majority of agriculture crops. They are ubiquitous in geographic distribution occuring with plants growing in arctic, temperate and tropical regions alike. These fungi are obligate symbionts and have not been cultured on nutrient media.

VAM fungi infect and spread inside the root. They possess special structures known as vesicles and arbuscules. The arbuscules help in the transfer of nutrients from the fungus to the root system and the vesicles, which are saclike structures, store P as phospholipids. VAM have been associated with increased plant growth, and with enhanced accumulation of plant nutrients, mainly P, Zn, Cu and S mainly through greater soil exploration by mycorrhizal hyphae. It has also been suggested that VAM stimulate plant growth by physiological effects other than the enhancement of nutrient uptake or by reducing the severity of diseases caused by the soil pathogens.

AZOLLA

Azolla is a floating fresh water fern inside which grows the nitrogen fixing BGA Anabaena. It contains 3.4% nitrogen and produces organic matter in soil. This biofertilizer is used for rice cultivation in different countries such as Vietnam, China, Thailand, Phillipines. It is also used in fish culture ponds these days. This can be easily grown in cooler regions. There is need to develop tolerant strains to high temperature salinity, and pests and disease-resistance for its wider adaption. Field trial indicated that rice yields are increased by 0.5-2t/ha due to Azolla appplication. In China, about 18% increase has been observed. In fish culture ponds, application of 25 kg/ha per day Azolla biofertilization has been worked out. Recent studies have revealed potentialities of Azolla as a nitrogenous fertilizer in carp culture ponds. Application of different doses of Azolla in fish culture ponds shown that a minimum of 25 kgN/ha/yr could be provided through application of 10-12 tonnes of Azolla/ha/year. There are six species of Azolla-A. caroliniana, A. nilotica, A. mexicana, A. filiculoides, A. microphylla and A. pinnata. It grows in ditches and stagnant water.

This fern usually forms a green mat over water. The plant has a floating, branched stem, deeply bilobed leaves and true roots which penetrate the body of water. The leaves are arranged alternately on the stem. Each leaf has a dorsal and ventral lobe. The dorsal fleshy lobe is exposed to air and contains chlorophyll. It has an algal symbiont (Anabaena azolla) within the central cavity. Azolla is readily decomposed to NH4 which is available to the rice plants. It has also been observed that N contents of rice receiving A. mexicana are 10 and 35 kg/ha respectively higher than that in controls.

BLUE GREEN ALGAE

Blue-green algae constitute an important group of microorganism capable of nitrogen fixation. Most of the species possessing nitrogen fixation ability to the order Nostocales and Stigonematales. Over 100 species of blue-green algae are known to fix atmospheric nitrogen. These have been found to be very effective on the rice and banana plantation. In field condition, overall increase in the gram yield of rice is amounted to about 586 kg/ha. In case of crops other than rice, algalization increased nearly 34 per cent yield.

India is one of the countries where agro-chemical conditions appear to be favourable where blue-green algae technology has been put forward. In some parts of the country, production of BGA inoculants has been commercialised. Producing inoculum in artificially controlled conditions is well defined, but relatively expensive. On the other hand open-air soil culture is more simple, less expensive and easily adaptable by the farmers. Field scale production of algae biofertilizer is also possible. 20-25 kg dry algae can be obtained on 40 m field. Adopting this method, 15 t/ha of wet BGA can be obtained by the farmers. Farmers can also produce algae for countryard of the house.

PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR)

A group of rhizosphere bacteria that exert a beneficial effect on plant growth is referred as PGPR. They belong to several genera, e.g. Actinoplanes, Agrobacterium, Alcaligenes, Amorphosporangium, Arthrobacter, Azotobacter, Bacillus, Cellulomonas, Enterobacter, Erwinia, Flavobacterium, Pseudomonas, Rhizobium and Bradyrhizobium, Streptomyces and Xanthomonas. Bacillus spp. are appealing candidates for biocontrol because their endospores are tolerant to heat and desiccation. Currently Pseudomonas strains also suppress major plant pathogens. Take all, an important root disease of wheat caused by Gaeumannomyces graminis var. tritici is controlled by fluorescent Pseudomonas.

PGPR are thought to improve plant by colonizing the root system and pre empting the establishment of suppressing deleterious rhizosphere microorganisms on the roots. The Plant growth promoting microorganisms improved potato growth and yield in short-but not long-rotation soils, primarily by suppressing cyanide - producing deleterious rhizosphere microorganisms. Large populations of bacteria established on planting material and roots become a partial sink for nutrients in the rhizosphere thus reducing the amount of C and N available to stimulate spores of fungal pathogens or for subsequent colonization of the root.

In field trials with wheat, potato, sugarbeet and zinnia conducted showed significant yield increases varying from -7 to 136% with an average increase of 7-35% in different crops over the control. Seed treatment with B.subtilis increased yield of carrot by 48%, oats by 33% and groundnut upto 37% and it has been marketed as a treatment for groundnut in USA. A multitude of factors could account for inconsistent results, given the complex interactions among host, inoculated organisms, other rhizosphere organisms and the environment which are discussed earlier. Research with PGPR in India is at a low level.

STATUS OF BIOFERTILIZER IN INDIA

As mentioned earlier the total potential of biofertilizers is very high and existing production units do not have the capacity to meet the requirement at the right time. Most of the production units do not have adequate instruments, production techniques, skilled staff, etc. for production of quality-based bioinoculants. The result is the production of poor quality products which are directly responsible for the failure so there is a

need for upliftment of biofertilizer industry in India.
Biofertilizers differ from fertilizer in the sense that the former do not directly supply any nutrient to crop plant and are the cultures of some specific bacteria and fungi. Bacterial cultures like Rhizobium, Azospirillum, Azotobacter have the ability to fix atmospheric nitrogen which in turn increases nitrogen supply to crop. Bacterial cultures of Pseudomonas and Bacillus species and fungal cultures of Pencillium and Aspergillus species help to convert insoluble phosphates into soluble (plant soluble) phosphate and thus improve phosphate availability to the plants. Similarly, fungi like vesicular arbuscular mycorrhizae (VAM) increased nutrient uptake particularly of P, Zn and other micronutrients due to increased contact of roots from larger soil volume. It is important to mention that so far biofertilizers available are able to take care of nitrogen only. Therefore, other plant nutrients have to be applied from other sources.
At present, in India there is a gap of about 10 million tonnes of plant nutrients between removal by crops and replenishment through fertilizers. Supply of nutrients from organic manure has not so far been able to fill up this gap and also in years to come nutrient supply from the source is unlikely to improve due to competitive demand for alternate uses like fuel and fodder. Of late, biofertilizers are being promoted as an important component in supplementing plant nutrient need of the country. It is a good beginning but we still have a long way to go.
India is one of the important countries in biofertilizer production and consumption in the world. The present production capacity of different biofertilizers production units in the country is about 4500 tonnes per annum. The maximum production capacity is in Agro Industries Corporation followed by State Agriculture Departments, National Biofertilizer Development Centre, State Agriculture Universities and private sector. Among the different states, the maximum production capacity is in Tamil Nadu followed by M.P., U.P., Gujarat, Maharashtra. The actual production of biofertilizer during 1994-95 was about 2000-2500 tonnes. The installed capacity of BF production in different fertilizer industries is about 400t/annum. Main BF producing companies are GSFC, MLF, SPIC etc. Some more fertilizer companies (IFFCO, KRIBHCO, NFL, RCF etc.) are likely to start production soon and many more are planning to join the biofertilizer business.
Based on the area under different crops and dose of biofertilizer to be applied, the National Biofertilizer Development Centre (NBDC), Ghaziabad and Biotech Consortium India Ltd. (BCIL) have estimated the total requirement of biofertilizers (Rhizobium, Azotobacter, Azospirillum and Blue Green Algae) to be about 5.07 and 3.44 lakh tonnes, respectively. The recent estimated potential demand of different kinds of biofertilizers by Government of Tamil Nadu are Rhizobium 35 thousand tonnes; Azospirillum 482 thousand tonnes; Azotobacter 162.61 thousand tonnes; Blue-Green Algae 267.72 thousand tonnes, Azolla 20.38 thousand tonnes and phosphate solubiliser 275.51 thousand tonnes. The total of all these amounts to be 12.44 lakh tonnes which is significantly higher than the estimates of NBDC and BCIL, mainly because they did not indicate phosphate solubiliser and their estimates for Azospirillum were also low.
Production technology of biofertilizer is relatively simple and its installation cost is very low compared to chemical fertilizer plants. Organised promotional and marketing strategy for successful biofertilizer business is very important. Most of the biofertilizer units lack in this respect. Those who have very good organised marketing network have done excellently well. For example, fertilizer company like GSFC has more than 200 farm information centres-cum-depots situated in remote areas. These are managed by experienced agricultural graduates to provide the technical know-how, conduct the demonstration and give before and after sales services to the farmers. In order to provide BF upto village level, GSFC has established its own distributor's network. MLF and SPIC have also well organised themselves in this respect.
TABLE-7 ESTIMATED INSTALLED CAPACITY FOR BIOFERTILIZERS IN DIFFERENT STATES
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State	Installed capacity (t)

Tamil Nadu	1100
Madhya pradesh	700
Gujarat	450
Maharashtra	250
Andhra Pradesh	175
Karnataka	40
Haryana	75
Orissa	75
West Bengal	72
Rajasthan	90
Punjab	75

Response of biofertilizers have been obtained in cereals, millets, pulses, legume oilseed, sugarcane and cotton grown under different agro-climatic conditions. In general, increase in yield due to biofertilizer application was of the order of 15-20 per cent. It is found that biofertilizer like Rhizobium can supply 20-25 kg N/ha. Of late, complex biofertilizers have been reported to be more effective in increasing nutrient supply and crop yield.

To promote biofertilizer use, fertilizer industry is engaged in a number of activities like (i) field experiments on Research & Development (R&D) farm (ii) field experiments on farmers' fields (iii) farmers' meetings and field days (iv) seasonal campaign (v) farm youth training programme (vi) audio visual display to educate farmers (vii) preparation of distribution of literature on biofertilizer in local languages (viii) distribution of paper stickers to institutional agencies, dealers, etc. (ix) publicity through local newspapers and (x) publicity through exhibitions, fairs, festivals etc. Though there had been a lot of improvement in biofertilizer development and promotion in supplementing plant nutrient supply, the bottlenecks which still need to be sorted out are: short shelf life, lack of suitable carrier material, suitable of high material, susceptibility to high temperature, problem in transportation and timely distribution in remote areas etc. Besides standard packaging and quality control measures etc. will help to develop healthy market in the time to come. There is urgent need to work out aggrasive promotional and marketing strategies for gaining momentum to BF use in the country.

THRUST IN RESEARCH AND DEVELOPMENT

The rising cost of chemically fixed nitrogen fertilizer and the massive inputs of non renewable resource will be devastating. As an alternative there is urgency of major research effort in biological nitrogen fixation. Nitrogen in the form of ammonia is used by plants and microbes as a building block for the synthesis of amino acids and of other nitrogenous compounds. The conversion of atmospheric Nitrogen into ammonia by the nitrogen fixing microbes, mostly certain bacteria and blue green algae is called biological nitrogen fixation. Although leguminous plants have been used extensively in agriculture for centuries, it is possible to exploit these nitrogen fixing plants meaningfully. The use of new leguminous crops as well as the breeding of more vigorous and effective traditional leguminous crops can be helpful in food production. As the bacteria are the agents of fixation in bacterial plant association, plant breeding has been neglected to enhance the effectiveness of this association

Rhizobial technology and soil microbiology are the neglected areas. It would be a right type technology that all farmers could use Legume-Rhizobial combinations constitute, a built-in nitrogen source for food crop production. Approximately 75 per cent of the nitrogen utilised by legume comes from the soil, with only 25 per cent from BNF. It is necessary to increase the rate of nitrogen fixation achieved, which would have a multiplier effect on the enhancement of crop productivity. There have been many research frontiers in BNF. The two genetic systems involved are microorganisms and the higher plants and their greater potential for improving the both. In nature, certain nitrogen-fixing agents do not perform well. As a result their nitrogen fixing efficiency remains less though their abundance is much. It is necessary to make them highly competitive through genetic engineering. It will help them to establish an association with the plants in competitions with the organisms occuring naturally in the ecosystem. Wherever possible, the agents should have a broad spectrum in their specificity so that they can associate with a variety of plants. Thus the competitive strains developed could be introduced into the soil for better interaction of plant bacterial association.

Although nitrogen fixers are present in the soil, enrichment of soil with effective strains is much beneficial for the crop yields. Chemical fertilizers have temporary effect while biofertilizers have permanent effect without any production problem. Use of composite biofertilizers can increase soil fertility. The cost is too much low for the biofertilizers and its proper use does not only include a correct application of the inoculant to the seed - soil but also good crop management and provision of additional capital nutrients for the plants and inoculum. Scientists have proved that the biofertilizers are cost effective, cheap and renewable source to supplement the chemical fertilizers. The rhizobia inoculant has been found to be effective for pulses and legume oilseeds like soyabean, groundnut and the blue green algae for low land paddy in our country. Much of the world today is concentrating on rhizobial technologies and the culture of other organisms having superior nitrogen fixing capabilities. As companion the legumes are being used as the soil improving crops and intercrop or in rotation with cereal grains and other high energy crops as is being practiced in China, South America, Africa, Phillipines and in India. They are becoming a part of cropping systems research in total farming systems. Active linkages of scientitsts engaged in basic fundamental research in biological nitrogen fixation with those in mission oriented, applied and problem solving research would speed up the process. Considering the prospects of biofertilizers in the country, the biofertilizer development centres are being established both in government and private sector. It is possible to establish joint venture in biofertilizer agro based industry.

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