BIOFERTILIZERS AND GREEN MANURING

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To meet the local market and export demand for organic produce more number of farmers and entrepreneurs are adopting organic farming. However, the availability of organic plant nutrient source for organic farming is a great challenge. Biofertilizers and green manuring can help in meeting the nutrient demand for organic farming. Both biofertilizers and green manuring crops are not only cost-effective but also a sustainable nutrient source for maintaining soil fertility.

The need for sustainable and ecological agriculture is increasingly felt in the country. Simply stating, organic farming is a production system which favours maximum use of organic material (crop residues, animal excreta, legumes, on and off-farm organic wastes, growth regulators, biofertilizers, bio-pesticides etc.) and discourages the use of chemical agro-inputs, for maintaining soil productivity and fertility and pest management under conditions of sustainable natural resources and healthy environment.

Biofertilizers and green manures are important pillars of organic farming that support higher yield and maintain soil health. Biofertilizers is a very cost-effective solution for providing nutrients to crops in a sustainable manner, unlike chemical fertilizers which are costly and need repeated application. Similarly, green manuring utilizes lean period between two main crops and improve soil fertility by providing fixed nitrogen and improving organic matter of the soil.

Biofertilizers

Biofertilizers are products of beneficial microorganisms which increase agricultural production by way of nutrient supply especially nitrogen and phosphorus. Biofertilizers can fix atmospheric nitrogen for plant use and can mobilize unavailable phosphorous pool which can be used by plants. These biofertilizers are inexpensive, simple to use and have no problem of environmental pollution. Use of biofertilizers not only help in sustaining productivity and soil health but also in reducing subsidy burden on the government by reducing the consumption of chemical fertilizers.

Types of Biofertilizers

The concept of microbial inoculation started with legume *Rhizobium* inoculant first patented by Nobe and Hiltner in 1896. In developed countries like USA, UK, France, Australia, biofertilization is restricted to *Rhizobium*, whereas in Brazil, China and India it has been diversified and a large number of bacteria, fungi and actinomycetes have been included in this group. Biofertilizers have been broadly classified as nitrogen biofertilizers, phosphate biofertilizers and plant growth promoting biofertilizers which also includes potassium solubilizing microorganisms (Figure 1).

Nitrogen-fixing Biofertilizers:

Only a few prokaryotic microorganisms fix nitrogen directly through a biological process. The organisms that fix atmospheric nitrogen are broadly grouped as symbiotic and non-symbiotic or free-living organisms. The symbiotic nitrogen fixers undertake the fixation in the association of plants whereas non-symbiotic organisms do not require any association.

Rhizobia

Rhizobium inoculants establish a symbiotic association with pulses, leguminous oil-seed and fodder crops. Many species of family Rhizobiaceae like *Rhizobium, Mesorhizobium, Bradyrhizobium, Sinorhizobium* and *Azorhizobium* are known to fix N in different crops.

Azotobacter

Azotobacter is free-living nitrogen fixing bacteria and unlike Rhizobia do not require any living host to fix N. *Azotobacter chroococcum* is the most abundant species of genus Azotobacter.

Azospirillum

It is also a non-symbiotic, most abundantly found in association with the roots of millets and grasses. *Azospirillum brasilense, A. lipoferum, A. amazonense, A. halopraeferens* and *A. irakense* are most commonly used species of this genus for inoculation.

Blue Green Algae (BGA)

BGA belong to a class of prokaryotic photosynthetic microorganisms also known, as cyanobacteria are capable of fixing atmospheric nitrogen aerobically in rice fields. Most commonly found blue-green algae in Indian rice fields are *Anabaena, Nostoc, Cylindrospermum, Calothrix, Scytonema, Tolypothrix*, etc.

Phosphate, Potassium and Zinc solubilizing microorganisms

Phosphorus and Potash, both native in soil and applied as inorganic fertilizers become mostly unavailable to crops because of its low level of solubility and immobilization in the soil. A large number of autotrophic and heterotrophic soil microorganisms have the capacity to solubilize/ mobilize minerals of P and K.Similarly, Zinc is also present in soil but in an unavailable form. These microorganisms are known to dissolve P, K and Zn by the production of an organic acid.

The research on KMB and ZSB is at an early stage and only a few KMB formulations are available in the market all over the world.

Arbuscular Mycorrhizae (AM)

AM which was earlier known as VAM (Vesicular Arbuscular Mycorrhizae) is an obligate symbiont and are known to improve plant growth due to the improved mobilization of phosphorus and micronutrients such as zinc and copper and also increases absorption of water.

Plant Growth Promoting Rhizobacteria (PGPR)

PGPR is a group of beneficial bacteria that improve plant growth by the production of plant hormones, such as auxins, gibberellins and cytokinins, or by providing biologically fixed nitrogen. These PGPR also suppress the bacterial, fungal and nematode pathogens by the production of siderophores, HCN, ammonia, antibiotics, volatile metabolites, etc.

Azolla

Azolla is a free-floating water fern which in symbiotic association with *Anabaena azollae* contributes 40-60 kg N per hectare per crop. The important factor in using *Azolla* as a biofertilizer for paddy is its quick decomposition in soil and efficient availability of its nitrogen to the crop.Its application improves soil physicochemical properties apart from fertilizer use efficiency.

Biofertilizers can also be classified into two different categories based on the type of formulation

Carrier-based formulations:

For bacterial biofertilizers, the carrier may be peat, lignite, peatsoil, humus, talc. For mycorrhizal inoculants, the base material may be fine powder/ tablets/granules/root biomass mixed with the growing substrate. For the application of carrier-based formulation, the seed has to be treated with some sticky liquid like jaggery solution.

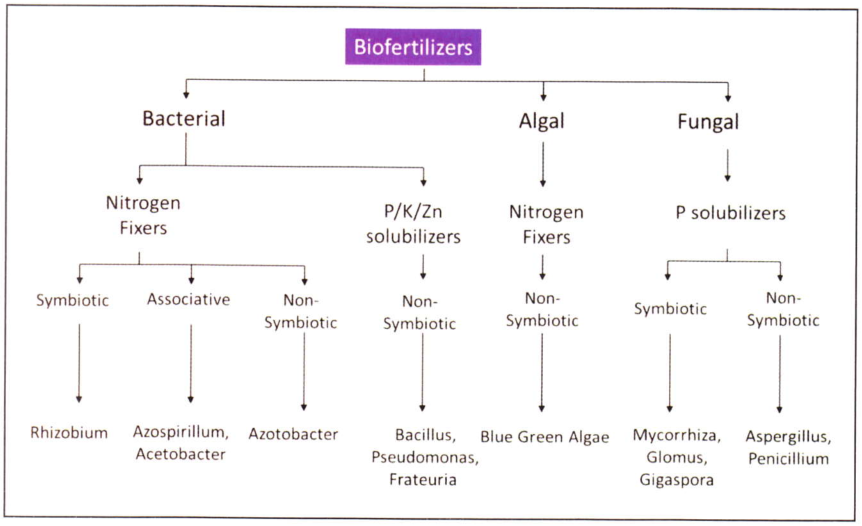

Fig.1 Classification of biofertilizers

Liquid formulations:

Liquid formulations are available for all bacterial biofertilizers. Liquid formulations are prepared by mixing bacteria with additives, stabilizers and nutrient solution that support bacterial population for a longer period. The main advantages of liquid formulations are (a) they are easy to apply as they can be directly applied to seed (b) they can be stored for a longer period (c) they require smaller space for storage compared to carrier-based formulations.

Some biofertilizers are crop specific like *Rhizobium, Acetobacter* and Blue-green algae while others can be used for all crops (Table 1)

Benefits of applications of different biofertilizers

Biofertilizers help in different ways to increase the crop yields some of which are:

1. Biofertilizers provide various nutrients to plants like N, P, K, etc. either by fixing the elemental form (N) or by solubilizing the unavailable nutrients like P, K and Zinc. VAM (AM) fungi benefit plants by mobilizing the nutrients from a larger root area. Azolla not only fixes N but also add organic matter to the soil.
2. Biofertilizers not only provide nutrients to plants but also protect plants from plant diseases as they secrete many antibiotic compounds which suppress the growth of disease-causing pathogens.

Fig. 2. Liquid biofertilizer formulations

3. Besides providing nutrients and suppressing diseases, biofertilizers also secrete some plant growth promoting hormones like auxins and gibberellic acid which makes plant healthy.
4. Many biofertilizers like VAM and PGPR also help plants in avoiding water stress by secreting some polysaccharide which helps in soil aggregation and conserving moisture for longer times.
5. Once the biofertilizers are established in the field after 2-3 years of continuous application, the dose of biofertilizers may be reduced

The average increase in yield of some common crops with anticipated benefits in terms of nutrients supplied is provided in Table 2.

Availability of inoculants: *Rhizobium, Azotobacter, Azospirillum* and PSB inoculants of popular brands of various companies and

Table 1.Major biofertilizers and target crops

Biofertiliser	**Target crop**
Nitrogen Fixing Biofertilizers	
Rhizobium	Pulses
Azotobacter	Wheat, maize, cotton, mustard and vegetables (Potato, onion, tomato, brinjal and others)
Azospirillum	Cereal crops like wheat, maize, millets, sorghum, barley; and sugarcane.
Acetobacter	Sugarcane
Blue green algae (BGA), Azolla	Rice
PGPR and Phosphate/Potassium/Zinc solubilizing microorganisms	All
Arbuscular mycorrhiza	Field crops, nursery-raised crops and orchard trees

Table 2.Crop response to biofertilizers

Biofertilizer	Anticipated benefits	Average increase in crop yields
Rhizobium	20-60 kg N	15-40%
Azotobacter	15-20 kg N	10-30%
Azospirillum	20 kg N	15-30%
BGA	25-30 kg N	10-20%
Azolla	3kg/t	10-20%
PSB	25 kg P_2O_5	10-20%
VAM	Availability of P, Zn, Fe etc.	10-20%

corporations (IFFCO, NFL, Kribhco) are generally available on their agency shops, seed, pesticide and fertilizer retail shops in the market. All State Agriculture Departments, research institutes like IARI, NCOF and agricultural universities also make them available during the season. Many private companies are also coming up in the production of biofertilizers, especially liquid inoculants.

Method of application of Biofertilizers:

The success of any biofertilizer organism depends on how close the organism is applied to seed, seedling or other planting material. Nearer the organism and planting material, the results in all probability would be positive. Seed application with bacterial inoculant is the most common practice of inoculation. Seeds should be sown as soon as possible after treating with cultures or inoculants to take the full benefit of the same.

Quality control of Biofertilizers in India

For effective management of Quality Control Regime, many important biofertilizers (*Rhizobium, Azotobacter, Azospirillum,* KMB, ZSB, and PSB) have been included under "The Fertilizer (Control) Order 1985" since March 2006 and standards have been set by the government to ensure the quality of these bio-fertilizers. Earlier under the Bureau of Indian Standards (BIS) product certification marks scheme licenses were granted to manufacturers for affixing BIS Mark on their products conforming to Indian Standards. Expiry period of 6 months for carrier-based formulations and 12 months for liquid formulations has been set under FCO.

Constraints

Biofertilizers are the most important source of nutrients in organic farming but farmers are not able to practice crop inoculation due to various reasons. Some of the difficulties faced by the government and extension agencies in popularizing the biofertilizers especially for organic farming are

1. The foremost constraint in the popularization of biofertilizers in the country is the timely supply of cultures in remote corners of the country where organic agriculture is practiced.
2. Lack of knowledge of the farmers about these biofertilizers and proper measures taken by the extension departments in demonstrating the benefits of inoculants to farmers.
3. Though mechanisms exist under Fertilizer Control Order (FCO 1985) to looks after the

Fig. 3.Green manuring practice (sunnhemp) for soil fertility improvement

quality control of biofertilizers, the persons involved in the quality control are not versed with the proper tools and techniques of handling biofertilizer samples.

Green Manuring:

Green manuring–a practice of ancient origin- can be defined as a practice of ploughing or turning into the soil undecomposed green plant tissues grown *in-situ* or cut and brought in for incorporation for the purpose of improving physical structure as well as the fertility of the soil. In another way, green manuring is the practice of growing lush plants on the site into which you want to incorporate organic matter, then turning into the soil while it is still fresh (Fig. 3). The plant material used in this way is called green manure. Green manuring is usually done in the lean period available between the two main crops. However, it can be practiced in between crop rows also *eg. in-situ* green manuring of Sunnhemp/ Sesbaniain between maize rows (Fig. 4).

Fig. 4.In-situ green manuring practice (sunnhemp) for soil erosion control

Kind of green manuring:

Green manuring can be broadly divided into two classes based on the basis of the cultivation method.

1. ***In-situ* green manuring:** Green manure crops are grown in the desired field and buried in the same field for green manuring. An ideal *in-situ* green manure crop should be fast growing with minimum nutrient and water requirements. Nitrogen-fixing legumes which produce heavy tender growth early in its life cycle are most

Table 3. Common legume crops for in-situ green manuring

S. No.	Common Name	Botanical Name	Growing Season
1.	Dhaincha	*Sesbania aculeata*	Zaid/Kharif
		Sesbania rostrata	Zaid/Kharif
2.	Sunhemp	*Crotalaria juncea*	Zaid/Kharif
3.	Mung	*Vigna radiata*	Zaid/Kharif
4.	Cowpea	*Vigna unguiculata*	Kharif
5.	Guar	*Cyamopsis tetragonoloba*	Kharif
6.	Senji	*Melilotus alba*	Rabi
7.	Berseem	*Trifolium alexandrium*	Rabi
8.	Khesari	*Lathyrus sativus*	Rabi

suitable for green manuring. The species commonly used for green manuring are given in Table 3.

Green leaf manuring:

In green leaf manuring, leaves and tender green twigs are grown in separate fields, bunds or wastelands and incorporated in the soil of some other field. The species commonly used for green leaf manuring are given in Table 4.

Table 4. Common shrubs/trees used for green leaf manuring

S. No	Common name	Botanical name
1.	Subabool	*Leucaena leucocephala*
2.	Glyricidia	*Glyricidia maculeata*
3.	Wild dhaincha	*Sesbania speciosa*
4.	Karanj	*Pongamia glabra*

Time of sowing of the green manure crop

Normally the green manure crops are sown in between the main crops. In north India, Dhaincha is sown as green manure crop after wheat harvesting and buried in soil one month prior to rice transplanting. Some farmer also takes pulse crop in between wheat harvesting and rice transplantation and bury the legume crop like moong as green manure. In some parts, green manure crops are grown immediately after the monsoon rains. No special soil preparation required for the sowing of green manure crops and the seed of the green manure crop is broadcasted preferably with higher seed rate followed by tillage. Majority of the green manure crops are buried deep in the soil after 6 to 8 weeks (flowering stage) after sowing. In principle, the green manure crop should be buried in soil at least 15-20 days prior to sowing/transplanting of next crop so that the crop is properly degraded before sowing of next crop to avoid nutrient immobilization during the degradation process.

Advantages of the Green manuring:

Following are some of the advantages of the green manuring-

1. Following degradation, it adds organic matter to the soil which helps in maintaining the activity of the beneficial soil microorganisms.
2. The green manuring crops improve the physical structure of the soil by increasing humus and organic matter content of the soil. Increase in organic matter also improves the water holding capacity of soil thus reducing the run-off and soil erosion.
3. Leguminous green manuring crops like dhaincha, add nitrogen to the soil for the succeeding crop besides increasing the availability of nutrients like phosphorus, potassium, calcium, magnesium and iron.

Disadvantages of the green manuring under organic farming:

Following are some of the disadvantages of green manuring-

1. If not properly decomposed, the green manure crop may hamper the germination and growth of subsequent crops by immobilization of plant nutrients. Decomposition is not proper especially under rainfed conditions in the absence of good rainfall.
2. An increase of diseases, insects and nematodes is possible if the green manure crop is not properly decomposed before sowing of next crop.

Conclusion:

Biofertilizers and green manuring are important sources of nutrients and organic matter respectively for sustaining the crop yields, especially under organic farming practice. Though both biofertilizers and green manuring are old and established technologies many farmers are not aware of the benefits of these technologies. Extension workers should train more farmers about the proper use of biofertilizers for maximum benefits. Timely availability of quality biofertilizers and green manure crop seeds can help in meeting the demands of organic producers especially in distant areas.

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