International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG(USA) Volume 7, Issue 1 -2020

Research Notes

DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.01.009

Plant Growth Promoters: A root army

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Abstract

Biofertilizers are the preparations containing efficient strains of Nitrogen fixing, Phosphate solubilizing and cellulose decomposing microbes which can be used along with seeds in order to augment the extent of availability of nutrients. These can be used as a substitute to chemical fertilizers as they are eco-friendly and hence enhance the crop production.

Keywords: Biofertilizers, Nutrients, Fertilizers

Introduction

Beneficiary soil microorganisms are involved in bio-geochemical cycling of mineral nutrients, humus synthesis and degradation, soil aggregation and stabilization and mobilization and transfer of mineral nutrients from soil to plant. Thus, these organisms can be used for the improvement of soil fertility. Green revolution revolutionised the Indian agriculture, but it prompted farmers for indiscriminate use of chemicals and fertilizers, pesticides and herbicides. It has plagued the environment and soil structure. Moreover in the subsidized Indian farming system, it attributes to high input cost to the farmers and due to these inherent financial strains they are unable to get the sufficient returns. Various approaches have been employed to augment sustainable agriculture. Active approach is manipulation and management of biological system not only to maximise yield but to stabilize the agro system and to minimise the industrial input demand thus, representing the integrated approach of appropriate modern technology with the traditional technique. This has led to the use of biofertilizers in combination with minimum chemical fertilizer and organic manure. It offers a great opportunity to increase crop production with less cost and saves environment. The exigency of this environment friendly technology becomes more meaningful in soils with nutrient deficiency. It can improve soil fertility and ultimately crop yield.

The biofertilizers are the preparations containing efficient strains of nitrogen fixing, phosphate solubilizing, cellulose decomposing microorganisms used for the application to seeds to augment the extent of availability of nutrients. The culture of these beneficiary organisms can be inoculated in charcoal or peat. These charcoal based cultures can be used along with seed and are sown. The commercial history of biofertilizers began with the launch of “Nitragin” by Nobbe and Hiltner, a laboratory culture of *Rhizobia* in 1895, followed by the discovery of *Azotobacter* and then blue green algae (BGA) and the host of other microorganism. After that the *Azospirillum* and Vesicular Arbuscular Mycorrhiza (VAM) was discovered. In India the first study on legume-*Rhizobium* symbiosis was conducted by N.B. Joshi and first commercial production started as early as

1956. However, the Ministry of Agriculture, under the ninth plan initiated the real efforts to popularize and promote the input with the setting of the National Project on development and use of biofertilizer (NPDB). The commonly explored biofertilizers in India are:

- ✓ Nitrogen fixing biofertilizers
- ✓ Phosphate solubilizing biofertilizers

Benefits of biofertilizers

- ✓ Cheap and eco-friendly technology
- ✓ Improves soil health
- ✓ Enhances crop yield
- ✓ Improves the yield of subsequent crops
- ✓ Reduces the input of costly fertilizers

Nitrogen fixing biofertilizers

Nitrogen is the key element responsible for enhancing crop production. But economic and environmental cost of heavy use of chemicals, nitrogen fertilizers in agriculture are global concern. The nitrogen fertilizer use efficiency is very low. Hence in turn contributes substantially to environmental pollution, eutrophication, plant toxicity and stratospheric ozone depletion. Nitrogen fixation is a process of conversion of nitrogen to ammonia. It is a reduction process and gives out energy

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

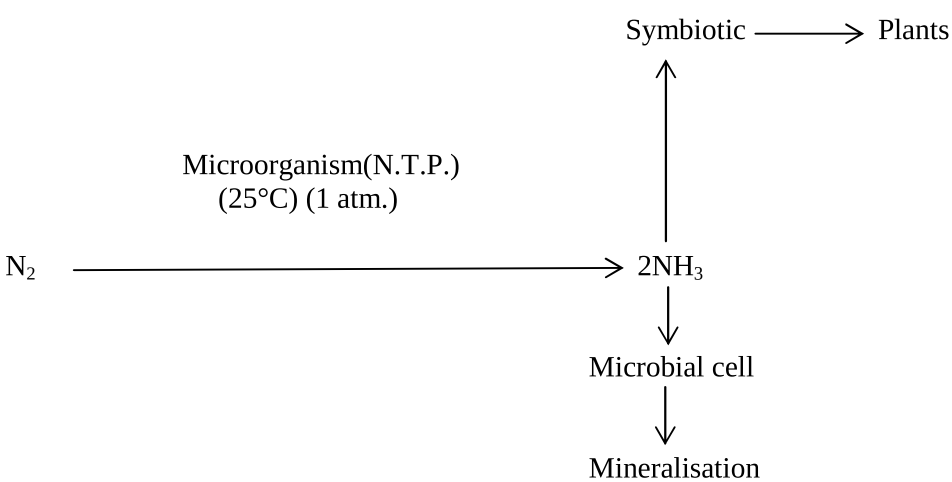
$$\Delta G = -33.39\ kJMol^{-1}$$

These two gases do not react together at normal temperature and pressure, because of the great stability of dinitrogen molecule. Both industrial chemicals and prokaryotic organisms have to provide the energy before the reaction to proceed. Moreover, Industrially very high temperature (400-500°C) and pressure (200-300 atm) are required (The Haber Bosch Process). But in biological nitrogen fixation, the enzyme nitrogenase can reduce the temperature and pressure so in BNF at normal temperature and pressure (25°C, 1 atm), the nitrogen is changed to produce ammonia.

Chemical process:

$$N_2 + 3H_2 \xrightarrow{(200\text{-}300\ atm.,\ 400\text{-}500°C)} 2NH_3 \longrightarrow \text{Soil}$$

Biological process:



In nitrogen cycle, nitrogen is changed to produce ammonia with the help of nitrogen fixers, ammonia is oxidized to nitrite with the help of *Nitrosomonas*, the nitrite produced is oxidised to produce nitrate with the help of *Nitrobacter*which in turn is assimilated after utilization by plants, animals and bacteria. A part of nitrite is denitrified to nitrogen gas with the help of *Thiobacillusdenitrificans*. This nitrogen produced is again fixed and the cycle goes on.

The nitrogenaseenzyme produced by nitrogen fixer is composed of Fe protein and Fe-Mo protein.

Mechanism of Nitrogen Fixation

During Nitrogen fixation, reduced Ferridoxin passes its electron to Iron protein (Fe) which inturn gets oxidized. In the presence of Mg-ATP, the oxidised iron component undergoes change in confirmation. Three electrons are being transferred during each cycle of association dissociation of Fe and Fe-Mo components. Then nitrogen is added to Fe-Mo components and by undergoing 5 electron transfer, ammonia is produced.

Biological nitrogen fixation (BNF) accounts for 65% of nitrogen (N) currently utilized in agriculture and of increasing important in future crop productivity especially for sustainable systems and is naturally available for crop productivity. Besides, the obvious science interest of nitrogen fixation as a fundamental biochemical reaction and in agriculture, it is of great ecological importance too. Since, it is a most important source of metabolizable nitrogen needed by all the organisms.

Nitrogen fixing microbes are classified as

- ✓ Symbiotic nitrogen fixers
- ✓ Asymbiotic nitrogen fixers
- ✓ Associative nitrogen fixers
- ✓ Photosynthetic nitrogen fixers

Symbiotic nitrogen fixers:

***Rhizobium*-** These inoculants are known for their ability to fix atmospheric nitrogen in symbiotic relationship with plants forming nodules (Stem nodules in *Sesbaniarostrata*). Rhizobia are very specific and only certain legumes are benefitted from their association.

Asymbiotic nitrogen fixers

***Azotobacter*:** It has been found beneficial to a wide array of crops covering cereals, millets, vegetables, cotton and sugar cane. It is free living and non-symbiotic nitrogen fixing organism and produces certain substances good for the growth of plant and produces antibiotics that can suppress many root pathogens.

Associative nitrogen fixers

Azospirillum: It is also a nitrogen fixing microorganism beneficial for non- leguminous plant. Like *Azotobacter*, it benefits transcend nitrogen fixation through production of growth promoting substances.

Photosynthetic nitrogen fixers

Blue green algae (BGA): They are found in abundance in India. They too add growth promoting substances including vitamin B_{12}, improve the soil aeration and water holding capacity and add to biomass when decomposed after lifecycle. *Azolla* is an aquatic fern found in small and shallow water bodies and in rice filed. It has symbiotic relationship with BGA and can help rice and other crops through dual cropping and green manuring of soil.

The table given below indicates major nitrogen fixing microbes and beneficiary plants.

Major nitrogen fixing microbes and beneficiary plants

Microorganism	Association	Plants	N- Fixation(Kg N/ ha/ crop)
Rhizobium	symbiotic with root nodules	legumes	up to 360
Azotobacter	free living in soil	Cereals, vegetables, cotton	20-30
Azospirillum	associative symbiosis	maize, millets, sugarcane	20-30
Blue Green Algae	free living in water	rice	10-80
Anabeana azollae	symbiotic with *Azolla*	rice	20-100
Frankia	symbiotic with	*Alnus, Casuarina,*	12-300
	Actinorhizal roots	*Elaeagnus, Myria, Hippophae,Cercocarpus*	10-85

Phosphate solubilizing biofertilizers:

Phosphorus is the second critical plant nutrient next to nitrogen. It is involved in several energy transformation and biochemical reactions including biological nitrogen fixation. Although, total phosphorus pool of soil is high, only a part is available to the plants depending on the solubility and availability of microbial load. It remains the major challenge to soil microbiologist, plant scientist and ecologist to increase the availability of phosphorus to the plant. Various approaches have been employed and universally accepted method is application of phosphatic fertilizers.However, these are expensive and not readily available in developing countries. Moreover, phosphorus in these fertilizers is initially plant available; it rapidly reacts with soil and progressively becomes less available to plants. So there is a need to develop cheap and eco-friendly alternative to phosphorus fertilizer also, keeping in viewthe aspect of sustainable agriculture.

Phosphate solubilizing microbes (PSM) are known to mobilise insoluble phosphate in soil and stimulate plant growth under conditions of poor phosphorus availability. PSM has been used singly or mixed inocula for improving soil fertility. Selection of ecologically well adapted native strains of phosphate solubilizers, large scale production of inoculum and development of field delivery system are critical to practical application of these beneficial microbes in the survival of plants in their natural habitat. Thus the enhanced adaptive ability imparted to the plant by these microbial additives would also be immensely helpful in soil amelioration, land reclamation and re-vegetation at the degraded forest land.

Table shown below indicates the micro-organisms involved in phosphate solubilisation.

Microorganisms and sources of phosphates involved in phosphate solubilization

Microorganisms	Mineral
Bacteria *Bacillus* sp., *B. pulvifaciens*, *B. megaterium*,	Tricalcium phosphate,
B. circulans, *B. subtilis*, *B. mycoides*,	Calcium phosphate
B. mesentericus, *B. flouresecence*,	Iron phosphate
B. circulans	Hydroxyapatite
Pseudomonas sp.,	Flourapatite
P. putida, *P.calcis*, *P. rathonia*,	Rock phosphate
Flavobacterium spp.	Calcium phosphate
Brevibacterium spp., *Serratia* spp.	Calcium glycer-phosphate
Fungi *Aspergillus* sp., *A. niger*, *A. flavus*, *Penicillium* sp., *P. lilacinum*, *Fusarium* sp., *Rhizoctonia* sp. *Trichoderma viride, Cladosporium* sp. *Candida* sp.	Tricalcium phosphate
Actinomycetes	

Phosphate Solubilizing Microorganisms

Phosphate solubilising microorganisms can be isolated on Pikovskaya Agar Medium having tri calcium phosphate or rock phosphate as the source of insoluble phosphate. The organisms forming a clear zone around them on this medium indicates their phosphate solubilisation capacity.

Aspergillus niger

Aspergillus fumigates

Colonies of *Aspergillus niger* and *Aspergillus fumigatus*, showing halo of phosphate solubilization

These organisms solubilize phosphate by the production of organic acids, chelating agents, carbon oxide, mineral acids, siderophore production, H_2S and phosphatase.

For the production of phosphatic inoculants, a suitable and cheap carrier material is required. Peat, farm yard manure, soil, cow dung manure are used as solid carrier for the preparation of efficient phosphate solubilizing bacteria and fungi.

Vesicular ArbuscularMycorrhiza (VAM): These are the fungal associations with a root of higher plants which help in the uptake of phosphorus from the soil. There are two different types of mycorrhiza :
Ectomycorrhiza and Endomycorrhiza

Ectomycorhiza

It forms a sheat around the root, its hyphae forms a Hartig net like structure with clamp connections.

Endomycorrhiza

Itenters inside the roots and form vesicles, arbuscules and spores.Endomycorrhizae also help in improving symbiotic nitrogen fixation along with *Rhizobium*.Mycorrhiza also help in reclamation of degraded sites.

The following table shows the role of mycorrhiza in reclamation of degraded lands.

Role of mycorrhiza in reclamation of disturbed lands

Site/ Location	Host Plant	Inoculant
Anthracite coal wastes (Pennsylvania)	*Pinus spp.*	*Pisolithus*
	Betula pendula	*Scleroderma citrinum*
	Quercus sp	*P.Tinctorius*
Coal spoils	*Pinus sp*	*P. tinctorius*
(Tennessee)	*(lobollyvirginia)*	*Hebeloma sp*
Tin mine spoils (South West Oregon)	*P. caribaea var. hondurensis*	*P. tinctorius, Thelephora terrestris*
Burrow pits, eroded ridges (South Carolina)	*lobolly pine*	*P. tinctorius, Laccaria sp*

Role of mycorrhiza in reclamation of disturbed lands

Success of Biofertilizer Technology

Government of India and their different state Governments have been promoting use of biofertilizers through grants, extension and subsidies on sales with varying degrees of emphasis. With time farmers to learn about the technology forming their perception on the basis of agronomic realities of their regions, the knowledge gained from experiences of farmers around them and including themselves and the information provided by different disseminating agents and form their own decisions of adoption. Above all the enterprise of the firms working through their marketing, research and development efforts would lead to the widespread use of inputs once the prospects of profit is sensed, commercial appeal with the passage of time and government support.

Conclusion

Critics have argued that Green Revolution simply borrowed production from future generations as it impoverished soils and destroyed ecological balances. Environmentalists have further pointed out that the emerging free trade regime would raise the scale of activity, especially with respect to products with comparative advantages, leading to greater environmental damage. While all this may be an extreme view and a debatable one, the need for undoing to the extent possible of ecological problems of the past and introducing more sustainable patterns in future cannot be over emphasised.

Government of India has been promoting the use of biofertilizers in agriculture through the NPDB and the state governments also added to the process via subsidization and extension. Based on the living micro-organisms these inputs can make nutrients abundantly available in atmosphere and soil accessible for plant use without the adverse impact that chemical fertilizers have on soil, water and air. The national scheme sought to spread the new biofertilizer based technology through field demonstration, research and financial assistance to investors.

Public interventions through monetary or other means is justified for building up a market for an input promising social and longer term gains. The emphasis of any government policy would be in popularizing the use at the farmer level through varietal improvement, information dissemination, risk coverage and also sales subsidies if justified by scientifically conducted studies. The acceptance at the farmers end would go a long way in providing commercial benefits to producing units and encouraging investments. The government must however help the units financially or otherwise in developing suitable strains and carriers, in accessing affordable finance for investment and in working out viable schemes for distribution especially since smaller and less experienced units are tending to dominate the market.

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	Subject: Biofertilizers
DOI:10.22192/ijarbs.2020.07.01.009	

How to cite this article:
Anshu Sibbal Chatli, Srishty, Irandeep Kaur and Parminder Kaur. (2020). Plant Growth Promoters: A root army. Int. J. Adv. Res. Biol. Sci. 7(1): 76-81.
DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.01.009