Cyanobacteria: A Potential Biofertilizer for Rice

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Application of high input technologies has resulted in significant increase in agricultural productivity. There is, however, a growing concern about the adverse effects of indiscriminate use of chemical fertilizers on soil productivity and environmental quality. Cyanobacteria offer an economically attractive and ecologically sound alternative to chemical fertilizers for realizing the ultimate goal of increased productivity, especially in rice cultivation. In a wetland rice ecosystem, nitrogen fixation by free living cyanobacteria also significantly supplements soil nitrogen.

Cyanobacteria – also called blue-green algae – evolved very early in the history of life, and share some of the characteristics of gliding bacteria on one hand and those of higher plants on the other. Cyanobacteria can both photosynthesize and fix nitrogen, and these abilities, together with great adaptability to various soil types, make them ubiquitous. Cyanobacteria also have a unique potential to contribute to productivity in a variety of agricultural and ecological situations. Cyanobacteria have been reported from a wide range of soils, thriving both on and below the surface. They are often also characteristic features of other types of sub-aerial environment and many intermittently wet ones such as rice fields. Most paddy soils have a natural population of cyanobacteria which provides a potential source of nitrogen fixation at no cost. Ammonia can be taken up by cyanobacteria through passive diffusion or as ammonium (NH_4^+) by a specific uptake system. The amino acids argenine, asparagine and glutamine have also been reported to serve as nitrogen sources. Nitrate and nitrite are important sources, which later reduce into ammonia. Many cyanobacteria are also capable of using atmospheric dinitrogen (N_2) as the source of nitrogen, and this is what is most commonly termed nitrogen fixation. Like in many other biological systems, nitrogen fixation in cyanobacteria

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is brought about by a high molecular weight, oxygen labile, metalloprotein enzyme known as nitogenase. Nitrogenase reduces molecular nitrogen to ammonia in presence of hydrogen.

Due to this important characteristic of nitrogen fixation, the utility of cyanobacteria in agriculture to enhance production is beyond doubt. Many studies have been reported on the use of dried cyanobacteria to inoculate soils as a means of aiding fertility, and the effect of adding cyanobacteria to soil on rice yield was first studied in the 1950s in Japan. The term 'algalization' is now applied to the use of a defined mixture of cyanobacterial species to inoculate soil, and research on algalization is going on in all major rice producing countries. The average of the results from all these studies have shown an increase in grain yield of 15-20% in field experiments. It has been suggested that the cyanobacteria introduced as a result of algalization can establish themselves permanently if inoculation is done consecutively for 3-4 cropping seasons.

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The basic method of mass production involves a mixture of nitrogen fixing cyanobacteria in shallow trays or polythene lined pits filled with water kept in open air, using clean, sieved farm soil as a carrier material. To each pit 10 kg soil and 250 g single super phosphate is added and water is filled upto a height of 12-15 cm. Starter culture, a mixture of *Anabaena, Nostoc, Aulosira* and *Tolypothrix,* is inoculated in each multiplication unit. Malathion (5-10 ml per tank) or carbofuran (3% granules, 20 g per tank) is also added to prevent insect breeding. In hot summer months, the cyanobacteria form a thick mat over the surface after 10-12 days of growth in open sun. The contents are allowed to dry and the dried flakes are collected, packed and used to inoculate rice fields. The basic advantage of this technology is that farmers after getting the soil based starter culture can produce the biofertilizer on their own with minimum additional inputs. An inoculum of 10-12 kg is considered sufficient to inoculate one hectare of paddy field 3-4 days after transplantation.

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Unfortunately, the open-air algal biofertilizer production technology for production at farmers' level is not popular among the farming community. The main limitations of this technology are:

- due to open air nature of production it can be produced for only a limited period in a year (3-4 months in summer; production has to be stopped during rainy and winter season),
- high level of contamination due to open type of production,
- slow production rate,
- low population density and hence need for heavy inoculum per hectare.

Therefore, efforts have also been made to improve the technology by developing new economically feasible protocols for production of quality inoculum so that these organisms can be practically exploited on a large scale. This is possible only if multiplication is carried out under controlled conditions. The production technology has been substantially improved with introduction of new and cheap carrier materials that support higher cyanobacterial load with longer shelf life, thus considerably reducing the quantity of inoculum per unit area. The basic changes the technology has undergone include, a) indoor production of algal biomass under controlled conditions; b) a suitable and cheap growth medium for faster growth of the organisms, and c) mixing with a suitable carrier material.

Figure 1. Indoor production of cyanabacterial biofertilizer in a polyhouse under semi-controlled conditions.

Indoor production involves the growth of algae in a unit that may be a polyhouse or glasshouse (*Figure* 1). The individual unit in the polyhouses can be of either RCC, brick and mortar, or even polythene lined pits in the ground. The algae are grown individually as species, by inoculating

Name of Village (Area)	Grain yield (Quintals per hectare)		
	Uninoculated	Inoculated	% Increase
Asoda Todran (7 ha)	19.25	23.00	19.48
Asoda Shivan (4 ha)	13.66	15.22	15.81
Jakhoda (9 ha)	17.93	20.13	12.26

Under farmer's own management practices

Table 1. Effect of cyanobacterial biofertilizer inoculation on rice grain yield at a farmer's field.

separate tanks with laboratory grown pure cultures, so as to ensure the presence of each required strain in the final product. Once fully grown, the culture is harvested, mixed with the carrier material, presoaked overnight in water and multani mitti (in 1:1 ratio) and sun dried. The dried material is ground and packed in suitable size polythene bags, sealed and stored for future use. The final product contains 10,000 to 1,00,000 units or propagules per gm of carrier material and, therefore, 500 g material is sufficient to inoculate one acre of rice growing area. A number of field trials conducted with this material have shown promising results both in terms of nitrogen saving as well as crop yield (*Table* 1). However, statistical analysis of the data on alagalization in experimental fields has suggested that the effects of inoculation are inconsistent. The best results appear to be obtained when mixed inocula are produced from local stocks, and the biofertilizers are used in combination with a low level of nitrogenous fertilizer. Addition of fertilizer to rice fields generally leads to accelerated growth of algae (*Figure* 2). Cyanobacteria form a major component of the flora as long as nitrogen content is not very high. If high nitrogen fertilizer is used, green algae tend to dominate the soil flora. Surface application of fertilizer generally checks the growth of cyanobacteria but deep placement of urea does not prevent their growth. Most cyanobacteria inoculated in soil fail to dominate over the flora

Figure 2. Luxuriant growth of cyanobacteria in a paddy field.

indigenous to soil receiving the inoculation, and inoculated species are able to dominate only when the indigenous flora is sparse. Thus, 'algalization' seems likely to be most useful where there are marked seasonal changes in land such as when ground is ploughed frequently before planting so that the natural soil inoculum is much reduced by the time of new paddy season. A number of studies have also been done on the selection of natural or mutant strains with the aim of maximizing the nitrogen fixing ability. These are strains that either show high levels of nitrogenase activity in laboratory studies, or in pot experiments, and it is, therefore, important to check whether they can also compete effectively with other native soil strains under field conditions.

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In India, considerable progress has been made in the development of cyanobacteria based biofertilizer technology. It has also been demonstrated that this technology can be a powerful means of enriching the soil fertility and improving rice crop yields. However, the technology needs to be improved further for better exploitation under sustainable agriculture systems. It is important to obtain a much more detailed understanding of cyanobacterial population dynamics over the whole annual cycle in agriculture systems. Extensive field studies aimed at developing region specific high quality inoculum are also needed. Understanding the biology of drought resistant cyanobacteria may be useful in terms of extending this approach to dry crops.

Suggested Reading

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