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# Cyanobacterial biofertilizers as an alternative to chemical fertilizers in paddy fields: a review

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**Abstract:** In India, rice is the most significant crop in terms of the total area of cultivation and fertilizers. Distributed in 44.7 million hectares, it accounts for 31.8% (5.34 million tons) of the net use of the chemical fertilizer. Continuously using chemical fertilizers in agricultural production poses a severe environmental risk. The cost of chemical fertilizers is expensive and contributing to less crop yield. There is a need to adopt alternatives for chemical fertilizers in paddy fields. Cyanobacteria are abundant in paddy fields, and it presents remarkable contribution in producing the rice crop. It fixes atmospheric nitrogen, increases the accessibility of available phosphorus, and produces innumerable plant growth-promoting factors. It requires sunlight as the source of energy for carbon and nitrogen fixation in the soil. It represents remarkable potential as a biofertilizer and thereby decreases fuel demand for chemical fertilizer production. Cyanobacterial biofertilizers are inexpensive, simple to use, and do not harm the environment. This review focuses on the potential application of cyanobacterial biofertilizers in paddy fields.

**Keywords:** chemical fertilizer; cyanobacterial biofertilizer; environmental pollution; paddy field; sustainable agriculture.

## Introduction

Rice (*Oryza sativa* L.) is the chief food crop in the world. More than 40 % of the world's total population mainly depends on rice for calories. Rice crop is cultivated in about 44.97 million hectares in India, with approximate net produce of 86.3 million tons [1]. It accounts for 31.8% (5.34 million tons) of total chemical fertilizer consumption. The use of chemical fertilizer on irrigated paddy (155 Kg/ha) is double that on rain-fed paddy (77.6 Kg/ha). The share of irrigated and rain-fed paddy in total use of chemical fertilizer were 22.2 and 9.6%, respectively. According to the Food and Agriculture Organization (F.A.O.), the average consumption of chemical fertilizer on rice cultivation was reported in India to be 119.1 Kg/ha (81.7Kg nitrogen per hectare, 24.3Kg $P_2O_5$ per hectare, and 13.1 Kg $K_2O$ per hectare) [2]. Continuous use of chemical fertilizers in agricultural production has a serious environmental concern, reduces soil fertility. In recent years there is an increase in chemical fertilizer costs instigating an additional economic burden on farmers. Therefore, there is a need to adopt alternatives for chemical fertilizers in paddy fields.

## Need of biofertilizers

The term biofertilizer denotes all forms of organic fertilizers, from composts to plant extracts. Biofertilizers are microbial preparations comprising different beneficial live microorganisms that can mobilize unusable plant nutrients to the usable form in the soil through the biological process [3]. Several disadvantages of using chemical fertilizers [4] are

i) it causes a disturbance to the plant-microbe associations

ii) softening of plant tissues ensuing in an augmented vulnerability to disease and pests.

iii) loss of nutrients from soils through leaching or greenhouse gas emission.

iv) it enhances the decomposition and depletion of soil, leading to the acidification or alkalization of soil, which reduces soil fertility

v) use of chemical fertilizers in excess causes weed problems in fields

vi) chemical fertilizers contain nitrates and phosphates when they are leached or removed from the soil enter into ground or surface water causing water contamination, leading to eutrophication of surface water. Eutrophication results in the growth of aquatic plants and algae.

Therefore, it is imperative to use biofertilizers for sustainable agriculture.

## Cyanobacterial diversity in paddy fields

The ecosystem of the paddy field offers a suitable environmental condition for the growth of cyanobacteria, such as appropriate light, water, and nutrient availability, resulting in its plenteous growth in paddy fields. Cyanobacteria exist in different forms in paddy fields. They can be a unicellular form (e.g., *Gloeocapsa* and *Aphanorhece*), filamentous heterocystous form (e.g., *Anabaena*, *Nostoc*, *Aulosira*, *Calothrix*, *Cylindrospermum*,

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and *Westiellopsis*), or the filamentous non-heterocystous structure (e.g., *Oscillatoria, Lyngbya, Phormidium*). The occurrences, distribution, and diversity of cyanobacterial species in Indian Paddy fields were studied by several workers [5-17].

## Significance of cyanobacteria in paddy fields

Cyanobacteria play an essential role in paddy fields. Under nitrogen-deficient conditions, they carry the fixation of atmospheric nitrogen. The filamentous heterocystous form is regarded to be significant in the nitrogen economy of rice cultivation. De and Mandel (1956) assessed cyanobacterial nitrogen fixation in West Bengal's six rice-growing fields and reported that the nitrogen fixed in rice cultivated is 13.8 to 44.4 Kg/ha [18]. Watanabe and Cholitkul (1979) estimated cyanobacterial nitrogen fixation to be 18-45 kg nitrogen per hectare [19]. Employing the $^{15}N$ technique, MacRae and Castro (1967) confirmed the accumulation of 10-15 Kg nitrogen per hectare [20]. Henriksson (1971) exhibited a yearly addition rate of 15-51 Kg N per ha per year in a field with an abundance of *Nostoc* [21]. Besides nitrogen fixation, it also plays an essential role in adding biological carbon to the soil. Nekrasova and Nekrasova (1982) established that the algal biomass substantially subsidizes the humus formation in the soil [22]. Roger et al. (1987) showed that a decent algal bloom in paddy fields on average produces about 6-8 tons of fresh biomass under favorable circumstances [23]. Cyanobacteria also mobilize essential micronutrient elements such as phosphorus and potassium from their non-usable to a usable form, which is critically improved by producing acidic metabolites or the excretion of enzymes by cyanobacteria [24, 25]. It also produces growth-promoting substances such as gibberellins, cytokinins, and auxins that benefit rice plants [1]. Shariatmadri et al. (2013) studied in detail and reported the importance and distribution of plant growth-promoting cyanobacteria in terrestrial habitats of Iran [26].

## Preparation of cyanobacterial biofertilizer

A potent strain of nitrogen-fixing cyanobacterial pure culture is grown on an agar slant. A loopful of culture is transferred in broth medium in a conical flask. Incubate the flask under an illuminated light source 16 hours in light and 8 hours dark for 3 to 7 days. The flask is monitored for the growth of the cyanobacterial culture. The inoculum is transferred in the successive increase in the medium volume in larger flasks containing broth medium and incubated for multiplication. For large-scale production in laboratories, the inoculum is transferred in photobioreactors. After incubation, broth culture is mixed with a sterilized carrier. The carrier materials used are peat, perlite, charcoal, etc. Carrier material along with inoculum is then packed in thin-walled polyethene bags [31].

## Mass production of cyanobacterial biofertilizers

There are different technologies developed for the mass cultivation of cyanobacteria [3, 27, 28]. These are very simple in operation and easy to adopt by Indian farmers. There are four methods for the mass production of cyanobacterial biofertilizers. These are:

i) Trough or cemented tank method,
ii) Pit method
iii) Field method and
iv) Nursery cum algal production

## Potential use of cyanobacterial biofertilizers in paddy fields

In 1972, the Indian Agriculture Research Institute (IARI) at New Delhi reported the production and use of cyanobacterial biofertilizer for the very first time [29]. The technology was often referred to as algalization. Currently, numerous technologies and methods are available for the production of cyanobacterial biofertilizer. The most commonly used species for biofertilizer production are *Anabaena variabilis, Nostoc muscorum, Aulosira fertilissima*, and *Tolupothrix tenuis*. Dixit and Gupta (2000) reported the average rise of 7.5% (0.24 ton/ ha) in grain yield of rice by the use of blue-green algal (BGA) biofertilizer [30]. Tripathi et al. (2008) stated that the rice crop produce showed the best growth response with BGA biofertilizer [31]. Dhar et al. (2007) emphasized newly developed biofertilizers based on Multani mitti and wheat straw helps increase the rice crop productivity and diminishes the requirement of chemical fertilizers [32]. Mishra and Pabbi (2004) concluded that the use of cyanobacteria as a biofertilizer is an economically appealing and environment-friendly alternative to chemical fertilizer to upsurge rice crop production potential [11].

## Research achievements and challenges to commercialization of cyanobacterial biofertilizers

The application of biofertilizers in crop fields improves soil fertility, increases carbon, nitrogen, and phosphorus [33, 34]. Several reports on the increase in growth parameters and yield of the crop [35-39]. The commercial production of biofertilizers is carried out on an industrial scale [3]. Laboratoire de Microbiologie in France manufactures N-germ products using cyanobacteria for rice crops. Recent advancement in Research and development has improved biofertilizer production technology and resulted in market expansion in cyanobacterial biofertilizers. However, there are challenges in the commercialization of cyanobacterial biofertilizer. These are:

i) Specific strains of cyanobacteria are not made available
ii) Availability of suitable carriers
iii) Farmers are not aware of the use of biofertilizers and
iv) Lack of experienced and adequate staff

## Conclusion

Cyanobacterial biofertilizers make an essential contribution in upholding the yield and sustainability of the soil system and, in turn, supports an increase in the output potential of rice. It is a sustainable, farmer-friendly, environment-friendly, and profitable alternative to chemical fertilizers in the paddy fields.

### Declarations

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