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Cyanobacterial Application as Bio-fertilizers in Rice Fields: Role in Growth Promotion and Crop Productivity

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Abstract
Nitrogen deficiency in rice fields particularly in developing countries is one of the major abiotic constraints which is generally managed by the extensive application of nitrogen fertilizers. Though, the application of chemical fertilizers efficiently increases soil fertility and productivity of the crop; however, ecological and environmental problems are grave concerns for ecosystem and environmental sustainability rendered by the unbalanced use of these chemicals. Instead, application of bio-fertilizers in cultivated fields have been well known for reducing heavy inputs of fertilizers and thereby contributing to environmental sustainability. Cyanobacteria, which have diverse range of species, many with beneficial agro-activities and nitrogen fixation capabilities, can serve as bio-fertilizers in rice fields because of greater dependency of rice crop on fixed nitrogen for its growth and production requirements. This paper focusses on the use of cyanobacteria as potential bio-fertilizer in rice fields and their beneficial roles in promoting growth and productivity of the crop.
Keywords: Bio-fertilizer, Environmental sustainability, Growth promoting bacteria, Pollution, Paddy fields.

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INTRODUCTION

Rice is among the most widely cultivated, used and nutritionally relied crops in the world, supplying food to more than 3 billion people globally (Muthayya *et al*., 2014). Among cereals, the crop has a prominent position and is popularly used worldwide as staple and food which has significant role in addressing food needs. Due to its major contributions in the past decades to hunger reduction and starvation in many parts of the world, significant efforts have been made to raise its production. Global rice production has gained significant production increase due to introduction of high yielding varieties (Long-ping, 2014), drought and salt stress tolerance induction in rice (Kumar *et al*., 2014; Singh *et al*., 2015), pesticides use to control weeds and pest in rice fields (Prakash *et al*, 2008) and increased application of fertilizers for coping with nutrient requirement of the crop (Dong *et al*., 2012). Rice has more thrust for nitrogen (N) and potassium (K) than other nutrients, hence, deficiency in these nutrients could adversely affect its growth and developmental phases (Fageria and Baligar, 2003). On the other hand, most of the cultivated fields including those of rice are deficient in N which is generally managed by huge application of nitrogen fertilizers (Linquist *et al*., 2013). Fertilizers application greatly overcome nutrient related abnormalities in crops and improve overall growth, physiological and yield performance of crops including rice in soils where nutrient deficiency is a major problem (Chaturvedi, 2006; Arshad *et al*., 2016, 2017). However, there are also reasonable concerns about the overuse of fertilizers in agriculture because of their long term effects on ecosystem and environment (Savci, 2012).

To maintain the ecological and environmental stability while getting maximum production, low input of fertilizers in cultivated soils is crucially necessary. Addressing N dependency of rice for its proper growth, bio-fertilizers with potential growth promotory effects and nitrogen fixation capacity can serves a suitable and attractive approach towards sustainable production of rice (Mishra and Pabbi, 2004). In that context, Cyanobacteria, which include diverse range of blue green algae, are significantly

important because of their well-known role in nitrogen fixation (Vaishampayan *et al*., 2001). Ghosh and Saha (1997) documented increased N uptake and growth of rice in response to inoculation with different species of cyanobacteria. Kannaiyan *et al*. (1997) reported increased growth of rice seedlings, ammonia production and nitrogenase activity in lab and field conditions following inoculation with cyanobacterial strain (*Anabaena azollae*). de Mulé *et al*. (1999) observed improved growth performance of rice seedlings and better nitrogen fixation when fields were inoculated with *Tolypothrix tenuis* and *Nostoc muscorum*. Saadatnia and Riahi (2009) recorded increased growth characteristics of rice plants and improved soil properties in rice cultivated pots which were inoculated with different genera of cyanobacteria. Prasanna *et al*. (2012) obtained 19% increase in rice yield and enhanced nitrogen fixation activities in soils which were contaminated with bacteria and cyanobacteria. The aim of this paper is to discuss the role of cyanobacteria as bio-fertilizer in rice fields and its effect on growth and productivity of the crop.

CYANOBACTERIA – APPLICATION AS BIO-FERTILIZER IN RICE FIELDS

Cyanobacteria are prokaryotic organisms with characteristic blue green coloration, hence commonly termed as 'blue-green algae' although not all organism included in this group are algae in true sense as many bacteria share similar characteristics (Vaishampayan *et al*., 2001; Thajuddin and Subramanian, 2005). Since majority of the organisms in cyanobacteria are capable of nitrogen fixation, growth promotion of rice and other plants and soil improvement (Nain *et al*., 2010); they have spacious potentials of being applied as bio-fertilizers in agricultural fields, particularly in rice fields because rice crop requires comparatively larger amounts of N (Fageria and Baligar, 2003). As a bio-fertilizer, cyanobacteria may be applied artificially by inoculating rice fields with appropriate cyanobacterial strains or the natural inoculation of such cyanophytes may be facilitated by anthropogenic activities. However, not all the cyanobacterial strains grow well in all types of ecosystems. Vaishampayan *et al*. (2001) has asserted that heterocystes cyanobacteria, *Azzola* and *Anabaena* spp. in particular, could greatly contribute to nitrogen fixation, excretion and synthesis of substances necessary for growth promotion of rice and thus, could be used as effective bio-fertilizers in rice fields. Choudhury and Kennedy (2004) have recommended cyanobacteria *Azzola* as biofertilizer for coping with nitrogen losses as urea-N in rice fields and stated that *Azzola* could manage urea-N losses by 30-50%. Mishra and Pabbi (2004) have also argued that based on the ability of nitrogen fixation, cyanobacterial application in rice crops as bio-fertilizer could prove ecofriendly and cost-effective measures for improving rice productivity.

Growth promotion of plants by cyanobacteria and other growth promoting organisms is a complex phenomenon which can operate either in rhizosphere or through endophytic relationship with host plants (Vessey, 2003). In case of rice, they can float over the surface of soil water or assemble on wet soil (Prasanna *et al*., 2009). Colonization of rhizosphere and subsequent growth, abundance and physiological activities of cyanobacteria depend on several ecological and environmental factors. First, root excretions in the form of sugars, amino acids and several other compounds may either attract or detract microbial communities through direct provision of materials for their metabolic activities or indirectly through modification of soil environment (Berg and Smalla, 2009). Second, environmental factors such as temperature, light, availability of moisture and soil nutrient status may have profound effects on the colonization process and its success or failure (Buée *et al*., 2009; Mendes *et al*., 2013). Thus, in rice-cyanobacterial interface, understanding of both ecological and environmental factors is necessary.

Plant growth promotion – mechanism

Plant growth promotion by cyanobacteria in rice or other cropping system is driven by several complex processes. Berg and Smalla (2009) elucidated that plant growth is influenced by abiotic (soil type, climate, geography, pesticide etc.) and biotic factors (grazing, plant species, health, developmental stages of plant etc.). They showed that rhizospheric microbial communities can modify these factors either positively (hence, growth promotion occurs) or negatively (growth suppression). They further demonstrated that positive interactions between microbial communities and host plants results in controlling plant pathogens, improvement of prevailing stressed conditions, release of plant hormones and stimulation of the availability of nutrients. While negative interaction were assigned to pathogenic activities of the microbial communities. Gamalero and Glick (2011) presented similar arguments stating that direct growth promotion of plants by PGPB occurs when these microbiota fix nitrogen, provide, facilitate the required nutrients and ion uptake by plants or indirectly contribute to improvement of plants by minimizing the pathogenic activities of pathogens and parasites. Considering cyanobacteria-rice interface, similar mechanisms of producing nutrients and facilitating growth condition as mentioned in the above studies may contribute to growth promotion of rice crop. Photosynthetic cyanobacteria fix nitrogen to ammonia (Fig. 1), utilizing their own metabolic machinery (Issa et al., 2014). The released ammonia into rhizosphere is taken up by plants which is further utilized by host plants for essential growth processes. Theoretically, the amount of nitrogen fixation would depend on the abundance and types of cyanobacterial species; however, in practice, variation in nitrogen fixation could occur as several factors contribute to

the process which range from ecological to environmental conditions.

Besides provision of nutrients to host plants, cyanobacteria are also known for their role in bio-control of plant pathogens which are important biotic limiting factors in growth and crops' yield. Antifungal compounds produced by different cyanobacteria were successfully evaluated against *Fusarium* wilt, damping-off, powdery mildew and grey mold with plausible reduction in disease severity (Kulik, 1995). Algal filtrates of *Oscillatoria, Anabaena* and *Nostoc* spp. have been documented for effective control of fungal diseases of faba bean (Abo-Shady *et al*., 2007). *Anabaena variabilis* were found efficient in controlling *Fusarium* wilt of tomato and improving soil characteristics and growth/yield of the crop (Prasanna *et al*., 2013). In the context of potent anti-pathogenic potentials of wide array of blue green algae, extensive studies directing the identification of antagonistic cyanobacterial strains and their possible use in rice fields for controlling prevailing soil borne diseases are necessary which can stimulate their application as bio-control agents and can result in minimal use of pesticide application.

CONCLUSION

Owing to high thrust for N, rice fields are generally fertilized with chemical fertilizers which effectively fulfill nitrogen requirements of the crop; however, losses of N and undesirable ecological and environmental effects of chemical fertilizers stresses for alternative methods to be employed in rice improvement. Several species of cyanobacteria, which fix nitrogen, provide nutrients, facilitate growth conditions and act as biological antagonists against a variety of plant pathogens in rice fields have been already in practice as 'bio-fertilizers' which further need stimulation for gaining improved growth and productivity of rice crop. Maximum utilization of cyanobacteria as bio-fertilizers will reduce heavy reliance on fertilizers application and could further strengthen efforts for sustainable environment and ecosystem.

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CONFLICT OF INTEREST

The authors verify having no interest in competition and have no conflicts of interest.

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