Microbial Technologies for Land Rejuvenation and Climate Resilient Crop Productivity

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Summary

Most of the cultivable lands around the world are severely affected by environmental factors leading to decline in the crop productivity by 10%. Besides these factors, indiscriminate use of chemical fertilizers along with pesticides and unavailability of organic manures also led to considerable reduction of crop productivity thereby deteriorating the sustainability of soil health and agricultural ecosystems including rice. Therefore, a wider range of adaptations and mitigation strategies would be required to meet the challenges of enhancing productivity of rice. Beneficial microorganisms are one of the best options to overcome these situations. Inadequate rice-specific biofertilizers and microbial pesticides prompted us to develop microbial technologies especially to manage nutrient and pest problems of rice. So far, ICAR-National Rice Research Institute, Cuttack has developed numerous microbial technologies such as *Azotobacter chrococcum* and *A.vinelandii* bioinoculants, soil-based *Azolla*sporocarp*,* phosphate solubilizing bacteria, arbuscularmycorrhiza, entomopathogens (*Bacillus thuringiensis*, *Beauveria* and *Metarrhizium*), exopolysachharide producing bioinoculants and straw decomposition microbial consortia, to resolve many problems allied to nutrient (nitrogen and phosphorous), climatic, pest and straw decomposition.

Key words: Rice, Biofertilizers, Microbial pesticides, Straw decomposition, *Azolla*

1. Introduction

Agriculture is highly dependent on the climate. Increases in temperature, carbon dioxide (CO_2), moisture, water availability and other factors directly or indirectly affect crop's growth and productivity. Increasing level of atmospheric CO_2 is not only causing global warming but also altering the agricultural ecosystem (Panneerselvam et al., 2019). Moreover, overuse of chemical fertilizers and pesticides also deteriorated the soil health and sustainability of the agriculture systems (Kumar et al., 2018a). Hence, concrete strategies would be required for enhancing crop productivity. Beneficial microorganisms are one of the best options to overcome this situation, by exploring their potentiality mostly unique properties of tolerance to extremities, ubiquity, genetic diversity, and their interaction with crop plants for sustainable rice production. In the present chapter, NRRI-developed rice-specific microbial technologies have been highlighted and these technologies may serve as a potential measures in suppression of some of the major global problems related to sustainability of rice crop.

2. Microbial technologies

2.1 Biofertilizer

Biofertilizers contain carrier based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop plants. Presently, biofertilizers have emerged as a highly potent alternative to chemical fertilizers because of their eco-friendly, easy to apply, non-toxic and cost-effective nature. In addition, biofertilizers are one of the promising technologies for rice productions, however, it is not popular among farming community, due to lack of knowledge and awareness of its effective use. Moreover, Government has also taken many steps to showcase its effective use in agriculture. Some of the most useful biofertilizers for rice and their recommended doses are mentioned in Table 1.

Table1. Recommendation of bio-fertilizers for rice crop

Inoculants	Recommendations	Nutrients supply to plants	Gain in grain yield
Cyanobacteria/ Blue green algae	50-60 kg fresh wt/ha (or) 6-7 kg dry weight	20-25 kg /ha/season	10-20%
Azolla	10-15 t fresh wt/ha	20-40 kg N/ ha/ 20-75 days	10-30%
Azospirillum	5-6 kg solid/ 500 ml liquid/ ha	5-10 kg N/ha	5-15%
Azotobacter	5-6 kg solid/ 500 ml liquid/ ha	5-10 kg N/ha	5-15%

AM fungi	1 ton soil based inoculums/ha (Upland rice)	Supplemented 30% Phosphorus	15-25% (upland rice)
Phosphate solubilizing bacteria (PSB)	5-6 kg solid/ 500 ml liquid/ ha	Supplemented 10-20% Phosphorus	5-15% (upland rice)

2.1.1. Bio-prospects of *Azolla*

Azolla technology is widely accepted throughout the world as efficient nitrogen contributor in rice ecology through symbiotically associated cyanobacteria (Kumar et al., 2019a). As regards to the biomass production, and quantity of nitrogen fixation and nutrient recycling, *Azolla* is highly efficient, cost-effective and ecologically sound biofertilizer. To produce *Azolla* inoculum in paddy fields, its vegetative fronds in large scale are required but there are several physical constraints in *Azolla* production and utilization. The thick wall of megasporocarp can withstand high temperature, drought condition, and pest attack. Most of the researchers have documented the sporocarp production of *Azolla* only from a limited number of species but it has to be studied thoroughly with 102 strains available at NRRI germplasm collections (Kumar and Nayak 2019; Kumar et al., 2018c). Soil-based *Azolla* sporocarp, *Azolla* pellets for livestock feed and *Azolla*-based microbial medium had been developed at NRRI.

2.2. Microbial formulations to manage rice pests

Adequate pest management is essential for sustainable agricultural production. In the worldwide agriculture system, the commonly used pesticides come under synthetic origin. Excessive use of these synthetic compounds led to environmental pollution. Hence, biopesticides are considered as an alternative to synthetic pesticides that are highly effective, target specific and reduce environmental risks. At NRRI, we are actively working since long to identify efficient entomopathogens to manage rice leaf folder and finally able to identify the following bacterial and fungal strains *viz., Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and formulations of these strains were also filed for Indian patents. In addition, recently we have identified one efficient entomopathogenic bacterium (*Skermanella* sp.) against rice leaf folder and pink stem borer (Panneerselvam et al., 2018).

2.3 Microbe-mediated paddy straw decomposition

In India, we are generating nearly 158 million tonnes of paddy straw every year and recycling of these wastes properly retrieve the considerable amount of nutrients to the soil in addition to improving soil health and reducing greenhouse gas emission to the environment. It has been frequently reported that the application of rice straw to paddy fields increases methane emissions. Therefore, promotion of the oxidative decomposition of rice straw in and out of the field is important for not only reducing methane emissions but also enhancing the carbon stock in the soil. At NRRI, *Bacillus*, *Aspergillus*, *Trichoderma*, and *Streptomyces* spp., consortia were identified to decompose paddy straw within 45 days.

2.4. Role of arbuscular mycorrhizal fungi (AMF) in rice

AMF colonization in rice plant has been documented by many researchers and this fungal association in rice found to enhancing P acquisition. At NRRI Cuttack**,** AMF association was studied in 72 different rice cultivars including two low P tolerant checks *viz*., Kasalath and Dular, which were raised in P deficient soil (<6.0 – 8.0 ppm). The AM fungal root colonization was recorded in the range of 20-90 %, whereas, it was 80-90 % in Kasalath and Dular cultivars. These two varieties have the dominant unique type of vesicle-forming AMF colonization, which was not observed in many low P tolerant varieties. This observation clearly indicates that some genera of AM fungi may prefer the specific rice genotype of rice.

2.5. Microbial products/ formulations developed at NRRI, Cuttack

Presently, the following microbial products/formulations are available at NRRI, Cuttack (Fig. 1; Fig. 2):

- ❖ Liquid bioinoculant of endophytic nitrogen fixing *Azotobacter chrococcum* AVi2 and rhizospheric *A. vinelandii* SRIAz3 for nitrogen management in rice which could replace ~25% of chemical nitrogen without compromising yield.
- ❖ Soil-based sporocarp formulation of *Azolla* has been developed to considerably reduce the initial inoculums load of *Azolla* in paddy field.
- ❖ *Azolla*-based microbial medium and *Azolla* pellets for livestock feed had been developed

- Six Indian patents on entomopathogens formulations for management of rice leaf folder were filed by NRRI with the following numbers 264/KOL/2015, 263/KOL/2015, 261/KOL/2015, 262/KOL/2015, 260/KOL/2015, 265/KOL/2015.
- Arka Microbial consortium and Actino plus microbial packages have been standardized for nutrient management in low-land and aerobic rice production systems.
- Phosphate solubilizing and exopolysachharide producing liquid bacterial bioinoculants had been developed in rice, respectively.

Fig. 1.(a) *Azolla* feed pellets; (b) NRRI *Azolla* medium for microbial growth; (c) bacterial liquid formulation for alleviating drought stress.

Fig. 2. Rice-specific microbial bioinoculants developed at NRRI, Cuttack (ENF: Endophytic nitrogen fixer; RNF: Rhizospheric nitrogen fixer; AS: *Azolla*sporocarop; AMF: Arbuscular mycorrhizal fungi; PSB: Phospahte solubilizing bacteria; ESP: Exopolysaccharide producing bacteria)

3. Conclusion and way forward

The present chapter describes the management of nutrient, pest, residue and drought stress alleviation by harnessing microbial resources especially for rice crop. In future, following microbe-mediated strategies are essentially required for sustainable development of rice crop particularly in eastern India.

- Microbial consortia must be developed for managing major and minor nutrients, pest, paddy straw and abiotic stress alleviation exclusively for rice crop.
- Molecular markers of *Azolla* must be identified for better understanding of *Azolla*-cyanobiont interactions for sustainable production of rice.
- Latest molecular tools must be explored to understand the soil biological nutrient cycling in paddy soil.

References

Kumar U, Nayak AK, Panneerselvam P, Kumar A, Mohanty S, Shahid M, Sahoo A, Kaviraj M, Priya H, Jambhulkar NN, Dash PK. 2019a. Cyanobiont diversity in six *Azolla* spp. and relation to *Azolla*-nutrient profiling.*Planta*.249 (5): 1435-1447.

Kumar U and Nayak AK., 2019.AzollaGermplasms at NRRI: Conservation, Characterization and Utilization *NRRI Research Bulletin No. 19.*ICAR-NRRI, Cuttack. 68.

Kumar U, Nayak AK, Shahid M, Gupta VVSR, Panneerselvam P, MohantyS, Kaviraj M, KumarA, Chatterjee D, LalB, Gautam P, TripathiR, Panda BB. 2018a.Continuous application of inorganic and organic fertilizers over 47 years in paddy soil alters the bacterial community structure and its influence on rice production.*Agriculture Ecosystems & Environment*. 262:65-75.

Kumar U, Pannereselvam P, Nayak AK. 2018b. Endophytic and rhizospheric nitrogen-fixing bioinoculants for rice crop.*NRRI News Letter*. 39(1):15

Kumar U, Pannereselvam P, Nayak AK. 2018c.*Azolla*-sporocarp formulationfor sustainable rice production.*NRRI News Letter*. 39(1):16.

Panneerselvam P, Kumar U. Sahu S, Mohapatra SD, Dangar TK, Parameswaran C, Jahan A, Senapati A and Govindharaj GPP. 2018. Larvicidal potential of Skermanella sp. against rice leaf folder (*Cnaphalocrosismedinalis*Guenee) and pink stem borer (Sesamiainferens Walker). *Journal of Invertebrate Pathology*.157: 74-79.

Panneerselvam P, Kumar U, Senapati A, Parameswaran C, Anandan A, Kumar A, Jahan A, Padhy SR, Nayak AK. 2019. Influence of elevated CO_2 on arbuscularmycorrhizal fungal community elucidated using IlluminaMiSeq platform in sub-humid tropical paddy soil. *Applied Soil Ecology*.https://doi.org/10.1016/j.apsoil.2019.08.006