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DIAZOTROPHS: A SUSTAINABLE RESOURCE FOR NITROGENOUS FERTILIZERS

Kamal Kant
Aspee Shakilam Biotechnology Institute
Navsari Agricultural University, Surat
E-mail: kamalkantphysio@gmail.com (*Corresponding author*)

Abstract: The nutrient equilibrium in the soil disrupts due to intensive use of chemical fertilizers which has a negative impact on rhizosphere, macro and micro fauna of soil, and results in reduction of population of beneficial micro-organism, impair soil structure and function. Microbes can be used to enhance the accumulation of macro and micro nutrients in the grains of staple crops and this has been successful in many crops particularly wheat and rice. However, its potential is still to be explored across the farming systems for enhancing the yield of crops, ecologies, and human health in place of chemical fertilizers and pesticides. Among microbes bacterial genera, species and strains have better and positive impacts on crop physiology in which they act as nitrogen fixer, nutrients mobilizer, phytohormones producer and biocontrol agents, which are commonly grouped as plant growth promoting rhizobacteria (PGPR). Recently, nanoparticle based nutrient and pest management approach minimize the amount and cost of fertilizers and pesticides and maximize their efficiency of effects. Moreover, PGPR played a major role in formulation of nanoparticle and bacterial consortium for multifaceted benefits. These approaches facilitate easy absorption and transportation of nutrients in plant vascular tissues as compared to application of fertilizers in bulk or conventional methods. Thus, microbes are the operational tools for efficient nutrient management practices particularly nitrogen in terms of sustainable development of crops and ecosystem.
Keywords: Diazotrophs, Nitrogen, Fertilizer, Legume, Non- legume.

Introduction

Nitrogen (N) plays important role in plant life processes due to integral component of chlorophyll, DNA, amino acid, NAD and ATP hence its availability in soil as well as plant determine the growth, development as well as harvest index of the plant. Mostly, N supplied in the form chemical fertilizers but their intensive uses have negative impacts on ecosystem results in depletion of microbes which decompose the organic materials (Jensen et al. 2020). The plant materials present or applied in soil in the form of organic matter that decompose by bacteria into inorganic form for absorption by the roots. Hence, their depletion in soil causes infertility and accumulation of plant residue as such in the fields. Among nutrients N requirement for plant is very high but its low uptake, nitrogenous fertilizers added to the field

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is about 10-fold higher than it is consumed hence excess N leaches down and becomes part of the soil or is emitted to the atmosphere (Xu et al., 2012). Mostly it is emitted in the form of ammonia, nitrogen oxide, nitrous oxide, etc., results in global N pollution. It causes global climate change mainly due to presence of nitrous oxide in the atmosphere because its capacity to trap heat is comparatively higher (approx.300x) than the carbon dioxide. Leaches nitrogen accumulates in the soil results in increased infestation of insects particularly aphids and increased quantity of heavy metals (e.g., lead, chromium, and cadmium), radionuclides, and carcinogenic compounds, NO_2 and NO_3. It affects drinking water by accumulation of salt, NO_2 and NO_3 and become very harmful for human and animal. Another harmful impact excess fertilizers are on water bodies where eutrophication is the major problems due to excess accumulation of nitrogen led to formation of dead zone in water bodies as well as harmful algal blooms. It affects the flora and fauna by creating oxygen shortage in water and its persistence in long term causing global warming, salinization and pollution in drinking water (Jia et al. 2015). High nitrite nitrogen in drinking water, rivers, etc., due to soil leachate causing potential health hazards to the ecosystems and mankind (Ward et al., 2018). Hence, there is need of the alternative of nitrogenous source in the form of efficient biofertilizers for protection of ecology and ecosystem.

Atmospheric nitrogen (N_2) which constitutes approx. 78% of total atmospheric gases a little amount fixed by physical processes by lightening and biological processes by Diazotrophs in legume and in cereals by non-symbiotic PGPR. In both cases roots are the main component of plants in fixing of nitrogen from the atmosphere (Grover et al., 2021). The biological nitrogen fixation process through which atmospheric (N_2) converted to ammonia (NH_3) is mainly mediated by bacteria, actinomycetes and cynobacteria. It consumes 16 ATPs, 8 electrons and 8 protons for conversion of one molecule of N_2 into ammonia that occurs in the root nodules by symbiotic bacteria and in soil or on plant roots by nonsymbiotic bacteria (Rilling et al., 2018). Hence it is a highly energy-expensive process but very safe to the ecosystem as well as soil and plant health. This process contributes approximately 128 Tg of N per annum globally and ≈30–50% of N fixed by diazotrophs under field which is equivalent up to 15% of the total plant's nitrogen. The biological nitrogen fixed in three major modes in plants by diazotrophs *viz*. rhizospheric, endophytic, and by formation of nodule through major genera of micro-organism *viz. Azospirillum, Azotobacter, Azorhizobium, Pseudomonas* and *Rhizobium.* They are mainly present in two forms 1. Symbiotic and 2. Associative or Non Symbiotic. Symbiotic association mainly occurs in legume where approximately 170-300 kg of nitrogen fixes per hectare per year and they are mainly dominant in the soil environment (Riaz et al. 2021). The free living plant growth-promoting rhizobacteria (PGPR) that mainly reside on the surface of roots specifically in the zone of elongation or in root hairs called associative diazotrophs while those found inside the shoot/root of the phyllosphere of the plants are classified as endophytic diazotrophs. Endophytic and symbiotic have the advantage over associative diazotrophs due to the establishment of better and stable niche within the plant tissues for nitrogen fixation (Xu et al. 2012). The Cyanobacteria and Firmicutes are another phylum diazotrophs which significantly fixed atmospheric Nitrogen and might be used as sources of biofertilizers (Jha et al. 2001).

Mostly legumes cultivated in rotation traditionally for keeping fertility of soil due to symbiotic association with *Rhizobia*, hence they are well acquainted genera among biological N fixers. 18 genera having 8 families viz. Methylobacteriaceae, Rhizobiaceae, Bradyrhizobiaceae, Phyllobacteriaceae, Brucellaceae, Hyphomicrobiaceae, Burkholderiaceae, Xanthobacteraceae have been identified. Rhizobia are specific to the host on the root and in a few cases on the stem of the legume (Rilling et al., 2018). The other symbiotic diazotrophs which associated with other non leguminous plant and form nodule for fixation of N are *Frankia*.It is filamentous, Gram-positive actinomycetes that forms a symbiotic relationship with plant species, so efficient fixation of nitrogen in food crops particularly in cereal might reduce the synthetic fertilizers (Sharma and Bali, 2018)

The associative diazotrophs almost present everywhere and they have many different genera and *Azospirillum* is one of them which are a facultative endophytic diazotroph of cereals. They reside in micro-aerophilic condition to protect the nitrogenase enzyme from O_2. *Azospirillum* and *Azotobacter* species are the good sources of biofertilizers for cereals due to their availability and ease of application (Wani et al., 2013). Another associative diazotrophs *viz*. *Herbaspirillum* and *Burkholderia* are the natural sources of N prominently found in sugarcane (Van Deynze et al., 2018).

Conclusion

The diazotrophs involved in different biotic and abiotic activities in support of soil and plant health and exert positive impact on ecology and ecosystem. Thus, it will be better strategy to use diazotrophs for biofertilizers in place of intensive use of chemical fertilizers and pesticides, for sustainable development of soil, plant, animal as well as human health.

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