AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 03 Issue: 12 December 2022 Article No: 12

Rhizo-Engineering with Biocontrol Agents

Shadab M. Khatib[1], Pooja P. S.[1] and K. A. Sindhura[2]
[1]Ph.D. Research Scholar, Department of Plant Pathology, UAS, GKVK, Bengaluru, Karnataka
[2]Department of Agricultural Entomology, UAS, GKVK, Bengaluru, Karnataka

SUMMARY

Microorganisms are a substantial component of the rhizosphere, the activity and composition of rhizosphere microbial populations markedly affect interactions between plants and the soil environment. In rhizosphere engineering, the microbial communities are modified by adding specific fertilizers, nutrients or by bio-inoculation with certain microorganisms such as bacteria and/or fungi. This new method suggests a potential for reaching a more sustainable agriculture development by reducing chemicals/ pesticide in the future.

INTRODUCTION

Food insecurity is a chronic issue that is likely to worsen as the human population is expected to be more than 9 billion by 2050. The population increase-mediated pressure in agriculture has led to intensive use of chemical fertilizers and pesticides to get the maximum yield out of the existing agricultural lands. Of the total, around 20–30 per cent of the applied fertilizer is taken up by the plant. Most of the crop varieties have low nutrient uptake efficiencies. Due to low nutrients use efficiency in agriculture and soil dynamics, more than 50 per cent of applied chemical fertilizers are lost to the environment (Fageria, 2014).Several strategies have been employed for enhancing the nutrient use efficiency (NUE) of crops and sustainable agriculture production. Of these approaches, the 4R strategy is more recently introduced that includes the use of the Right Source of nutrients at the Right Rate, Right Time, and in the Right Place. This strategy can be further expanded and made more comprehensive if we include two major players in this interaction i.e., the plant which is using the nutrient and the rhizosphere where the nutrients are applied. In this scenario, the emphasis should be focused on the selection of low-fertilizer responsive crop germplasm and incorporation (inoculation) of the biocontrol agents for rhizosphere engineering.

What is Rhizo-engineering?

The rhizosphere is the narrow zone of soil that is in direct proximity to plant roots and the hotspot of various microbes. The plant influences the nearby soil through the release/secretion of different compounds known as rhizo-deposits, which mainly consist of carbohydrates, secondary metabolites organic acids, and amino acids (Ahkami *et al.*, 2017). The rhizosphere harbors diverse microbial groups that perform various functions and exert numerous effects on plant growth. They are involved in nutrient cycling, protecting from phytopathogens as well as under biotic and abiotic stress conditions, and some may act as plant pathogens. These microbial activities in the rhizosphere lead to changes in the composition, quality, and quantity of root exudates released by the plants, which in turn affect the microbial component. This phenomenon known as rhizosphere feedback proposes that plants, through rhizodeposition, shape the microbial community composition in the rhizosphere which subsequently influences plant growth and productivity (Dessaux *et al*., 2016). Such a relationship suggests that the rhizosphere can be exploited and/or engineered to promote the growth, nutrient uptake, and production of plants (Fig. 1).

Fig. 1: Rhizosphere engineering

Mechanisms involved in rhizo-engineering with biocontrol agents:

One of the most important strategies to engineer the rhizosphere is the manipulation and engineering of the microbiome. Microbes can positively influence plant growth and counteract most of the problems of modern agriculture, thus represent a promising approach for agriculture sustainability. Due to the complexity of the microbiome, there is limited ability to manage and manipulate the whole rhizosphere microbiome, however, the most direct and eco-friendly way to alter the microbiome is the inoculation of artificially multiplied microbes. Various products containing one or several species of bacteria or fungi in the form of biofertilizers have been commercially synthesized and are available for the improvement of plant growth and sustainability. Biocontrol agents contain various traits which exert positive effects on plant growth through direct and indirect mechanisms. Major direct mechanisms of actions of PGPR include mobilization of nutrients (P, Zn, and Fe) nitrogen fixation, and production of phytohormone. Biocontrol of pathogens by the production of ACC-deaminase, siderophores, antibiotics, lytic enzymes, induced systemic resistance, and induction of resistance against abiotic stresses are described as indirect mechanisms of action of biocontrol agents. Figure 2 summarizes the direct and indirect growth-promoting effects exerted by biocontrol agents on plants and the rhizosphere.

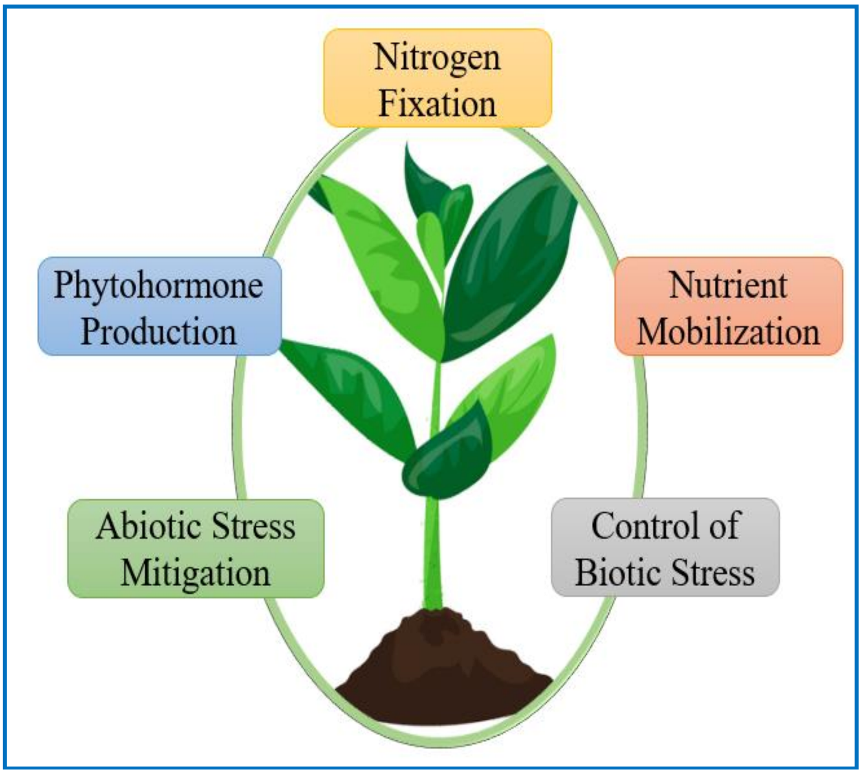

Fig. 2: The benefits of biocontrol agents mediated rhizosphere engineering to the plant growth

Various approaches of rhizosphere microbiome engineering:

Plants, microbes, and soil are three key components of the rhizosphere as described in Figure 3 (Hakim *et al*., 2021). All can be engineered (manipulated) to improve plant productivity. The soil amendment (which has been practiced for two millennia) can influence the rhizosphere functioning for plant growth promotion. Soil amendments such as biochar, silicon, zeolites, plant residues, coal fly ash, cattle manure, and sewage sludge have been used. Despite the recent progress in microbial ecology, soil analytical tools, and plant genetics, soil amendments remain an empirical technique providing descriptive information.

As the rhizosphere activity and functioning is shaped by the plant traits such as root architecture and root exudates, so these traits can be engineered through the genetic engineering of plants. Several plants have been engineered through breeding and gene editing techniques for the uptake of nutrients such as P, Fe, and Zn, protection from diseases as well as the removal of heavy metals (Gunarathne *et al*., 2019). Although plant engineering brings favorable advantages to soil restoration, and plant growth, nutritional quality, and resistance to pathogens, but their application remain low due to the lack of social acceptance and concerns regarding human health and environmental sustainability.

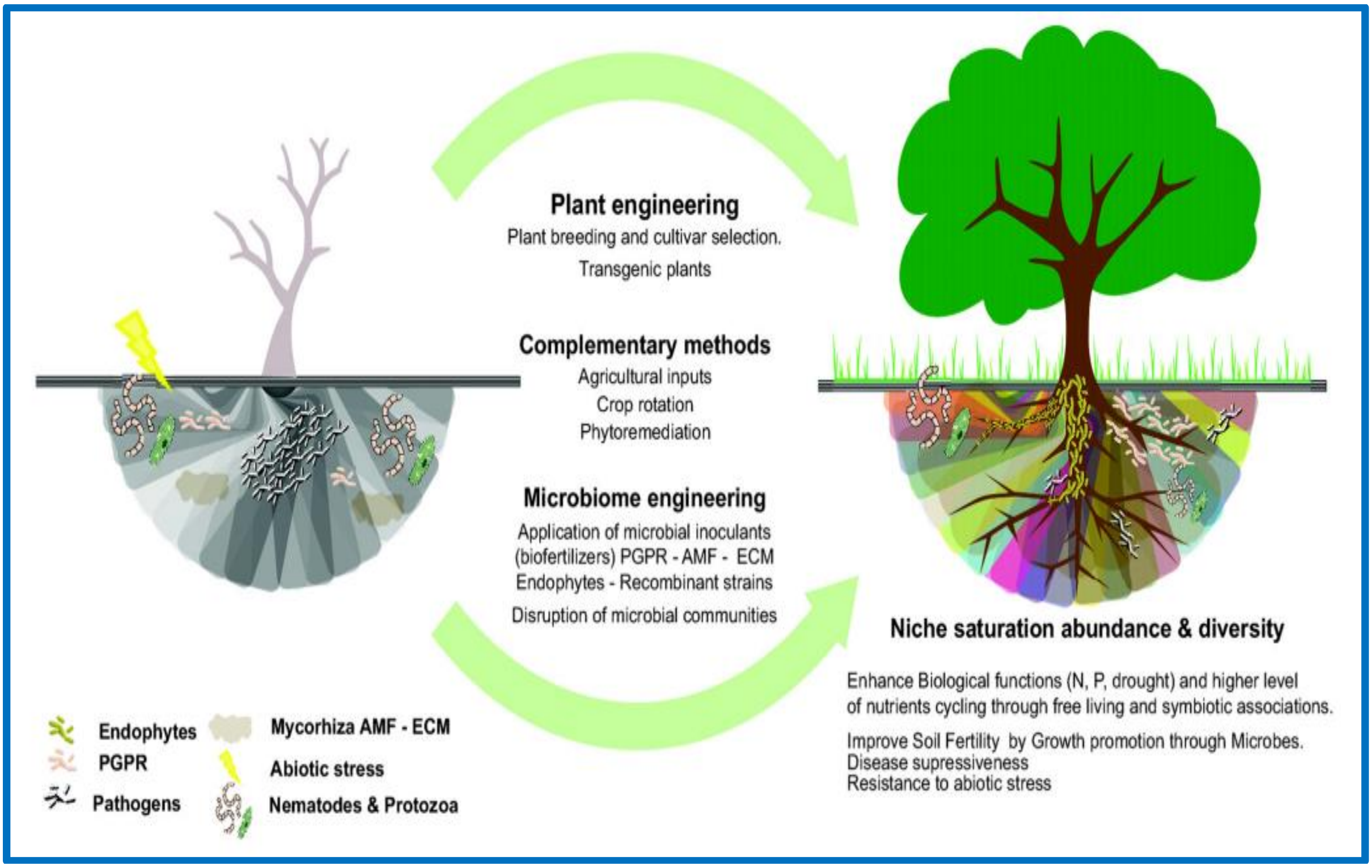

Fig. 3: Different approaches to rhizosphere microbiome engineering

CONCLUSION

The emerging field of rhizosphere engineering is more than a promising way and the knowledge of plant-microbe interactions can help in developing new sustainable, eco-friendly, and economical systems for agriculture. In the future, the investigation for elucidating the role of those genes involved in microbe-plant interaction will help develop new tools for improving plant and soil health.

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