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Microbial Inoculation can Enhance SRI Performance and Reduce Biotic and Abiotic Stresses in Rice

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Abstract

Microbes play crucial roles in plant survival and fitness by mobilizing soil nutrients, enhancing plant performance by producing phytohormones, and protecting plant from biotic and abiotic stresses. SRI crop management system, extrapolatable to improve production of other crops beyond rice, aims to create the best growing environment above- and below-ground and to mobilize various services from microbes to increase factor productivity. Inoculating crop plants with effective microbial agents, either in consortia or separately, enhances rice crop performance in various ways. This paper presents results from field experiments and offers some explanation of mechanisms accounting for the higher productivity and performance of SRI rice plants with augmentation of microbial agents in soil.

Keywords: *Trichoderma, Bacillus*, microbial ecological services, biotic and abiotic stresses

Introduction

Plant growth-promoting microorganisms (PGPMOs) play significant roles in soil fertility, plant productivity, and plant health by enhancing plant growth and alleviating the impact of biotic and abiotic stresses such as pests and diseases, water and nutrient deficiencies, and unfavorable environmental stresses. PGPMOs can colonize plant tissues, organs and cells as endophytes, among other things influencing phytohormone production and the plants' expression of genetic potential. Within the rhizosphere around plant roots and within plant roots, they can fix nitrogen and solubilize phosphates, thereby reducing the costs of production and curtailing environmental pollution by curbing reliance on agrochemicals (de Souza *et al.,* 2015).

A major explanation for this is that the recruitment of microorganisms in plant rhizospheres is influenced by the composition of nutrients in root exudates. For example, exudates that are rich in sugar, amino acids, and micronutrients will be more attractive to microbes, and this will enhance their ecological services for plants (Hayat *et al.,* 2017). Also, plants that are healthy and at a particular physiological stage can produce root exudates that are more alluring to microbial communities than can unhealthy plants (Habig *et al.,* 2015).

The System of Rice Intensification (SRI) is an evolved set of crop-growing practices that creates a more favorable soil environment, conducive for greater physiological yield. SRI methods improve soil physical, chemical, and biological qualities by favoring the use of organic materials for soil amendment and by aerating the topsoil with a simple mechanical rotary weeder when soil oxygen content gets reduced by the puddling of rice fields. This aeration enhances the abundance and activity of beneficial microbial communities, most of which are aerobic. It also reduces the generation and emission of methane (CH_4), which is produced by anaerobic methanogens.

Continuous flooding of paddy fields as practiced in conventional rice production has several deleterious effects for rice root systems such as creating a hard pan that limits their depth of growth, reducing oxygen supply and causing root necrosis over time, and accumulating toxic chemicals such as short-chain fatty acids in rhizospheres, produced by anaerobic respiration related to hypoxia. The impact of these factors results in a deformed root cortex, creating air pockets (aerenchyma) in the roots (Kirk & Bouldin 1991), and reducing root respiration due to hypoxic soil conditions. These lead to root systems that are unfavorable for colonization by beneficial microbes such as arbuscular mycorrhizae, which thrive only under aerobic soil conditions.

SRI creates a better soil environment for the growth and colonization of microbial agents in soil in one side and makes rice plants at the optimum physiological stage to exudate better root and shoot leaches attractive for beneficial microbes. The combination of these has a synergistic impact in crop yield and physiology (Khadka & Uphoff 2019).

Roles of microbial agents in rice performance

The soil contains a vast ocean of microbes. Among them, some microbes have a better ability to decompose organic matter in the soil (more saprophytic ability), while others are more competitive within rhizospheres in their ability to colonize roots, while some other microbes are pathogenic for plants. These characteristics of microbes can vary among the different strains or isolates found within the same species and genus. Therefore, it is always advisable for purposes of inoculation to select microbial isolates or groups of isolates that have better rhizosphere-colonizing ability and that can provide better ecological services for the target plants. For example, we have previously reported (Khadka *et al.,* 2022) on the differential roles of *Bacillus* spp. and *Trichoderma* spp. strains in promoting root and shoot growth of rice seedlings under controlled environmental assays (**Figures 1 and 2**).

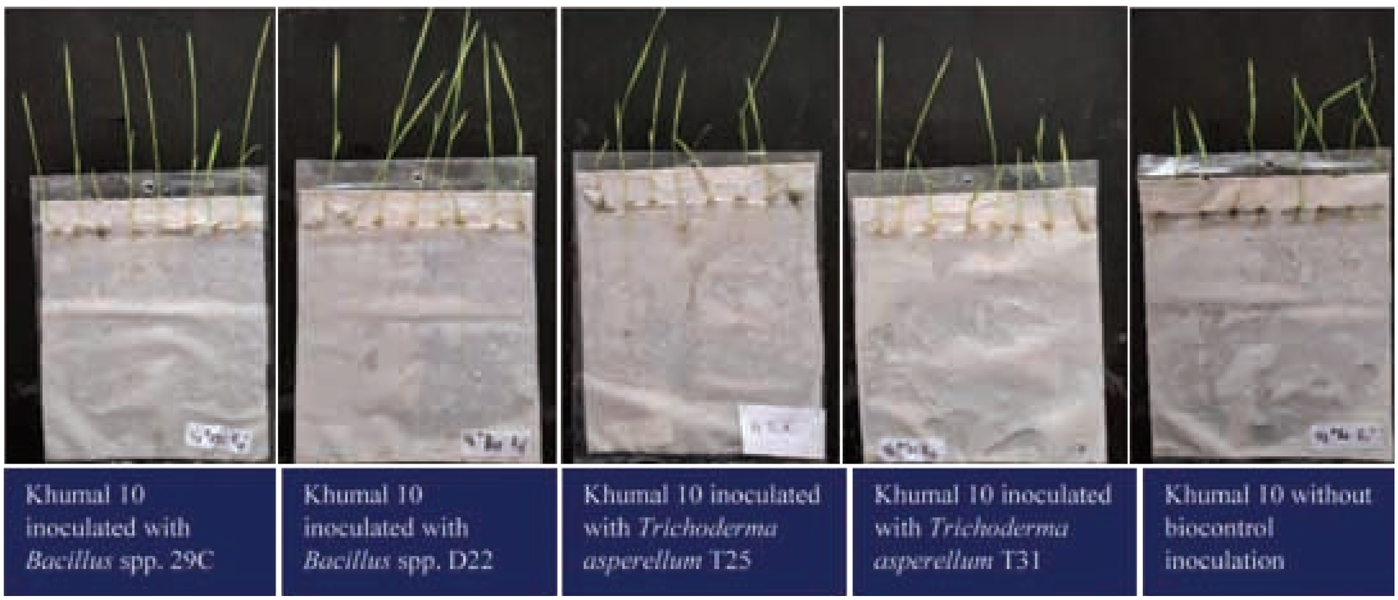

Figure 1: Effect of different strains of Bacillus spp. and Trichoderma spp. in root and shoot growth of rice seedlings

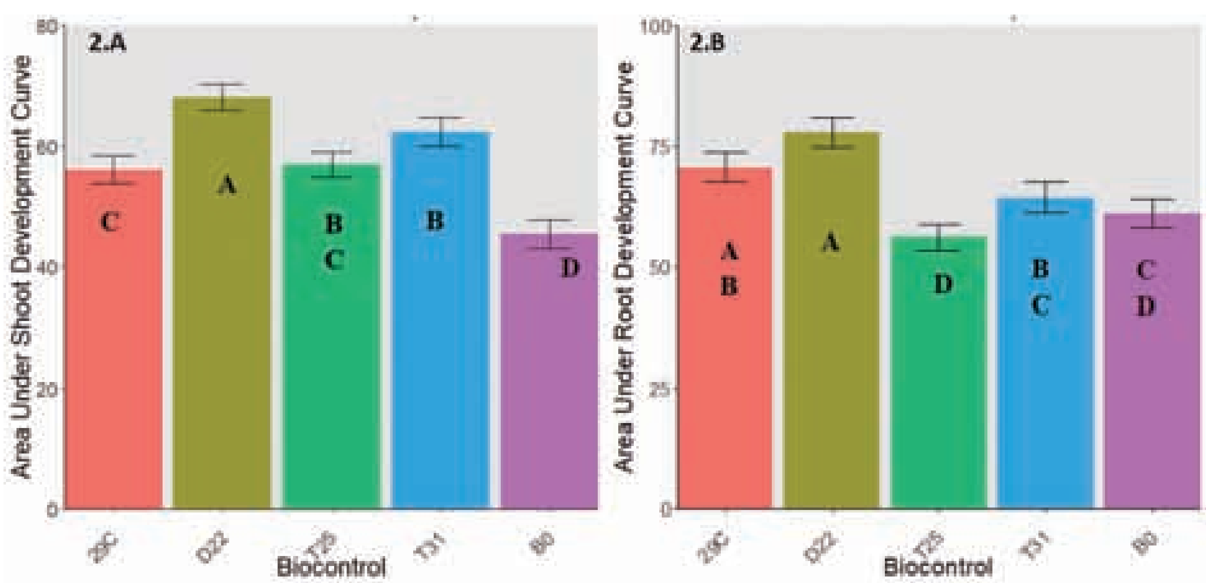

Figure 2: Effect of different strains of *Bacillus* spp. (29C and D22) and *Trichoderma* spp. (T25 and T31) in root and shoot growth of rice seedlings. B0 = no inoculation.

The inoculation of rice plants with different strains of either *Bacillus* spp. and *Trichoderma* spp. stimulated the plant root and shoot growth differently (**Figures 1 and 2**) The root and shoot growth were significantly higher in plants grown from seeds inoculated with *Bacillus* spp. D22 and 29C compared to the non-inoculated control (B0). Inoculation with *Trichoderma asperellum* T25 and T31 increased shoot growth, but did not change root growth as much compared to the non-inoculated control. Shoot growth was increased by 19%, 33%, 20% and 27% by microbial inoculation with 29C, D22, T25, and T31, respectively.

These results indicate that a symbiotic association of microbes changes the rice phenotypes, including their growth greatly. These changes will have an impact on the yield and quality of grains.

System of Rice Intensification enhancement by microbial inoculation

The System of Rice Intensification (SRI) promotes the optimum environment for rice growth by applying its principles through optimizing practices that create a congenial environment for growth of soil microbes and plants, so rice plants can achieve the best plant architecture close to the ideotype for maximum yield. For example, SRI management provides a better soil environment for soil microbial communities by providing more soil organic matter (SOM). Diverse populations of microbial communities thrive better in an area where there is a higher soil organic matter, because SOM supplies greater variety of nutrients, enhances soil resilience in a fluctuating soil environment, with varying pH, drought, temperature, and salinity thereby protecting microbes from environmental shocks.

At the same time, higher soil OM is important for plant growth so that healthy plants can leach nutrient-rich exudates into the soil as a source of microbial food. SRI practices include planting rice seedlings at an early age with and wider spacing which reduces inter-plant competition for space, light, and soil niches, optimizing the use of available resources. The practices enhance the architecture of both roots and shoots, making roots more robust, deeper, and well-distributed in the soil, and tillers more horizontal while leaves are more vertical, to intercept more light. compared to conventional transplanting. The higher number of feeder roots means they provide higher ecological niches for microbial colonization. SRI practices not only increase productivity but also increase soil biodiversity.

Conventional transplanting of seedlings into standing water creates suffocation of plant roots due to a limited supply of oxygen, and there is synthesis of ethylene and short-chain fatty acids due to anaerobic soil respiration in the rhizosphere region of rice resulting from continuous flooding which is deleterious to beneficial microbial colonization. SRI practices promotes more aerobic soil conditions due to alternate drying and wetting of rice paddies, and active soil root aeration by rotary weeders, which creates hospitable environments for soil microbial colonization.

Better performance of rice is achieved when rice seedlings are inoculated with beneficial microbes in SRI compared to conventional practice. Khadka and Uphoff (2019) concluded that the efficacy of *Trichoderma* inoculation is better in combination with SRI practices than in conventional rice growing. Doni *et al.,* (2017) also reported on how SRI growing conditions provided a better environment for *Trichoderma* and rice interaction compared to conventional rice crop management. They observed higher rice growth, nutrient uptake, physiological traits and yield with SRI management inoculated with *Trichoderma asperellum* SL2 compared to *Trichoderma*-inoculated rice with conventional management**.** The conventionally- grown rice tends to inhibit microbial services to rice physiology and yield compared to SRI rice due to anaerobic conditions and less organic matter in the soil. Therefore better crop yield along with a healthy, resilient and sustainable rice system could be achieved by fortifying SRI rice with appropriate microbial communities. This study also indicated production and inoculation of *Trichoderma* can be managed profitably by farmers themselves.

Environmental protection

Microbes have significant roles in soil ecology, environment and crop productivity. The flooding of rice fields is the second largest contributor to methane production in the agricultural sector. This could be reduced by adopting SRI practices since they promote alternative wetting and drying which greatly reduces methane production.

At the same time, beneficial microbes protect the crops from a variety of biotic stresses including fungi, bacteria, viruses, and even insects through the activation of plants' defense systems, direct production of antibiotics that are lethal to plant pathogens, directly parasitizing pathogens, or suppressing them competitively by occupying ecological niches and utilizing their resources (Harman *et al.,* 2021). Furthermore, several endophytic bacteria are recognized to directly contribute in biological nitrogen fixation, and this may have substantial potential to reduce the application of nitrogenous fertilizer which is becoming one scarcest resource currently due to the increasing energy demand. The application of SRI combination with an appropriate microbial agent could provide better yield without depending on expensive fertilizers, and protect crops from varieties of ailments caused by soil and environmental fluctuations, pests and pathogens.

Thus, SRI rice fortified with suitable microbial agents could solve contemporary environmental issues by curtailing the use of agrochemicals such as fertilizers, and pesticides, reducing global energy demand and consumption in production and transportation of agrochemicals and their environmental costs and contamination that they cause to soil and water.

Conclusion

The use of microbial agents in crop production is gaining greater attention in research and application due to its multiple benefits in the farming system. The combination of SRI and appropriate microbial agents could provide sustainable solutions for multiple issues of crop production. However, the selection of appropriate microbial agents which are active root colonizers and provide better ecological services to plants is equally important.

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