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Short Communication

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Rice endophytes and their potential applications

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ABSTRACT

Endophytic microbial communities in crop plants are beginning to be explored. These microbes are either carried through seeds or establish colonization in the plants from soil based on chemotaxis of root exudates. Variability and diversity of endophytic bacteria and fungi have been observed in rice plants in different plant parts and growth stages. Genotypic variations are observed between Indica and Japonica. Pseudomonas, Bacillus, Streptomyces, Azospirillum, Azotobacter are some of the dominating genera of bacteria in internal tissues of rice plants. These endophytes provide benefits such as tolerance to abiotic stresses, defense against pest and diseases, nutrient solubilization and mobility. In addition, many metabolites are characterized from the endophytes that are useful in other branches of biotechnology including bioremediation. Complete characterization of microbiome of rice plants under various soil agro-climatic zones and understanding their population dynamics, co-occurrence and networking will help in identifying useful strains for developing new biofertilizers, plant growth promoting microbes and biopesticides.

KEYWORDS: Bacteria, endophytes, fungi, microbiome, plant growth, rice, stress tolerance.

INTRODUCTION

Endophytes are microorganisms living inside the plant tissues. They colonize all parts of the plants including roots, stem, branches, leaves, flowers, fruits and seeds. The endophytic microbes present in the seeds establish within the growing seedlings upon seed germination. In addition, microbes in the soil enter the root system during crop cultivation. Endophytes in plants are dominated by bacteria followed by fungi and yeasts. They remain symptomless and interact with host plants in many ways and their interaction can be beneficial or neutral. Some of the neutral organisms are those which help in forming the microbial network among the endophytes, thus facilitating the beneficial effects of other microbes. Microbiome analyses of endophytes have revealed useful microbes for plant growth promotion, bioremediation, abiotic stress tolerance, pest and disease resistance as well as production of bioactive metabolites for various applications.

RICE ENDOPHYTES

Rice is the staple food cereal for more than half of the world population. As like other plants, rice also harbours enormous number of endophytic microbes. Enumeration of these microbes from various tissues have helped in identifying useful microbes that can be further explored to develop new biofertilizers, biocontrol agents against pests and pathogens as well as new bioagents for bioremediation and abiotic stress tolerance.

Root associated bacterial endophytes have proven to be highly effective against fungal pathogens of rice. They produce antibiotics, lytic enzymes, siderophores and many other metabolites. These endophytes also develop a competitive colonizing environment for the phytopathogenic microbes. *Pseudomonas fluorescens*, *Bacillus subtilis* and *Bacillus pumilus* are shown to have antagonistic abilities against many important pathogens of rice such as *Magnoporthe oryzae* causing blast disease, *Rhizoctonia solani* causing sheath blight and *Sarocladium oryzae* causing sheath rot. *Pseudomonas fluorescens* and *Bacillus subtilis* are successfully used as biocontrol agents and are available as commercial formulations. They are known to induce systemic resistance against pests and pathogens by triggering important defense related proteins in rice plants. *Harpophora oryzae* and *Pseudomonas chlorapis* are reported to defend against blast causing fungi. Grain discoloration caused by *Burkholderia glumae* produces a toxin and this can be suppressed by metabolites of *Bacillus* sp. *Streptomyces hygroscopicus* isolated from inner tissues of rice plants has antagonistic activity against rice blast fungus. The metabolites of Streptomyces are known to disrupt the integrity of cell wall of the target fungi. *Lysinibacillus* sp induces systemic resistance against sheath blight by producing defense enzymes like polyphenol oxidase and peroxidase.

Endophytic *Azotobacter*, root colonizing *Azospirillum* are examples of successful biofertilizers in rice cultivation. They are non-nodulating root associated bacteria in rice crop. *Phomopsis* sp. can improve decomposition of rice straw in the soil and transform the nitrogen to assimilable form for the plants [1]. *Herbaspirillium*, *Bacillus paralicheniformis* and *Pseudomonas stutzeri* enhance the nitrogen availability in rice fields.

Pigmented endophytic fungi in rice provide salt and water stress tolerance to the plants [2]. The melanin pigment responsible for the dark pigmentation of the fungus serves as antioxidant agents and protects the rice root cells from reactive oxygen species which are otherwise known to cause cellular damage under these stress conditions. Through the ACC deaminase activity, an important enzyme involved in abiotic stress tolerance, Streptomyces, *Methylobacterium* and *Pantoea* provide salt tolerance in rice. Endophytic bacteria can also improve mineral nutrition and growth under heavy metal contaminated soil conditions by inducing the accumulation of organic acids in rice plants. Enterobacter sp confers protection of rice plants from heavy metal toxicity, particularly nickel and cadmium, regulating the detoxifying mechanism. This is mediated through balancing between salicylic acid and abscisic acid pathways. Some of the rice endophytes like *Paraconiothyrium* were found to have weed inhibiting properties as well.

AGRO-BIOTECHNOLOGICAL APPLICATIONS

With the advent of metagenome sequencing of all the microbes present in the plants, it is now possible to elucidate the complete set of microbes in different plant parts at different growth stages. Edwards et al. [3] sequenced the bacterial species associated with Japonica rice. Such studies are yet to be carried out in Indica rice although data from tissue specific identification are available. Endophytic establishments inside the crop inner environment vary between cultivars (genotype specific), plant parts and the growth stages. The understanding of the composition and structure of the rice endophytes and the factors influencing them are more important in exploring the beneficial endophytes through biotechnological approaches. Since the inner tissue microenvironment is shared by too many microbes, some of them may not be useful and some may be pathogens, facilitating the establishment of beneficial microbes becomes the target for microbiome engineering. Outnumbering the pathogenic and non-beneficial microbes would be the appropriate strategy for which the cultivable beneficial endophytes have to be characterized, mass multiplied and applied to rice plants via seed treatment or soil application. Mass multiplied beneficial endophytes can thus colonize and establish in the initial stages of rice crop growth and keep the harmful microbes away.

FUTURE PROSPECTS

Commercial production of biofertilizers and biocontrol agents has doubled in the past decade. With many farming systems changing to organic, the demand for these products is in the rise. These include *Rhizobium*, *Azospirillum*, *Azotobacter*, phosphobacteria, zinc solubilizing bacteria, *Pseudomonas fluorescens*, *Bacillus subtilis*, *Trichoderma* etc. Consortia of beneficial microbes for growth and health of crops were also developed and proven successful under field conditions. However, consistent and effective plant growth promotion and control of pests and diseases is still challenging. It is high time to explore the complete endophytic microbiome of crops like rice and validate new species under field conditions. To achieve this, metagenome characterization of the microbes associated with different varieties and hybrids of rice under different agro-climatic zones and soil conditions during critical stages of crop growth are the approaches to be followed. Futuristic development of effective consortia of endophytic microbes for rice that can offer multiple benefits like plant growth promotion, biocontrol and abiotic stress tolerance would greatly influence the production and productivity of rice.

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