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Microbial Involvement in Growth of Paddy

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Abstract: This study reviews the role of Plant Growth Promoting Rhizobacteria (PGPR), Plant Growth Promoting Fungi (PGPF) and Mycorrhizal Fungi in the enhancement of rice growth and yield. A total 70 papers spanning from 1970 to 2013 was screened and noted its conclusion to enhance rice growth and yield. The mechanisms employed by microbes in enhancing rice growth and yield includes; the production of growth regulating substances, phosphate solubilization, N-fixation, cellulose degradation and side rophore production. Some microbes are also involved in cell regulation and signaling in rice plants. We can conclude that there are significant influences on the growth and yield of rice plant by microbes.

Keywords: Growth PGPR, mycorrhizal fungi, PGPF, rice

INTRODUCTION

Currently growth of paddy uses a lot of chemical fertilizer and chemical pesticide. Over the years this has led to serious environmental problems such as depletion of soil quality and health, emergence of resistant pathogens and elimination of soil microbes involvement in growth of paddy. The increase of production of paddy must be achieved through improvement in agricultural productivity. Microbes considered as beneficial are key factor in maintaining soil quality and paddy production. As such decades, Interest in beneficial microorganism in rice has increased due to their potential use as plant growth regulator (Diem *et al*., 1978; Barraquio *et al*., 1986; Mehnaz *et al*., 2000; Jha and Subramanian, 2012).

Previous studies have reviewed the microbial producers of plant growth stimulators and their practical use (Tsavkelova *et al*., 2005), use of plant growth-promoting bacteria for biocontrol of plant diseases (Compant *et al*., 2005), plant-microbes interactions in enhanced fertilizer-use efficiency (Adesemoye and Kloepper, 2009), bacterial and fungal contributions to carbon sequestration in agroecosystems (Six *et al*., 2006), biological nitrogen fixation (Kumar and Rao, 2012) and impact of root exudates and plant defense signaling on bacterial communities in the rhizosphere (Doornbos *et al*., 2012).

This review discusses the ability of Plant Growth Promoting Rhizobacteria (PGPR) to enhance rice growth and yield, the ability of Plant Growth Promoting Fungi (PGPF) to enhance rice growth and yield, the ability of mycorrhizal fungi to enhance rice growth and yield and rice plant and microorganism molecular interaction.

RESULTS AND DISCUSSION

Plant growth promoting rhizobacteria: PGPR (Plant Growth Promoting Rhizobacteria) are the rhizosphere bacteria which may grow in, on or around plant tissues and have ability to improve plant growth by several mechanisms namely Phosphate-solubilizing, siderophore-producting, nitrogen-fixaxing, phytohormone-producing and exhibiting antifungal activity. (Bhattacharyya and Jha, 2012; Vessey, 2003). The mechanism of PGPR to improve plant growth is highlighted on Table 1.

Reports on the application of PGPR to improve rice growth and yield have been published by many researchers. Carreres *et al*. (1996) stated that application of cyanobacteria to the rice plant significantly increased the uptake of N by the rice plant. Further, Malik *et al*. (1997) stated that five strains of bacteria, namely, *Azospirillum lipoferum* N-4, *A. brasilense* Wb-3, *Pseudomonas* 96-51, *Zoogloea* Ky-1 and *Azoarcus* K-1 were able to increase biomass and nitrogen content of the rice tissue. Ashrafuzzaman *et al*. (2009) isolated 10 PGPR strains from Mymensingh soil to improve rice growth. Most of isolates resulted in a

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Table 1: Growth factor produced by PGPR

PGPR	Factor produced	References
Azospirillum lipoferum	Gibberellins N-Fixation	Cassan *et al*. (2001) and Nayak *et al*. (1986)
Azospirillum brasilense	GibberellinsIAAN-Fixation	Cassan *et al*. (2001), Mehnaz and Lazarovits (2006) and Tien *et al*. (1976)
Zoogloea	N-Fixation	Xie and Yokota (2006)
Azoarcus	N-Fixation	Hurek *et al*. (2012)
Bacillus	Phosphate-solubilizing	Rodríguez and Fraga (1999)
Rhizobium	N-Fixation	Yani *et al*. (2000)
Pseudomonas fluorescens	N-FixationPhosphate-solubilizing Siderophore producing	Park *et al*. (2004) and Vyas and Gulati (2009) Kloepper *et al*. (1980)
Pseudomonas putida	Siderophore producing Phosphate-solubilizing	Kloepper *et al*. (1980) and Wahyudi *et al*. (2011)
Azetobacter	N-Fixation	Park *et al*. (2004)
Azorhizobium	N-Fixation	Anyia *et al*. (2004)
Azospirilium	N-Fixation	Park *et al*. (2004)

Table 2: Growth factor produced by PGPF

PGPF	Factor produced	References
Gliocladium virens	Lytic enzymes	Sreenivasaprasad and Manibhushanrao (1990)
Trichoderma virens	Auxin Jalicylic acidJasmonic acid	Contreras-Cornejo *et al*. (2009, 2011)
Trichoderma harzianum	Phosphate-solubilizing Siderophore producing	Saravanakumar *et al*. (2013) and Rawat and Tewari (2011)
Trichoderma viride	Phosphate-solubilizing Siderophore producing cellulose degrading	Saravanakumar *et al*. (2013), Rawat and Tewari (2011) and Jiang *et al*. (2011)
Aspergillus niger	IAA GibberellinsPhytase producing	Bilkay *et al*. (2010) and Gujar *et al*. (2013)

significant increase in plant height, root length and dry matter production of shoot and root of rice seedlings. Mia *et al*. (2012) has inoculated 4 PGPR strains to rice seedlings growth. The results stated that inoculation those PGPR strains have been increasing the seedling emergence, seedling vigor and root growth.

The ability of PGPR to enhance rice yield has been reported in several studies. Sakthivel and Gnanamanickam (1987) reported that application of *Pseudomonas fluorescens* to rice plant significantly improve plant height, number of tillers and grain yields. Mohammadinejhad-Babandeh *et al*. (2012) demonstrated that Azotobacter, Azorhizobioum and Azospirilium were able to enhance rice yield components. Vahed *et al*. (2012) found that Phosphate Solubilizing Bacteria (PSB) had a significant influence on grain yield and biological yield of rice. Gopalakrishnan *et al*. (2012) reported that four PGPR isolates from rhizosphere of a SRI field significantly enhanced rice tiller numbers, stover and grain yields, total dry matter, root length, volume and dry weight. Ruíz-Sánchez *et al*. (2011) examined the response of rice plants to inoculation with *A. brasilense*. Result showed that *A. brasilense* is able to enhance ascorbate content on rice plants. Pedraza *et al*. (2009) assessed the Azospirillum inoculation on effect on grain yield in a rice rainfed crop. The results suggested that Azospirilium significantly increased rice yield. Further, Banayo *et al*. (2012) evaluated three different biofertilizers. The result showed significant yield increases for all biofertilizers in some seasons but the most consistent results were achieved by the *Azospirillum*-based biofertilizer.

Plant growth promoting fungi: Plant Growth Promoting Fungi (PGPF) is a class of beneficial fungi that have ability to enhance plant growth. The PGPF are including; hormone production, substrate degradation (mineralization) and suppression of deleterious microorganism (Hyakumachi, 1994; Nenwani *et al*., 2010). The mechanism of plant growth promotion by PGPF is listed in Table 2.

The ability of PGPF to enhance growth and yield of rice has been reported by many researchers. Four fungal (*Gliocladium virens, Trichoderma virens, T. harzianum and Aspergillus niger*) were examined for their effect on germination, root and shoot length and seedling weight of rice. The results suggested that seed root length, shoot height and fresh weight of rice seedlings were significant increased (Mishra and Sinha, 2000). Further, Al-Taweil *et al.* (2009) has applied *T. viride* to rice seedling and the results reported that *T. viride* is effectively increasing rice seedlings growth. Khan *et al*. (2005) examined activity of *T. harzianum* on rice seed germination and seeding vigor. The result showed that *T. harzianum* has ability to increase seedling emergence, root and shoot length, fresh and dry weight of root of rice seedlings. The same result of the ability of *T. harzianum* on improving rice seedling growth was also reported by Shukla *et al*. (2012). Choi *et al.* (2010) reported that imidazole-4-carboxamide (ICA), a plant-growth regulating compound that was isolated from a fairy ring forming fungus, *Lepista sordida*, in a greenhouse experiment, this compound increasedricegrain yield by 26% compared with control. Amprayn *et al*. (2012) investigated the ability of *Candidatropicalis*HY(CtHY) to stimulate rice seedlings growth. The application of CtHY on germinated seedlings resulted in better rice plant root growth and the colonization of CtHY was confirmed to persist on plant roots at least for 3 weeks. Furthermore, Banaay *et al*. (2012) reported that *T. ghanense* has ability to promote seedlings growth of aerobic rice variety.

Mycorrhizal fungi: Arbuscular mycorrhizal (AM) fungi are group of beneficial fungi that symbioses with the roots of around 80% of vascular plants and often increasing Phosphate (P) uptake and growth (Smith *et al*., 2003). Hajiboland *et al*. (2009) stated that Mycorrhizal colonization on rice significantly contributes to the uptake of P and K in rice plants. The ability of AM to enhance rice growth and yield has been reported by Secilia and Bagyaraj (1992), Secilia and Bagyraj (1994), Solaiman and Hirata (1997), Li *et al*. (2011) and Zhang *et al*. (2012). Yeasmin *et al*. (2007) stated that Mycorrhizal fungi significantly improved rice plants growth by increasing soil nutrients such as nitrogen and phosphorus. Isahak *et al*. (2012) examined the influence of AM to influence rice seedlings growth, as the result showed that AM is significantly enhancing plant height. Zhang *et al*. (2005) investigated the ability of AM to increase upland rice growth under combined soil contamination. The results showed that Mycorrhizal colonization on upland rice had a large influence on rice growth by increasing the shoot and root biomass. The inoculation of AM also gave the protective effects on upland rice under the combined soil contamination Further, Xu *et al*. (2013) stated that AM is able on enhancing rice production when growing in As-contaminated soils.

Paddy and microorganism molecular interaction: Plant-microbe interactions may occur at several core spaces, specific spaces and sub-spaces within the specific space of choice and inter-spaces. These may include amongst others; Phyllosphere, Endosphere and Rhizosphere as core spaces. Phyllosphere is related with the aerial domains of the plants and endosphere being related with the internal cellular systems and its attendant transport systems. Rhizosphere can be defined as any volume of soil specially and specifically influenced by the plant roots or in association with the roots and plant-produced material. Rhizosphere, the term, can be defined as any volume of soil specially influenced by the plant roots or in association with the roots and plant-produced material. Bhattacharyya and Jha (2012) also mentioned in relation to the existence of the secorespaces. Plantexudes some phenolic compounds into the rhizosphere as signal to attract microorganism (Peters and Verma, 1990; Bais *et al*., 2004). Bacilio-Jiminez *et al*. (2003) identified rice root exudates which fall into two separate groups, amino acids (histidine, proline, valine, alanine, glycine, aspartic, arginine, tyrosine and methionine) and carbohydrate (mannose, galatose, glucose and glucuronic acid).

The abundance of rice root exudates might attract microorganism to colonize rice root that penetrate to root tissue. Reinhold-Hurek and Hurek (1997) examined the ability of *Azoarcus* to colonize rice roots endophytically. The result showed that bacteria invade the roots in the zone of elongation and differentiation, colonize the cortex intra- and inter-cellularly and penetrate deeply into the vascular system, entering xylem vessels, allowing systemic spreading into the rice shoot. Blilou *et al*. (2000) stated that the expression of a Lipid Transfer Protein (LTP) gene is regulated in *Oryza sativa* roots in response to colonization by the mycorrhizal fungus *Glomus mosseae*. And then, Transcript levels increased when the fungus forms appressoria and penetrate the root epidermis and decreased at the onset of the intercellular colonization of the root cortex. Further, Rediers *et al*. (2003) examined *Pseudomonas stutzeri* A15 genes that are switched on during rice root colonization and are switched off during free-living growth on synthetic medium. This strain is able to promote rice growth. Further, Guimil *et al*. (2005) stated 12 genes has transcribed only when the mycorrhizal fungus *Glomus intraradices* colonized rice root and those 12 genes were not detected in the absence of symbiosis.

CONCLUSION

This review has shown that there are significant influences of microbes to the growth and yield of rice plant. Many studies investigate the role of microbes to enhance rice growth and yield including producing of growth regulating substances, phosphate-solubilizing, N-fixation, cellulose degrading and siderophore producing. Some microbes are also involving in cell regulation and signaling in rice plants.

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