Microbes in Growth of Paddy: a Particulate in a State of Equilibrium with Associated Particulates

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Abstract

Microbe is a dynamic form of bi-particulate (usually positive or negative charge) existence. An entity that has life (the intrinsic energy that sustain the physical form), able to propagate radially and horizontally (usually referred to as growth) and ultimately undergoes the cessation of nett growth (referred to usually as death or misunderstood as cryptic growth). The complete cycles of existence as understood till now are in seven stages. They are namely; 1-lag (the beginning, assessing the complete core space, spaces and sub-spaces), 2-pre-exponential (assessing for spaces and sub-spaces specific for growth), 3-exponential (maximising associations of myriads of particulates within the core space and sub-spaces usually associated with a maximum specific growth rate, SGR for production of primary metabolites), 4-pre-stationary (assessing for survival strategies usually at reduced SGR in relation to repressions by catabolites), 5-stationary (expression of survival strategies, at an equilibrium SGR accompanied with growth rate approaching zero and accompanied by enhanced production of secondary metabolites. May involves denaturation of catabolites and storage products), maintainance of extreme stationary phase in preparation for the final phase (have been reported to be associated with autolysis and discharge of macro and micro-nutrients) and the death phase (the end and the start of a new beginning, and may be investigated as the nett outcome of genetic and cultural restrictions). In field situations, the particulates and associated particulates at all stages or phases are in constant search for that unique equilibrium state for growth, biosynthesis of growth-designated and non-growth-designated materials and an optimised deployment of intrinsic energies for specific purposes. This cultural conditions involves endogeneous energy economy usually measured by dimentionless yield coefficients ($Y_{x/s}$, for increased in biomass, $Y_{p/s}$, for product synthesis, $Y_{e/s}$, for enzyme synthesis, $Y_{me/s}$, for maintainance energy, $Y_{t/s}$, for transport energy). The cycle of microbial positive and negative charge particulates interactions follow a pre-determined settings (begins-end-begins-end much like a binary computer codification) that are regulated by both the genetic and cultural environs, and more so by cultural environs (approximately 70%). Thus, the specificity of spaces and sub-spaces needs to be fully understood in order to elucidate the myriads of interactions of all particulates involved. The micro sub-spaces do not overlap but experience associations at the interface (membraneous in nature). Thus, microbes that secrete biosurfactant contribute significantly to interfacial diffusion of micro-nutrients from their specific sub-spaces. For microbes involve in growth of paddy, we may envisage the soil as the core space and that the spaces occupied by each of the participating and attendant microbes reside in their designated sub-spaces. The paddy seedlings particulates occupy its own unique sub-space alongside the organics and inorganics particulates, also residing in their own sub-spaces. They all reside in designated sets of sub-spaces separated by a membraneous interface. The interaction of these particulates within the microbes-mineral-paddy in a water-based ecosystem is discussed with the notion that each particulate continually searches for a state of equilibrium for all particulates at every stage of paddy growth. Factors that interfere with the inherent ability to attain the designated communal state of equilibrium is understood to contribute to a degradation of environs for a balanced growth of paddy. The result will inevitably leads to poor yield and poor quality.

Keywords: Microbes, Growth, Paddy, Particulates

1. Microbes as particulates in designated space.

Plant–microbe interactions may occur at several core spaces, specific spaces and sub-spaces within the specific space of choice and inter-spaces (voids containing latent energies). 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. Bhattacharyya and Jha, 2012 also mentioned in relation to the existence of these core spaces. Plant exudes phenolic compounds and others into the rhizosphere. Microorganisms have evolved mechanisms to recognize the signals for active interaction (Peters and Verma, 1990). 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) all would require specific spaces to be effective in the required residence time for the specific and global interactions. Bais *et al*. (2004) suggested that root exudates, as a specific function, might initiate, regulate and manipulate biological and physical interactions between roots and soil organisms.

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 colonize and infect rice roots and provide rice plants with fixed nitrogen and hence promote plant 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.

2. Microbes involve in growth of paddy (Microbial positive and negative charges to set the equilibrium environs)

a. Bacteria in designated space, commonly referred to as habitat.

Numerous species of soil bacteria which flourish in the rhizosphere of plants, but which may grow in, on, or around plant tissues, stimulate plant growth by a plethora of mechanisms. These bacteria, residing in their natural spaces, are collectively known as PGPR (plant growth promoting rhizobacteria) (Vessey, 2003). PGPR are the rhizosphere bacteria that can enhance plant growth by a wide variety of mechanisms like phosphate solubilization, siderophore production, biological nitrogen fixation, rhizosphere engineering, production of 1-Aminocyclopropane-1-carboxylate deaminase (ACC), quorum sensing (QS) signal interference and inhibition of biofilm formation, phytohormone production, exhibiting antifungal activity, production of volatile organic compounds (VOCs), induction of systemic resistance, promoting beneficial plant-microbe symbioses, and interference with pathogen toxin production (Bhattacharyya and Jha, 2012). All the above mechanisms are as a result of association of subspaces in the specific spaces within the core spaces. 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. Another group of researchers, Malik *et al*. (1997) reported that five strains of bacteria, namely, *Azospirillum lipoferum* N-4, *Azospirillum 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 significant increase in plant height, root length, and dry matter production of shoot and root of rice seedlings. Mia *et al*. (2012) inoculated *Bacillus sphaericus* UPMB10, *Rhizobium* strains SB16, UPMR1006 and UPMR1102 to rice seeds. The results suggested that inoculation of relevant microbes significantly increased the seedling emergence, seedling vigor, root growth, in terms of root length, root surface area and volume. Thus, within the core space, we would witness the emergence of new bodies requiring own space to reside at least for the duration of the specific process requiring their contribution. These are rather complex association of complementary, not contending, spaces that resulted in a certain outcome, namely the product(s) of the associations. Thus an understanding of these spaces associations would greatly enhanced our appreciation of myriads of events marked by ‘life’ and ‘death’, be it at molecular, cellular or organismic levels. 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. This may happens only when the inherent equilibrium of spaces are met. 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 fields significantly enhanced rice tiller numbers, stover and grain yields, total dry matter, root length, volume and dry weight. This event may have been contributed by the special condition in SRI core spaces that moves upwards the basic metabolic rate of all attendant microbes to the rice plant. Ruíz-Sánchez *et al*. (2011) examined the response of rice plants to inoculation with *Azospirillum 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.

Table 1 Growth factor produced by PGPR

PGPR	Factor Produced	Reference
Azospirillum lipoferum	Gibberellins	Cassan *et al*. (2001)
	N Fixation	Nayak et al. (1986)
Azospirillum brasilense	Gibberellins	Cassan *et al*. (2001)
	IAA	Mehnaz and Lazarovits (2006)
	N Fixation	Tien *et al*. (1979)
Zoogloea	N Fixation	Xie and Yokota (2006)
Azoarcus	N Fixation	Hurek *et al*. (2002)
Bacillus	Phosphate-solubilizing	Rodriguez and Fraga (1999)
Rhizobium	N Fixation	Yanni *et al*. (2000)
Pseudomonas fluorescens	N Fixation	Park *et al*. (2004)
	Phosphate-solubilizing	Vyas and Gulati (2009)
	Siderophore producing	Kloepper (1980)
Pseudomonas putida	Siderophore producing	Kloepper (1980)
	Phosphate-solubilizing	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)

b. Fungi

Plant Growth Promoting Fungi (PGPF) is a class of beneficial fungi that has the ability to enhance plant growth. As for mechanism of plant growth promotion of PGPF 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 on Table 2.

The ability of PGPF to enhance growth and yield of rice has been done 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 (2009) has applied *Trichoderma viride* to rice seedling and the results reported that *Trichoderma viride* is effectively increasing rice seedlings growth. Khan *et al*. (2005) examined activity of *Trichoderma harzianum* on rice seed germination and seeding vigor. The result suggested that *Trichoderma harzianum* significantly increased seedling emergence, root and shoot length, fresh and dry weight of root of rice seedlings. The same result of the ability of *Trichoderma 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 increased rice grain yield by 26% compared with control. Amprayn *et al*. (2012) investigated the ability of Candida tropicalis 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. Further, Banaay *et al*. (2012) reported that *Trichoderma ghanense* has ability to promote seedlings growth of aerobic rice variety.

Table 2 Growth Factor Produced by PGPF

PGPF	Factor Produced	Reference
Gliocladium virens	Lytic enzymes	Sreenivasaprasad and Manibhushanrao (1990).
Trichoderma virens	Auxin	Contreras-Cornejo *et al*. (2009)
	Jalicylic acid	Contreras-Cornejo *et al*. (2011)
	Jasmonic acid	Contreras-Cornejo *et al*. (2011)
Trichoderma harzianum	Phosphate-solubilizing	Saravanakumar *et al*. (2013)
	Siderophore producing	Rawat and Tewari (2011)
Trichoderma viride	Phosphate-solubilizing	Saravanakumar *et al*. (2013)
	Siderophore producing	Rawat and Tewari (2011)
	Cellulose degrading	Jiang *et al*. (2011)
Aspergillus niger	IAA	Bilkay *et al*. (2010)
	Gibberellins	Gujar *et al*. (2013)
	Phytase producing	Gujar *et al*. (2013)

c. Arbuscular mycorrhizal

Arbuscular mycorrhizal (AM) fungi are vital components of nearly all terrestrial ecosystems, forming mutually beneficial (mutualistic) 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 enrichment greatly improved the soil nutrients such as nitrogen and phosphorus as well as growth of rice plants. 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

3. Conclusion

This paper has shown that the idea of microbes as particulate residing in its specific space within a core space unable a clearer appreciation of why microbes contribute significant influences to the growth and yield of rice plant. Within the microbial space are subspaces where several studies were cited that investigate the role of microorganism to enhance rice growth and yield including production of growth regulating substances, phosphate-solubilizing, N-fixation, cellulose degrading and siderophore producing. Some microorganisms are also involving in cell regulation and signaling in rice plants.

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