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DYNAMISM OF RHIZOSPHERE ORGANISM IN THE ENHANCEMENT OF AGRICULTURAL PRODUCTIVITY

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ABSTRACT

Rhizosphere includes many microorganisms which show different types of interactions with the soil. Rhizospheric effect is more in bacteria than any other soil microorganisms. Rhizospheres help in bioremediation. Some bacteria namely *Pseudomonas, Aerobacter, Agrobacterium* have the ability to solubilize the insoluble inorganic phosphates like tricalcium phosphate, rock phosphate etc. Some enzyme producing microorganisms like *Triticum viridae* which produces cellulase and chitinase degrades cellulose and chitin respectively. In the rhizospheric soil some nitrogen fixing bacteria are found like *Azorhizobium, Allorhizobium, Rhizobium*. Some free-living bacteria found helps in the plant growth. Some organic acid producing fungi like *Aspergillus niger* which produces citric acid is used as blood anti-coagulant, descaler etc. These organic acid producing fungi have many economical uses like tanning and leather industry, plastic, cosmetic industry. Siderospores are present which are iron-chelating protectant produced by all aerobic rhizospheric organism.

KEY WORDS: Rhizosphere, phosphate solubilization, nitrogen fixation, organic acid, siderospores

INTRODUCTION

The term Rhizosphere was said by Hiltner in the year 1904. Rhizosphere may be defined as the soil micro-ecological zone that surrounds the root and influences the roots of the plants. Different root activities like root growth, nutrition, respiration physically and chemically affect the rhizosphere. The soil particles attaches to the roots and helps in the uptake of water and growth of the nitrogen fixing bacteria and other useful micro-organisms. This is done by a slime lubricating substance called mucigel.

Micro-Organisms In The Rhizosphere and Their Interaction

The most common methods to study the qualitative and quantitative population of soil microflora are plate count and serial dilution method. The microorganisms that likely show rhizospheric effect are as follows.

Bacteria

They show the highest rhizospheric effect. It was observed that Gram positive bacteria were less in rhizospheric soil than Gram negative bacteria. Some gram negative bacteria reported which showed root exudates were Pseudomonas and Agrobacterium. Gram positive bacteria present were Bacillus, Clostridium. Nitrogen fixing and phosphate solubilising bacteria were found more in rhizospheric soil. Due to the decrease in the oxygen level in the soil due to root respiration, aerobic bacteria were comparatively less.

Fungi

Some fungal genera showed rhizospheric effect like Penicillium, Aspergillus, Verticillium, Fusarium. In the rhizospheric soil the mycelial fungal forms are dominant.

Actinomycetes, Protozoa and Algae

These are found less in the rhizospheric soil. Actinomycetes may increase if antibacterial agent is sprayed in the soil. Phosphate-solubilizer actinomycetes (Nocardia, Streptomyces)are more common.

Phosphate Solubilization In The Rhizosphere

Dissolved inorganic phosphate exists in the sea mainly as ionic form s of orthophosphoric acid. Because of the negative charge of phosphate ions they are quickly absorbed after weathering of clays or detritus particles forming insoluble forms of aluminium, calcium or iron phosphates. fungi and bacteria have the ability to solubilize these compounds. (Illmer 1995). Organic acids solubilize insoluble forms of phosphate to a useable form such as orthophosphate, thus increasing the potential availability of phosphate for plants(kucey et al.1989) Inorganic phosphate solubilizing bacteria (IPSB) have been isolated from the rhizosphere of many terrestrial plants (Sundarta-Rao and Sinha 1963). These bacteria may benefit crop plants lik legumes, maize and lettuce by increasing their phosphate content when inoculated alone or in combination with mycorrhizal fungi. In marine environment IPBS have been found in the water column, in sediments and also associated. Phosphorus (P) is one of the major essential macronutrients for plant growth and development. Phosphorus exists in two forms in soil, as organic and inorganic phosphates. To convert insoluble phosphates (both organic and inorganic) compounds in a form accessible to the plant is an important trait for a PGPR in increasing plant yields(Igual et al.2001; Rodríguez et al.2006). The concentration of soluble P in soil is usually very low. The plant takes up several P forms but major part is absorbed in the forms of HPO_4^{-2}or $H_2PO_4^{-1}$. The phenomenon of P fixation and precipitation in soil is generally highly dependent on pH and soil type. Microbial P release from organic P sources have been observed. Bacterial strains belonging to genera *Pseudomonas, Bacillus, Rhizo-bium, Burkholderia, Achromobacter, Agrobacterium, Micro-ccocus, Aerobacter, Flavobacterium* and *Erwiniahave* the ability to solubilize insoluble inorganic phosphate (mineral phosphate) compounds such as tricalcium phosphate, dical-cium phosphate, hydroxyl apatite and rock phosphate The efficacy of a strain of *Mesorhizobium mediterraneum* to enhance the growth and phosphorous content in chickpea and barley plants was assessed in a soil with and without addition of phosphates in a growth chamber. Six strains of *Aspergillus* have been found in the study of phosphate solubilization namely *A.vadensis,A.tubingensis,A.foetidus,A.awamori,A.niger,A.costaricaensis*

Enzyme Activities In The Rhizosphere

Lytic enzymes are produced mainly from ericoid and ectomycorrhizal fungi. Arbuscular mycorrhiza function as efficient pumps for N and P forms from the soil. Chitinase and protease activity are found in ericoid and ectomycorrhizal types. The rhizosphere enzyme activities involves increase in soil fertility, indicator of soil functions such as organic matter deposition, nitrogen fixation, nitrification, denitrification. The hydrolase enzymes present in the rhizospheric soil are important as they indicate the potential of a soil to carry out specific biochemical reactions. The hydrolytic enzyme maintains the soil fertility and also helps in plant productivity. Acid phosphatase/phytase genesfrom *Escherichia coli* (appA and appA2 genes) have also been isolated and characterized (Golovan et al.2000; Rodríguez et al.1999). Neutral phytase genes have been recently cloned from *Bacillus licheniformis* (Tye et al.2002) The mycelium of *T.viride* produce different enzymes like celluloses which degrades cellulose and chitinases which degrades chitin. Plant bacterial interactions in the rhizosphere are the deter-minants of plant health and soil fertility. Free-living soil bacteria beneficial to plant growth, usually referred to as plant growth promoting rhizobacteria (PGPR), are capable of promoting plant growth by colonizing the plant root. PGPR are also termed plant health promoting rhizobacteria (PHPR) or nodule promoting rhizobacteria (NPR). These are associated with the rhizosphere, which is an important soil ecological environment for plant microbe interactions. Sym-biotic nitrogen-fixing bacteria include the cyanobacteria of the genera *Rhizobium, Bradyrhizobium, Azorhizobium, Allorhizobium, Sinorhizobium* and *Mesorhizobium*. PGPR have the potential to contribute to sustain-able plant growth promotion. (P)-solubilizing bacteria such as *Bacillus* and *Paenibacillus*(formerly *Bacillus*) sp. have been applied to soils to enhance the phosphorus status of plant

Some enzymes and their source from microorganisms

SOURCE	NAME OF THE ORGANISM	ENZYME
FUNGAL	*Aspergillus oryzae*	Amylases
	Aspergillus flavus	Glucosidases
	Aspergillus niger	Proteases
	Aspergillus niger	Pectinases
	Penicillium notatum	Glucose oxidase
	Aspergillus niger	Catalase
BACTERIAL	*Bacillus subtilis*	Amylases, Protease, Penicillinase
YEAST	*Saccharomyces cerevisiae*	Invertase
	Saccharomyces fragilis	Lactase

ORGANIC ACID PRODUCTION

Organic acids play significant and varied roles in rhizosphere acidification and mineral weathering, contributing protons and serving as ligands that complex metals (Buol et al. 1997) Organic acids carries out redox reactions with electron-deficient metals and produces proton and helps in consumption (a rhizosphere-promoted process that occurs as a part of redox cycling). Many organic compounds have acid functional groups, namely carboxylic or phenolics. These organic acids are formed from decomposition and carbon oxidation. It also exudates from plant roots and associated microbes. Molecular weight of organic acid ranges from small compounds such as oxalic and citric acids to much larger humic compounds with enormous numbers of carboxylic and phenolic functional groups. Organic acids are effective ligands that complex metal cations such as Al and Fe, which facilitates mineral dissolution and metal translocation within soils, thereby enhancing weathering processes.

The different organic acids, their sources and applications are given in the chart below:

Organic acid	Source	Application
Citric acid	*Aspergillus niger*	Used as a blood anticoagulant, a metal cleaning agent and a de-scaler. used as acidulant in the food and beverage industries. Aspergilllus produces the key enzyme, pyruvate carboxlase, in abundance.

Gluconic Acid	*Aspergillus niger*	Used in food and beverage, pharmaceutical, detergent and construction industries. Calcium and ferrous glutamate are used in calcium and iron deficiencies. It is essential to the tanning process of leather and is also used in metal processing. Sodium glucanate is used in cement mixes and is also used in the presence of sodium hydroxide as a sequestering agent of calcium in glass bottle washing. An enzyme, glucose oxidase, which is also produced in gluconic acid fermentation is used widely in the food industry as a flavour and colour stabilizer. More importantly in terms of health and disease, this enzyme is used in diagnostic kits to assay glucose in the urine of diabetes patients.
Lactic acid	*Lactobacillus delbrueckii ,L. leichmannii ,L. bulgaricus*	It plays a role in the manufacturing of many food and drink products including coffe and tea.
Kojic Acid	*Aspergillus flavus* and *A. oryzae*	Used in the cosmetic industry. This acid inhibits the production of melanin and also can be used as part of skin lightening cosmetics.
Itaconic acid	*Aspergillus itaconicus* and strains of *A. terreus*	Used in the plastic industry. Itaconic acid forms copolymers with its esters and other monomers, which are used in the paper industry for wallpaper and other paper products. Itaconic acid is also used in the production of adhesives.
Acetic acid	*Gluconobacter* and *Acetobacter*	Vinegar preparation, used as a solvent for recrystallization

PATHOGENIC INTERACTIONS IN THE RHIZOSPHERIC SOIL

Roots exudates can attract beneficial organisms (see below), but they can also be equally attractive to pathogenic populations (Schroth et al., 1964), that many express virulence on only a limited number of host species. Many pathogenic organisms, bacteria as well as fungi, have coevolved with plants and show a high degree of host specificity (Raaijmakers et al., 2009). In nature however, plant disease is the exception rather than the rule because the conditions that are optimized for the plant growth may not be favourable for pathogens . Plants are not defenceless. In fact, it is estimated that only about 2% of the known fungal species are able to colonize plants and cause disease (Buchanan et al., 2000). Even though plants are in permanent contact with potential pathogens such as fungi, bacteria or viruses, successful infection is rarely established. Such a general resistance against most pathogens has been named "horizontal resistance". This reflects the fact that the plant is not a suitable target for infection by a specific pathogen due to preformed, passive resistance mechanisms resulting in "basic incompatibility". These resistance mechanisms comprise structural barriers and toxic compounds that are present in the unaffected, healthy plant and limit successful infection to specialized pathogens that have the ability to overcome these factors and therefore exhibit "basic compatibility". These low molecular weight secondary metabolites are mainly stored in inactive form in the vacuoles or organelles and are released upon destruction of the cells. Since destroying the integrity of the plant tissue is part of the colonization strategy by fungi, phytoanticipins represent an important resistance mechanism against these pathogens. However, in some instances, pathogens can over come the pre-formed barriers and develop virulent infection processes leading to plant disease. Plant diseases play a direct role in the destruction of natural resources in agriculture.

Rhizosphere as protectant

Siderophores are iron-chelating plant protectants produced by all aerobic rhizospheric organisms. Siderophores selectively avail iron which is essential for plant growth by active transportation to both rhizospheric organisms and plants, by their capability of chelation and selectively deprive it to phytopathogens, thus suppressing them and improve the plant growth (Messenger et. al 1986; Chincholkar et. al 2000). Iron is important to all forms of life due to the catalytic role of iron in the generation of oxidizing radicals from superoxide and peroxide(Flitter et el.1983). Siderophores are low molecular weight compounds, produced under iron-limiting conditions, chelate the ferric ion with high specificity activity and serve as a vehicle for transport of Fe(III) into a microbial cell. Siderophores produced by flouroscent pseudomonads which inhibit in the plant rhizosphere are important because of their role in the biological control of soil borne plant pathogens and in disease suppressive soils(Scher 1986;Leong 1986;Loper 1990;Schippers et al.1987). the fluorescent pseudomonads are characterized by the production of yellow-green pigments that fourensce under ultra-violet light and functions as siderophores. The fluorescent siderophores termed as pyoverdines, pyoverdins or paeudobactins represent only one class of siderophores produced by the fluorescent(Cox 1980;Demange et al.1987;Teintze et al.1981).

As viral biopesticides

Baculoviruses or NPVs (nuclear polyhedrosis viruses) are the viruses that infect insects, mostly of the order Lepidoptera (butterflies, moths), Hymenoptera (sawflies) and Coleoptera (beetles) and have also been found to infect crustaceans. They are rod shaped ('baculo' meaning rod-shaped) and have double stranded DNA as their genome. In nature, they are found occluded within proteinaceous crystals known as 'polyhedra' on plant foliage, plant debris and soil. Insect larvae get infected when they feed on plant foliage, and after a few days, show feeding cessation and ultimately die. Being uninfectious for non-arthropod organisms, including man, and being of a restricted host range, they have every potential to be exploited for use as a biopesticide.

As biofertilizer

Trichoderma, a versatile fungi are used commercially in a variety of ways, including the following:

Foods and textiles

Trichoderma spp. are highly efficient producers of many extracellular enzymes. They are used commercially for production of cellulases and other enzymes that degrade complex polysaccharides. They are frequently used in the food and textile industries for these purposes. For example, cellulases from these fungi are used in "biostoning" of denim fabrics to give rise to the soft, whitened fabric--stone-washed denim. The enzymes are also used in poultry feed to increase the digestibility of hemicelluloses from barley or other crops.

Biocontrol agents

As noted, these fungi are used, with or without legal registration, for the control of plant diseases. There are several reputable companies that manufacture government registered products.

Plant growth promotion

For many years, the ability of these fungi to increase the rate of plant growth and development, including, especially, their ability to cause the production of more robust roots has been known. The mechanisms for these abilities are only just now becoming known.

As a source of transgenes

Biocontrol microbes, almost by definition, must contain a large number of genes that encode products that permit biocontrol to occur. Several genes have been cloned from *Trichoderma* spp. that offer great promise as transgenes to produce crops that are resistant to plant diseases. No such genes are yet commercially available, but a number are in development. These genes, which are contained in *Trichoderma* spp. and many other beneficial microbes, are the basis for much of "natural" organic crop protection and production. The fungicidal activity makes *T. viride* useful as a biological control against plant pathogenic fungi. It has been shown to provide protection against such pathogens as *Rhizoctonia*, *Pythium* and even *Armillaria*. It is found naturally in soil and is effective as a seed dressing in the control of seed and soil-borne diseases including *Rhizoctonia solani*, *Macrophomina phaseolina* and *Fusarium* species. When it is applied at the same time as the seed, it colonizes the seed surface and kills not only the pathogens present on the cuticle, but also provides protection against soil-borne pathogens.

CONCLUSION

Hence it can be seen that the rhizosphere is a dynamic zone which not only promote the growth of different microbial organism but it also helps in reduction of soil pollution increases the availability of nutrients promotes the enzymes activity and also effectivity. It reduces pathogenic organism resulting in better plant productivity.

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