English Version

Interactions among groups of microorganisms with rhizosphere

Jussara Silva Dantas[1] ; *Adailson Pereira de Souza*[2]; *Maryzélia Furtado de Farias*[3]; *Virgínia de Fátima Bezerra Nogueira*[4]

Abstract

The physicochemical properties of the rhizosphere have high stability, which, coupled with the constant supply of organic substrates and growth factors, favor intense metabolic activity of the populations, directly and positively influencing the microbial generation time. Soil is a place of great number and variety of biological interactions, including competition, predation, parasitism, commensalism, mutualism and phoresy. The biological interactions have the capacity to sustain the life of both plants and animals and other creatures that live in soil. The rhizosphere microbial community is represented by numerous and diverse populations in a state of dynamic equilibrium, reflecting the physical, chemical, biological environment and their relations. Therefore, the purpose of this review was to demonstrate that there is interaction among groups of microorganisms with the rhizosphere. The populations of microorganisms are important constituents of the microflora of the rhizosphere, either by plant root exudates as a carbon source favored by the metabolism of these microorganisms, or by the ability to synthesize antibiotics, allowing the use of its antagonist capacity in the biocontrol of phytopathogens, or by the influence that promotes the establishment of beneficial microorganisms such as mycorrhizae and diazotrophic; and also by the formation of actinorhizal, where it is able to fix atmospheric nitrogen.

Keywords: organic exudates; biocontrol; phytopathogens.

Introduction

Soil is a complex natural environment that influences the growth, proliferation, survival and other activities of organisms (FERNANDES JÚNIOR et al., 2002). The microorganisms do not live in the soil in the form of pure cultures, but in the form of a complex community, where a wide variety of interactions are developed. Rhizosphere, soil region under direct influence of the presence of roots with different characteristics of soil, is the region where most of the interactions between microorganisms and plants occur. (PEREIRA, 2000).

Rhizosphere is a mutable habitat, and its composition and structure are influenced during vegetative cycle. Its dimensions are also determined by the type, composition and soil moisture. The plant can modify the chemical characteristics of soil near their roots through the fragments of the peeled surface of roots and soluble root exudates, enriching the soil with a variety of organic compounds; through O_2 consumption and CO_2 release, modifying the root atmosphere; through selective absorption of nutritious ions, decreasing the salt concentration, and through consumption of H_2O, reducing humidity, etc. (NIELSEN e ELSAS, 2001).

The exudates spread to different distances through the adjacent environment, representing a very attractive niche for microorganisms where the most diverse types of interactions can be observed between these and plants, as well as among different members of the microbiota (CARDOSO e FREITAS, 1992).

The presence of roots and the physical and chemical changes they produce create a specialized ecosystem, where the growth of populations in the microbial community can be benefited or inhibited. The influence of roots on soil microorganisms is assessed by relating the densities of microbial populations at different distances from its surface (R), and the adjacent soil (S). Thus, the number of microorganisms of different species in the

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[1] MSc. Of the Center of Agricultural and Environmental Sciences of the Federal University of Maranhão CCAA/UFMA) Chapadinha-MA, CEP: 65500-000, email: jussarasd@yahoo.com.br

[2] Professor Adjunto* of the Department of Soil and Rural Engineering, Center of Agricultural Sciences of the Federal University of Maranhão, Campus II, Areia-PB, CEP: 58397-000

[3] Prof Dr. of the Center of Agricultal and and Environmental Sciences of the Federal University of Maranhão CCAA/UFMA) Chapadinha-MA, CEP: 65500-000, email: maryzelia@ig.com.br

[4] Prof. MSc. of the Center of Agricultal and and Environmental Sciences of the Federal University of Maranhão CCAA/UFMA) Chapadinha-MA.

*Brazilian Academic Degree

rhizosphere is usually greater than in soil free of roots and the ratio R / S is almost always greater than 1 (CARDOSO and FREITAS, 1992). It has been observed that the rhizospheric populations can be 100 times higher than the adjacent soil (SMITH and FRANCO, 1988).

The physicochemical properties of the rhizosphere have high stability, which, coupled with the constant supply of organic substrates and growth factors, favor intense metabolic activity of the populations, directly and positively influencing the microbial generation time. *Pseudomonas* and *Bacillus* species have generation times respectively 15 and 2.5 times lower in the rhizosphere than in non-rhizosphere soil, due to increased availability of substrates. Therefore, the rhizosphere is considered the "paradise for microorganisms" (MOREIRA and SIQUEIRA, 2002).

The bacterial mass can reach 36 mg of bacteria per gram of root. Studies with electronic microscopy have shown that bacterial populations may reach 120-160 x 10^6 CFU / cm^2 root.

The activities of the roots provide a favorable habitat for the development of fungal populations. However, the rhizosphere effect over these microorganisms appears to be more limited than for bacterial populations. The proximity of the roots results in the germination of dormant spores, which are predominant in non-rhizosphere soil. Some of the most representative genera found in the rhizosphere of cultivated plants are: *Alternaria, Aspergillus, Acaulospora, Fusarium, Gigaspora, Glomus, Mucor, Penicillium, Pythium, Rhizoctonia, Scutellospora* (SIQUEIRA and FRANCO, 1988). The species of ectomycorrhizae and endomycorrhizae are encouraged to form symbiotic associations. As a result there is an increase in the volume of soil under influence of the root (mycorrhizosphere), leading to substantial increases in the number of microorganisms (FOSTER, 1986).

Generally, the densities of the fungal populations in rhizosphere reach 10 ^{7} CFU / g of rhizosphere soil. For populations of actinomycetes, the rhizosphere also turns out as a favorable niche. It has been noted that the genera commonly found in the rhizosphere of cultivated plants are *Streptomyces* and *Nocardia.* In general, the influence of rhizosphere on populations of actinomycetes is smaller than on the populations of other bacterial and on fungal populations, since actinomycetes are microorganisms which grow slowly with low competitive ability. Thus, they can not prevail on organic substrates in which other microorganisms have higher capacity for colonization. The population densities of actinomycetes in the rhizosphere are variable and may reach 10 ^{6} to 10 ^{7} CFU / g of dry rhizosphere soil (SMITH and FRANCO, 1988, PEREIRA et al., 1999a).

Interactions of microorganisms in the rhizosphere

Soil is a place of great number and variety of biological interactions, including competition, predation, parasitism, commensalism, mutualism and phoresy. The biological interactions have a key role in soil functioning, that is, in its ability to sustain life of both plants and animals and other creatures that live in soil (BROWN, 2002).

Rhizosphere microorganisms can be divided into opportunistic and strategists. Opportunists are small, fast-growing, have high competitive ability and are located mainly in the younger roots. Strategists are larger, have slower growth and have high longevity, are specialized and are prevalent in older roots. They can be further divided into saprophytes, symbionts and pathogens (MOREIRA and SIQUEIRA, 2002).

For Melo (2001), soil microorganisms can be divided, as to the effect that they cause to plants, into beneficial, harmful or neutral. The harmful are divided into minor and major pathogens, according to the symptoms they cause to plants. The beneficial microorganisms, symbiotic and non-symbionts, can affect plant growth by increasing the availability of mineral nutrients, by the production of growth hormones like auxins and gibberellins and by the suppression of harmful microorganisms from the rhizosphere of plants.

In the context of events occurring in the root-soil interface, the microorganism interaction is crucial for understanding the characteristic of the dynamic process of stability of the rhizosphere and the maintenance of nutrient recycling, where these microorganisms that interact with the rhizosphere participate in several cycles, such as nitrogen, carbon, phosphorus and sulfur. These organisms interact with the roots of plants, supply nutrients and have an active participation in nutrition and plant growth (ANDRADE, 1999 cited by BRAZIL JÚNIOR, 2002).

Brasil Júnior et al. (2002) state that a microbial population that participates in the same biochemical transformation of compounds of the environment, and within the same population of microorganisms, is a functional group. The functional groups are concentrated in the rhizosphere soil where they have an important activity to promote or inhibit plant growth according to environmental conditions.

The rhizosphere microbial community is represented by numerous and diverse populations in a state of dynamic equilibrium, reflecting the physical, chemical, biological environment and their relations. Thus, the community reflects its *habitat,* where the density of a microbial population increases to meet limitations of abiotic and biotic nature. So, the existence of a microorganism at a particular time and place follows its evolution, the existence of abiotic factors favorable or unfavorable to its development and beneficial and/or deleterious interactions performed by other populations of the microbial community. Therefore, the various kinds of influences from the biological interactions are determining the densities and activities of populations in the rhizospheric microbial community (MOREIRA and SIQUEIRA, 2002).

The chemical composition of the rhizosphere differs from the chemical composition of the soil volume. The differences occur mainly because of absorption of water and nutrients, changes in pH of the rhizosphere, the exudation of organic acids and microbial activity. Many of these processes may influence the availability of nutrients such as P, Fe, Mn, Zn, Cu, as well as the solubility of toxic elements such as Al (BRACCINI et al., 2000).

Interactions with bacteria in general

Bacteria that grow near or attached to the roots, stimulated by root exudates, are called rhizobacteria. Several rhizobacteria have the ability to promote plant growth. This effect is attributed to the production of growth regulating substances, to the production of antibiotics and siderophores, mineralization and solubility of nutrients such as phosphorus and nitrogen fixation (CATTELAN and HARTEL, 2000).

Among the beneficial microorganisms, the rhizobacteria, named for aggressively colonizing the root system, are noteworthy. These bacteria can be symbiotic or free-living saprophytes. Among plant growth-promoting rhizobacteria (PGPR), bacteria of the genus *Pseudomonas* spp. are the best studied. This is due mainly to their great ability to suppress soil-borne pathogens, to their occurrence in a natural way and at higher populations, to the fact that they are nutritionally versatile and possess the ability to grow in a wide range of environmental conditions, in addition to producing a large variety of antibiotics, siderophores and plant hormones. The rhizobacteria of the fluorescent group *(P. fluorescens-putida)* have a versatile metabolism and may use various substrates released by roots and also by xenobiotic molecules that reach the rhizosphere (Melo, 2001).

The gram-positive bacteria such as *Bacillus,* have their wall composed of peptidoglycan, with or without teichoic and teicuronic acids. The gram-negative bacteria such as *Pseudomonas* type, are about 20% less peptidoglycan, however, they have outer membrane with phospholipids and lipopolysaccharides. Proteins and lipoproteins occur in both types of bacteria (VOSS and THOMAS, 2001).

The production of antibiotics in soil may be concentrated in microsites where, such as the rhizosphere, there is a concentration of nutrients and competition is intense. The production of antibiotics has been associated to differentiation in cell morphology, such as the production of spores, limited or impeded by nutritional deficiencies, which would be supplied by the rhizosphere, given the amount of exudates from nutrients (OWEN and ZDOR, 2001).

Studies have shown changes in bacterial populations in the rhizosphere of maize, wheat, beans and soybean promoted by operations of use and management of soil, increasing the population densities of actinomycetes and antibiotic resistant bacteria (BALDANI et al., 1982, PEREIRA et al., 1999a). In these cases, the increased production of antibiotics, caused by increased populations of actinomycetes in the rhizosphere, led to a selection pressure on the microbial community, promoting the persistence of genotypes with resistance to antibiotics produced.

Interactions with rhizobium

Problems in the establishment of rhizobial lineages in the field have been described, which may be associated with the presence of antagonistic microorganisms (MARSCHNER et al., 2001). Several studies have shown inhibition of growth of Rhizobium *in vitro* by bacteria, fungi and actinomycetes isolated from rhizosphere soil, there are also data on the inhibitory effect of actinomycetes on nodulation and nitrogen fixation (PEREIRA et al, 1999b).

The high resistance of several strains of isolated *Bradyrhizobium japonicum* from nodules of plants from the Amazon and the Brazilian cerrado, to antibiotics streptomycin, penicillin, chloramphenicol and gentamicin, shows the presence of one or more antibiotics in the rhizosphere of plants from which they were isolated (DÖBEREINER et al., 1981). Later, circumstantial evidence was found that antibiotics are produced in soil-plant system, inhibiting the formation of nodules and that the probable site of production is the rhizosphere (RAMOS et al., 1987). These results show the importance of ecological studies of rhizospheric populations in order to evaluate the role of these populations in the establishment of efficient nodulation.

Interactions with mycorrhizae

The interaction between mycorrhizal fungi and soil phytopathogenic fungi have shown that mycorrhizal plants generally have less damage than non-mycorrhizal, as a result of the decrease in the incidence of the disease or by inhibiting the development of the pathogen. The action mechanisms involved in the increased tolerance of the mycorrhizal plant to the pathogens appear to be related to: the change in the quality and quantity of nutrients in the rhizosphere, the production of amino acids and reducing sugar, changes in the physiology of the roots and wall thickness increase of cortical cells, the physical competition for space in the root, the stimulation of antagonistic rhizospheric population, the greater lignification of roots, and increased nutrient uptake by mycorrhizae, especially phosphorus, which gives it more vigor and growth. Mycorrhizal protective effect against soil pathogens occurs when both species are simultaneously present in the rhizosphere or in the root of the plant, and the pre-colonization of roots by mycorrhizal fungi provides a more efficient protection (OLIVEIRA and TRINDADE, 2000).

The dense colonization of the root system of plants by mycorrhizae and the resulting changes of this association in the physiology and exudation of roots suggest that mycorrhizal associations influence specific groups of bacteria and actinomycetes in the rhizosphere (MIKOLA and KYTÖVIITA, 2002). By growing crops in pots, significant increases have been observed in populations of actinomycetes of the genera *Nocardia, Micromonospora and Streptomyces,* promoted by mycorrhizal fungi *Glomus fasciculatum, Gigaspora margarita, Acaulospora laevis* and *Sclerocystis dressi* (SECIL and BAGYARAJ, 1987). Still, populations of actinomycetes inhibit colonization of *Glomus macrocarpum* and *Glomus etunicatum* in the rhizosphere (PEREIRA et al., 1991).

These findings may be related to the characteristics of populations of actinomycetes such as: antibiotic production and decomposition of chitin, the main component of the cell wall of fungi, including the mycorrhizic. These features increase the significance of populations of actinomycetes as a major biological factor that influence colonization by mycorrhizal fungi populations in the rhizosphere.

Not all fungi that inhabit the roots form mycorrhizae. Many live in the rhizosphere or grow on the root surface, without any communication or effects over them. Relations of this type are generally regarded as neutralistic, and as of the locational criteria, they are called peritrophic associations (Moreira and Siqueira, 2002).

Actiorhizae

The term actinorhizae is used to describe symbiotic clusters, capable of fixing molecular nitrogen, comprised of some non-leguminous plants and actinomycetes. Thus, the actinomycetes also feature as a point of great interest the symbiotic association they form with plants belonging to the genera *Casuarina, Myrica, Alder, Eleagnus* among others (Akkermans et al., 1992), the species of the genus *Frankia* as an endosymbiont, forming nodules similar to the association of Rhizobium-leguminous plant (actinorhizal).

The economic importance of the use of non-leguminous plants that nodulate with *Frankia* is greater for silviculture than for agricultural crops. Trees like *Alnus* and *Casuarina* supply timber, and *Alnus* is widely used to colonize altered soils and the ones with integrated urban waste in consortium with non-fixative forest oils such as *Fraxinus, Liquidambar, Pinus, Platanus, Populus Pseudotsuga* and (Cardoso e Freitas, 1992). Besides the symbiosis, *Alnus* also provides and releases organic compounds into soil that can stimulate the growth of free-living fixative microorganisms. Herbaceous and shrubby plants associated with *Frankia* as, for example, *Ceanothus,* can be employed for the enrichment of forest soils with nitrogen deficiency mainly in consortium (BAI et al., 2002). The production of wood pulp, for locksmiths and energy, and biomass, erosion control and revegetation of semi-arid areas and deserts are other uses of actinorhizal plants.

Final Considerations

The populations of microorganisms are important constituents of the microphlora of the rhizosphere, either by plant root exudates as a carbon source favored by the metabolism of these microorganisms, or by the ability to synthesize antibiotics, allowing the use of their antagonist ability in the biocontrol of phytopathogens, or by the influence that promotes the establishment of beneficial microorganisms such as G. diazotrophicus and mycorrhizas, and even the formation of actinorhizal, where it is able to fix atmospheric nitrogen.

Despite this evidence, it should be noted that other studies have yet to be brought to term, aiming at understanding the ecophysiology of these microorganisms in the rhizosphere of cultivated plants and consequently, the increases in agricultural productivity.

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