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Research Article

RHIZOSPHERE EFFECTS: AN EVALUATION

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ABSTRACT

This paper deals with the concept and effects of rhizosphere zone and the microorganism found around the roots of plants. The micro organism are of very high importance for plant growth. However, some of them exert negative effects also on the growth of the plants. The conditions affecting rhizosphere region are also highlighted in the paper. The deleterious rhizosphere micro-organisms (DRMO) affecting plant growth (fungi & bacteria) are especially mentioned in the paper. Besides, modes of growth promotion activities of PGPF and antagonism between soil micro organisms and their impact on plant pathogens are also thoroughly reviewed and discussed in the light of empirical results.

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INTRODUCTION

If one reviews the historical background of the concept of rhizosphere, he or she will find that the term rhizosphere was firstly used by Lorenz Hiltner (1904). Since then numerous researches have been conducted covering this concepts and as a result of it a number of useful conclusions have been given which are gradually adding to our existing knowledge regarding rhizosphere.

The term rhizosphere is used to denote the region of the soil around the roots in which maximum microbial growth and activities operate. This region of the soil is subject of intense influence of root of the plants. In other words, greater the distance from the plant roots lesser the microbiological activities and vice-versa. There is a general agreement among the researchers that amount of nutrition to be available to the plants depends upon the composition of the soil flora in the rhizosphere. Thus, greater the favourable composition of soil flora available, greater the availability of nutrition and vice-versa (Dessaux, Hinsinger, & Lemanceau, 2009; Bhardwaj, 2006, 2017).

As regards the classification of the rhizosphere, variations are noticed in the view of the researchers. For example Graf (1930) and Poschenriadder (1930) have distinguished two types of sphere called outer rhizosphere and inner rhizosphere. Another researcher has divided rhizosphere in three categories, namely outer surface – comprising the region of soil immediately surrounding the roots of the plants as well as microbial population which inhabitate in this area. Inner Rhizosphere – it is also called as endorhozisphere and it is formed by the root cortical tissues and is influenced by saprophytic soil microorganisms and root surface - this (rhizosphere) is formed by root surface and the microorganisms present in this area.

It may be mentioned in this context that it was Clark (1948), who suggested the term rhizoplane to indicate the real surface of the plant roots together with closely adhering particles of soil derbies. For practical convenience the two terms can be defined apart, but it is very difficult to study microbiology of the two regions separately. The rhizosphere and rhizoplant taken together may be referred to as the root soil interface (Dessaux, Hinsinger, & Lemanceau, 2009; Madigan & Martinko, 2005).

Effects of Rhizosphere

Within the rhizosphere, the plant roots exert a direct influence on the soil microorganisms, known as 'rhizosphere effect'. Likewise, the microbial populations in the rhizosphere have pronounced effect on the growth of the plant. Due to rhizosphere effect, higher number of microorganisms are found in the rhizosphere than in the non-rhizosphere soil (Bowen, & Rovira, 1999). In the rhizosphere soil, generally bacterial, cyanobacteria, microfungi, microalgae and protozoans occur. Tables-1 shows that high numbers of microbes occur in association with plant root (Sharma, 2003).

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Table 1 Microbes in Plant root

Distance from Plant root (mm)	Microbes I/g dry wt soil		
	Non-filamentous bacteria (X 10^7)	Streptomycetes (X 10^7)	Fungi (X 10^6)
0	16.0	4.7	3.6
0-3	5.0	1.6	1.8
3-6	3.8	1.1	1.7
9-12	3.7	1.1	1.3
15-18	3.4	1.0	1.2

The major proportion of the microbial biomass is fungi. Generally Ascomycetes and Basidiomycetes fungi occur in the fertility layer of soil. Fungi occur as free-living or associated with plant roots. Many soil fungi play a significant role in soil by forming Mycorrhiza in association with the roots of plant. Microrrhiza is a symbiotic association between the root-system of the higher plants and fungal hyphae. Hyphae are the main mode of vegetative growth, and are collectively called a mycelium (Madigan & Martinko, 2005; Maheshwari, 2016; Steinberg, 2007; Moore, *et al*., 2011). The fungus derives nutrients from the root and helps the plant in uptake of minerals (Sneh *et.al*., 1986, Smith *et.al*. 1994, Varma, 1995; Walker, 1995, Moore *et al*., 2011). The most important factor which is responsible for rhizosphere effects is the great variety of organic matters available at the root region in the form of root exudates. It has been reported that there may be slight differences in the rhizosphere and non-rhizosphere mycoflora which may be due to root exudation (Parkinson & Thomas, 1969).

The rhizosphere effect is generally influenced by several factors such as soil type, its moisture, pH, temperature, oxygen, CO_2 and the age and condition of plants. Soil is a complex medium, consisting of morganic minerals and organic debris which serve as boundaries to channels and pores containing air and water. Thus, the movement of water, air and energy transfers is interlinked with the porosity of soil (Madigan & Martinko, 2005; Maheshwari, 2016).

The rate of plant growth is also affected by pH and water retaining capacity of soil. The water holding capacity of soil is related to pore space and capillary action of soil particle, but pH is related with chemical composition of soil. Acidic or alkaline nature of soil is also influenced by the plant growth (Humphreys *et.al*., 1963). Generally high low percentage of acid or alkaline does not favour the growth of plants, but neural soil favour the plant growth and development of rhizosphere mycoflora. The important of these microorganism is, degradation or decomposition of some organic compounds. These organic compounds are the polysachharides, organic acid, lignin, sugars, alcohols, amino acids, lipid protein, nucleic acid and that are characteristics of life. After decomposition the organic compounds are returned to the environment in their inorganic or mineral form (Madigan & Martinko, 2005; Maheshwari, 2016).The conversion of organic compounds into inorganic form is also beneficial for plants, because these are absorbed by root and increase the growth of plants. It has been reported that roots of many plant exert rhizosphere effect according to the age and species of plant (Madigan & Martinko, 2005; Kamal & Singh, 1969).

The suppression and stimulation of growth of soil microorganisms are due to selective action of actively growing plant roots. The rhizosphere microfloras are active and changing population. Generally some environmental factors and dominant species of rhizosphere influence the equilibrium of rhizosphere microflora. Dwivedi (1968) reported that, the dominant species may be disappears at one time giving place to other forms favoured by the environment. The active colonization of rhizophane and rhizosphere microflora due to nutritionally active dominant species, because when a nutrient solution is inoculated with a mixed microbial population, the organisms that can grow most rapidly under these conditions will soon predominate. It is well understood that the root exeudates attract soil microbes and may also have a selective effect on the growth of microbial population of the rhizosphere (Madigan & Martinko, 2005; Maheshwari, 2016).

The moisture of soil and temperature of the environment also affect in the rhizosphere region. The moisture content of soil is more important factor of fungus growth. Fungi are more active at moderate than at high soil moisture.

Root Exudates

Root from an instable habitat for microorganisms for the interfaces between the root, soil and microbes continually changing. There are several factors responsible for rhizosphere effect ((Madigan & Martinko, 2005; Maheshwari, 2016; Walker *et al*., 2003). Among them, one of the most essential factors is the presence of organic substances in the region of rhizosphere. These organic substances available at the root region by way of root exudates from root which directly or indirectly influence the growth of microbes and microbial population (Bhardwaj, 2017a). According to some researchers, the substances exuded by plant roots include amino acids, sugar, glycosides, organic acids, vitamins, enzymes, growth factors and a variety of unidentified substances (Frankenberger *et.al*.,1991; Chen, *et.al*., 2009; Madigan & Martinko, 2005; Maheshwari, 2016). Some volatile compounds such as fatty acid, alcohols and alkyl sulphide etc. are also found in root exudates which play significant role in modulating the microbial activities (Bowen & Rovira, 1999; Bhardwaj, 2017; Singh, 2002).

Microorganisms of Rhizosphere

There are several types of microorganisms found in rhizosphere. These microorganisms are bacterial, fungi, algae, protoza, actinomycetes and microarthropods. The availability of these microorganisms depends upon soil type, and soil conditions. Table-2 shows the number of microorganisms in per gram of a fertile soil (Madigan & Martinko, 2005; Maheshwari, 2016).

Table 2 Number of Microbes/per gram a fertile soil (Nicholas, 1965)

Types	Number
True bacteria	10^6 to 10^9
Actinomycetes	10^5 to 10^6
Protozoa	10^4 to 10^5
Algae	10^1 to 10^3
Fungi	10^4 to 10^5

These numbers are invariably higher for the rhizosphere than rhizoplane microflora. According to Whipps (2001), the environmental factors which influence the growth and distribution of bacterial flora, also influence the fungal flora of the soil.

Types of Rhizosphere Microorganisms

Rhizosphere have many different microhabitats (Newman & Reddel, 1987; Dessaux, Hinsinger, & Lemanceau, 2009). In Rhizosphere, harmful and useful both types of microorganisms occur. The harmful microbes may be deleterious or inhibitory to root and plant growth, but the useful microbes increase the growth and development of root and shoot of plants. The interactions of plant roots and rhizosphere microbes are based largely on interactive modifications of the soil chemical environment by processes such as water uptake by the plant, release of organic chemicals in soil by roots, microbial production of plant growth factors and microbially mediated availability of mineral nutrients (Mucciarelli, *et.al*., 1995 ; Saha *et.al*., 2005), There are three types of rhizosphere microbes namely - beneficial microorganisms (symbiotic), harmful microorganisms (pathogenic) and neutral- having no effect on the plant neutral (Madigan & Martinko, 2005; Maheshwari, 2016).

The Deleterious Rhizosphere Microorganisms (DRMO)

The DRMO includes deleterious rhizosphere bacteria (DRB) and deleterious rhizofungi (DRF). The DRMO affect plant growth negatively (Chen, *et.al*., 2009). The DRMO act by causing alteration in the supply of water ions and plant growth substances by affecting root function and by limiting root growth. Their effects must be assessed for protecting the plants (Dessaux, *et al*, 2009; Maheshwari, 2016). Several species of Penicillium and Eupencillium inhibit the plant growth of Zinnia by 23 to 57 percent. Retardation of growth root discolouration, wilting necrotic reaction, distortion of root leaves or stunting of plants are caused by DRMO. Some deleterious Rhizosphere microorganisms and their deleterious effect are given below (Singh, 2002; Bhardwaj, 2017).

Table 3 Some deleterious pathogens

S. N.	Deleterious Pathogens	Disease
(a)	Fungi *Fusarium oxysporum f.sp.*	Plugging and browning of vessels, wilting of plants
	Alternaria spp.	Leaf spots of several plants
	Pyricularia azyzae	Blast of rice
	Cercospora spp.	Leaf spots of beet and other plants
(b)	Bacteria *Pseudomonas synringae*	Leaf spots of many plants
	Xanthomonas rubsilineans	Red strip of Sugarcane
	Erwinia amylovora	Fire blight of apples and pears.

Beneficial Rhizosphere Microorganisms

Within rhizosphere synergistic interactions between plant and microbes are important in providing the nutritional requirements (Madigan & Martinko, 2005; Maheshwari, 2016). Many symbotic bacteria (Rhizobium spp), fungi (like Rhizoctonia tricholoma etc.) and actinomycetes are known as beneficial rhizosphere micororganisms. These microorganisms play important beneficial roles in the rhizosphere because these microorganisms increase the availability of nutrient or plant growth substances for plants and parasitic and non-parasitic pathogens.

Mycorrhizae

These specialized fungi colonize plant roots and extent for into the soil resource. Mycorrhizal fungal filaments in soil are truly extensions of root system and more effective in nutrient and water absorption than the root themselves. Over 90% of the world's plant species form mycorhizae and require the association for maximum performance in non-artificial conditions (Molina *et.al*. 1992; Madigan & Martinko, 2005; Maheshwari, 2016).

Some researchers have reported that the mycorhhizal fungi increase the surface absorbing area of roots 10 to 100 x thereby greatly improving the ability of the plants to utilize the soil resource (Pacovsky, Fullar and Paul 1985). Newman *et.al*. (1987). Mycorhizal fungi increase nutrient uptake not only by increase the surface absorbing area of roots, they also release powerful chemicals into the soil that dissolve hard to capture nutrients such as phosphorous, iron and other 'tightly bound' soil nutrients (Mucciarelli, and Scannerini *et.al*., 1995).

Plant Growth Promoting Fungi (PGPF)

Plant growth promoting fungi play important role in the production of crops. Plant growth promotion has attracted renewed interest very recently among researchers. (Kirk, 2004; Zhang *et.al*., 2010; Baker 1991). Trichoderma and Rhizoctoma have been found to promote plant growth as well as supress plant pathogens. (Kleneifield & Chet, 1992; Lugtenberg & Kamilova, 2007). The sterile fungal isolates from rhizosphere of wheat are very effective for plant growth promoters (Narita and Suzui, 1991). Shivanna *et.al*. (1993) reported that certain fungal isolated from turf grass rhizosphere, particularly from Zoysia grass rhizosphere enhanced growth of wheat and Soyabean through the seed harvest stage in the green house. For example, Zoysia grass rhizosphere also promote growth and increase yield of wheat plant in the field. Similarly, Hyakumachi (1994) found that *Trichoderma, Fusarium, Penicillium and Mucor spp.* have ability to promote growth of a plant and disease suppression. *Penicillium* and Mucor also bind the soil properties, because mucilogenous substances secreted by them are helpful in soil aggregation. Some researchers reported that PGPF promote the germination of seeds, elongation of stem and roots, early flowering, fruiting and yield of crops (Hyakumachi 1994).

Mode of Growth Promotion Activities of PGPF

Plant growth promotion by PGPF is yet to be properly explored. The mechanism of plant growth promotion is concerned with hormone production, organic and inorganic substrates degradation and suppression of harmfull microorganisms. The PGPF fungi decompose the complex organic substances of soil into their inorganic components and increase the soil fertility. It also helps the plants to derive necessary mineral elements. According to Hyakumachi (1994), the of production NH_4-N and NO_2-N compounds in soil is accelerated by amendment with PGPF infested barley grains. The PGPF reduce the soil-born disease of crop plants and suppress the deleterious soil microbes. Some growth promoting isolates of *Philophora graminicola* increase the mineral nutrients uptake by plants in the same way as do mycorhizal fungi (Zhang *et.al*., 2010; Lugtenberg & Kamilova, 2009; Khan *et.al*. 2009; Maheshwari, 2016).

Kohara *et.al*. (1993) found a significant correlation between the cellulose and starch degrading activity of certain sterile PGPF isolates and plant growth promotion. According to Halvorson *et al*. (1987), an increase in ammonium content owing to grain colonization PGPF directly affects plant growth, since ammonium is a dominant source of nitrogen utilized by plants in agricultural fields. Thus, the PGPF fungi increase the uptake of mineral nutrients by plant roots and production of growth regulating substances in soil. Some researchers have reported that the mechanisms of growth promotion by microbes have been related to increase the absorption in mineral nutrients by plants or production of growth regulating substances (Lugtenberg & Kamilova, 2009; Arshad and Frankenberger 1991; Khan *et.al*, 2009).

Antagonism between Soil Microorganisms

There are several interactions found between soil microorganisms. Such interactions may be important in controlling pathogens. The microbial antagonism is the result of increased quality and quantity of microorganisms occurring in the soil (Marton and Strobue, 1955). Antagonism plays an important role in biological control. Some plant pathologists define the biological control of plant pathogens are ecological association between organisms where one or more of the participants harm or minimize its activities (Madigan & Martinko, 2005; Maheshwari, 2016; Khan *et.al*. 2009; Chen *et.al*., 2009). The biological control are of three types namely, Competition (for nutrient and space), Antibiosis (which may be by the production of antibiotics) and Hyperparasitism (one fungus parasiting another).

All of these mechanisms may operate together or independently and their activities can result in the suppression of microbial plant diseases (Chen *et.al*., 2009; Madigan & Martinko, 2005). In soil, microorganisms compete for available nutrients and space for their growth and colony development. Garrett (1970) reported that the behaviour of root injecting fungi and their interaction with other microorganisms depend upon several factors including antagonism. It has been reported that the addition of huge quantity of organic residues to the soil creates problem (Maheshwari, 2016; Bhardwaj, 2017, Singh, 2002). Production of antibiotics is wide spread among the fungi occurring in comparatively few of the lower fungi. The majority of the fungi producing antibiotics are soil fungi which often give these fungi an ecological advantage (Singh, 2002; Dix & Webster, 1995; Maheshwari, 2016).

CONCLUSION

The review of researches on rhizosphere effects approve that it has so many positive outcomes for the plants. However, there are some conditions which cause deleterious effects also on plant growth. These negative effects can be controlled and the target of higher growth and yields can be realized. The interactions between different microorganisms play very important role in growth of the plants and crops which lead to increase in production and also the profit for the crop growers.

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