THE RHIZOSPHERE*

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Ladies and Gentlemen,

I am deeply moved by the overwhelming kindness which the Indian Botanical Society has done me by awarding the Birbal Sahni Medal for 1967. It has been instituted in the name of my teacher and one of the greatest botanists of the world, the late Professor Birbal Sahni. It fills me with pride and gratitude and in all humility I have accepted it.

I gave much thought to the topic of my address to you today and ultimately I decided to present my views on a fascinating field of research—the Rhizosphere.

The region of intense microbial activity around the roots of chlorophyllous plants is known as the "Rhizosphere". This term was suggested by Hiltner in 1904, which according to him refers to that region of the soil which is under the influence of plant root. This interesting field of Microbiology, however, remained neglected till 1929 when R. L. Starkey of New-Jersey did a really creative work to stimulate interest in the relationship between the soil micro-organisms and the green plants. During the last three decades substantially rich contributions have been made in this field and the interactions involving the soil microbes, soil-borne pathogens and higher plants have received attention of several plant pathologists and microbiologists. Some terms like "Rhizoplane" for external surface of plant root together with closely adhering particles of soil or debris as well as "Outer rhizosphere" or "Closer rhizosphere" to designate the sites of microbial concentration have also been in use. Several types of relationships may exist between the plants and its rhizosphere population but "Commensalism" or "Protocooperation" is usually the most dominant type of interaction. Rhizosphere is a highly favourable habitat for proliferation and metabolism of the microorganisms. This population has been intensively investigated by the microscopic, cultural and biochemical techniques. Different plant species establish different type of subterranean flora. The variations have been attributed to the differences in the rooting habits, tissue composition and excretion products of the microorganism. The primary root population is determined by the habitat created by the plants and the secondary flora is, however, influenced by the activities of the initial population.

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Microscopic examination reveals the presence of vast microbial population which include bacteria, actinomycetes, fungi, algae and protozoa.

Age of the plant and environmental conditions profoundly influence the microecology of this region. Timonin (1940) recorded the establishment of a rhizosphere microflora within three days of seed germination. Further development of the rhizosphere population depends on the growth pattern of the plant. Usually, maximum activity in the rhizosphere region is reported when the vegetative growth is at its peak. Available data indicate that not all the parts of the root are equally similar in supporting the rhizosphere population. Maximum activity is usually exhibited in the central or crown portion of the root which decreases with the increasing distance in horizontal as well as vertical direction from the base of the stem. Because of beneficial influence exerted by very young seedlings, it would seem that during the initial stages the micro-organisms respond to root excretions rather than to decomposable dead tissue, while during the latter stages the dead and sloughed-off tissue contribute substantially to the microbiological composition of the environment.

There is little or negligible residual microbial effect carried to the following year. To a great extent the new crop determines its own rhizosphere composition. Voroshilova (1956) reported that crop residues, animal manures and chemical fertilizers did not cause any appreciable qualitative or quantitative changes in the microflora of root region and in general the nature of the crop played a more decisive role than the fertility level of the soil.

The influence of root on fungal genera is selective to type rather than to the total number. Continuous cultivation of a single crop frequently favours the growth of *Rhizopus*, *Chaetomium*, *Aspergillus*, *Penicillium* and *Fusarium* but the genera dominating the environment vary with the crop, the soil and the climate. Agnihothrudu (1957) reported that *Aspergilli* were much more frequent than any other group of organism. Working with the rhizosphere microflora of fifteen crop plants he (Agnihothrudu, 1955) concluded that most of the fungi were present in vegetative state on the root surface whereas in soil away from the roots nearly 60–70 per cent colonies were derived from the spores. Panwar *et al.* (1967) recorded a large number of fungal species from the rhizospheres of some common desert plants colonising the sand-dunes. *Rhizopus*, *Aspergillus*, *Penicillium*, *Chaetomium*, *Neocosmospora*, *Alternaria*, *Helminthosporium*, *Curvularia* and *Fusarium* were some of the common genera which occurred practically all the year round, while the activity of certain forms like *Choanephora*, *Cunninghamella*, *Sordaria*, *Monocillium*, *Myrothecium*, *Cladosporium*, *Cylindrocephalum*, *Cephalosporium*, *Trichothecium*, *Sporotrichum* and *Phoma* varied with the plant and the season.

There are numerous reports to show that microbial flora of rhizosphere is significantly richer than the flora of non-rhizosphere soil. Forest soils are known to be profusely rich in microflora. Out of the various factors which contribute to the affluence of the microorganisms in forest soil, the "continuous rhizosphere effect" cannot be ruled out and possibly it plays a fairly dominant role. Tresner *et al.* (1954) found a definite correlation between higher plant communities and soil micro-fungi. Pugh (1962) while studying the fungi in coastal soils concluded that in upper part of the marsh the dense cover by higher plants provided a "continuous rhizosphere" and this enabled *Cercospora salina* to become widespread.

Some interesting work has been carried out on the rhizosphere population of desert plants. Webley *et al.* (1952) observed that plants colonising the partly reclaimed sand-dunes on Scottish coast had in their rhizosphere much larger number of microorganisms than were found in the surrounding sand. Milosevic (1956) obtained similar results for the sand-dunes of Yugoslavia. Panwar *et al.* (1967) while studying the rhizosphere populations in sand-dunes of Western Rajasthan concluded that the vegetation cover and seasonal fluctuations had a profound influence on the micropopulation growing under the influence of plant roots. A dominant plant species may influence the soil microflora in two ways, first by the development of its own root region flora and secondly by contributing litter and humus to the soil which in turn have again a direct bearing on the growth of the plant. The fact that the development of soil microflora is so closely associated with the vegetational succession is of considerable significance. A comparative study of the plant succession and rhizosphere microflora leaves little doubt about the significant role which the micro-organisms play in shaping the plant communities and in this respect the micropopulation constitutes an important biotic factor.

Some of the substances released by the plant roots have been identified and isolated, but the list is far from being complete. The excreted compounds include amino-acids, simple sugars and nucleic acid derivatives. The products vary from plant to plant both in quality and quantity. Katznelson *et al.* (1954) reported the excretion of ten amino-acids and a reducing sugar with R_f similar to that of glucose from the roots of tomatoes, soyabean, barley and oats. Rovira (1956) obtained 22 amino-acids excreted from the pea roots. Bhuvaneswari and Subba-Rao (1957) spotted several organic acids and sugars from the root exudates of *Sorghum vulgare* var. *dochna* and *Brassica juncea.* Roy and Dwivedi (1967) listed leucine, methionine, alanine, glutamic acid, aspartic acid, cystine, phenylalanine, arginine, rhamnose, arabinose, glucose, fructose, sucrose and raffinose as the constituents of root exudates of some leguminous crops.

The root excretions have been found to have pronounced influence on the germination of fungal spores. Barton (1957) reported the germination of oospores of *Pythium mamillatum* when they were placed in soil before growing turnip seedlings while in non-rhizosphere soil or in distilled water they were incapable of germination. Coley-Smith and Hickman (1957) made similar observations regarding the germination in soil of sclerotia of *Sclerotium cepivorum* in the presence of onion. Roy and Dwivedi (1967) found complete inhibition of conidial germination of *Helminthosporium sativum* and *Fusarium culmorum* on glass slides in unsterilized soil but majority of the conidia were able to germinate when wheat seedlings were grown on the slides. There are several other examples also which demonstrate that roots liberate the water-soluble compounds which activate the germination of fungal spores. Roberts and Roberts (1939) reported that substances inducing an auxin-like response in *Avena* coleoptile were produced in agar media by 77 per cent of bacteria, 66 per cent actinomycetes and 46 per cent of soil fungi. Some common rhizosphere bacteria like species of *Pseudomonas* and *Agrobacterium* are capable of synthesizing indole acetic acid. It is possible that auxin biosynthesis may be an important means of plant stimulation.

The intense microbiological activity in the rhizosphere has direct or indirect effect on plant pathogen. Usually, it has been observed that soil-borne pathogens are more destructive in sterile than in normal unsterilized soil. The major composition of rhizosphere population consists of non-pathogenic organisms. Therefore, pathogenic organisms have to face this barrier in order to initiate the infection. In many cases the resistance or susceptibility between the different varieties of single-plant species are linked with microflora of rhizosphere. Varieties of flax susceptible to wilt caused by *Fusarium oxysporum* f. *lini*, possess a greater number of micro-organisms than the resistant varieties. Similarly, tobacco varieties susceptible to *Thielaviopsis basicola* root rot are known to support a larger number of bacteria, actinomycetes and fungi in their root zone than the resistant varieties. While studying the rhizosphere microflora of tea in relation to charcoal stump rot caused by *Ustilina zonata*, Agnihothrudu (1959) reported that there was enormous difference in the density of fungi and bacteria in the rhizosphere flora of apparently healthy plants and infected ones. A greater varieties of species were recorded in the rhizosphere of diseased plants. Sulochana (1958) made quantitative studies of rhizosphere flora of two genetic strains of two species of cotton (the diploid susceptible varieties of *Gossypium arboreum* race *indicum* L. and tetraploid resistant *Gossypium hirusutum* L.) and obtained interesting results about the nature of the root exudates and their role on the activity of the plant pathogen. In most of the cases, no satisfactory answer is available for the differences in the disease resistance between the varieties of a single-plant species. To a certain extent such variation can be attributed to the differences in the rhizosphere flora. It seems quite probable that in resistant varieties root excretions may induce the development of a flora which is competitive with or antagonistic to the pathogen. Brian (1957) mentioned that successful control of root diseases probably lies in development of satisfactory method for influencing the rhizosphere microflora. In this light the rhizosphere may be considered as the microbiological buffer zone in which microflora serves to protect the plant from the attack of the pathogen.

Many workers in the recent years have envisaged the possibilities of improving the plant growth and crop yield by modification of rhizosphere microflora. In a number of cases the rhizosphere microflora has been altered by giving certain treatments to the plant. Helleck and Cochrane (1956) observed changes in the rhizosphere microflora of bean plants which were sprayed with bordeaux mixture. Ramachandra Reddy (1959), while studying the rhizosphere microflora of rice, observed that urea sprays modified the rhizosphere environment by exerting a change both in nature and amount of root exudates which in turn possibly influenced the microbial balance. Roy and Dwivedi (1967) reported that foliar spray of certain hormones like indole acetic acid or 3-yl-propionic acid resulted increase of rhizosphere population.

There are many faces of this intricate type of relationship which exists between the plant and its rhizosphere population. Undoubtedly the most important plant contribution to the rhizosphere flora is the provision of excretion products and sloughed-off tissue which serve as the sources of energy, carbon, nitrogen or growth factors. As a result of root respiration there is evolution of carbon dioxide which alters the pH of the sorrounding environment and ultimately influences the availability of the inorganic nutrients. On the other hand, root penetration improves soil structure which facilitates microbial oxidation. Respiration of both macro- and micro-organisms leads to greater CO_2 production from the rhizosphere than from non-rhizosphere soil. Starkey (1929) has shown that stimulation of organic matter breakdown in soil of root zone is far more pronounced with mature than with young plants. Comparative study of the two types of soils has shown that about two-third of the carbon mineralized is the result of microbial respiration. Larger CO_2 liberated in rhizosphere has, therefore, an obvious influence on the crop nutrition.

Harris (1953) reported that nodulation and nitrogen fixation by some partially effective *Rhizobium* strains are enhanced by simultaneous inoculation with several rhizosphere bacteria and fungi. Nilsson (1957) suggested that organic phosphorus mineralization using glycerophosphates and nucleic acids as substrates was more rapid in rhizosphere than in soil away from the root effect. There are also evidences to show the capacity of rhizosphere microorganisms to alter the solubility and subsequent utilization of iron and manganese.

Ladies and gentlemen, in short, I have tried to present before you some of the important microbial activities of the rhizosphere region. Like mutualism which usually exists between macro- and microorganisms in this region, this field of investigation needs co-ordinated efforts of microbiologists, plant pathologists, ecologists and soil chemists. I am sure that each will benefit by the results obtained by the other.

In the end, I thank you all for hearing me with patience.

References

AGNIHOTHRUDU, V. 1955. State in which fungi occur in the rhizosphere. *Naturwissenschaften* **42**: 515–516.

———. 1957. Aspergilli from soils of South India. *Ibid.* **44**: 65.

AGNIHOTHRUDU, V. 1959. Rhizosphere microflora of tea in relation to chorcoal stump rot caused by *Ustulina zonata* (Lev.). *Sacc. Annual Rep. Tocklai Exp. Staion*: 214–230.

BARTON, R. 1957. Germination of oospore of *Phytium mamillatum* in response, to exudates from living seedlings. *Nature, Lond.* **180**: 613–614.

BHUVANESWARI, K., AND N. S. SUBBA-RAO. 1957. Root exudates in relation to the rhizosphere effect. *Proc. Indian Acad. Sci.* **45 B**: 299–301.

BRIAN, P. W. 1957. Effect of antibiotics on plants. *A. Rev. Pl. Physiol.* **8**: 413–426

COLEY-SMITH, J. R., AND C. J. HICKMAN. 1957. Stimulation of sclerotium germination in *Sclerotium cepivorum* Berk. *Nature, Lond.* **180**: 445.

HALLECK, F. F., AND V. W. COCHRANEE. 1950. The effect of fungistatic agents on the bacterial flora of rhizosphere. *Phytopathalogy*, **40**: 715-718.

HARRIS, J. R. 1953. Influence of rhizosphere micro-organisms on the virulence of *Rhizobium trifolii*. *Nature, Lond.* **172**: 507–508.

HILTNER, L. 1904. Über Neuere, Erfahrungen and Probleme auf dem Gebiet dert Bodenbakteriologie und unter besonderer Berucksichtigung der Grundungung und Brache. *Arb. Dt. Landw. Ges.* **98**: 59–78.

KATZNELSON, H., J. W. ROUTT, AND T. M. B. PAYNE. 1954. Liberation of amino-acids by plant roots in relation to desiccation. *Nature, Lond.* **174**: 111.

MILOSEVIC, R. W. 1957. Rhizosphere effect in sand-dunes. *Ibid.* **178**: 313.

* NILSSON, P. E. 1957. *Lantbruks-Hogskol.* Ann. **23**: 175–218.

PANWAR, K. S., SAROJ PANWAR, AND K. S. BILGRAMI. 1967. Rhizosphere mycroflora in the sand-dunes of Western Rajasthan. *Proc. natl. Acad. Sci. India B.* (Communicated).

PUGH, G. J. F. 1962. Studies on fungi in coastal soils. I. *Cercospora salina* Southerland. *Trans. Br. mycol. Soc.* **45**: 255–260.

RAMACHANDRA REDDY, T. K. 1959. Foliar spray of urea and rhizosphere microflora of rice (*Oryza sativa* L.). *Phytopath. Z.* **36**: 286–289.

* ROBERTS, J. L., AND E. ROBERTS. 1939. *Soil Sci.* **48**: 135–139.

ROVIRA, A. D. 1956. Plant root excretions in relation to the rhizosphere effect. II. A study of the properties of root exudate and its effect on the growth of micro-organisms isolated from the rhizosphere and control soil. *Pl. Soil* **7**: 195–208.

ROY, R. Y., AND R. S. DWIVEDI. 1967. Rhizosphere study of cultivated legumes. *Proc. Indian Sci. Congr.*: p. 294.

STARKEY, R. L. 1929. Some influence of the development of higher plants upon the micro-organisms in the soil. I. Historical and introductory. *Soil Sci.* **27**: 319–334.

SULOCHANA, C. B. 1958. Doctoral Thesis, University of Madras, Madras, India.

TIMONIN, M. I. 1940. The interaction of higher plants and soil micro-organisms. I. Microbial population of rhizosphere of seedlings of certain cultivated plants. *Can. J. Res.* **18**: 307–317.

TRESNER, H. D., M. P. BAKUS, AND J. T. CURTIS. 1954. Soil microfungi in relation to the hard wood forest continuum in Southern Wisconsin. *Mycologia* **46**: 314–333.

* VOROSHILOVA, E. A. 1956. *Microbiologiya* **25**: 697–699.

WEBLEY, D. M., D. J. EEASTWOOD, AND C. H. GIMINGHAW. 1952. Developmen. of a soil microflora in relation to plant succession on sand-dunes, including the "rhizosphere" flora associated with colonizing species. *J. Ecol.* **40**: 168–1 78

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