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Introduction

What's new in the rhizosphere?

What's new in the rhizosphere? That is the question that arises after each symposium dealing with the rhizosphere, and it is not different after the "International conference on the mechanisms of the relationship between soil-plant-microorganisms in the rhizosphere" that was held in Montpellier in September 1989.

We progress non-stop, it is true, but there is still much to be learned about the multiple roles of rhizosphere processes in plant development, nutrient availability, microbial behaviour, etc. Even though our current concept of the rhizosphere, and of the influence that rhizosphere may have on plant nutrition and growth as well as on plant pathogens, was clearly defined as early as 1904, by Hiltner, there have been many achievements since then. The pioneer works of Starkey (1929), Garret (1956), Rovira (1956), Bowen (1980), etc. were landmark achievements in developing a modern characterisation of the root environment.

Many of the interactions of organisms and the root environment were discussed throughout the meeting with emphasis on plant-microorganisms associations. This lead to the conclusion that plant development and health can not be accurately understood without considering their microbial component, whose nature and activity inturn are highly dependent upon the biotic and abiotic environment. Interactions, interfaces, dynamic were thus some of the words used to define that highly complex environment, the rhizosphere. Indeed, there are very few places in the biosphere where organisms are so numerous in such a confined and heterogenous space, and so intermingled in their actions than in the rhizosphere.

Not knowing the many facets of these interactions we often have to cope with the following situations: How can we understand microflora's contribution to plant mineral nutrition if we do not know how roots get their minerals, nor how does absorption works? Similarly, how can we determine the effect of a certain type of microorganism on plant behaviour if we do not know even how it is attracted to the root zone in the first place, nor if it has a chance to survive and operate in a such difficult and highly competitive environment.

We have however to continue with two main approaches, the analytical, or specific approach and the global one. As Bowen (1980) recommended, in his classic paper on "misconceptions, concepts and approaches in rhizosphere biology", microbial growth, physiology and interactions in a well prepared laboratory media or in nutrient solutions are not necessarily meaningful undertanding real-world events for a plant growing in soil. The continued and indeed increasing collaboration between plant physiologists, microbiologists, soil scientists, geneticists, ecologists, and other specialists over the last few years may well have been our major achievement during this period.

However, both analytical and global approaches have their advantages and limitations. The analytical approach serves as a means to desassemble mechanisms in order to get a clear understanding of the functioning of each individual compartment, whether an organism or a single type of activity. This requires its isolation, or magnification, through artificial means. It is a legitimate will to improve the beneficial organisms as it has already been successfully achieved for N_2 fixing symbiosis, mycorrhizae and many other associative organisms New technologies have made possible such improvements but also the possibilities of changing microbial populations by selecting beneficial organisms or through introducing genetically-engineered organisms.

Before release of such organisms however, we have to evaluate the potential ecological consequences of the planned introduction through the study of each organism's (1) fitness, and therefore survival and reproductive capacity, (2) decrease of fitness compared to parent organisms, (3) interactions with other organisms, (4) effects on ecosystem functions in environments that may be limited in resources, and (5) lateral transfers with other organisms. The risk of new organisms in a new biota becoming a pest by displacing resident species functions, e.g. nitrogen fixers, lignin decomposers, etc has to be seriously considered. We must learn how to improve the mechanisms in native organisms, while still searching for, and engineering others, in order to maintain and protect biological diversity.

Globally, the role played by the rhizosphere and by the so-called "rhizosphere effect" in plant colonization, competition and survival in natural environments have also to be investigated Root exudation and rhizo-deposition studies in more or less artificial conditions, in the laboratory and the greenhouse, have often been unsuitable for extrapolation to contrasted natural conditions. In the future, such experimentation, must be designed (1) to compare plant environments, (2) to investigate the role of fluctuating conditions (temperature, oxygen, water), as are found in nature, and (3) to encompass studies of greater time scale than have been the rule in the past.

In view of global increase in CO_2 concentration and temperatures, the so-called greenhouse effect, the role of soil in carbon storage or release must be studied in more detail. This role can only be estimated if we possess good knowledge of carbon fluxes in the plant soil system, particularly in the active root zone. The need to understand rhizosphere processes at different levels of organisation, and to end up with globally significant results, also requires new methodology and new concepts for studies undertaken in various new spatial and temporal scales. The rhizosphere effect is a very dynamic one at the microsite level, due to root growth and displacement in the soil, but what are the relevant and meaningful factors at higher levels: whole plant, ecosystem, biome? The answer is far from clear.

In conclusion, the rhizosphere is a highly changing and complex domain requiring constant adaptation on the part of resident organisms of all sorts. Naturally the Realm of this new race of scientists, the "rhizospherists" – which do not belong to any of the traditional disciplines of biology but are rather hybrids of them all – is not different. The current shift of attention from increasing plant productivity and reducing crop losses due to pathogens and stresses, towards greater environmental protection and related concerns call for a new adaptation in rhizospheric studies. However the models used for earlier studies can serve us well in future studies of less known or less defined plant microbial associations, and the future of the discipline can be seen with optimism.

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