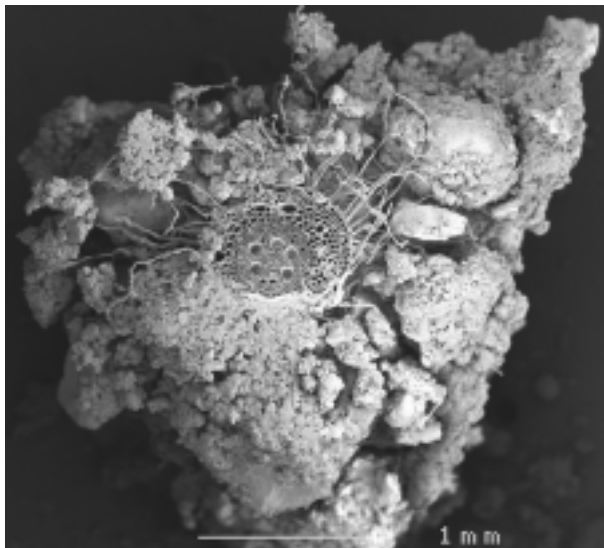


The rhizosphere

What is the rhizosphere?

The rhizosphere is the zone of soil surrounding a plant root where the biology and chemistry of the soil are influenced by the root. This zone is about 1 mm wide, but has no distinct edge. Rather, it is an area of intense biological and chemical activity influenced by compounds exuded by the root, and by microorganisms feeding on the compounds.



Above: This electron micrograph shows a cross section of a wheat root and its rhizosphere, in which soil particles are held together by exudates from the root and root hairs. Photo: Michelle Watt et al. *Functional Plant Biology* (2005)

As plant roots grow through soil they release water soluble compounds such as amino acids, sugars and organic acids that supply food for the microorganisms. The food supply means microbiological activity in the rhizosphere is much greater than in soil away from plant roots. In return, the microorganisms provide nutrients for the plants.

All this activity makes the rhizosphere the most dynamic environment in the soil. Because roots are underground, rhizosphere activity has been largely overlooked, and it is only now that we are starting to unravel the complex interactions that occur. For this reason, the rhizosphere has been called the last frontier in agricultural science.

What do the roots do in the rhizosphere?

The roots exude water and compounds broadly known as exudates.

Root exudates include amino acids, organic acids, carbohydrates, sugars, vitamins, mucilage and proteins. The exudates act as messengers that stimulate biological and physical interactions between roots and soil organisms. They modify the biochemical and physical properties of the rhizosphere and contribute to root growth and plant survival. However, the fate of the exudates in the rhizosphere and the nature of their reactions in the soil remain poorly understood.

The exudates have several functions.

Defend the rhizosphere and root against pathogenic microorganisms.

Root cells are under continual attack from microorganisms and survive by secreting defence proteins and other as yet unknown antimicrobial chemicals. Research has found that exudates in the rhizosphere vary according to the stages of plant growth. For instance, there are more carboxylates and root mucilage at the six leaf stage than earlier.

Attract and repel particular microbe species and populations.

High levels of moisture and nutrients in the rhizosphere attract much greater numbers of microorganisms than elsewhere in the soil. The composition and pattern of root exudates affect microbial activity and population numbers which, in turn, affect other soil organisms that share this environment.

Keep the soil around the roots moist.

Research has found that rhizosphere soil is significantly wetter than bulk soil, which protects roots from drying out. Exudates released from roots at night allow expansion of roots into the soil. When transpiration resumes with daylight, the exudates begin to dry out and adhere to the soil particles in the rhizosphere. As the soil dries and its hydraulic potential decreases, exudates lose water to soil.

Obtain nutrients.



The exudates help roots adsorb and store ions for plant use. For instance, flavonoids in legume roots activate *Rhizobium meliloti* genes responsible for root nodulation that enable the plant roots to obtain nitrogen from the air. Exudates enable the transfer of up to 20% of all photosynthetically fixed carbon to the rhizosphere. Exudates may also be responsible for encouraging vesicular arbuscular mycorrhizae that colonise roots and send out miles of thread-like hyphae into the soil, increasing the surface area and distance covered by the roots and taking up nutrients for the plant.

Change the chemical properties of the soil around the roots.

The rhizosphere environment generally has a lower pH, lower oxygen and higher carbon dioxide concentrations. However, exudates can make the soil in the rhizosphere more acid or alkaline, depending on nutrients roots are taking from the soil.

For example, when a plant takes up nitrogen as ammonium it releases hydrogen ions which will make the rhizosphere more acid. When a plant takes up nitrogen as nitrate, it releases hydroxyl ions which make the rhizosphere more alkaline. This action doesn't usually affect the bulk pH of the soil but is important for the small organisms that live in the rhizosphere because many soil organisms do not move far in the soil.

Stabilise soil aggregates around the roots.

Sticky mucilage secreted from continuously growing root cap cells is believed to alter surrounding soil.

Inhibit the growth of competing plant species.

Plant roots are in continual communication with surrounding root systems and quickly recognise and prevent the presence of invading roots through chemical messengers. This process is known as allelopathy. In agriculture it can be beneficial when crop plants prevent weeds from growing nearby; or detrimental when the weed plants prevent crops growing.

What do living organisms do in the rhizosphere?

The rhizosphere is a centre of intense biological activity due to the food supply provided by the root exudates. Bacteria, actinomycetes, fungi, protozoa, slime moulds, algae, nematodes, enchytraeid worms, earthworms, millipedes, centipedes, insects, mites, snails, small animals and soil viruses compete constantly for water, food and space. Soil chemistry and pH can influence the species mix and functions of microbes in the rhizosphere.

Interact with plant roots.

Most soil microorganisms do not interact with plant roots, possibly due to the constant and diverse secretion of antimicrobial root exudates.

However, there are some microorganisms that do interact with specific plants. These interactions can be pathogenic (invade and kill roots and plants), symbiotic (benefit plant growth), harmful (reduce plant growth), saprophytic (live on dead roots and plants) or neutral (no effect on plants). Interactions that are beneficial to agriculture include mycorrhizae, legume nodulation, and production of antimicrobial compounds that inhibit the growth of pathogens.

Mineralise nutrients.

Microorganisms convert organic forms of nutrients into inorganic forms that plants roots can take up. In legumes, microbial root nodulations enable plants to fix nitrogen from the air.

Encourage plant growth.

Rhizosphere microorganisms produce vitamins, antibiotics, plant hormones and communication molecules that all encourage plant growth.

Stabilise soil aggregates.

Waste products and secretions from microorganisms help combine soil particles into stable aggregates around plant roots. These aggregates hold moisture within, but allow drainage between aggregates, so that root hairs do not get waterlogged.

More information

Soil biology basics is an information series describing basic concepts in soil biology. For more detailed information we recommend the Australian book *Soil biological fertility: A key to sustainable land use in agriculture* (2003), edited by Lyn Abbott & Daniel Murphy.

NSWDPI has online soil biology information at <http://www.agric.nsw.gov.au/reader/soil-biology>.

The University of WA has online soil biology information at

<http://ice.agric.uwa.edu.au/soils/soilhealth>.

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The information contained in this publication is based on knowledge and understanding at the time of writing (2005). However, because of advances in knowledge, users are reminded of the need to ensure that information on which they rely is up to date, and to check the currency of the information with the appropriate officer of NSW Department of Primary Industries or the user's independent adviser.