THE ROOTS OF NUTRIENT MANAGEMENT

We clearly see that plant growth suffers when there are low amounts of nutrients in the soil, when the nutrients are not sufficiently soluble, or if nutrients do not move to the roots. In our quest to grow abundant and healthy crops, it is easy to overlook all of the complex chemical and biological activity occurring around the plant roots that make nutrients available for uptake.

The availability of plant nutrients for roots is controlled by factors such as soil properties, root characteristics, and interactions with surrounding microorganisms. Traditional soil testing techniques measure the availability of nutrients in the general soil, but this may differ from the nutrient concentration in the immediate vicinity of the root (the rhizosphere). Nutrients with restricted mobility in the soil (such as P, K, zinc, iron, manganese, and copper), may be in adequate supply in the bulk soil, but their concentration may be low near the root if the transport is too slow to replenish the nutrients entering the root.

Focusing on P as an example, supplying this nutrient to the root includes several complicated mechanisms. This involves excretion of organic acids, increased root hair formation, and enzyme release.

• **Release of Organic Acids:** When soil P supplies are low, many plants excrete a wide range of organic compounds to increase the availability of relatively insoluble compounds, such as some calcium phosphate minerals. The organic acids have a role in dissolving nutrients (due to pH) and providing an excellent growth substrate for soil microorganisms.

Most soils have populations of microorganisms that are capable of dissolving P-containing minerals, so addition of an organic substrate may encourage their growth in low-P conditions. Mycorrhizal fungi also form complex relationships with most plant species, where the fungi provide various benefits for the plant, including improved nutrition, in exchange for carbohydrate for fungal maintenance and growth.

• **Changes in Root Structure:** Plants growing in a low-P soil tend to direct more of their photosyntate carbohydrates to root development and often have more fine roots with a small diameter, resulting in a larger surface area. A large root surface area allows plants to access more of the soil and scavenge any soluble phosphate that may be present.

• **Enzyme Release:** In low-P conditions, plants generally increase the production of enzymes that enhance the rate of P release from soil organic matter, especially from phytate. Phytase, the enzyme responsible for phytate hydrolysis, is primarily released by microorganisms, which indirectly improves the P availability for nearby roots.

These root modifications occur as a result of low soil P availability, requiring plants to devote additional energy to the roots and away from above-ground growth. The excretion of organic compounds from roots can consume as much as half of all the carbon allocated to the root system, although this number is highly variable. The energy costs of mycorrhizal associations with various plant species ranges from 4 to 20% of the daily net photosynthesis. Plant geneticists are looking for ways to make plant roots more efficient at recovering nutrients from the soil. While we wait for improved plant genetics, there are many practical things that can be done to get the maximum benefit from added nutrients. Place nutrients in the soil in the proper form and in the correct place so plant roots can support abundant yields of high-quality products.

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