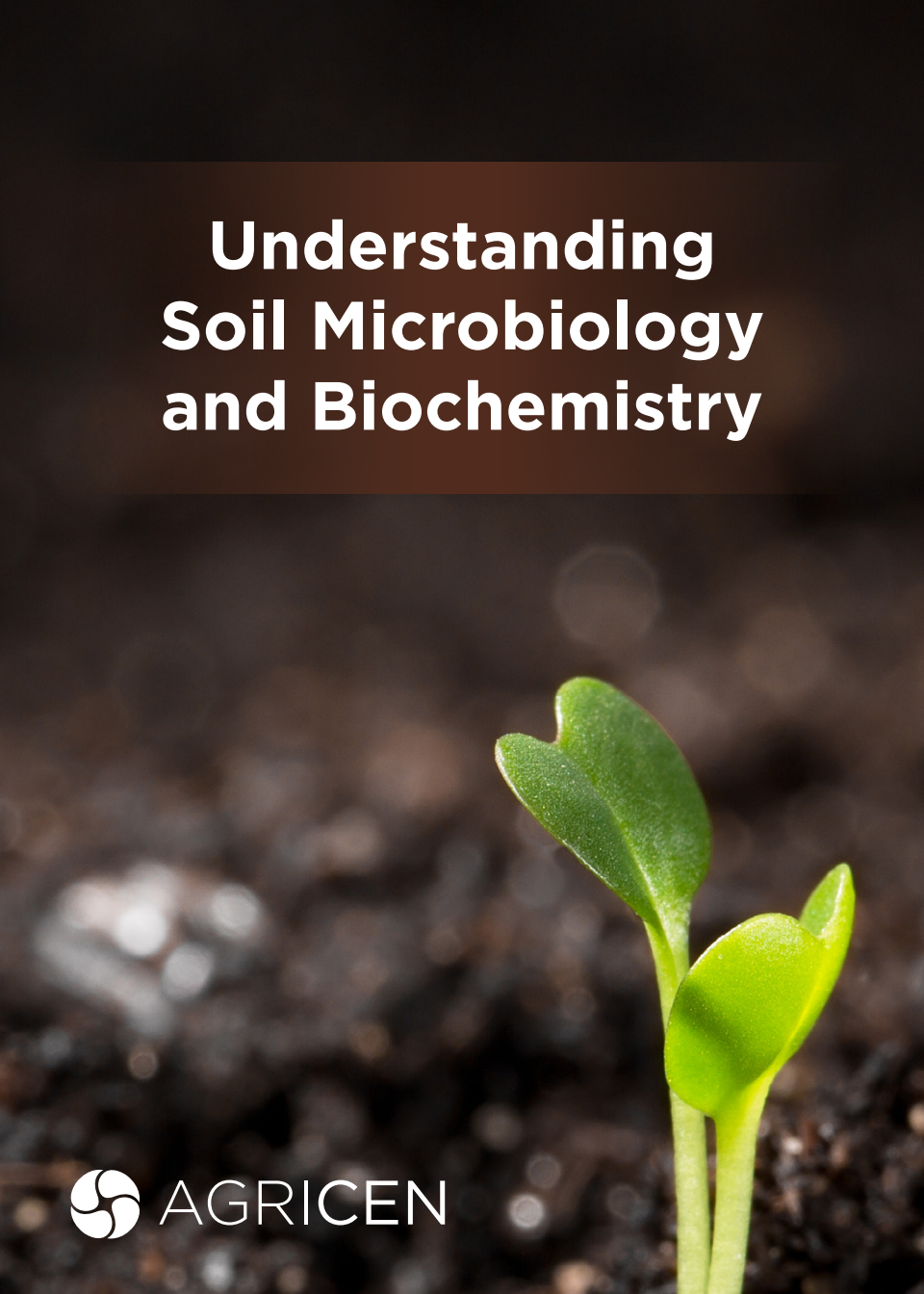
Understanding Soil Microbiology and Biochemistry



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Understanding the **microbiology** and **biochemistry** of the soil is an important part of understanding how plants grow, but what are soil microbiology and soil biochemistry? And how do they influence plant health and nutrition? To answer these questions, let's turn to the soil.

MICROBIOLOGY

Field of science concerned with microscopic organisms, such as bacteria and fungi. The microbiology of the soil deals with the microscopic living system within the soil.

BIOCHEMISTRY

Field of science concerned with chemical processes within or relating to living organisms. The biochemistry of the soil deals with the products/byproducts of the living system within the soil.

The Soil Is a Living Environment

The soil is a living environment, full of organisms that influence plant growth and health.

These organisms include visible inhabitants, such as earthworms, as well as a multitude of **microorganisms**—including bacteria, fungi, protozoa, nematodes and microarthropods. Together, soil organisms large and small make up about 5% of the **soil organic matter**. Plants—through their growing roots—are also part of this living environment. Many microorganisms live in close proximity to plant roots, an area known as the **rhizosphere**, where there is a rich food source for them in the form of **exudates** released from the roots.

MICROORGANISMS

Organisms that are too small to be viewed without a microscope, such as bacteria. Also called microbes.

SOIL ORGANIC MATTER

Matter in the soil that consists of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms.

RHIZOSPHERE

Region of the soil immediately around the roots. Microbial activity is very high in this area.

EXUDATES

Sugars, amino acids and other compounds secreted by plant roots. These provide a food source for microorganisms.

As soil organisms interact with each other and with the soil, they influence the **soil-plant system** physically, chemically and biochemically. Temperature, moisture, aeration, pH, soil pore spacing, and types of food sources affect how active soil organisms will be, as well as how many and what types of species will be present.

SOIL-PLANT SYSTEM

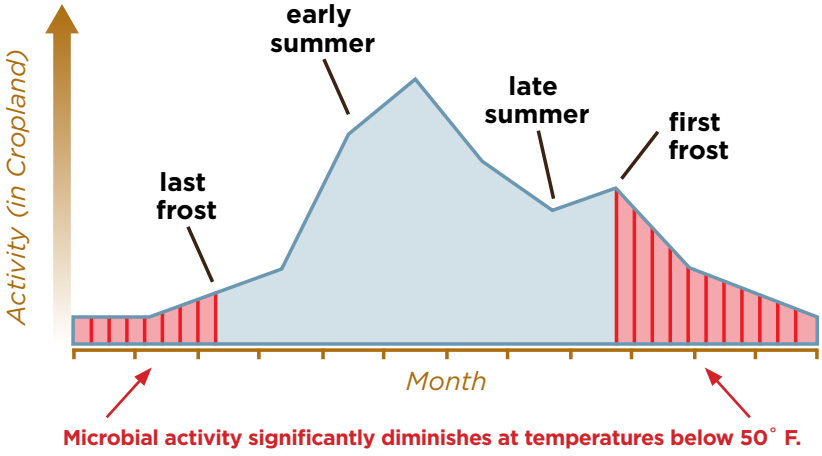
The interactions between plants and the soil, including the physical, chemical, and biological elements of the soil.

Microorganisms in a Gram of Soil

Microbial Group	Numbers in a Gram of Soil
Bacteria	100 million – 1 billion
Fungi	100 thousand – 1 million
Algae & Cyanobacteria	1 thousand – 1 million
Protozoa	1 thousand – 100 thousand
Nematodes	<100

Source: Sylvia D, Fuhrmann J, Hartel P, Zuberer D. Principles and Applications of Soil Microbiology. 1997. Prentice Hall: Upper Saddle River, NJ.

Seasonal Bacterial and Fungal Activity



Source: Tugel A, Lewandowski A, Happe-vonArb D, eds. Soil Biology Primer. Rev. ed. 2000. Ankeny, Iowa: Soil and Water Conservation Society.

Key beneficial roles of soil microorganisms:

- Decompose organic materials
- Recycle nutrients in the soil by converting organic materials into forms plants and other soil organisms can use (**mineralization**)
- Generate oxygen in the atmosphere, which is important for plant respiration
- "Fix" nitrogen from the atmosphere by converting it to ammonium (**nitrogen fixation**), making it available to plants
- Retain nutrients such as nitrogen or carbon in their cells, keeping them in the root zone (**immobilization**)
- Feed on each other, releasing immobilized nutrients in their excretions (e.g., protozoa and nematodes that excrete excess nitrogen when they eat bacteria and fungi)
- Give plant roots access to soil nutrients by transporting them to the plant (i.e., the mycorrhizal fungi that colonize plant roots)
- Bind soil particles into aggregates, helping with soil structure and water dynamics
- Help to suppress plant diseases by competing with or feeding on pathogens
- Degrade soil pollutants

Soil Microorganisms in Plant Health and Nutrition

Microorganisms play many beneficial roles in plant health and nutrition. Through their activities, they help plants extract the nutrients they need for growth and functioning. They also affect the soil structure, influencing water dynamics on, in and through the soil. In addition, although some microorganisms can cause disease, many more help protect the plant from pathogens.

MINERALIZATION

Conversion of organic forms of nutrients into inorganic forms that plants can use. As soil organisms metabolize nutrients, transforming them into inorganic forms that are then excreted, the nutrients are mineralized and are available for plant use.

NITROGEN FIXATION

Conversion of atmospheric nitrogen to ammonium, a plant-available form of nitrogen.

IMMOBILIZATION

“Storage” of nutrients within soil organisms as they live and grow. When soil organisms consume soil nutrients, the nutrients are immobilized and are not available for plant use.

Biochemical Interactions in the Soil-Plant System

Many of the interactions in the soil-plant system—whether among the microorganisms and between microorganisms and plants—occur through **biochemical signaling**, particularly in the rhizosphere.

Biochemical compounds produced by microorganisms and by plant roots are the tools by which biochemical signals are created and transmitted. They are the tools that microbes need to function in the soil, and determine their ability to process nutrients (including the nutrients in fertilizers), stimulate root growth and perform other functions critical to plant health and nutrition.

With up to 50 billion microbes in a teaspoon of soil, imagine the number of biochemical compounds that are produced during their lifecycles. Each of these microorganisms may be the source of unique biochemical compounds that affect a variety of soil, plant and microbial community functions.

BIOCHEMICAL SIGNALING

Interactions and communication within and among organisms through the biochemical compounds produced by those organisms.

BIOCHEMICAL COMPOUNDS

Chemical compounds that are part of the makeup of a living cell or produced by or in an organism; hormones, amino acids, organic acids, sugars and enzymes are examples of biochemical compounds.

Biochemistry: The Backbone of Soil Microbial Functioning

Biochemical compounds produced by soil microorganisms include:

- **Enzymes** that break down organic matter, transform N for energy and perform many other functions
- Proteins that signal changes in microbe response
- **Chelators** that mobilize nutrients
- Antibiotics that reduce competition
- Compounds that induce plant rooting, change physiological functions, induce immune responses and increase salt tolerance

ENZYMES

Molecules that speed up chemical reactions.

CHELATORS

Molecules that bind tightly to metal ions, forming complexes with them.

Spotlight on N-P-K

When it comes to the "big three" macronutrients that plants need—nitrogen, phosphorus and potassium—why do soil microbiology and soil biochemistry matter?

- **Nitrogen:** In the soil profile, the great majority of nitrogen (>90%) is typically in an organic form (e.g., in crop residues, manures, litters, composts) and needs to be converted into inorganic forms—that is, ammonium (NH_4^+) or nitrate (NO_3^-)—that plants can take up and use. This transformation is called the mineralization process. Biochemical compounds produced by microbes in the soil profile mineralize organic nitrogen into an inorganic form that plants can use.
- **Phosphorus:** A good portion (25%-65%) of phosphorus in the soil profile can be tied up in organic matter. Biochemical compounds help to dissolve, solubilize and mineralize soil phosphorus, transforming it into inorganic forms ($H_2PO_4^-$ or HPO_4^{2-}) that are available for plant use.
- In the soil, potassium quickly gets locked in between soil layers, becoming unavailable to the plant. Unlike nitrogen or phosphorus, where mineralization or solubilization is necessary, potassium remains in the K^+ form in both the soil and the plant—but requires a release from the soil profile. Biochemical compounds produced by microorganisms help to improve the soil structure and a plant's ability to take up potassium.

Soil microbes and the biochemical compounds they make play a major role in nutrient release and nutrient use efficiency. By taking care of soil health—including by using products that enhance the microbial and biochemical activity in the soil—growers can capture the power of soil microbiology and biochemistry and improve the productivity of their growing operations.

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