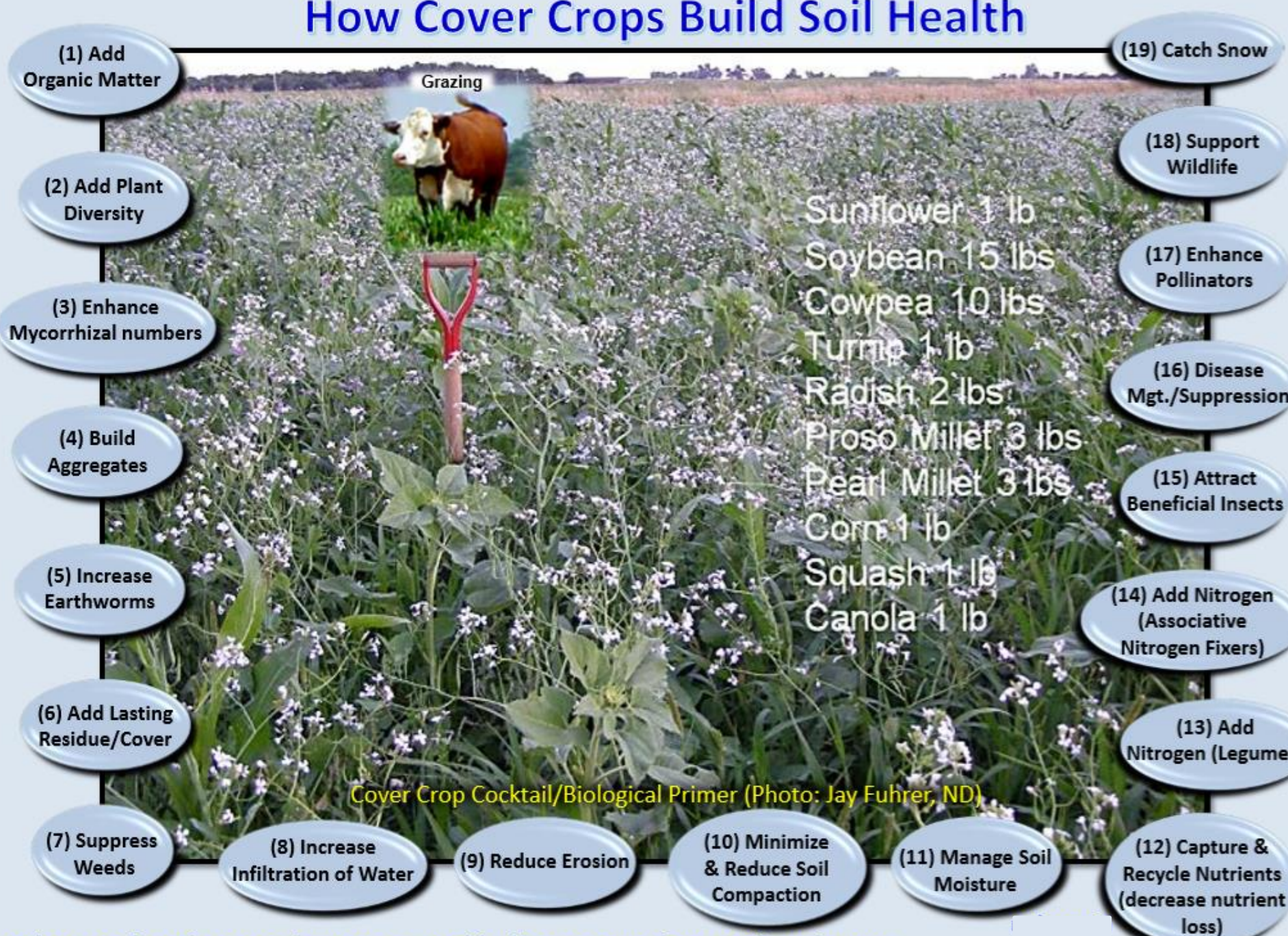


A photograph of a large agricultural field filled with rows of green cover crops. The crops are planted in neat, parallel lines that recede into the distance. The ground between the rows is a light brown, sandy soil. In the far background, a dark silhouette of a barn or farm building is visible against a clear sky. The overall scene is bright and sunny, with the green of the plants contrasting sharply with the brown of the soil.

# **Cover Crops and Their Benefits**



# How Cover Crops Build Soil Health



Other Benefits: Clean Air, Clean Water, Healthy & Nutritious Plants, and much more.



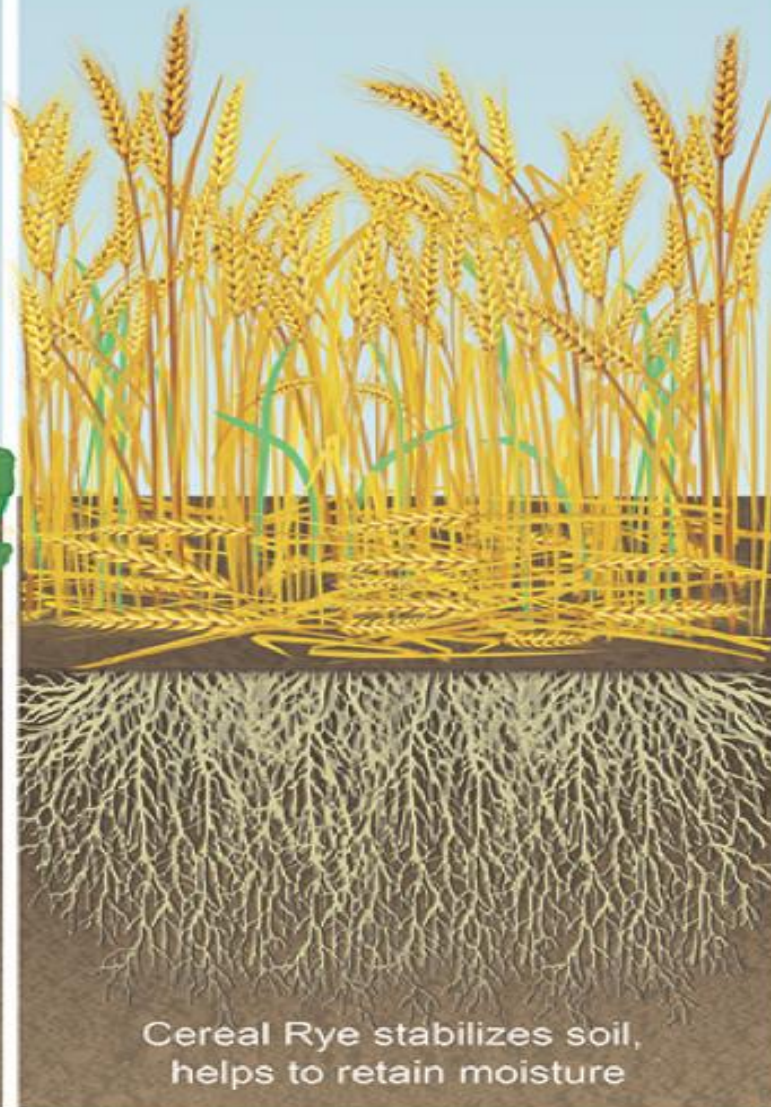
### Summer 1

Soybeans  
Before Cover  
Crop



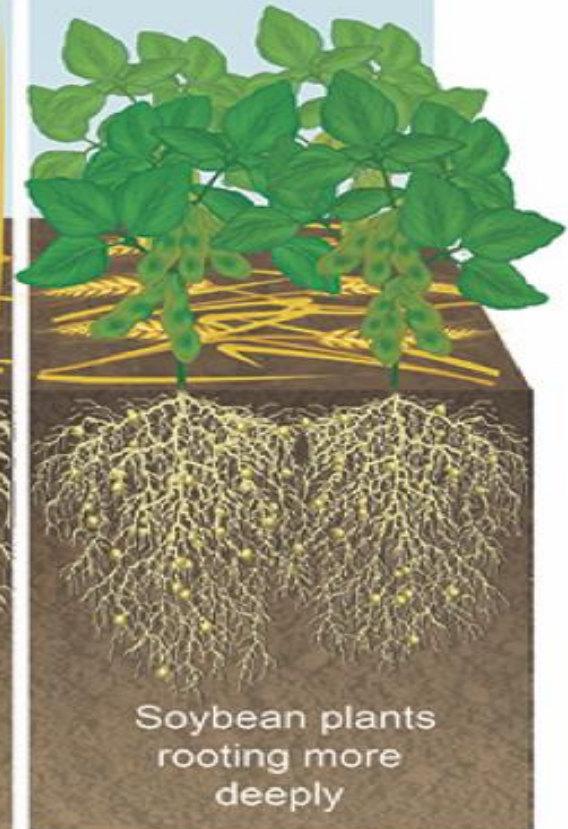
### Fall 1

Cereal Rye Cover Crop



### Summer 2

Soybeans  
After Cover  
Crop



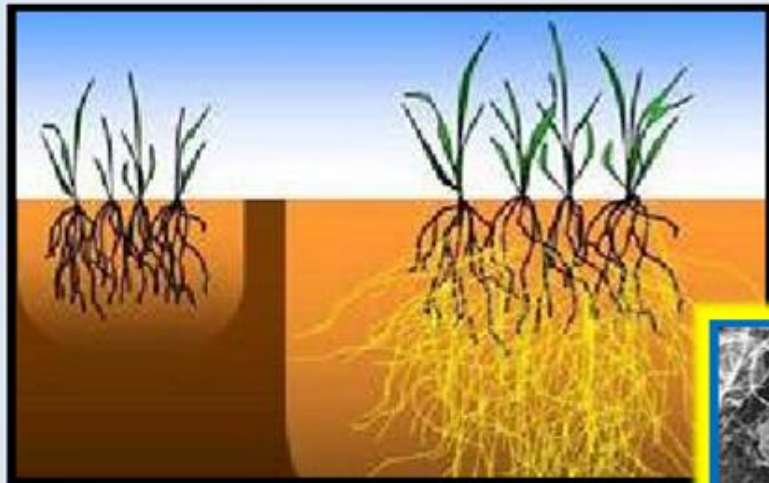


### (3) Cover Crops Enhance Mycorrhizae numbers:

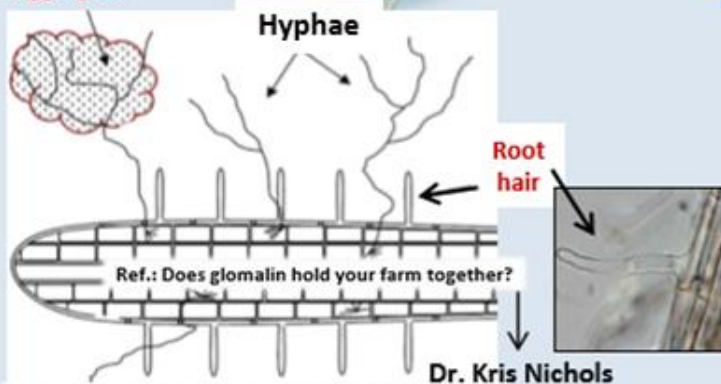
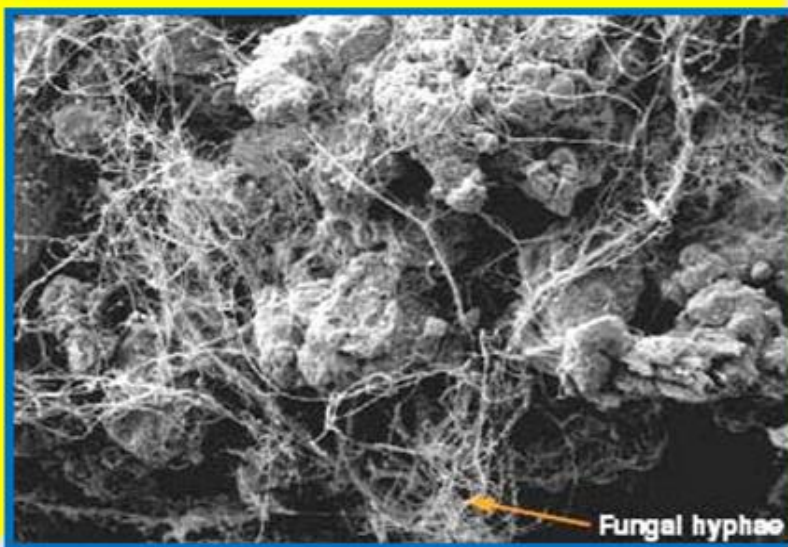
#### Soil Humus Formations:

- 1) Photosynthesis
- 2) Resynthesis
- 3) Exudation
- 4) Humification

Dr. Christine Jones



Fungal hyphae binding soil particles together into aggregates.



Hyphae of arbuscular mycorrhizae fungi grow beyond nutrient depleted zones found around roots and root hairs.



Although mycorrhizae don't make humus, it is difficult to start the humification Process without them. They bring large quantities of soluble Carbon in to the soil from plant roots, which feeds the microbes involved in the complex process.  
Photo: Jill Clapperton



## **(14) Cover Crops Add Nitrogen (Associative Nitrogen Fixers):**

**Nitrogen: the double-edged sword**

**Christine Jones, PhD**

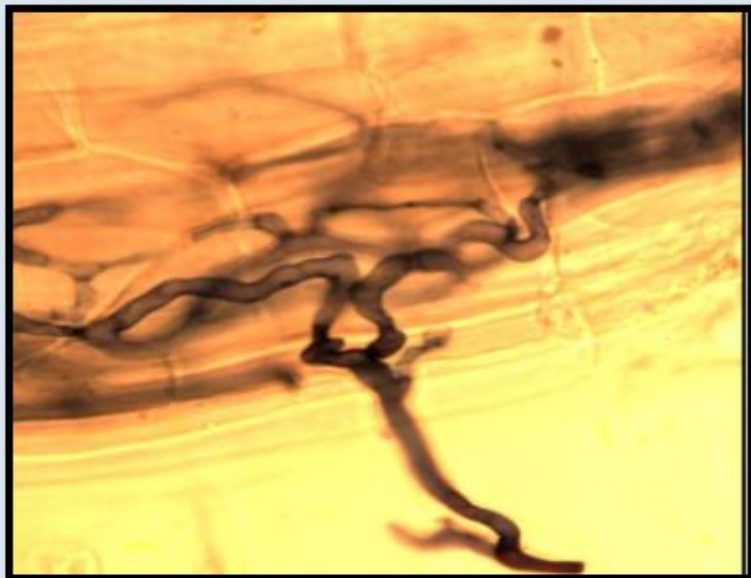
**[www.amazingcarbon.com](http://www.amazingcarbon.com)**

**It is important to recognize that the ability to fix nitrogen is not limited to bacteria associated with legumes.** Chlorophyll is part of a protein complex - hence wherever you see green plants - there will also be an association with nitrogen-fixing bacteria or archaea.

In addition to nitrogen-fixing bacteria and archaea, mycorrhizal fungi are also vitally important to the N-fixing process.

**Although mycorrhizal fungi do not fix nitrogen, they transfer energy, in the form of liquid carbon (Jones 2008) to associative nitrogen fixers.** They also transport biologically fixed nitrogen to plants in organic form, for example, as amino acids, including glycine, arginine, chitosan and glutamine (Leake *et al.* 2004, Whiteside *et al.* 2009).

**The acquisition and transfer of organic nitrogen by mycorrhizal fungi is highly energy efficient.** This pathway closes the nitrogen loop, reducing nitrification, denitrification, volatilization and leaching. Additionally, the storage of nitrogen in the organic form prevents soil acidification.



**Fig.1.** Cross section of a plant root showing the thread-like hyphae of mycorrhizal fungi. **Mycorrhiza deliver sunlight energy packaged as liquid carbon to a vast array of soil microbes involved in plant nutrition and disease suppression.** Organic nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron and essential trace elements such as zinc, manganese and copper are returned to plant hosts in exchange for carbon. **Nutrient transfers are inhibited when high rates of inorganic nitrogen and/or inorganic phosphorus are applied.** Photo Jill Clapperton.



## (5) Cover Crops Increase Earthworms:

Earthworms consuming cover crops and making healthy soil



Earthworm Population On The Cover Crop Side  
3X Greater Than Non Cover Crop Side.



Earthworms  
in Temple, TX



Earthworms in Temple, TX



(5) Cover Crops Increase Earthworms:

Earthworms

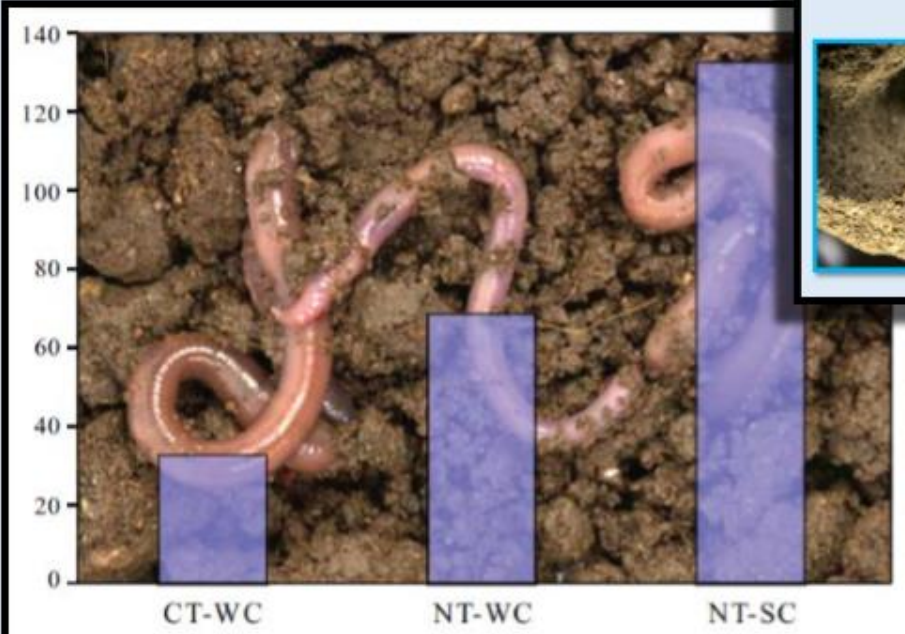


Figure 1. Effect of tillage and crop on earthworm number/m²  
CT=conventional till, NT= no-till; W=wheat, C=corn, S=soybean  
Adapted from Hubbard, et al. 1999.

Ref.: NRCS Soil Quality Indicators

Earthworms

Poor soils contain 250,000 earthworms per acre while good soils contain 1,750,000 per acre

1 or less per shovel indicates poor soil health

10 or more per shovel indicates good soil health

Burrowing through lubricated tunnels forces air in and out of soil

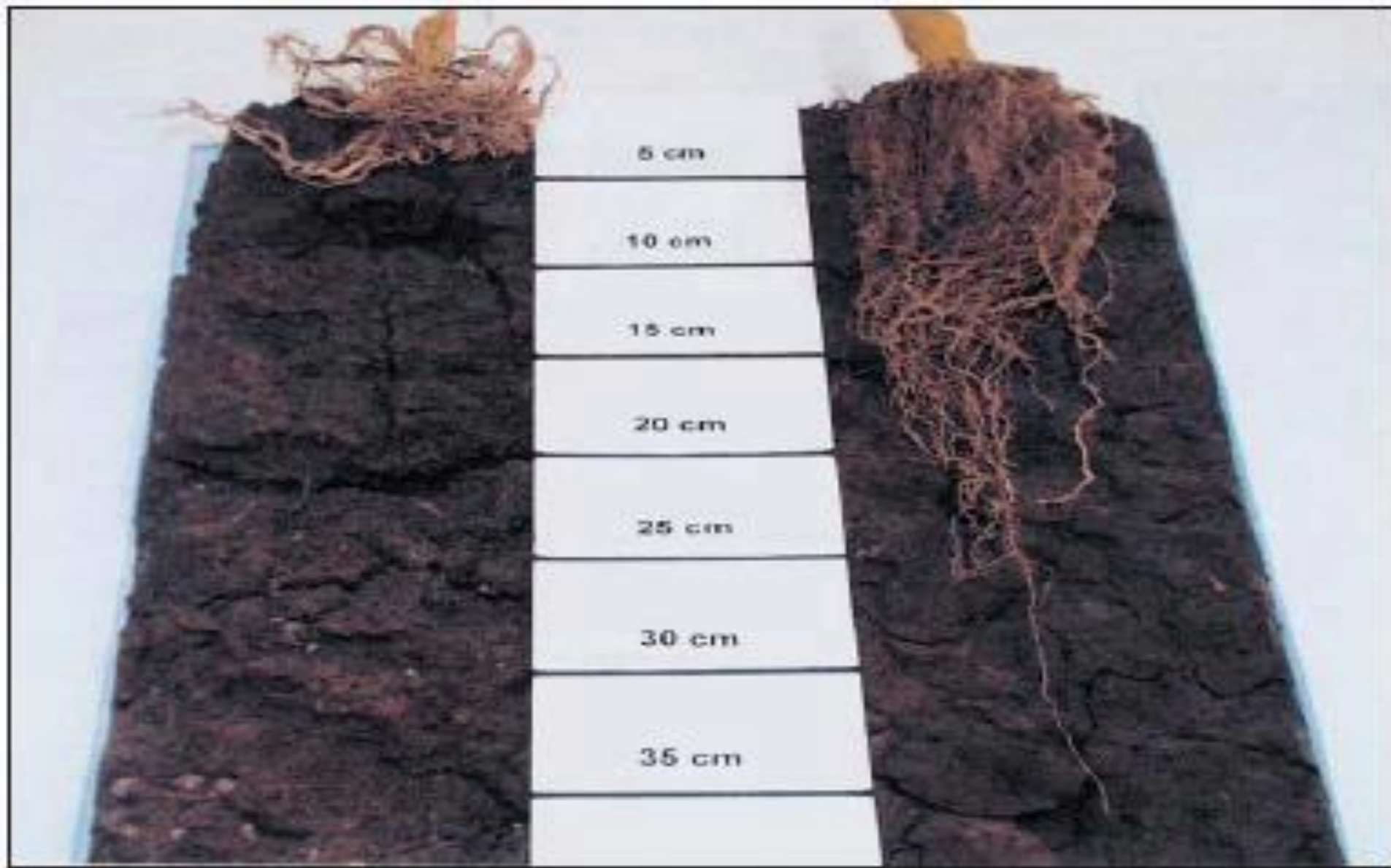
Earthworm casts contain

- 11% of the humus
- 7X the nitrogen
- 11X the phosphorus
- 9X the potash
- than surrounding soil



Earthworms bury litter, shred organic matter, & stimulate microbial decomposition.

# Effect of Soil Compaction on Roots





# What Do Soil Organisms Do In Soil?



Soil  
Biota

## Organic Matter Dynamics

- Shred, mix, fragment residues
- Decompose residues
- Release nutrients
- Sequester C

## Soil Structure

- Form & stabilize aggregates
- Create biopores
- Influence H<sub>2</sub>O, gas exchange

## Nutrient Cycling

- Transform, store, release C, N, P, S and micronutrients
- Solubilize nutrients from soil minerals (e.g. P)
- Fix atmospheric N<sub>2</sub> → NH<sub>4</sub><sup>+</sup>

## Plant Protection

- Biocontrol to suppress pathogens and disease

## Plant Growth

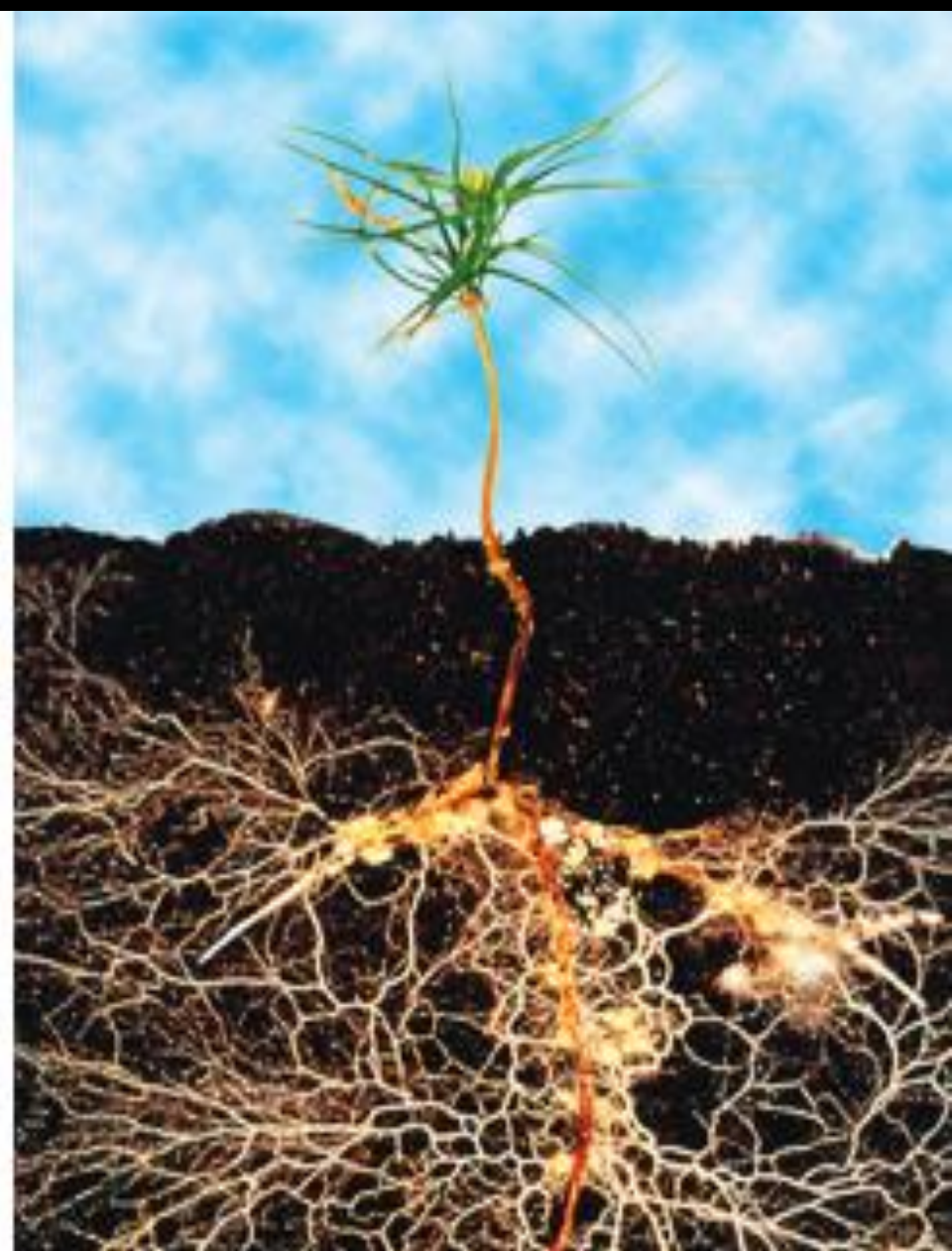
- Release biochemicals that stimulate plants
- Symbiosis

## Detoxify Pollutants

- Agrichemical sources
- Industrial sources



# Mycchorhizal Fungi



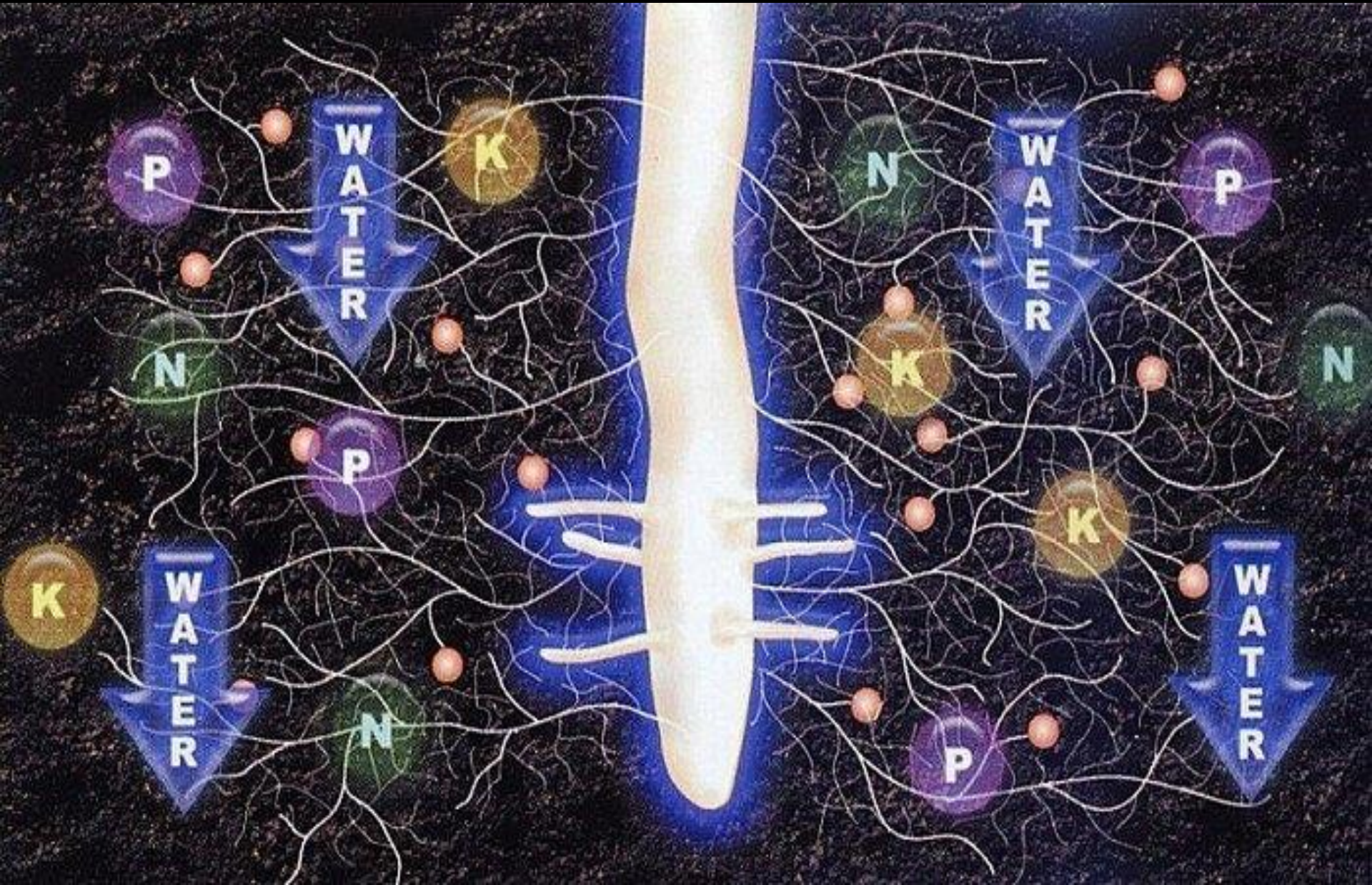


# Mycchorhizal Fungi Extend the Root Area





# Mycchorrhizal Fungi Provide Nutrients



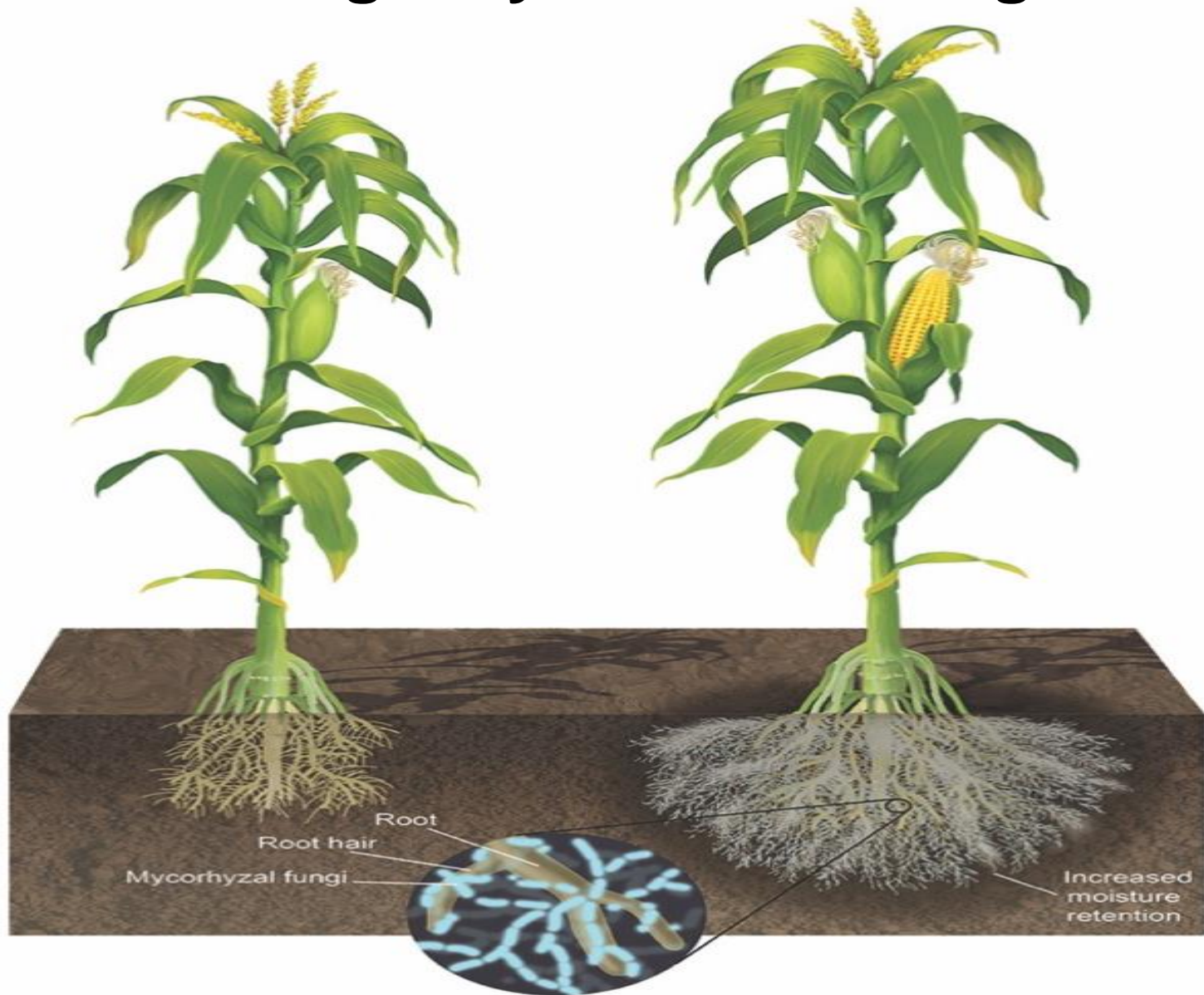


# Some Benefits of Mycchorhizal Fungi

- Fungi and their hyphae extend the reach of root systems by about 200 times. As a result, the roots can absorb 100 times the amount of nutrients they would be able to on their own.
- Mycorrhizae benefit seedlings, transplants, and cuttings by growing strong root systems for them and establishing them in the soil much more quickly than usual.
- The hyphae's long network allows roots to reach down into deeper soil and help the plants stay healthy in times of drought.

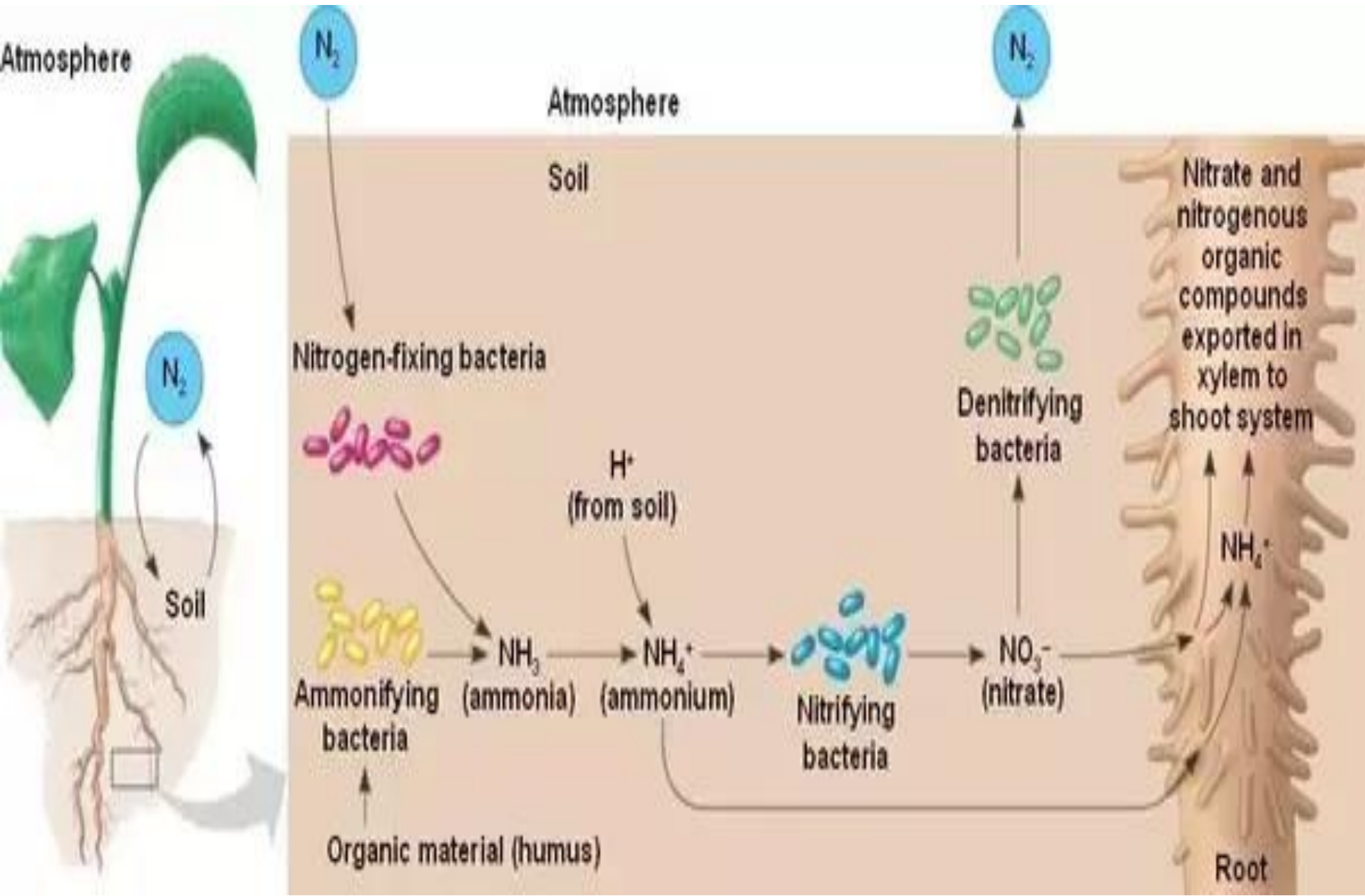


# Extension of Maize Root Surface Area Through Mycorrhizal Fungi



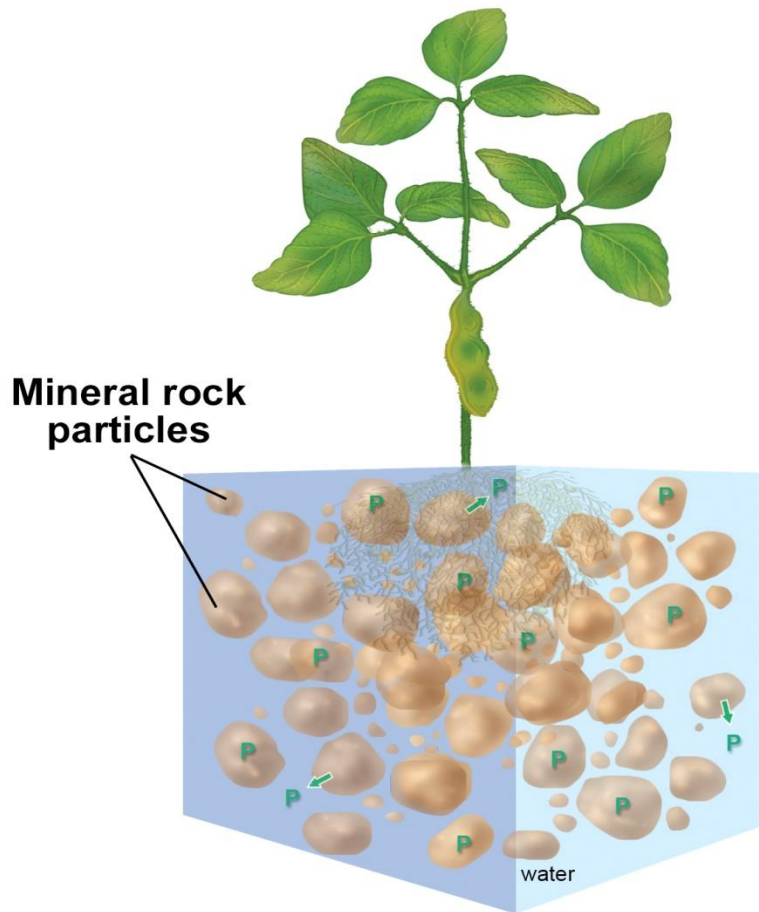


# Nitrogen-Fixing Bacteria in Air and Compost

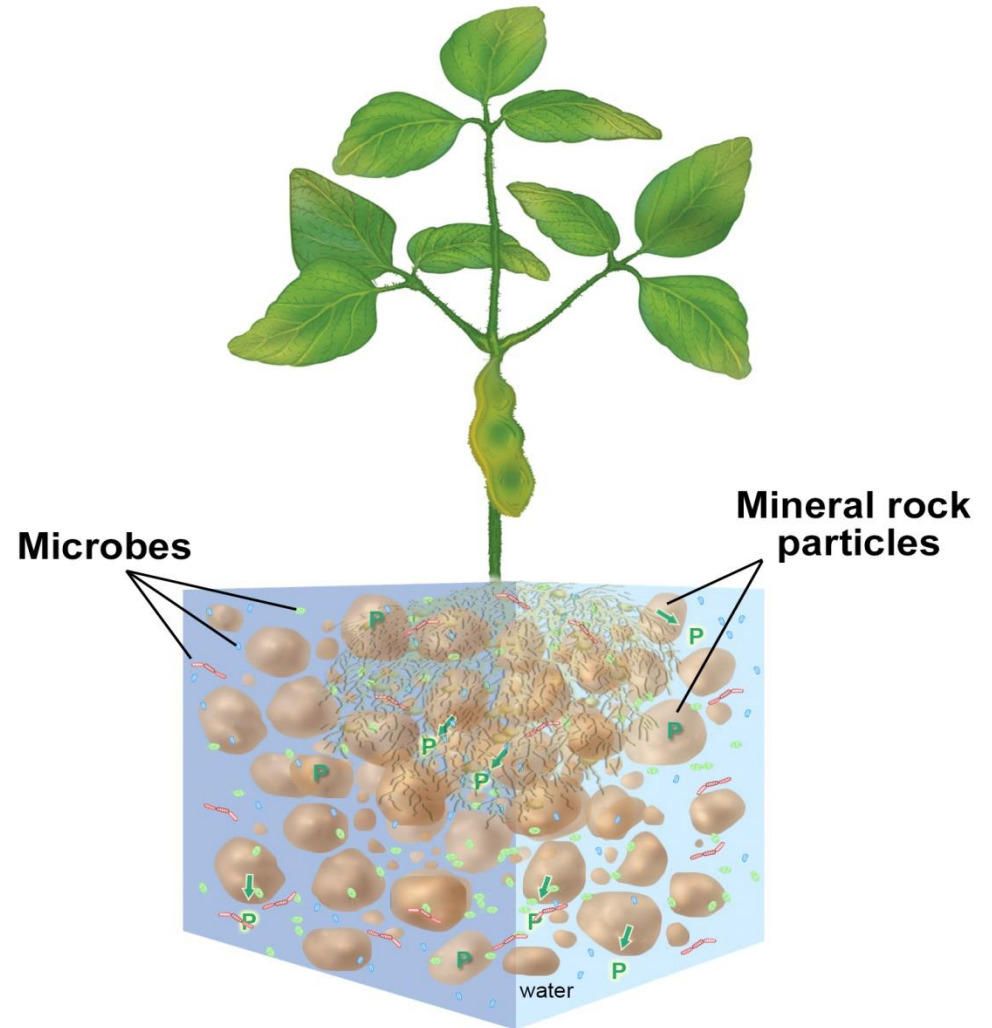




## Low availability of Phosphorus for plants

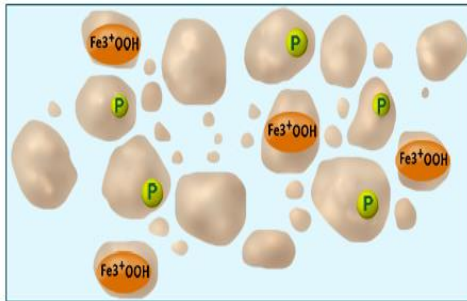


## Biological activity increases soluble Phosphorus for plant use

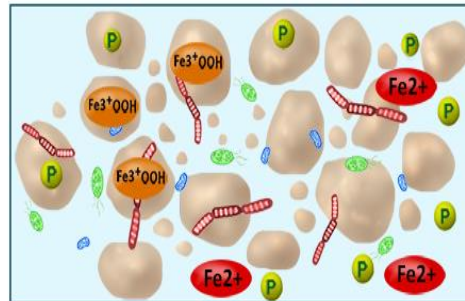




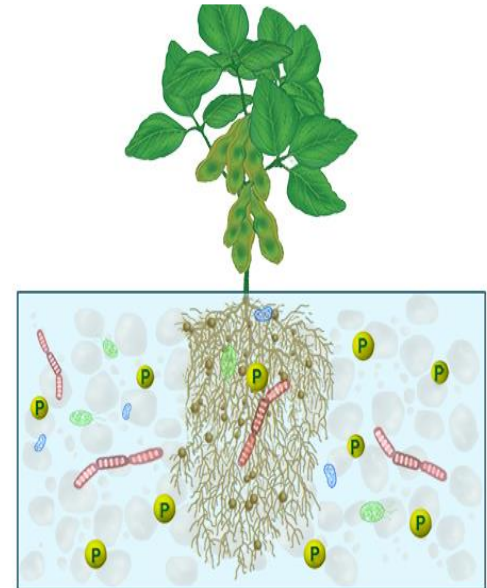
# Fungi Free Up Phosphorus (and Other Nutrients) by Dissolving the Particles to Which It Is Bound



Soil contains water and particles of organic and inorganic matter. Nutrients, like phosphorus, and minerals, like iron oxide, are bound to these particles.



Microbes can dissolve the minerals and free up phosphorus.



The phosphorus is then available for plants to use.

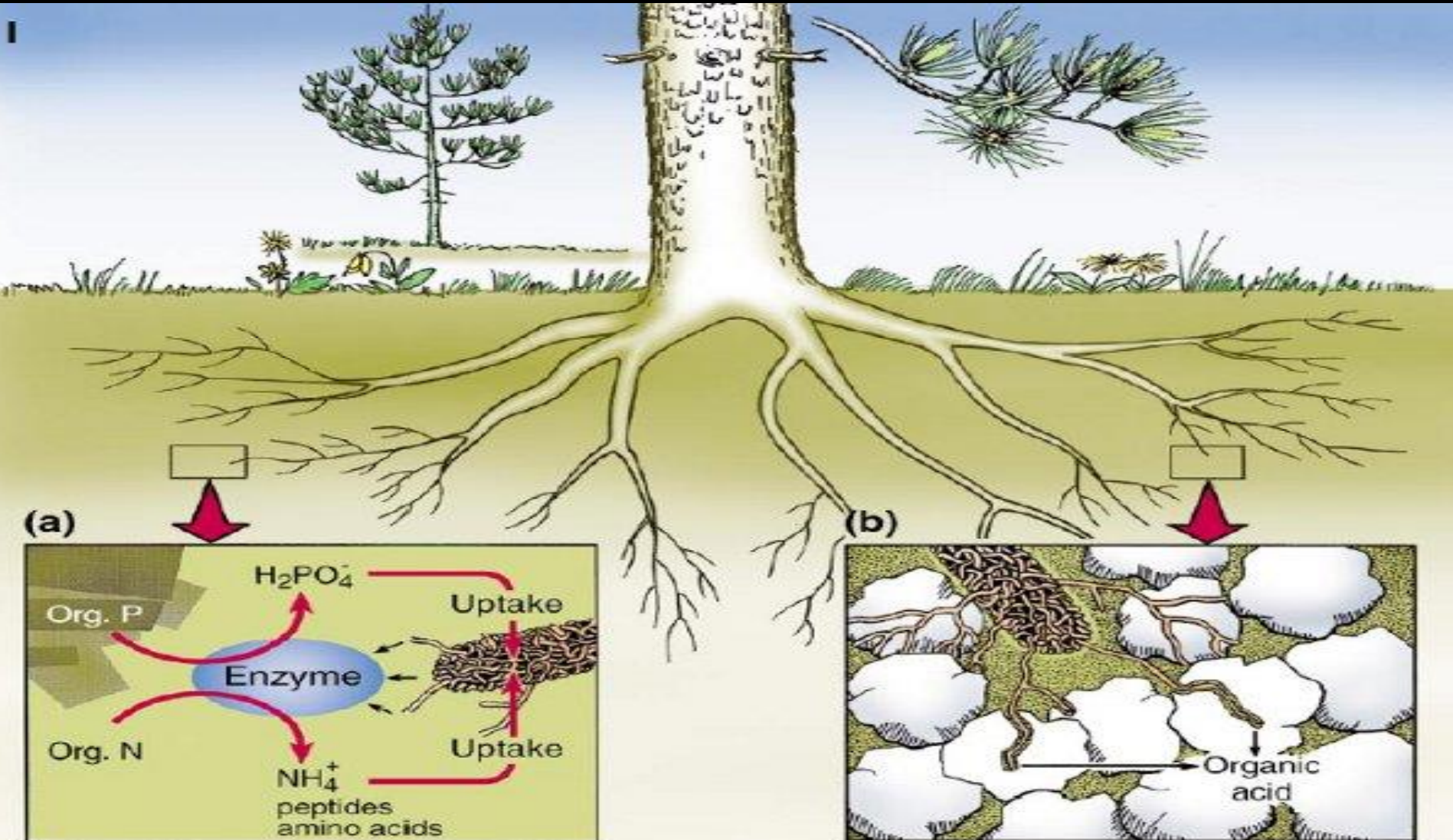


# **Mycchorhizal Fungi Obtain Nutrients in 2 Ways**

Fungi can access organic sources of phosphorous and nitrogen that would otherwise be unavailable to trees via enzymes they make, but also by mining soil minerals.

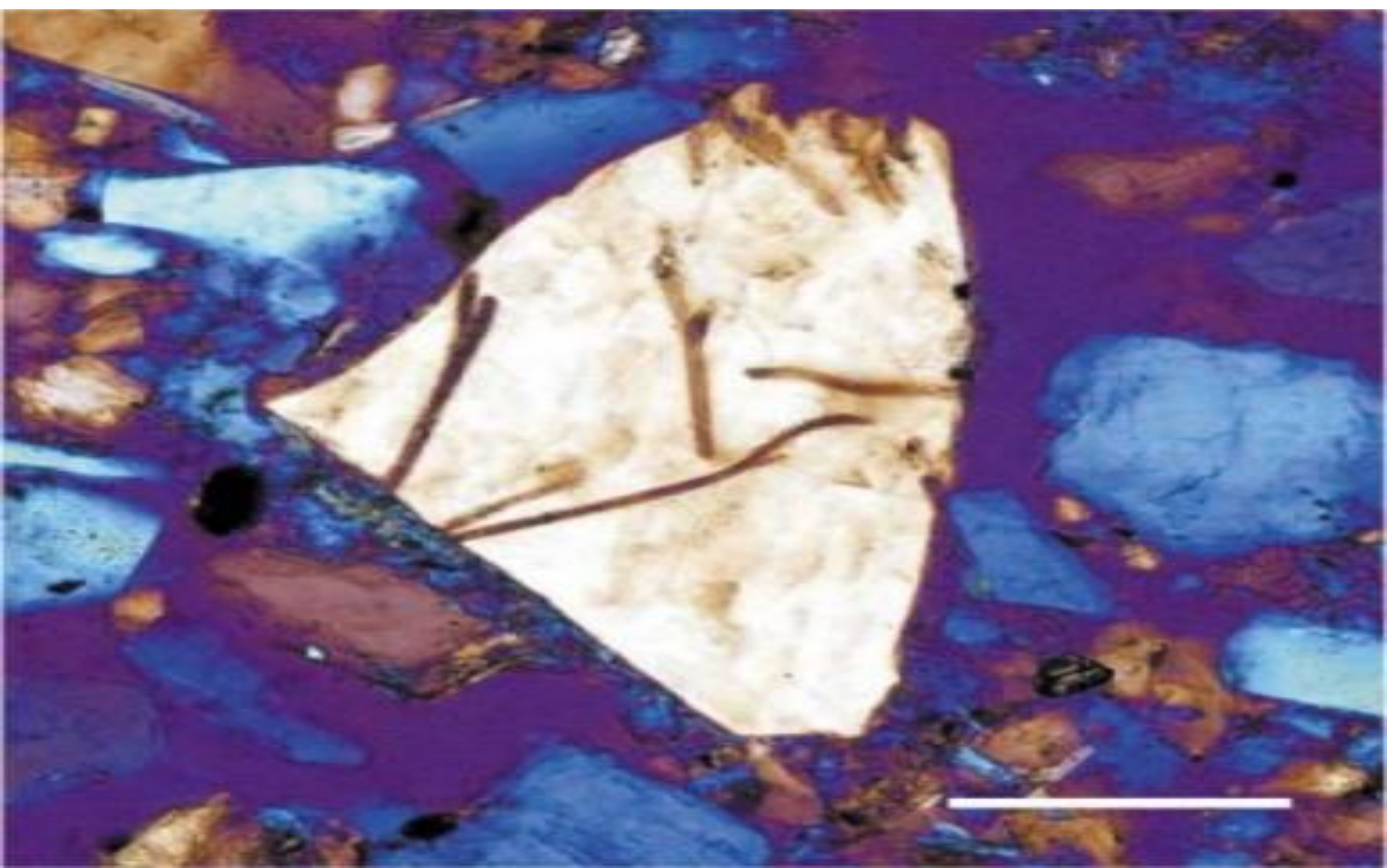


# Mycorrhizal Fungi Obtain Nutrients in 2 Ways



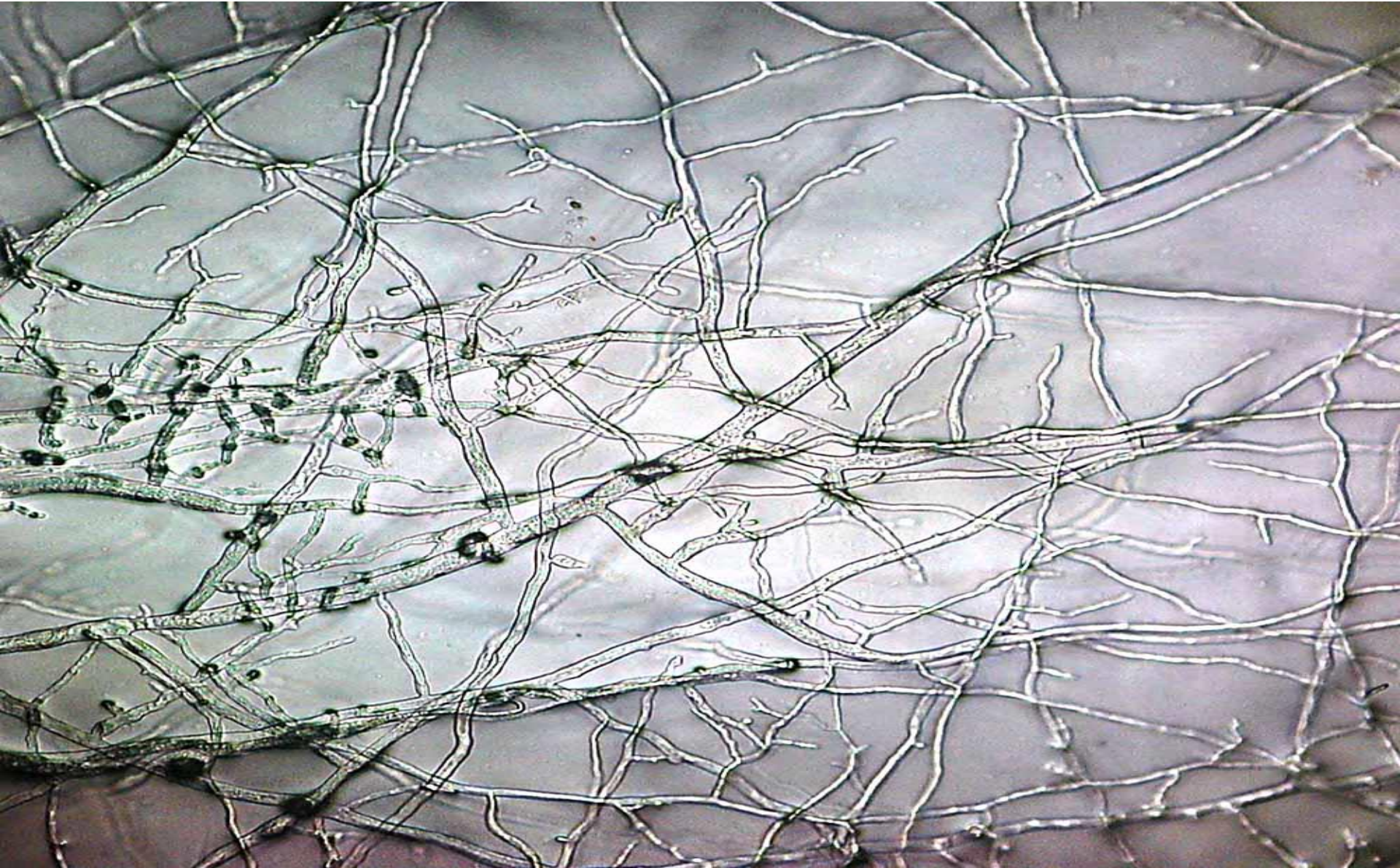


# Mycchorhizal Fungi Also Mine for Minerals





# Mycorrhizal Fungi Also Mine for Minerals





# **Mycchorhizal Fungi Create Soil Structure**

Beneficial fungi also produce a glue-like substance called glomalin that acts as a stabilizer by keeping soil compact without restricting the flow of air and water through it.

# **Mycchorhizal Fungi Increase Resistance to Disease and Pests**

- Fungal networks boost their host plants' immune systems. This is because, when a fungus colonises the roots of a plant, it triggers the production of defense-related chemicals. These make immune system responses quicker and more efficient. So, plugging into mycelial networks makes plants more resistant to disease.
- When plants are attacked by harmful fungi, they release chemical signals into the mycelia that warn their neighbours.



# Trees Provide Food to Each Other Via Mycchorhizal Fungi

- Large trees help out small, younger ones using the fungal internet. Without this help many seedlings would not survive.
- In a 1997 study, seedlings in the shade – which are likely to be short of food - received more carbon from donor trees.

# Mycchorrhizal Fungi Connect Trees





# Trees Help Each Other Via Mycchorhizal Fungi

- Trees in every forest are connected to each other through underground fungal networks.
- Trees share water and nutrients through the networks, and also use them to communicate.
- To communicate through the network, trees send chemical, hormonal and slow-pulsing electrical signals, which scientists are just beginning to decipher.
- They send distress signals about drought and disease, for example, or insect attacks, and other trees alter their behaviour when they receive these messages.

# Trees Help Each Other Via Mycchorhizal Fungi



By linking to the fungal network trees can help out their neighbours by sharing nutrients and information – or sabotage unwelcome plants by spreading toxic chemicals through the network.



# Summary of the Benefits of Mycchorhizal Fungi

- Produce more vigorous and healthy plants.
- Increase plant establishment and survival at seeding or transplanting.
- Increase yields and crop quality.
- Improve drought tolerance, allowing watering reduction.
- Enhance flowering and fruiting.
- Optimize fertilizers use, especially phosphorus.
- Increase tolerance to soil salinity.
- Reduce disease occurrence.
- Contribute to maintain soil quality and nutrient cycling.
- Contribute to control soil erosion.

# Benefits of Mycchorhizal Fungi on Soil Structure

- Greater water infiltration and water holding capacity.
- More permeability to air.
- Better root development.
- Higher microbial activity and nutrient cycling.
- Better resistance to surface sealing (crusts).
- Better resistance to erosion (water/wind).
- Better resistance to compaction.



# Which crop(s) should I plant?

## ▶ **Legumes**

- ▶ Fix nitrogen and add organic matter
- ▶ Peas, clovers

## ▶ **Cereal grains**

- Fast-growing: add organic matter and control erosion
- Deeply tap-rooted plants: relieve compaction
- Cereal rye, winter wheat, barley



“Bio-drilling” relieves compacted soil

# Cover Crop Comparison

When determining which cover crop is most beneficial to your farm, it is important to consider what purpose you want that crop to serve. Legumes, grasses and brassicas are common cover crops that can offer a wide variety of benefits to the soil and following crop. Depending upon your individual field's needs or conditions, you should plan your cover crops accordingly.

## LEGUMES

Nitrogen Fixing

Increase Soil Microbes

Recycles Nutrients

Increases Organic Matter

Increase Soil Porosity

Break Pest Cycles

## GRASSES

Holds onto Nitrogen

Scavenges Nutrients

Reduces Erosion

Suppresses Weeds

Conserves Soil Moisture

Increases Organic Matter

## BRASSICAS

Suppresses Soil Pests

Breaks up Soil Compaction

Improves Rainfall Infiltration

Increases Disease Suppressive Bacteria

Reduces Erosion

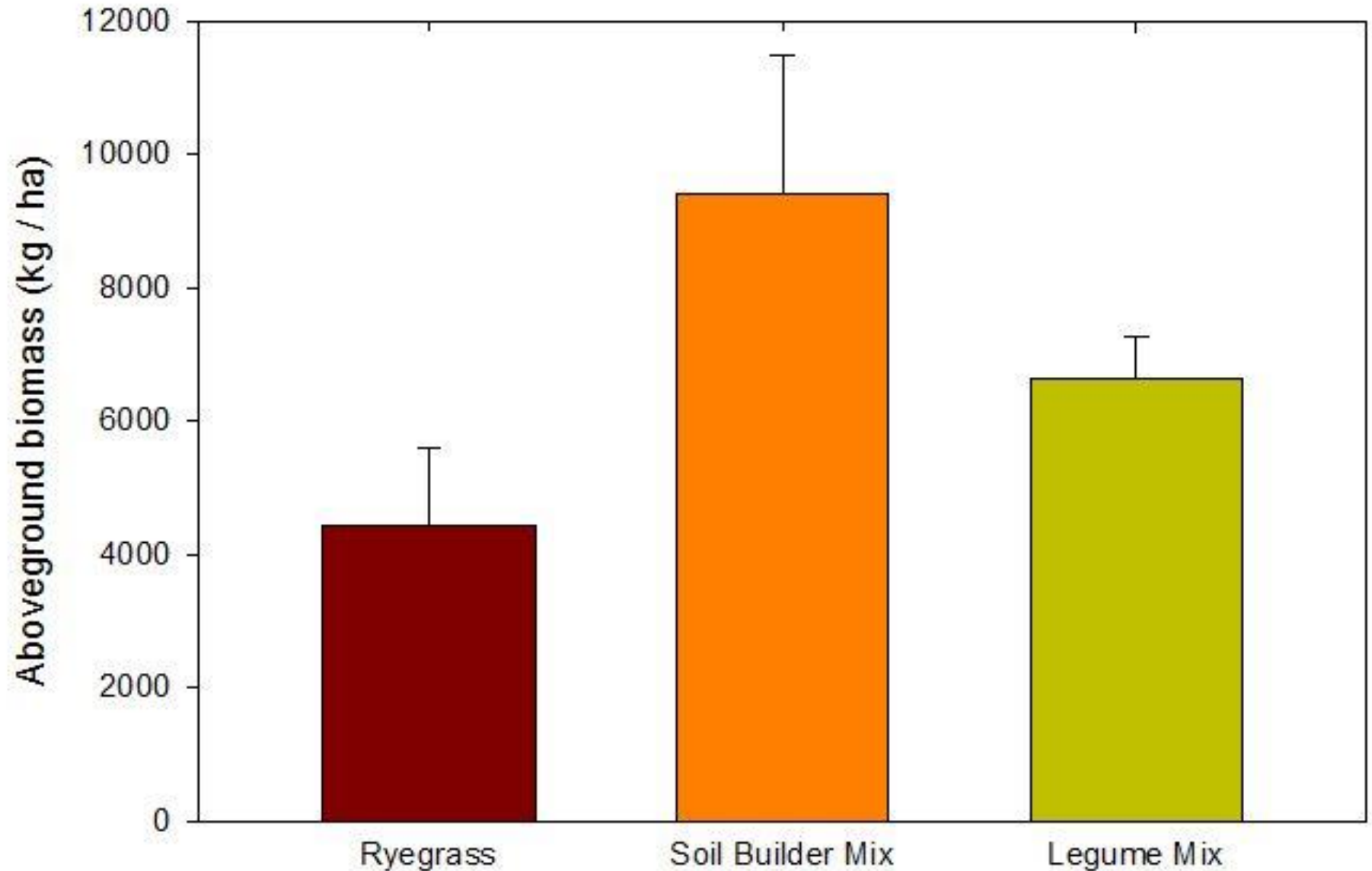
Suppresses Annual Winter Weeds



# Cover Crop Chart

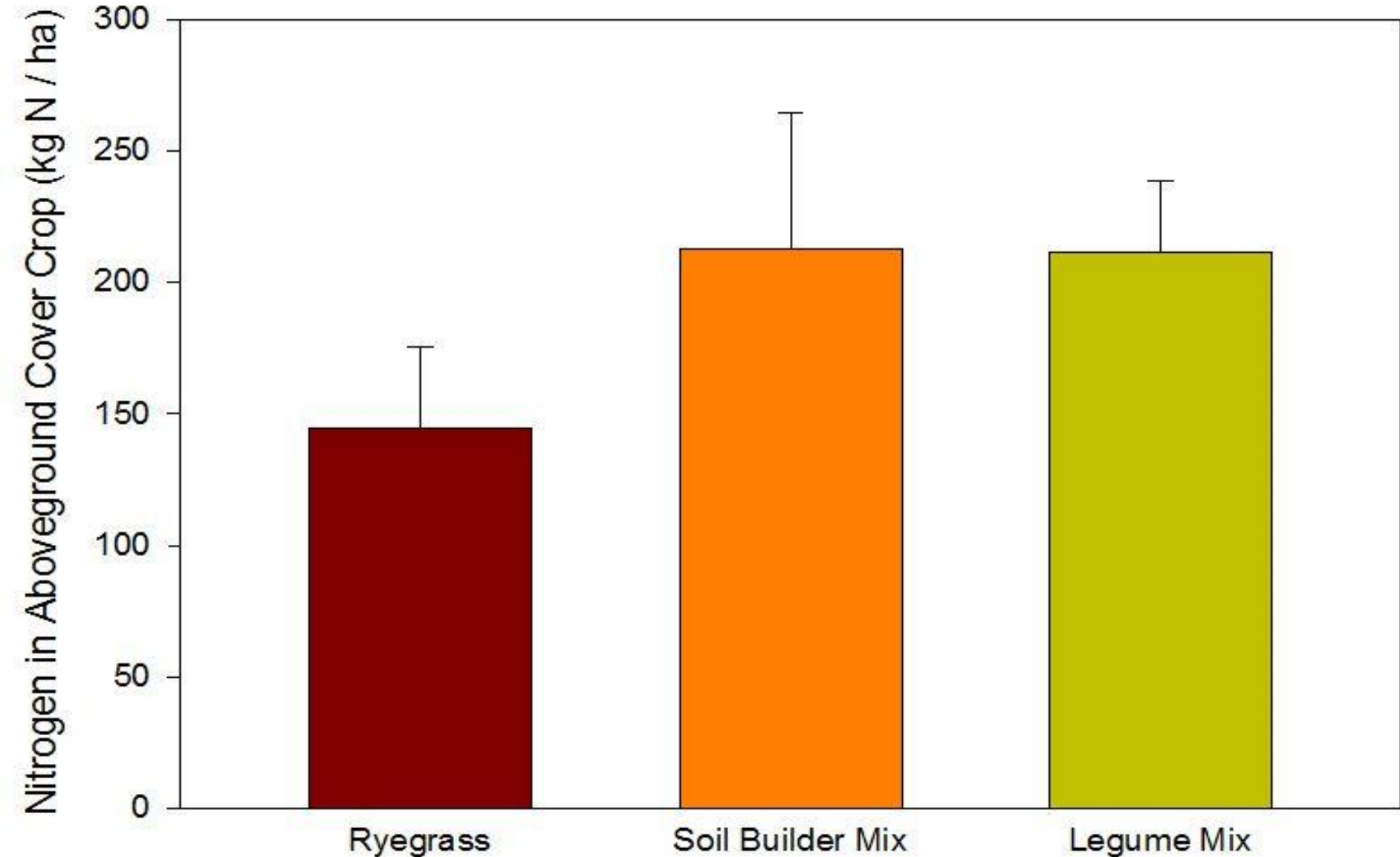
[Click here.](#)

# Amount of Biomass Provided





# Amount of Nitrogen Provided



# Terminating a Cover Crop





# Terminating a Cover Crop





# Maize Planted into a Terminated Cover Crop, Which Is Now Breaking Down





# **A Crop Planted into a Terminated Cover Crop, Which Is Now Breaking Down**





# Using a Cover Crop to Manage Weeds, Conserve Moisture, and Provide Nutrients







**A Buckwheat Flowers Cover Crop Attracts  
Pollinating Insects and Provides the  
Usual Benefits of Cover Crops**



A photograph of a walnut plantation. In the foreground, there is a dense, green cover crop. In the background, rows of walnut trees are visible, spaced out in a field. The trees have dark trunks and green foliage. The overall scene is a lush green field with rows of trees in the distance.

**Using a Cover Crop to Manage Weeds,  
Conserve Moisture, and Provide Nutrients  
in a Walnut Plantation**



# Using a Cover Crop to Manage Weeds, Conserve Moisture, and Provide Nutrients



**Cover Crop**

**No Cover Crop**



# Effect of Calopo as a Cover Crop

- *Calopogonium mucunoides* (calopo), *Crotalaria juncea* (sunn hemp), *C. retusa* (devil bean) and *Mucuna pruriens* were assessed in 1996-1997 at three locations in Northern Ghana for their dry matter production, nutrient accumulation, mineralization, as well as their effect on the yield of a succeeding maize crop.
- The dry matter yield of cover crops across locations ranged from 5 to 15 t ha<sup>-1</sup> with a corresponding total N accumulation of 115 to 306 kgs. ha<sup>-1</sup>.



# Effect of Calopo as a Cover Crop

- Cover crop residue amendments increased maize grain yield 2- to 4-fold above the 1-year weed fallow control. Calopo was the best cover crop in increasing maize yield.
- On the other hand, devil bean, which outperformed all the other cover crops in dry matter and N accumulation, did not increase maize yield commensurate with its dry matter and N yields due to high N immobilization.
- **Summary:** Small-scale farmers in Northern Ghana can improve their maize yields by growing cover crops in rotation with their maize.



# Calopo





# The Effects of a Cover Crop on Soil Compaction





# The Effect of Leaf Litter Decay





# Leaf Litter Compost



# Leaf Litter With Added Microorganisms



**Day 0**



**Day 14**



**Day 36**

# Leaf Litter Without Added Microorganisms

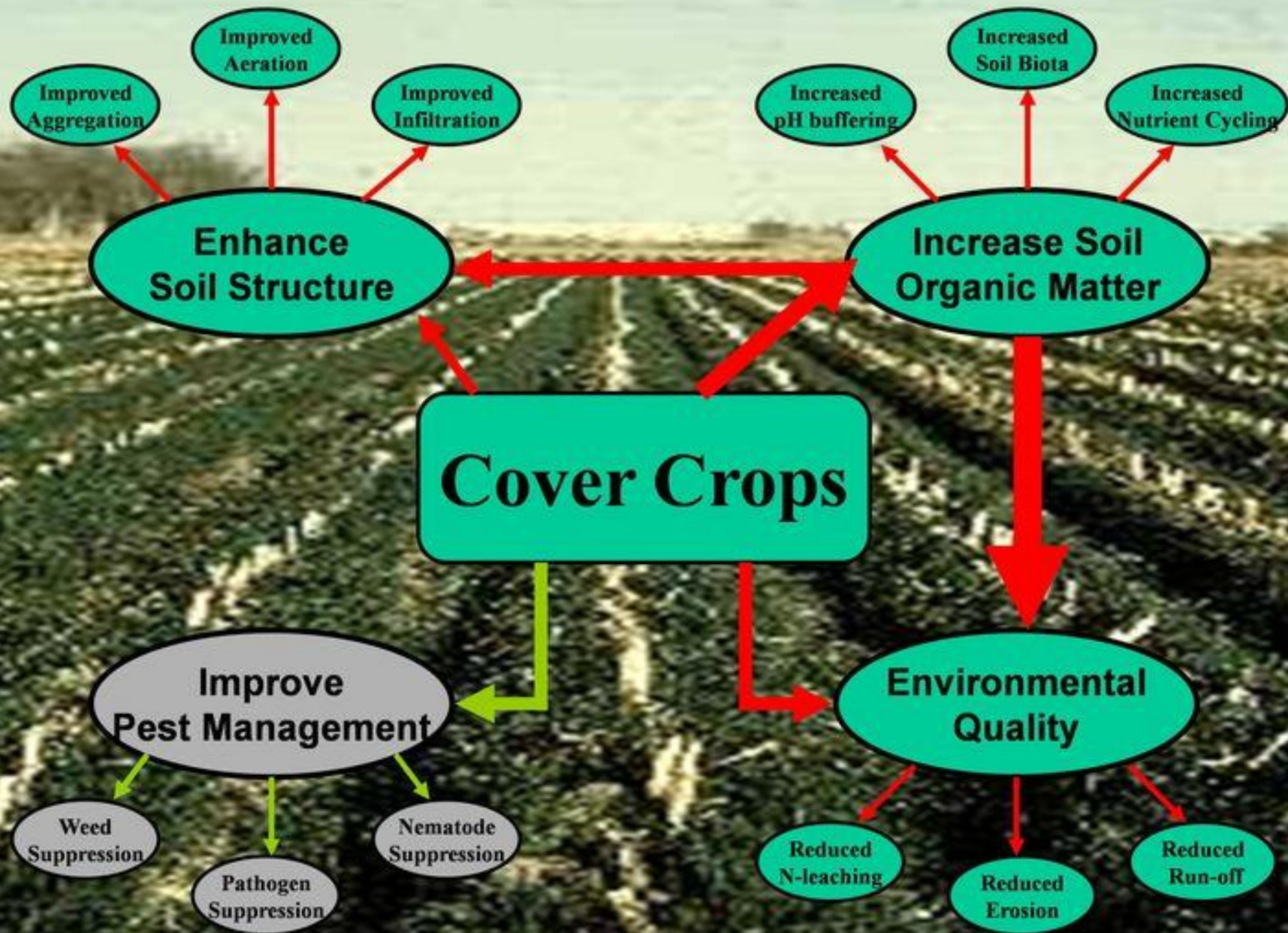


**Day 0**



**Day 30**







# Cover crops can:

- ▶ Increase soil organic matter
- ▶ Increase nitrogen balance in the soil
- ▶ Suppress pests (weeds)
- ▶ Provide habitat for beneficial insects
- ▶ Enhance soil biological activity
- ▶ Control erosion
- ▶ Prevent compaction



What do you want your cover crop to do?