



SOIL MICROBIOLOGY AND NUTRIENT CYCLING

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Industry/Academe: Division of Soil Science, CAFS, UPLB

Order of Presentation

- Mood Slides
- Introduction (secrets of the soil)
- Essential Functions of the Soil
- Basic Soil Nutrient and Mechanisms of Plant absorption
- Major groups of Soil Microbiology
- Beneficial Soil Microbes and Plant Interaction

MOOD Slides

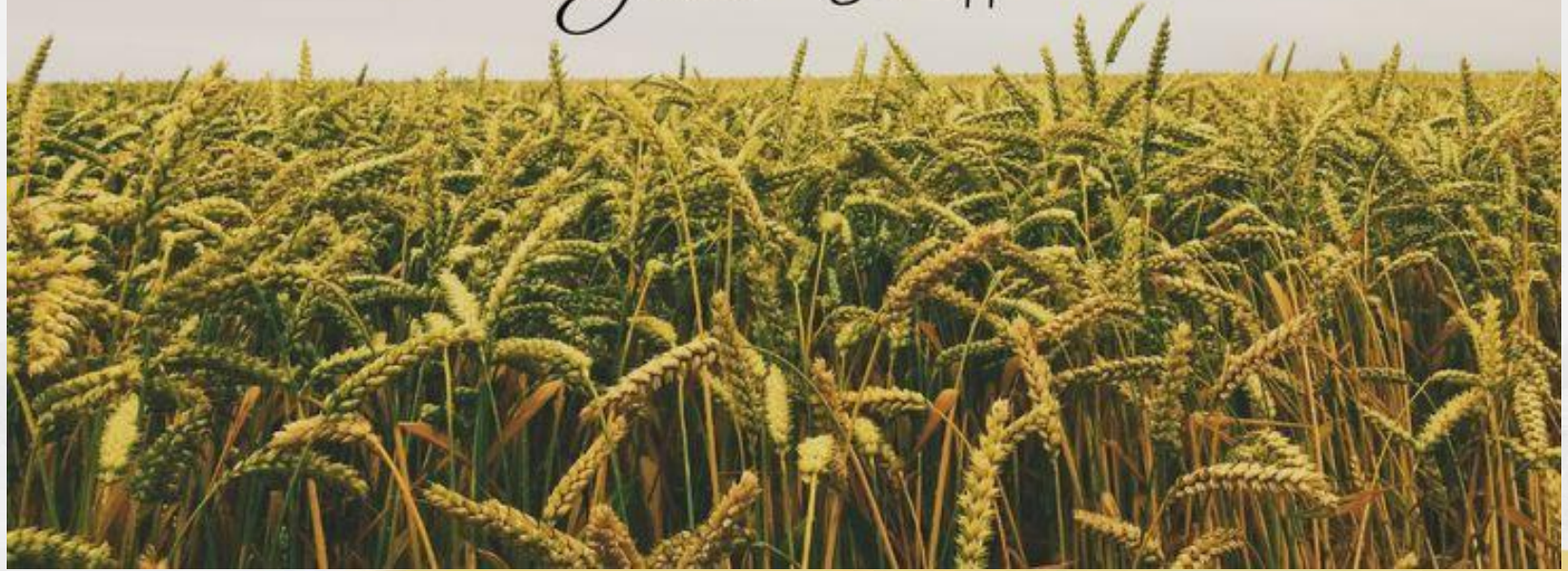
**If speaking kindly
to plants helps them
grow, imagine what
speaking kindly to
humans can do.**



MOOD Slides

“My grandfather used to say that once in your life you need a doctor, a lawyer, a policeman and a preacher, but every day, three times a day, you need a farmer.”

Brenda Schoepp



MOOD Slides

Wheat makes beer.
Corn makes whiskey.
Grapes make wine.
Potatoes make vodka.
Agave makes tequila.
Rice makes sake.
Sugarcane makes rum.

You can't get drunk without farmers.
You're welcome.



"We know more about the movement of celestial bodies than about the soil underfoot."

-Leonardo da Vinci



Secrets of the Soil

Living in the soil are plant roots, bacteria, fungi, protozoa, algae, mites, nematodes, worms, ants, maggots, insects and grubs, and larger animals.

science of soil

soil is made of about **45% minerals**, **25% water**, **5% organic matter**, and **25% air**



what's underneath



Healthy soil has amazing water-retention capacity.

Every **1%** increase in organic matter results in as much as **25,000** gal of available soil water per acre.



One teaspoon of healthy soil contains **100 million-1 billion** individual



All of the soil microbes in **1ac/ft** of soil weigh more than **2 cows**

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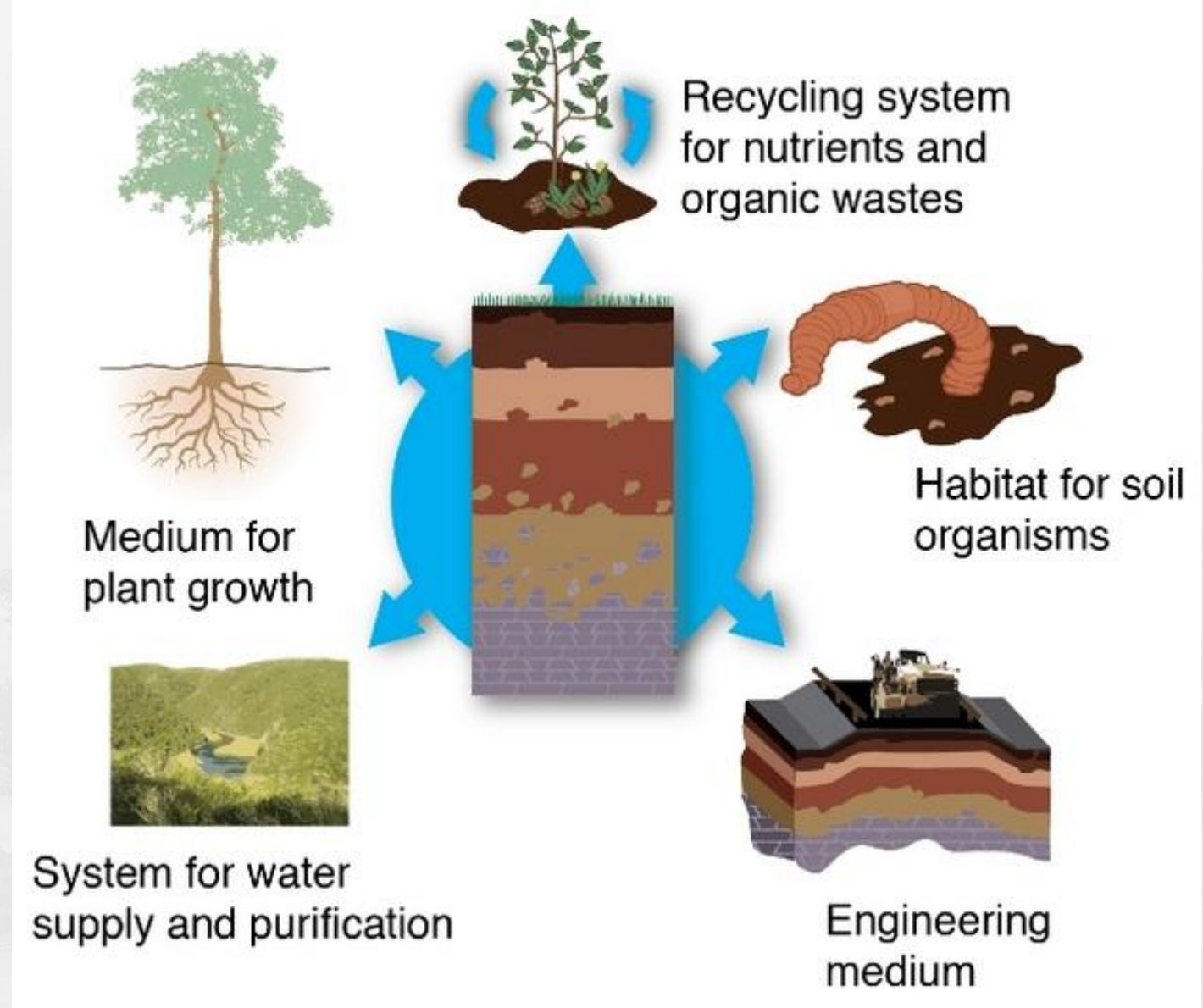


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Essential Functions of the Soil



How many organisms are there in a handful of soil?

Three hundred?

Four hundred million -
Aerobic bacteria?

One million -
Actinomycetes?

One thousand -
Arthropods?

Eight million -
protozoa?

Sixty-five million - Fungal
cells?

There are more living organisms in a handful
of soil than there are people on earth.

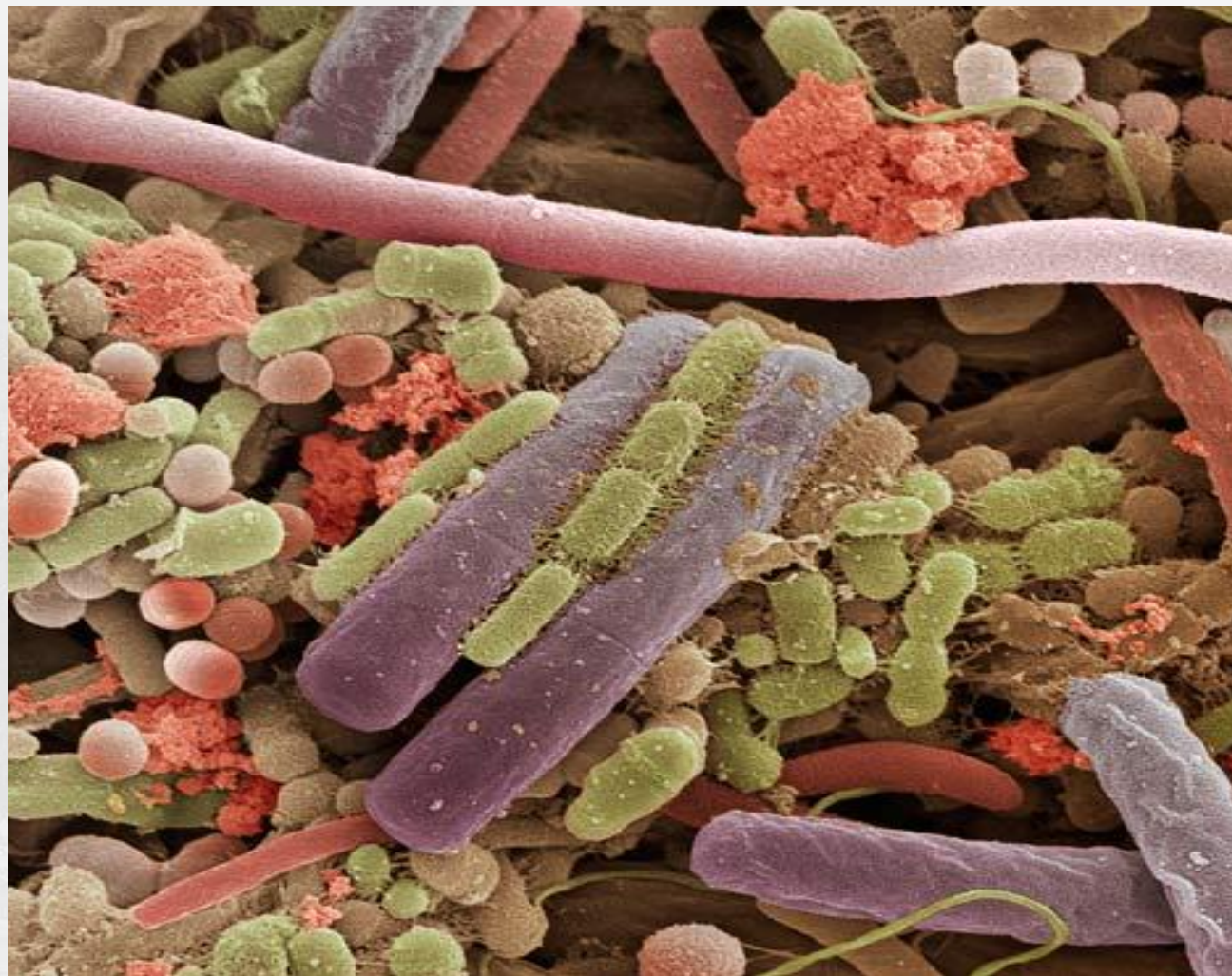
Major Groups of Soil Microorganisms

Major Groups of Soil Microorganisms

1. Bacteria
2. Fungi
3. Actinomycetes
4. Protozoa
5. Algae



Bacteria



Bacteria

- Prokaryotic, single-celled, microscopic organisms.
- Probably the most important in terms of their effect on soil properties.
- Involved in nitrogen transformation, sulfur oxidation and reduction, and other chemical processes.
- Population: 10^6 - 10^9 CFU/g soil
- Biomass: ~2,000 kg/HFS

Functional groups of Bacteria

1. Decomposers

- Breakdown of organic matter
- Breakdown of pesticides and other pollutants
- Release/immobilization of nutrients

2. Mutualists

- Form “partnerships” with plants
- Nitrogen-fixing bacteria

Functional groups of Bacteria

3. Pathogens
4. Lithotrophs or chemoautotrophs
 - Obtain energy from compounds of nitrogen, sulfur, iron or hydrogen instead of from carbon compounds
 - Important in nutrient cycling.

Fungi



Fungi

- Large group of eukaryotic organisms that includes microorganisms such as yeast and molds, as well as the more familiar mushrooms.
- Fungal cell walls are made up of chitin.
- **Mycology** - a discipline of biology devoted to the study of fungi.

Fungi

- Fungi are microscopic cells that usually grow as long threads or strands called **hyphae**, which push their way between soil particles, roots, and rocks.
- Hyphae are only a few micrometers in diameter, but can span in length from a few cells to many yards.

This image of a plant associated with a mycorrhizal fungi showing how extensive a fungal hyphae can be



Source: <https://galianoconservancy.ca/claremont-2-day-adventure/micorrizas-1/>

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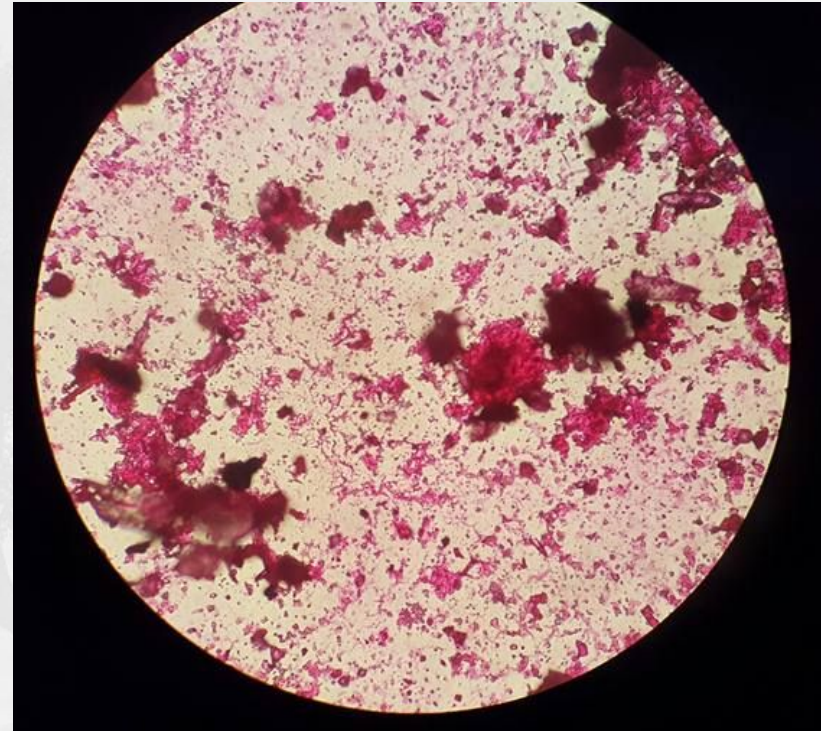
Fungi

- Dominant in acid soils, because acidic environment is not conducive / suitable for the existence of either bacteria or actinomycetes.
- Also present in neutral and alkaline soils and some can even tolerate PH beyond 9.0
- Population : $10^4 - 10^5$ CFU/g soil
- Biomass: ~8,000 kg/HFS

A microscopic image of a soil microcosm showing the presence of several fungal hyphae in upland soils while very few were present in a lowland soil.

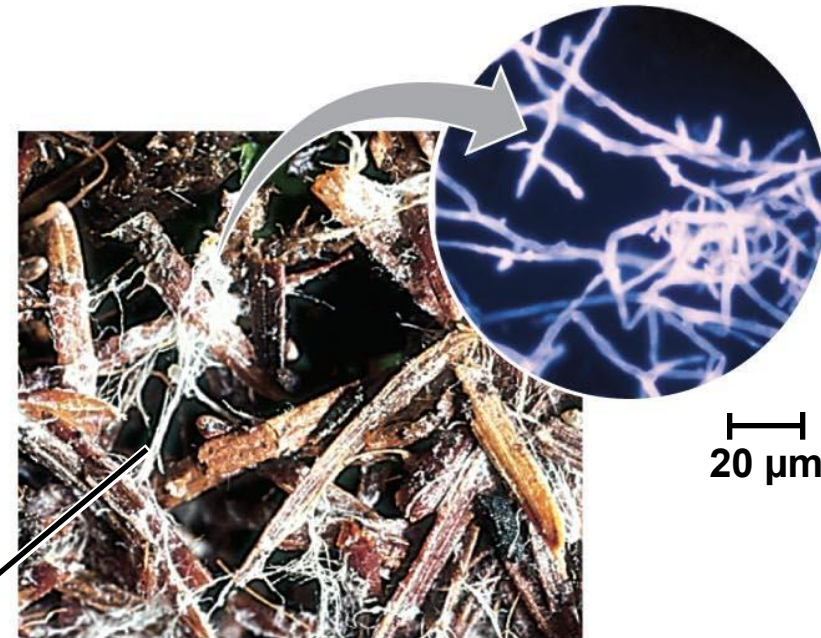
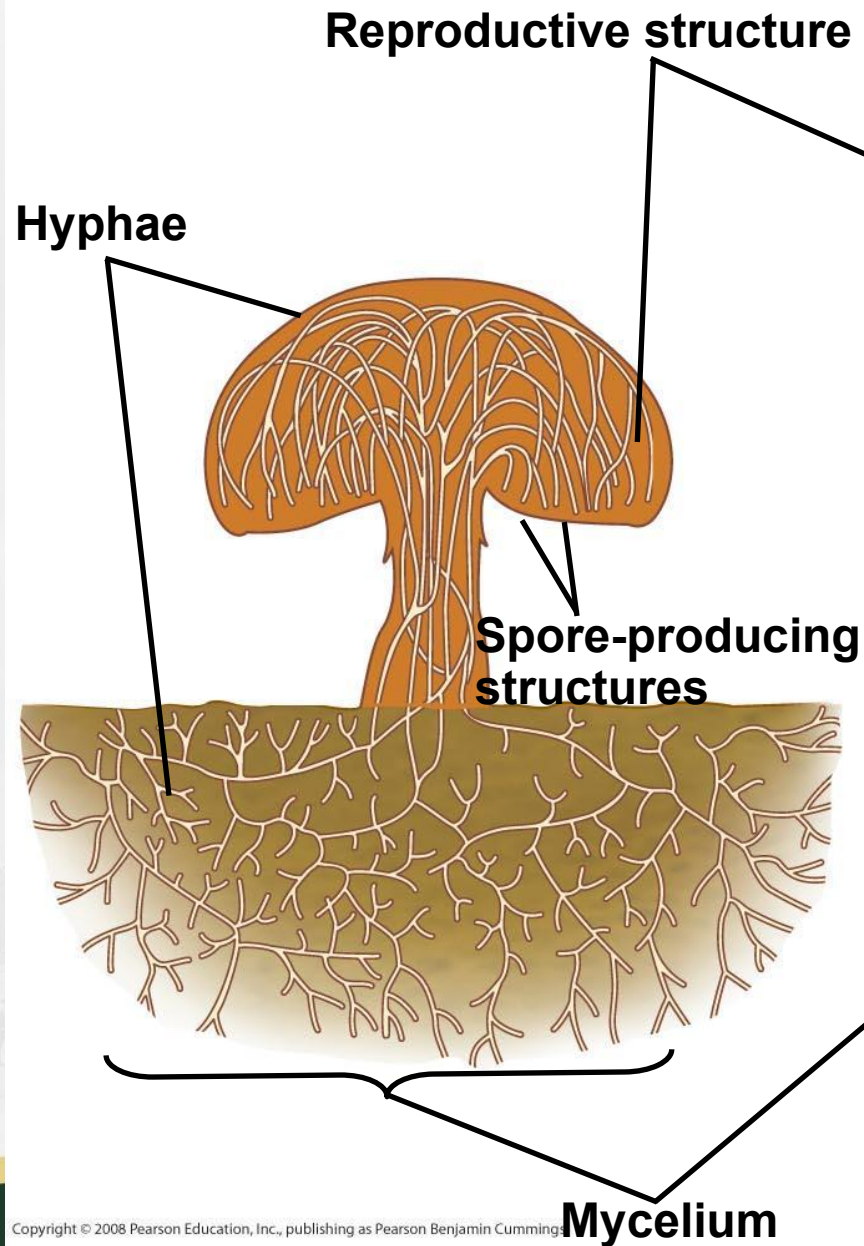


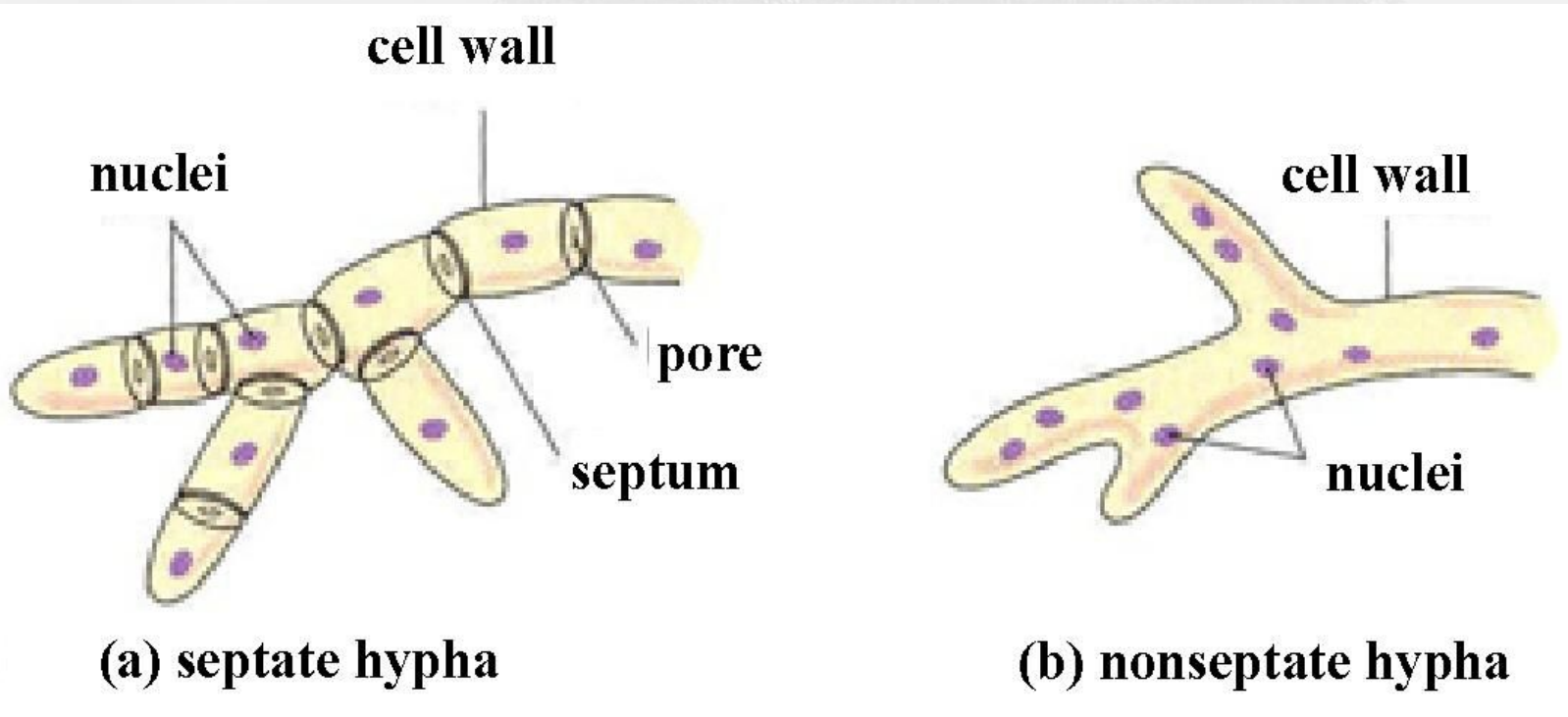
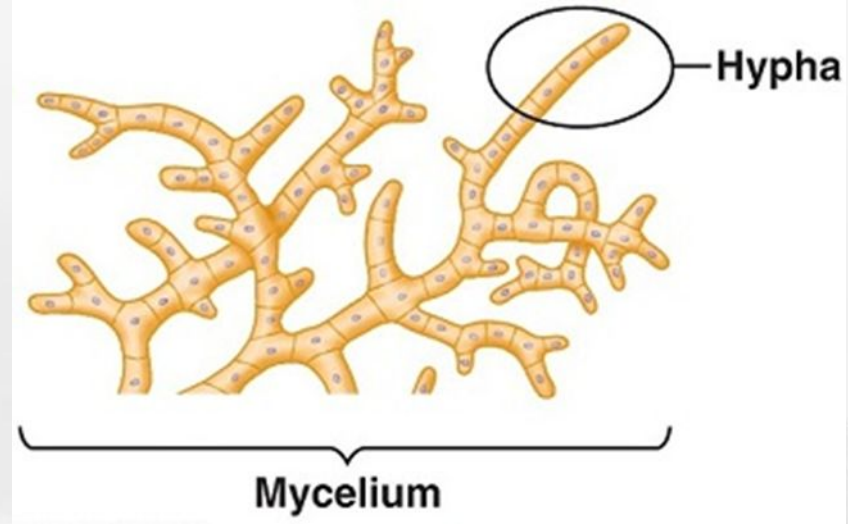
Upland soil

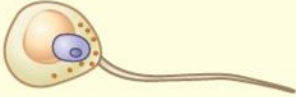






Lowland soil

Image courtesy of SOIL 120 Class of 2017





Fungal Phylum	Distinguishing Features of Morphology and Life Cycles	
Chytridiomycota (chytrids)	Flagellated spores	
Zygomycota (zygote fungi)	Resistant zygosporangium as sexual stage	
Glomeromycota (arbuscular mycorrhizal fungi)	Form arbuscular mycorrhizae with plants	
Ascomycota (sac fungi)	Sexual spores (ascospores) borne internally in sacs called asci; ascomycetes also produce vast numbers of asexual spores (conidia)	
Basidiomycota (club fungi)	Elaborate fruiting body (basidiocarp) containing many basidia that produce sexual spores (basidiospores)	

Functional Groups:

- Decomposers
- Pathogens (Parasites)
- Mutualists - Mycorrhizae

Roles of Fungi

- Play an important role in the decomposition of cellulose, hemi cellulose, starch, pectin, and lignin in the organic matter added to the soil.
- Serve as food for bacteria.
- A number of soil fungi form **mycorrhizal association** with the roots of higher plants and helps in mobilization of soil phosphorus and nitrogen.

Mycorrhiza

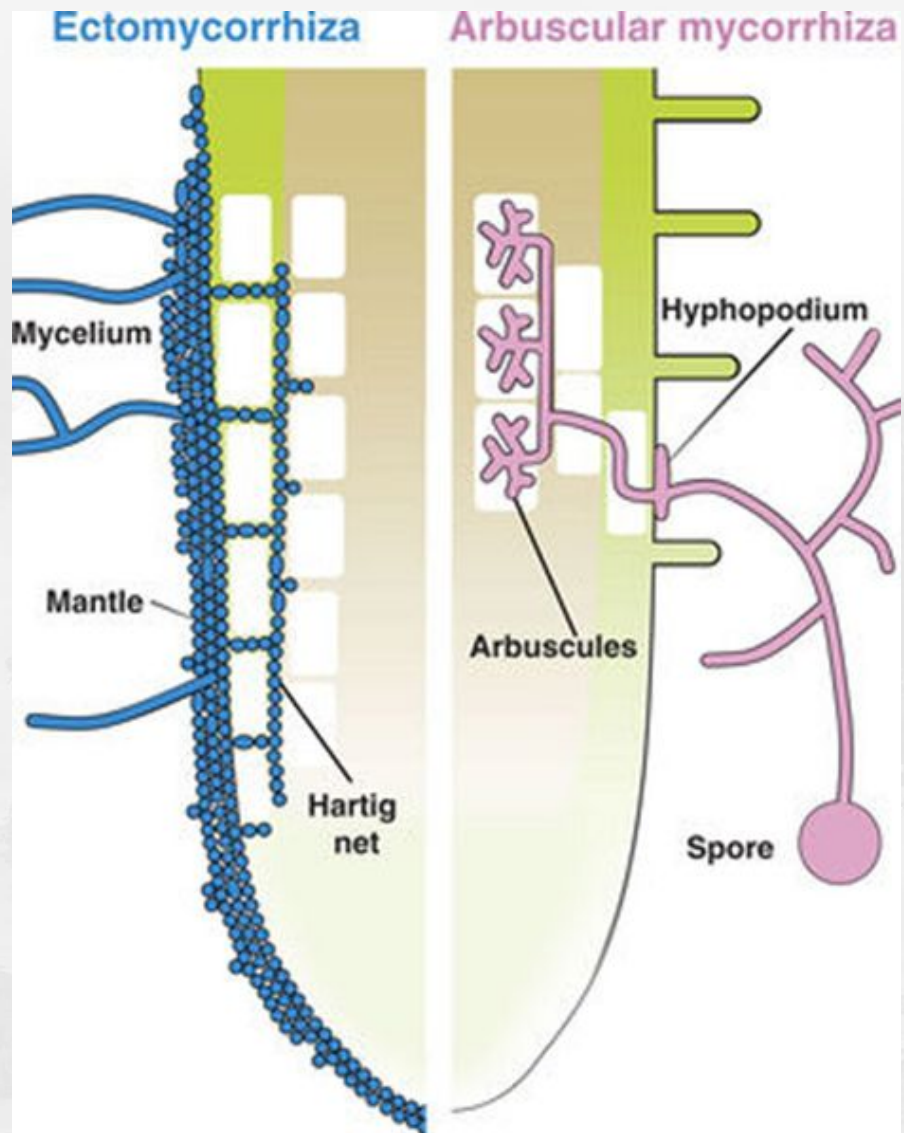
- From the Greek words “mykós” (fungus) and “riza” (root).
- A symbiotic association composed of a fungus and roots of a vascular plant.
- The fungus helps the plant to capture water and nutrients (N, P, S).

Mycorrhiza

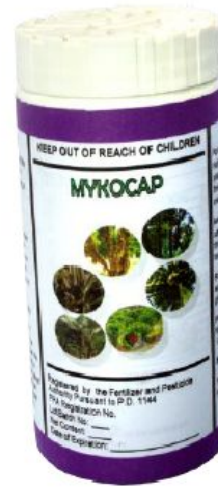
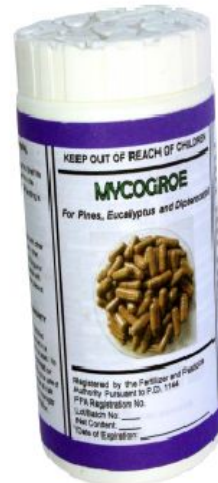
- Mycorrhizal plants are often more resistant to diseases, such as those caused by microbial soil-borne pathogens.
- Fungi have been found to have a protective role for plants rooted in soils with high metal concentrations.

Mycorrhiza

- Two types
 - **Ectomycorrhiza**
 - *Amanita, Boletus, Entoloma, Lactarius*
 - **Endomycorrhiza**
 - Arbuscular mycorrhiza
 - *Glomus, Gigaspora, Aculospora*



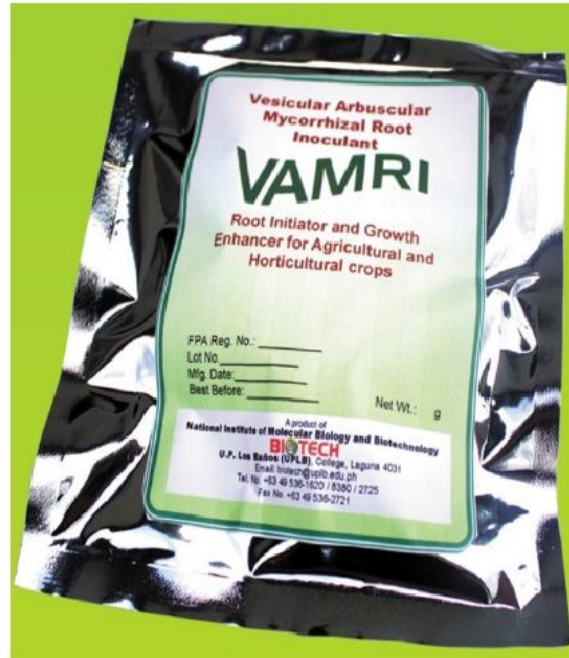




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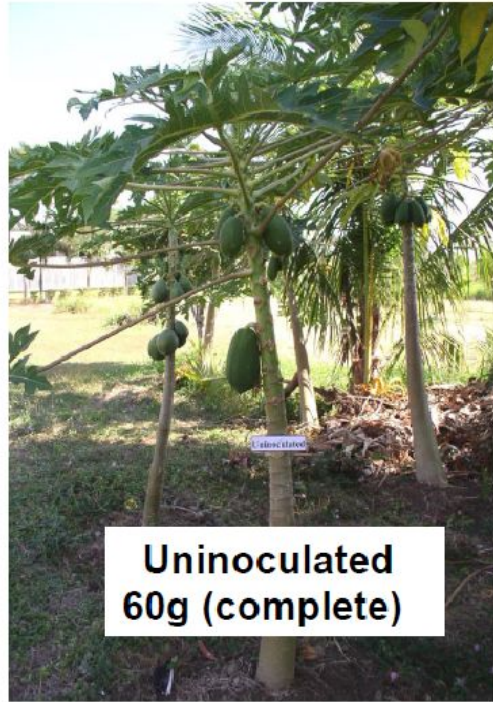
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- VAM fungus either *Glomus mosseae* or *G. fasciculatum*
- Enhance absorption of water and nutrients particularly phosphorus; also serves as biocontrol agent of soil-borne diseases of different crops.

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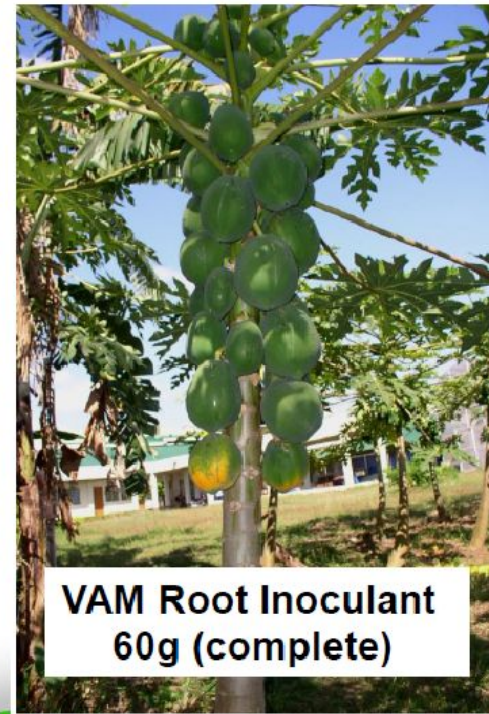




**Uninoculated
60g (complete)**



**VAM Root Inoculant
30g (complete)**



**VAM Root Inoculant
60g (complete)**

**More fruits were produced by
papaya with VAM Root Inoculant**

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FPA Registration No. 1-2LF-1231

MYKOVAM™
Soil-based biofertilizer
for fruit trees,
agricultural crops,
reforestation species,
and ornamentals

- For better absorption of water and nutrients
- Replaces about 60-85% chemical fertilizer requirement of plants

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Lanzones of **Dr. Alexis de Manuel** in Cotabato after applying Mykovam

Source: Dr. Nelly S. Aggangan, 2013

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Actinomycetes



Actinomycetes

- Aerobic, Gram-positive bacteria which predominantly and essentially give rise to specific branching filaments or asexual spores or hyphae.
- Genus **Actinobacteria**
- Intermediate between bacteria and fungi.
- Unicellular like bacteria.
- Produce conidia / sporangia like fungi, but produce a non-septate and more slender hyphae.

Actinomycetes

- Heterotrophic
- Aerobic : some microaerophilic
- Acid Sensitive (Critical pH = 5.5)
- Population: $10^5 - 10^6$ CFU/g soil
- Biomass: ~ 4000 kg/HFS
- On culture media, actinomycetes colonies grow slowly, show powdery consistency and stick firmly to agar surface.

Actinomycetes

Roles:

1. Important in the degradation of organic materials in the soil, including lignin.
2. Contribute to the formation of stable humus.
3. Ability to produce antibiotics –streptomycin, neomycin, erythromycin, tetracycline.



ACTICon

Actinomycete-based
biocontrol agents against
Fusarium oxysporum f. sp.
cubense that cause
Fusarium wilt or Panama
wilt in Cavendish banana



On the foreground are Cavendish banana plants that died due to *Fusarium oxysporum* TR4 while at the background are ACTICon-treated plants in a field trial in Sto. Tomas, Davao del Norte.
(Image credit: UPLB-BIOTECH)

Algae



Algae

- Present in most of the soils where moisture and sunlight are available.
- Photoautotrophic - obtain CO₂ from atmosphere and energy from sunlight and synthesize their own food.
- Aerobic
- They can be unicellular, filamentous or colonial.
- Population: 10³ – 10⁵ CFU/g soil
- Biomass: ~ 250 kg/Ha

ALGAE

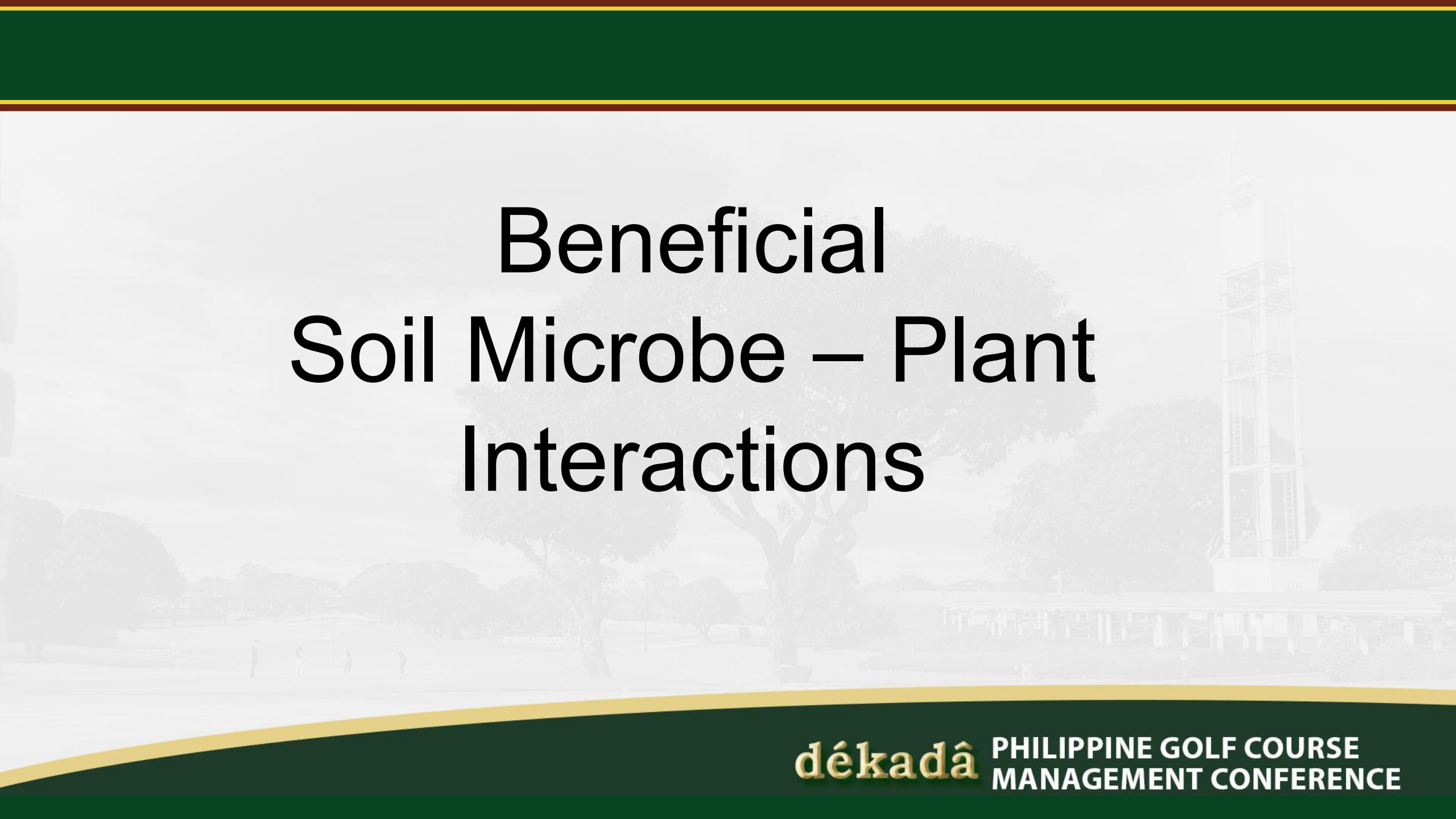
- Two major groups:
 - Eukaryotic algae
 - Prokaryotic cyanobacteria
- Major groups in the soil
 - Cyanobacteria or Blue-green algae (Cyanophyta)
 - Green algae (Chlorophyta)
 - Diatoms (Bacillariophyta)
 - Yellow-green algae (Xanthophyta)

Roles in the Soil

1. Primary producers
2. Biological weathering of minerals
3. Nitrogen fixation
4. Stabilization of aggregates
5. Beneficial interactions
 1. Endosymbiotic algae and plants
 2. Lichen- combination of algae and fungus



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Beneficial Soil Microbe – Plant Interactions

Rhizosphere

- The zone of soil immediately adjacent to plant roots in which the kinds, numbers, or activities of microorganisms differ from that of the bulk soil (Sylvia, 1999).

The root environment zone that stimulates the growth of microorganisms that use root-derived compounds as sources of C, N, and energy.



Rhizosphere

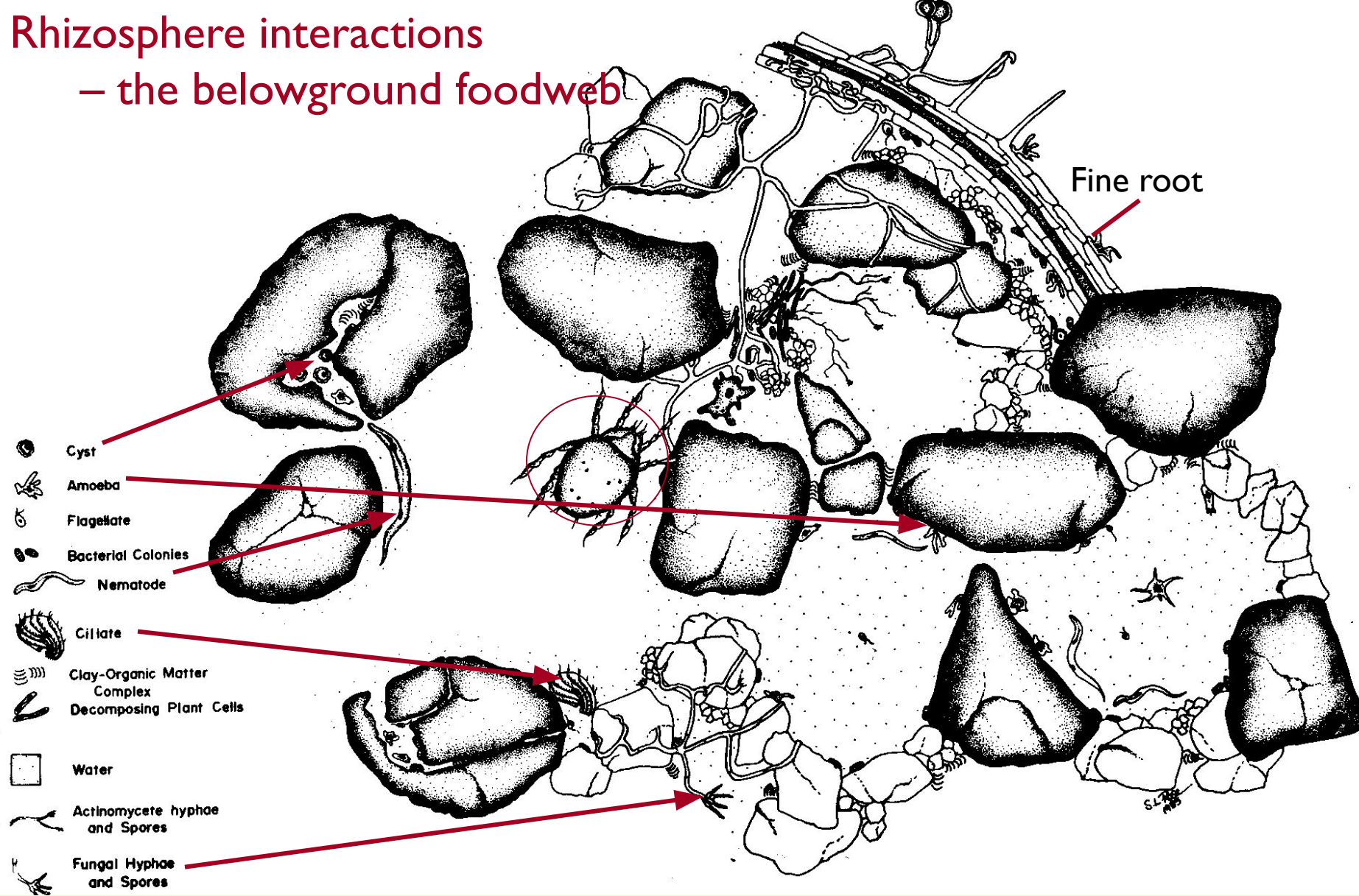
- The term was first used by Hiltner in 1904 to describe the zone of soil under the influence of roots.
- The area of increased microbial activity
- Can extend to more than **5 mm** from the root.
- The significance of the rhizosphere arises from the **release of organic materials** from the root and the subsequent effect of increased microbial activity on **nutrient cycling and plant growth**.

Rhizosphere

- “**bio-influenced zone**” - the portion of the environment with which an organism interacts (Hinsinger et al., 2008)
- Also considered as “**a hot spot of activity**” within soils and the ‘bottle neck’ of:
 - Supply of vital elements to sustain ecosystem productivity and integrity and food security

Rhizosphere interactions

– the belowground foodweb



Zone within 2 mm of roots – hotspot of biological activity

- Roots exude C & cells slough off = lots of goodies for soil microbes □ lots of microbes for their consumers (protozoans, arthropods)
- “Free living” N_2 -fixers thrive in the rhizosphere of some grass species

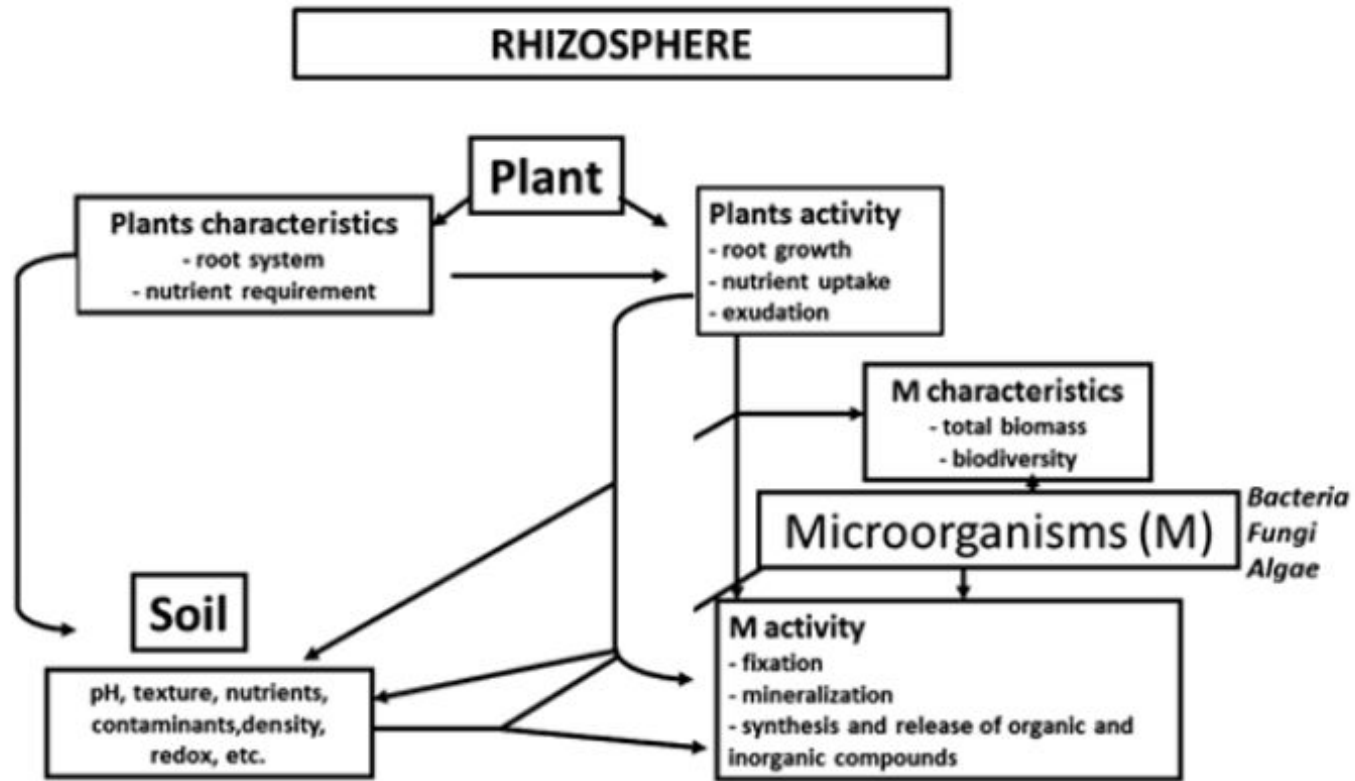


Figure 1. Description of rhizosphere and interactions occurring in it

Rhizosphere

- The physiological activities of all organisms in the rhizosphere will result in changes of soil parameters and processes that determine nutrients' availability.
- Bioavailability of nutrients varies from one species or even from one genotype to another within a single species, depending on plant ability to alter rhizosphere processes and properties.

Other areas in the plant-soil interface:

- **Spermosphere**: area of increased microbial activity around seed (imbibing, germinating) in soil - 1 to 20 mm zone.
- **Rhizoplane**: The surface of a plant root and any strongly adhering soil particle
- **Root**: The area inside the plant root. Microorganisms that colonize the inside of a plant root are called **endophytes**.
- *** Ectorrhizosphere and Endorhizosphere

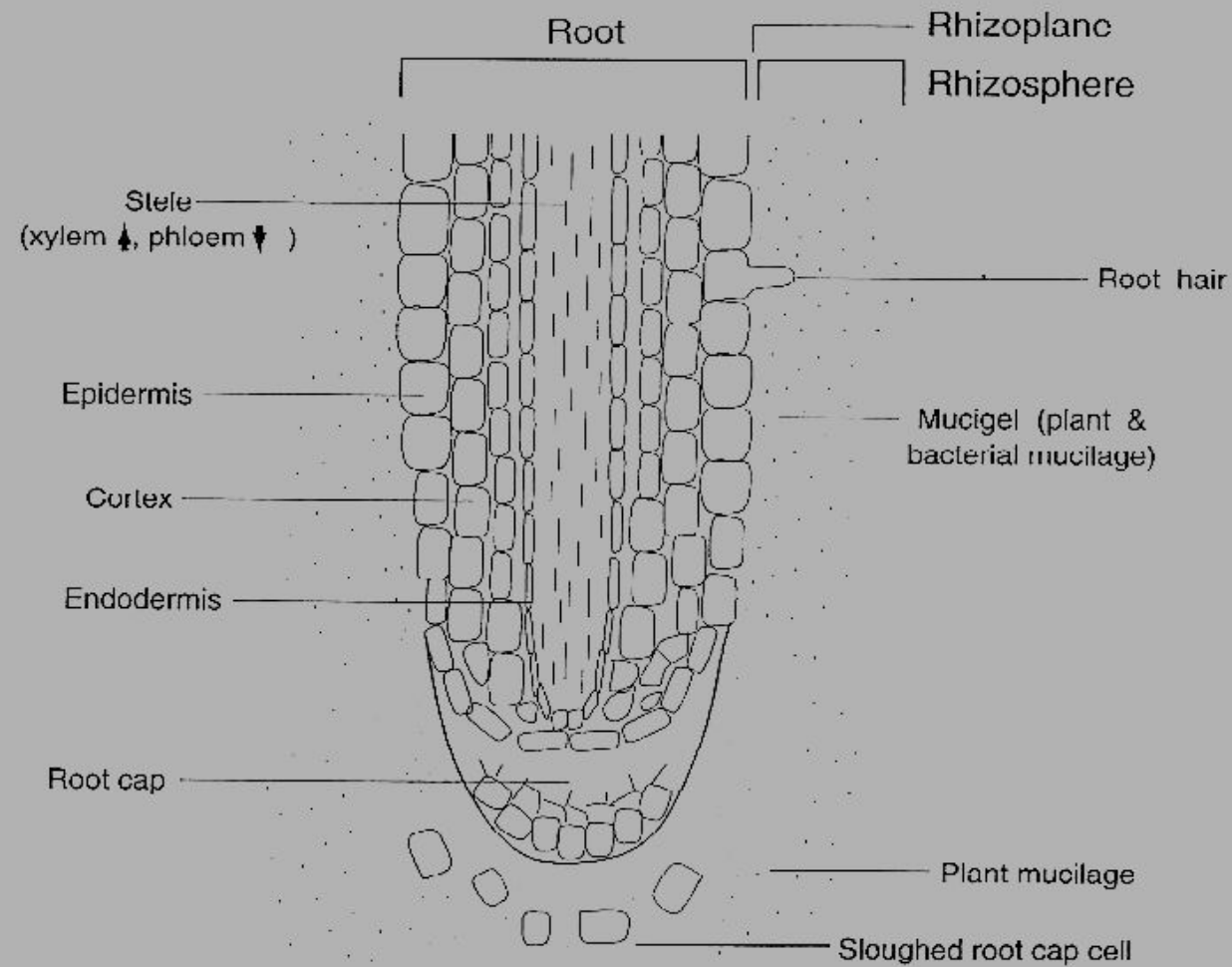
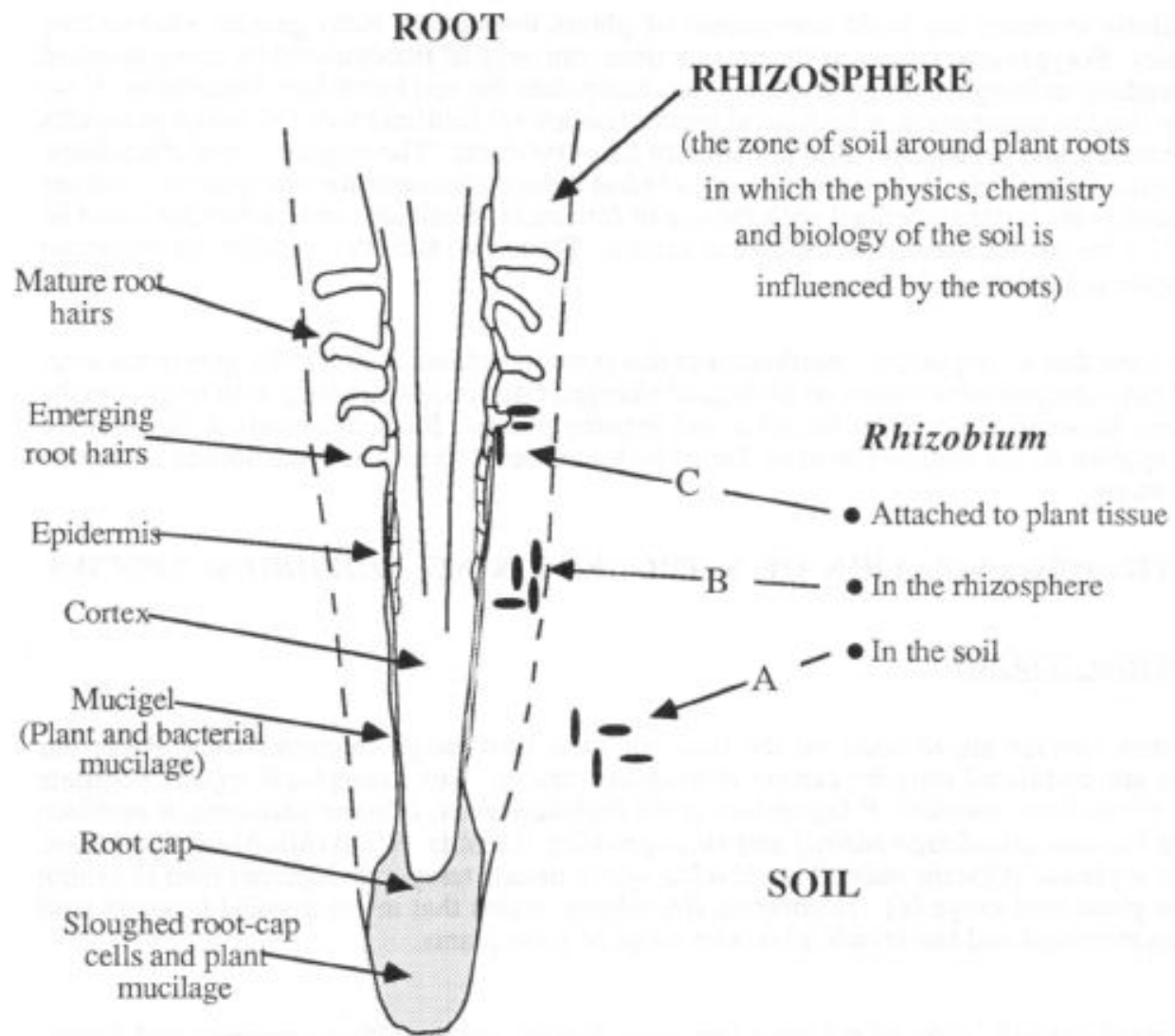


Figure 17-2 A root and corresponding rhizosphere and rhizoplane.



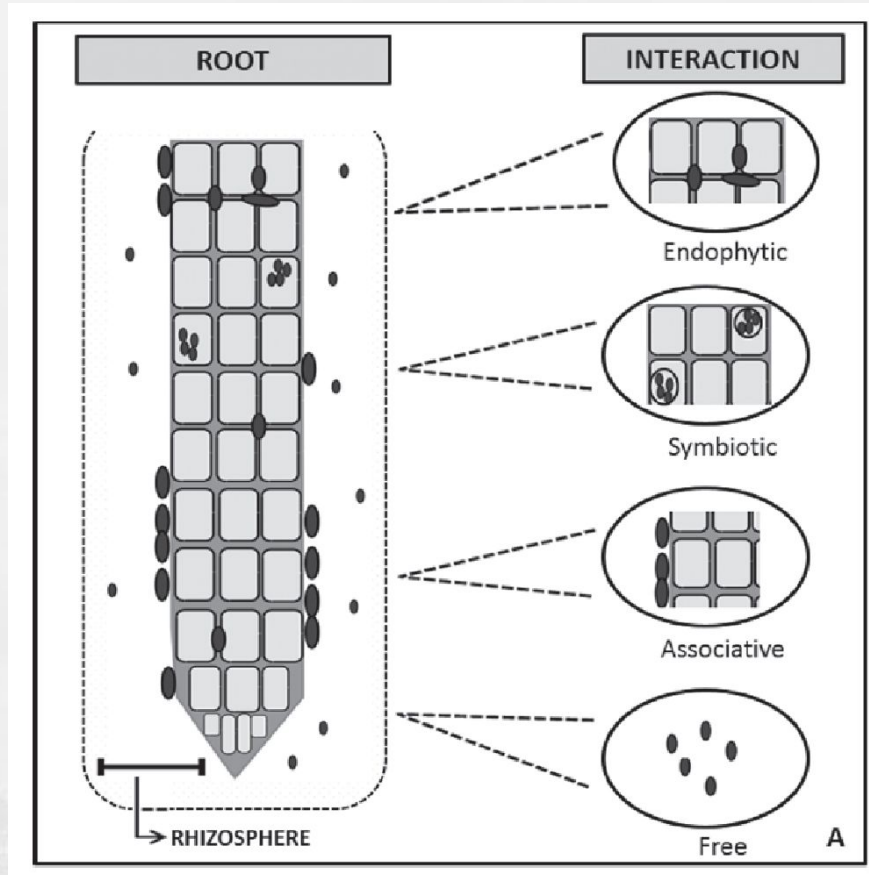
Beneficial microbe-plant interactions in the rhizosphere

- Various microbial interactions occur in the rhizosphere.
 - Beneficial, harmful or neutral
- Beneficial activities of microorganisms in the rhizosphere include:
 - ✓ Decomposition of plant residues and mineralization of nutrients.
 - ✓ Biological nitrogen fixation
 - ✓ Production of plant growth hormones
 - ✓ Biocontrol of pests
 - ✓ Increased nutrient availability through mycorrhizal associations

Plant Growth-Promoting Rhizobacteria (PGPR)

- Beneficial bacteria that colonize plant roots and enhance plant growth through a variety of mechanisms that include improvement of plant nutrition, production and regulation of phytohormones, and suppression of disease-causing organisms.

Types of plant-microbe associations



Different types of association between plant roots and beneficial soil bacteria

- Endophytic
- Symbiotic
- Associative
- Free-living

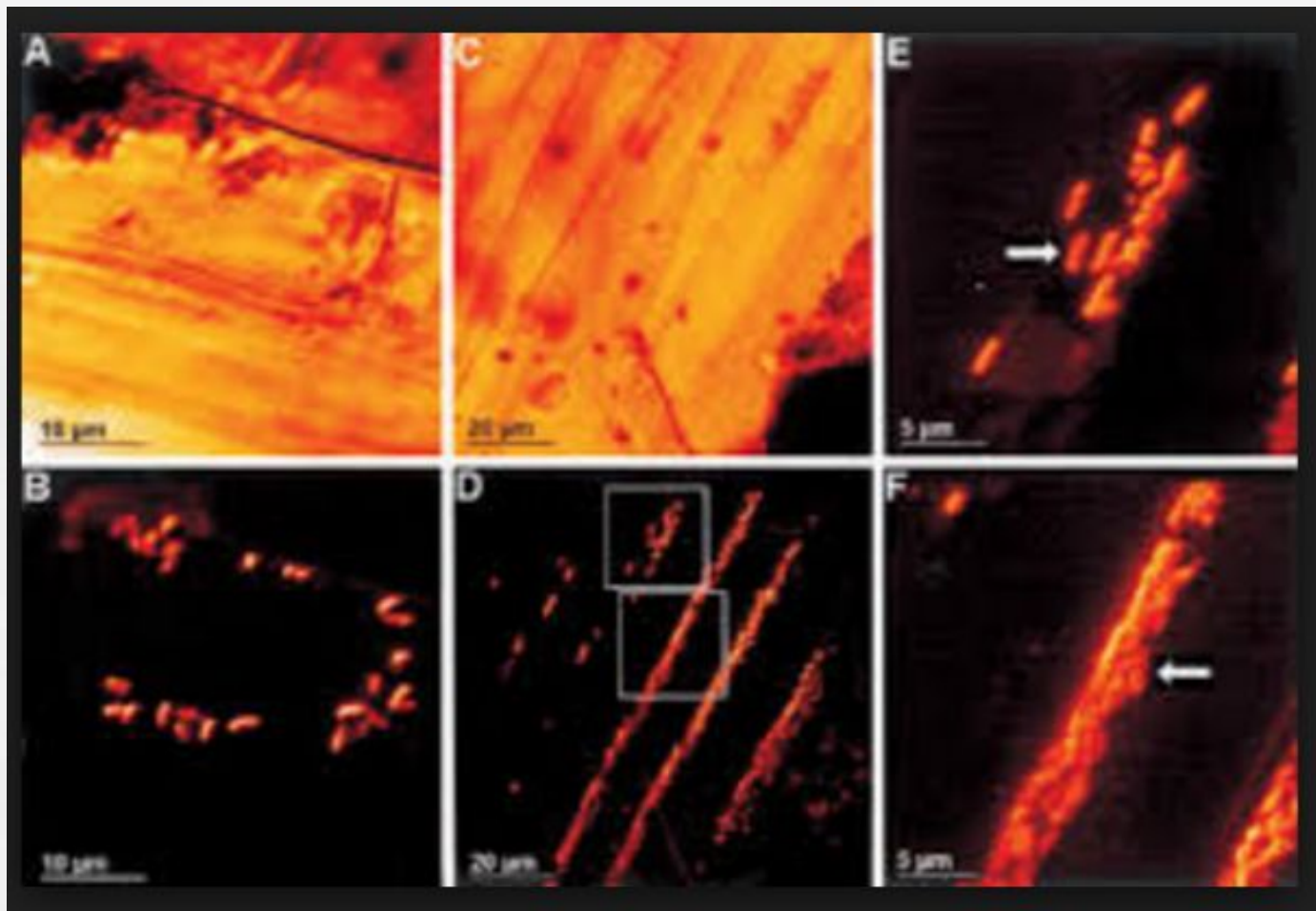


Fig. 3. Transmission and fluorescence images by CLSM of *Pseudomonas fluorescens* DF57 colonizing 7-day-old barley roots. Transmission image A and corresponding fluorescence image B show bacterial cells around the whole cell line of root epidermis. Transmission image C and corresponding fluorescence image D (including images E and F, which correspond to the areas indicated on image C) show a dense rhizoplane population of bacteria assembled in strings in the crevices between root epidermal cells. Dividing cells can be seen in images E and F (arrows).

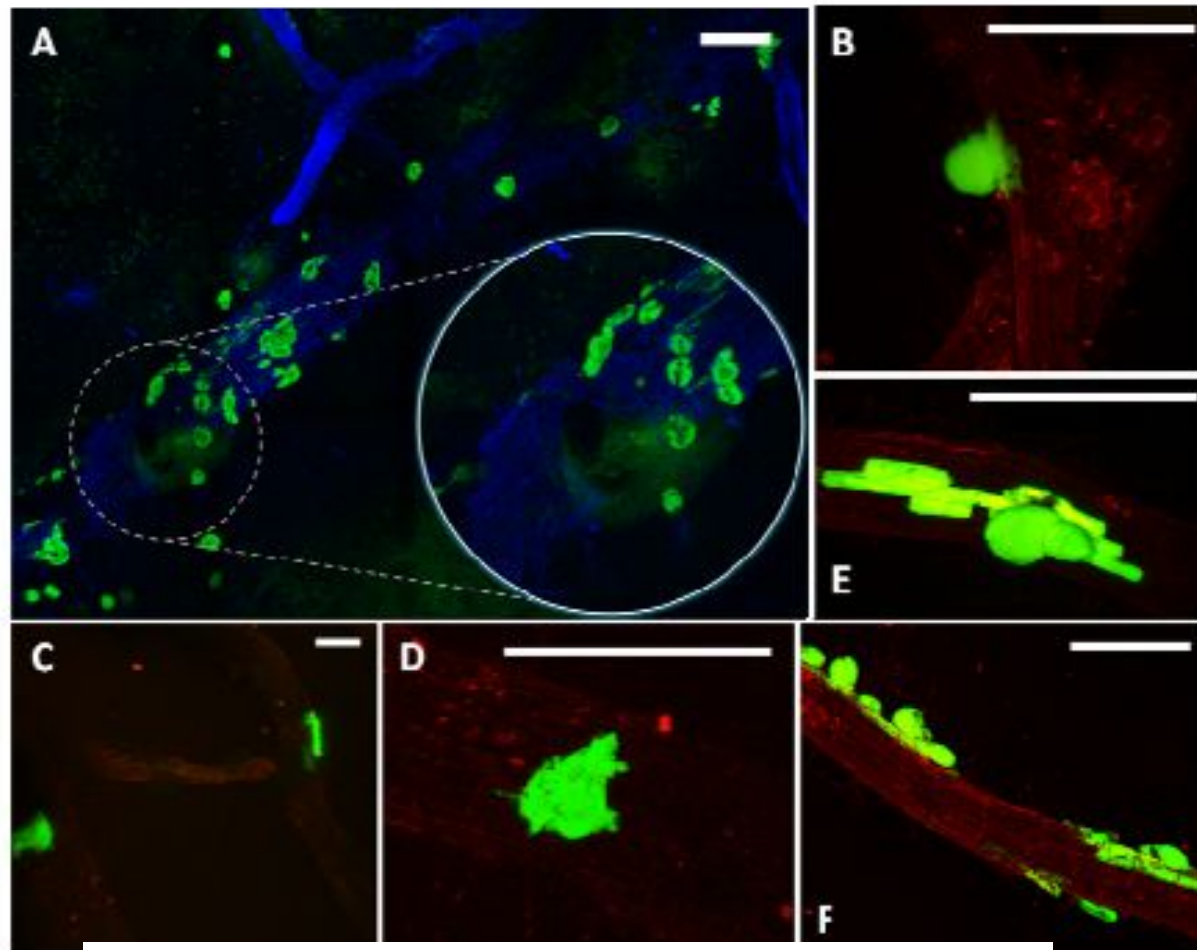
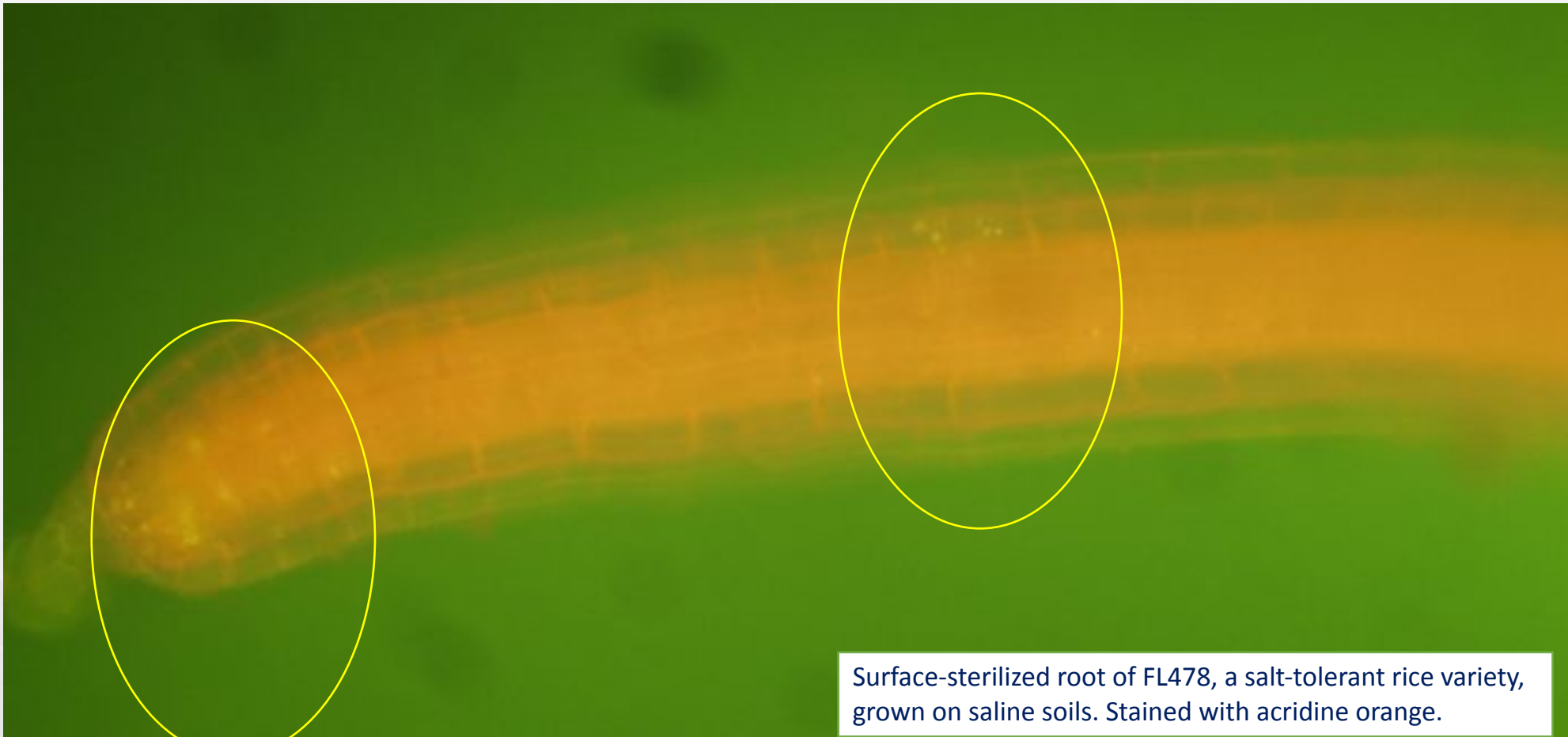


Figure 2. Colonization of potato roots by three different GFP-tagged bacterial strains. Images were obtained with Leica TCS LSI Macro Confocal. Green pseudocolor indicates the position of GFP-expressing mini-colonies. ((A), (B)) *Ochrobactrum* sp. A44 GFP. Figure A is a result of subsequent scanning of 6 fields of view, followed by automatic juxtaposition of the images. The preparation in figure A was stained with Fluorescent Brightner 28; ((C), (D)) *B. subtilis* MB73/2; (E, F) *Pseudomonas* sp. P482. Scale bar in (A-F), 500 μ m.



Source: Organo, 2013

Plant Growth-Promoting Bacteria (PGPB)

- Bacteria that can promote plant growth.
- Include bacteria that are:
 - Free-living or associative
 - Form specific symbiotic relationships with plants (e.g., *Rhizobia* spp. and *Frankia* spp.)
 - Bacterial endophytes that can colonize some or a portion of a plant's interior tissues
 - Cyanobacteria (formerly called blue-green algae)
- Mechanism could either be direct or indirect.

Direct mechanism of PGPB

- A. Resource Acquisition
 - a. Nitrogen fixation*
 - b. Phosphate solubilization*
 - c. Sequestering Iron
- B. Modulating phytohormone levels
 - a. Cytokinins and Gibberellins
 - b. Indole acetic acid (IAA)
 - c. Ethylene
 - d. ACC-deaminase

Indirect mechanism of PGPB

- ❖ Biocontrol
 - ✓ Production of antibiotics
 - ✓ Production of siderophores
 - ✓ Competition
 - ✓ Induced Systemic Resistance (ISR)
- ❖ Modulating the effect of environmental stress



Technologies Developed Through Research on Beneficial Plant-Microbe Interaction

Our Biofertilizer Technologies

Nitrogen =



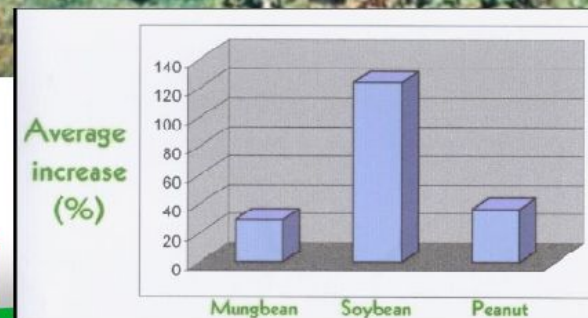
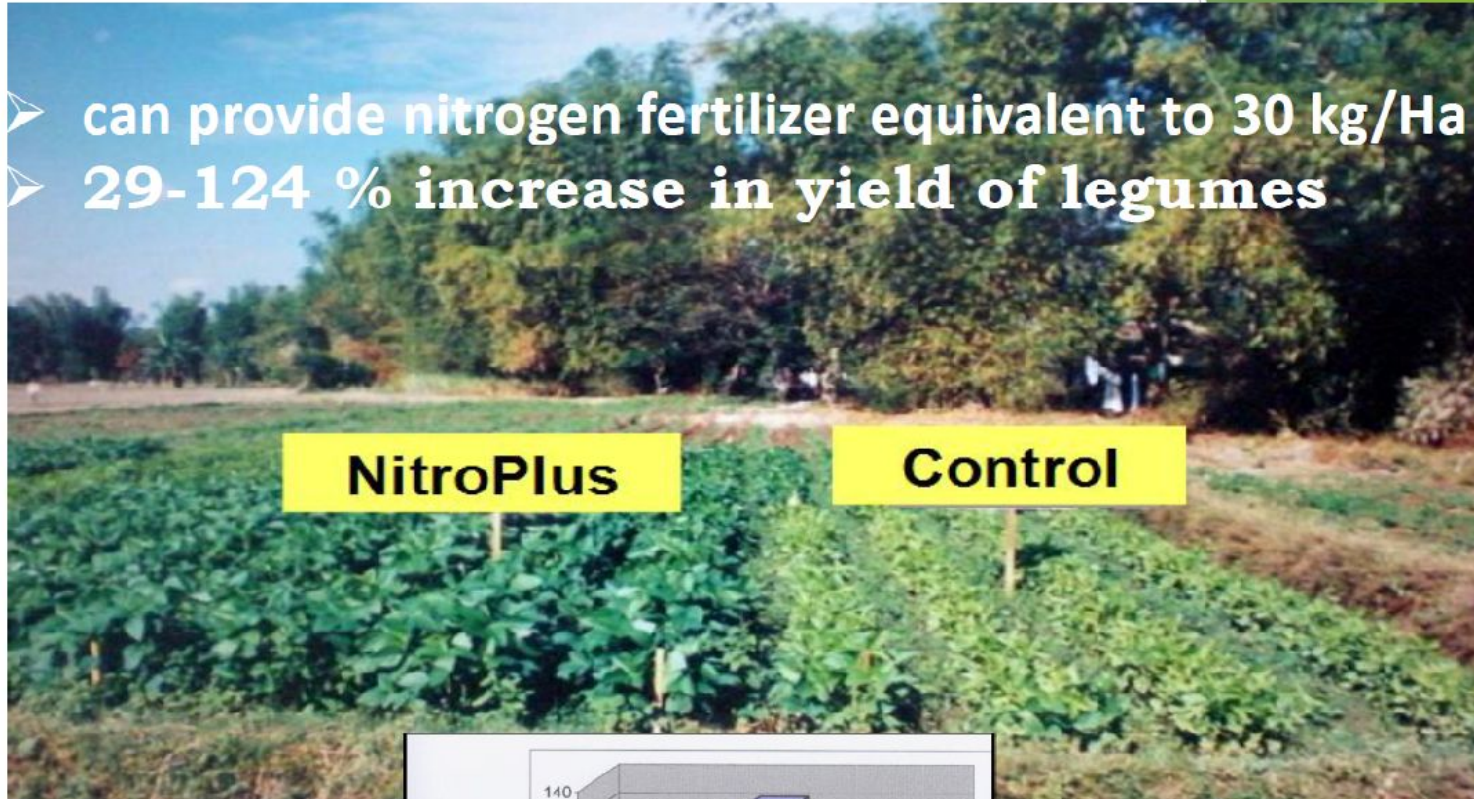
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Effect of NitroPlus on Soybean, Tarlac

- can provide nitrogen fertilizer equivalent to 30 kg/Ha
- 29-124 % increase in yield of legumes



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Taken from the presentation of Dr. Pedro, resource person

BIO-N FOR RICE



W/o BIO-N

With BIO-N



W/o BIO-N

With BIO-N



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Taken from the presentation of Dr. Pedro, resource person

Recent research initiatives: Endophytes



Value Proposition

Treatment	Ton cane/ha	Lkg/Tc	Lkg/ha	% Increase in Lkg per Ha
RRF	173.9	1.5	262.6	-
1/2RRF	148.2	1.5	219.8	-
1/2 RRF + Nutrio	155.7	1.7	261.6	19

Source: Dr. Virginia M. Padilla, 2018



Taken from the presentation of Dr. Pedro, resource person

Our Biofertilizer Technologies

Phosphorus =



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PHOSPHOFER

Phosphate Solubilizing Bacteria



Sampaguita



Control

C

BioGroe

Effect of BioGroe on the propagation of sampaguita at 4 weeks after planting.

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Industrial Development of Biofertilizer & Biopesticides in Thailand

Current status:

Biofertilizer

18 products

- PGPR
- PSB
- Blue green algae

Biopesticides

14 products

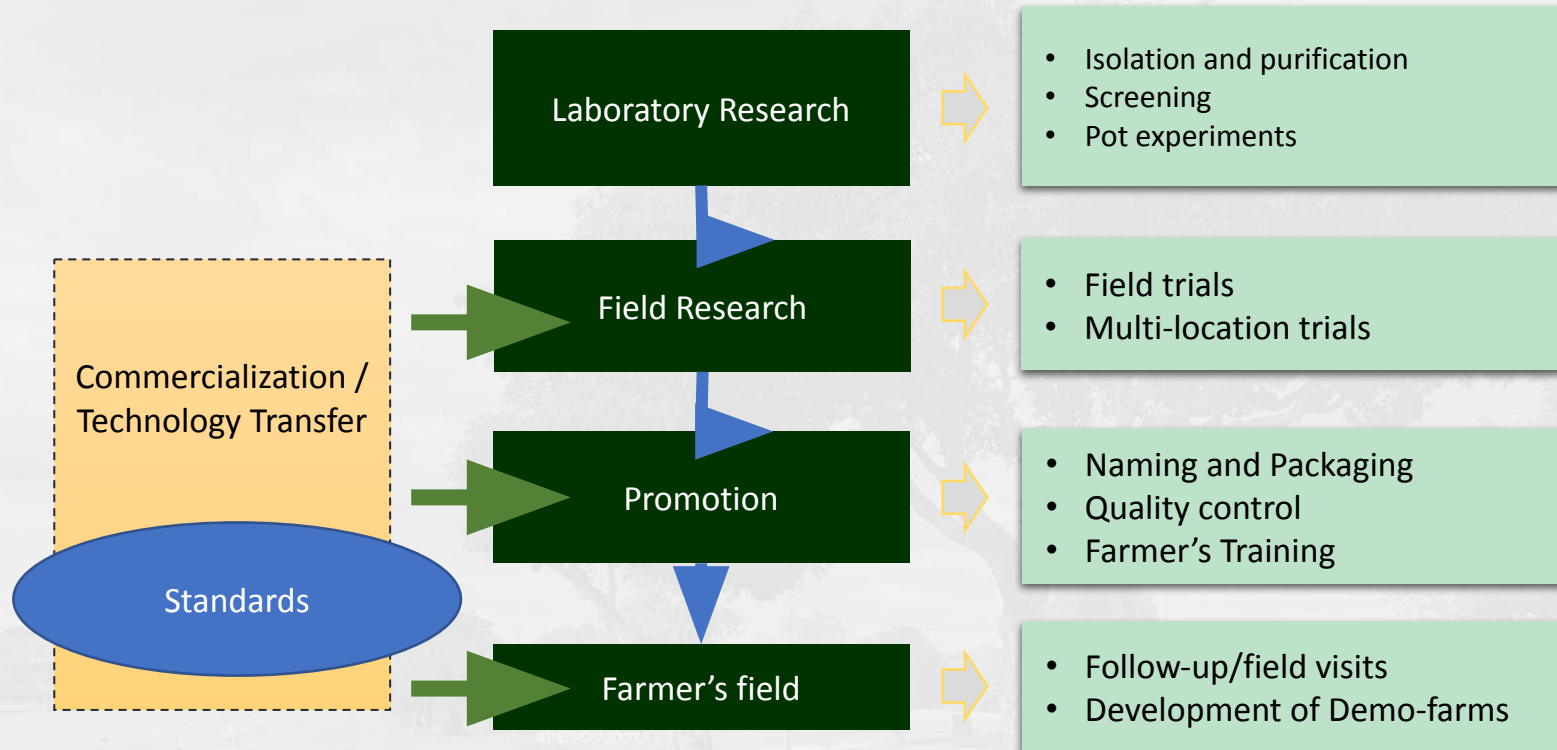
- Neem
- *Beauveria bassiana*
- *Metarhizium anisopliae*
- *Bacillus thuringiensis*



Biofertilizers product in Vietnam



Major Activities in the Development of Microbial Inoculants



Thank you!



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Questions and Clarifications

