What is SumaGrow

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What is SumaGrow?

- Unique, synergistic consortium of native soil microbes compatible with soil ecosystem
- Enhances productivity of a broad spectrum of food, fodder, and vegetable crops
- Multiple beneficial functions including N_2 fixation, PO_4 solubilization, biocontrol, and higher cation exchange capacity
- Consistent with sustainable agriculture by reducing chemical fertilizers & pesticides

What is Sustainable Agriculture?

- Sustainable agriculture systems are designed to produce abundant food, feed, and fodder without depleting the earth's resources or polluting its environment.

- No agriculture is sustainable if it's not also profitable.

Sustainable Agriculture is Key to Alleviation of World Food Crisis

- Rapidly growing population (7 billions now and projected to be 9.3 billions in 2050).
- Need to raise world food production by 110% in the next forty five years
- Traditional approach of increasing food production using high amounts of chemical fertilizers and pesticides is not practical: 1. dwindling fossil fuel resources; 2. increasing costs; 3. adverse environmental consequences; 4. growing concern about global warming; and 5. decreasing arable land.
- Need for energy efficient and eco-friendly product

Primary Research Objective

- Stable, efficacious, and eco-friendly polymicrobial formulations
- Diverse groups of microbes with complementary functions
- Enhance productivity of a broad spectrum of plants: legumes, non-legumes, vegetables, cereals, ornamentals, and fodder crops
- Lowered input of nitrogen fertilizers and phosphate fertilizers and chemical pesticides

Soil Microbes: Magnitude

- 1 gram of soil contains:
  - **> 1 billion bacteria; 13,000** species
  - > 15 million Actinomycetes
  - > 0.5 to 1 million fungi
- Bacteria and Actinomycetes = half of soil biomass
- Bacteria/acre of soil weigh as much as a cow.

  10 g of soil has>bacteria than earth's population

  2 acre plot of wheat would have more than 30,000 miles of roots (> than earth's circumference)
- ***"We know more about the movement of celestial bodies over our head than about soil under feet"***

Importance of Soil Microbes

- Key role in soil fertility and crop yield
- Practically every important chemical trans-formation in soil occurs because of microbes
- Increase N availability to plant by fixing N_2
- Increase phosphorus (P) availability
- Produce vitamins/hormones [phytostimulants]
- Biocontrol agents -inhibit pathogens by competing for nutrients or by direct inhibition
- *[Note: 75% soil organisms are in the top 2" of soil]*

Soil Bacteria

- High diversity: adds to stability, productivity, and sustainability of soil
- Diverse metabolic activities
- Key role in degrading soil organic matter
- Both AEROBIC and anaerobic microbes
- Most grow between 70 to 100° F
- Grow best between pH 6 to 8 (neutral soils)
- Produce extracellular compounds that help bind soil particles into aggregates

Soil Actinomycetes

- Filamentous bacteria intermediate between bacteria and fungi
- Active in organic matter decomposition
- Streptomyces amount to 90% of Actinomyces
- Produce antibiotics; Inhibit pathogens in soil
- Abundant in neutral to alkaline soils
- Produce compounds that give soil its distinctive aroma

Soil Fungi

- Important contributors to soil biomass
- Obligate aerobes
- Thrive in well-drained, neutral to acidic soils
- Key role in organic matter decomposition
- Nutrient cycling
- Key role in degrading recalcitrant environmental pollutants
- Important in inhibiting plant pathogens

MYCORRHIZAE

- Myco=fungus; rhizo=root; Fungi with mutualistic relationship with the roots of most plant species
- Plant provides carbohydrates to the fungus; fungus helps the plant in uptake of water & nutrients
- Smaller in diameter than the smallest root; form mycelial network providing a large surface covering wider soil area
- Especially beneficial to plant in nutrient poor soils (barren soils)
- Absence of mycorrhizae decreases plant growth
- 2 Major groups: Ecto- and Endo-mycorrhiza
- Association with about ~3000 plant species

A picture of mycorrhizae on an evergreen seedling. Mycorrhizal filaments can explore volumes of soil hundreds to thousands of times greater than roots themselves.

Rhizosphere and Rhizobacteria

Rhizosphere

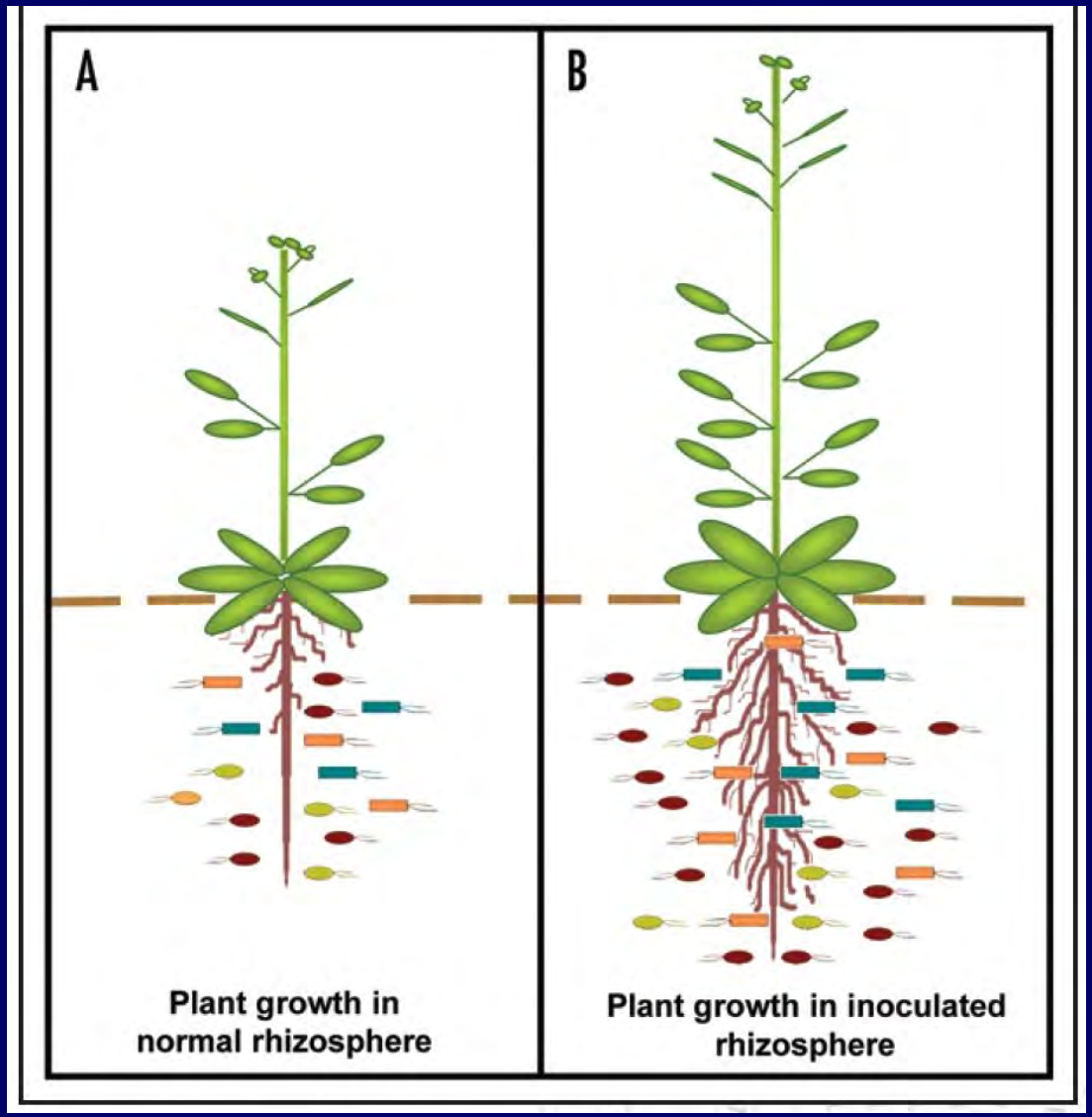
The region around the root rich in nutrients. Almost 40% of the plant photosynthate leaks from the roots.

Rhizobacteria

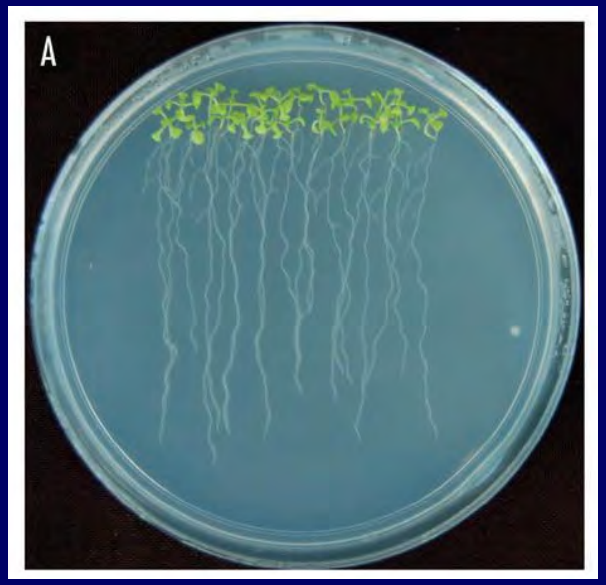
Complex diverse microbial population in rhizosphere.

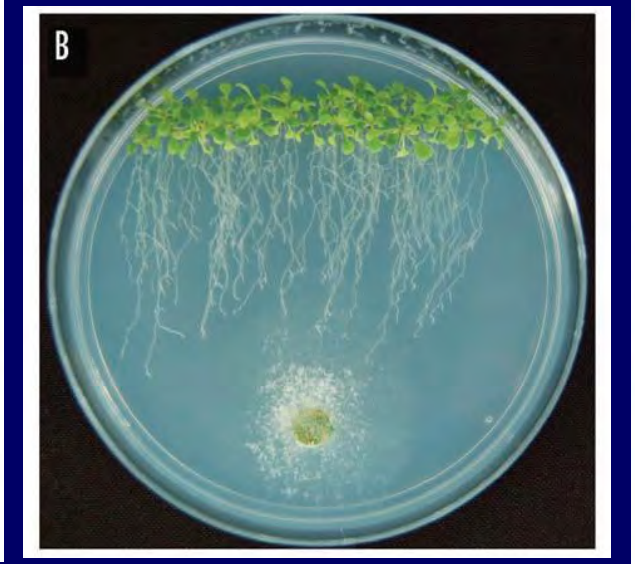
- Contribute to root health
- Important role in making N and P available to the plant
- Important in nutrient uptake by the plant
- Resistance to environmental stress
- Protect plant against pathogens

Rhizosphere modification improves plant productivity



Plant-microbe interactions: Arabidopsis thaliana





Control

T. atroviride

B. megaterium

Enhancement of plant growth by Microbes
(PGPR=plant growth promoting rhizobacteria)

- Fixing of atmospheric nitrogen (N_2)
- Solubilization of insoluble phosphates and make phosphorus available to the plant.
- Direct (or indirect) protection against plant pathogens
- Induce systemic resistance to plant pathogens
- Synthesis of plant growth regulators such as auxins, cytokines, and gibberlins.
- Production of siderophores that chelate iron and make it available to the plant.
- Direct enhancement of mineral uptake by influencing ion fluxes at the root surface.
- Help uptake of manganese, zinc, etc.
- Amenable to genetic manipulation to increase effectiveness

Polymicrobial Inoculants

- Multiple functions and multiple modes of action in enhancing plant growth
- Major contributions to N , P, and various minerals such as manganese, zinc, etc
- Applicability to wider range of crops
- Protection against multiple fungal pathogens
- Give the product more stability and more consistency in action
- Effectiveness enhanced via molecular techniques

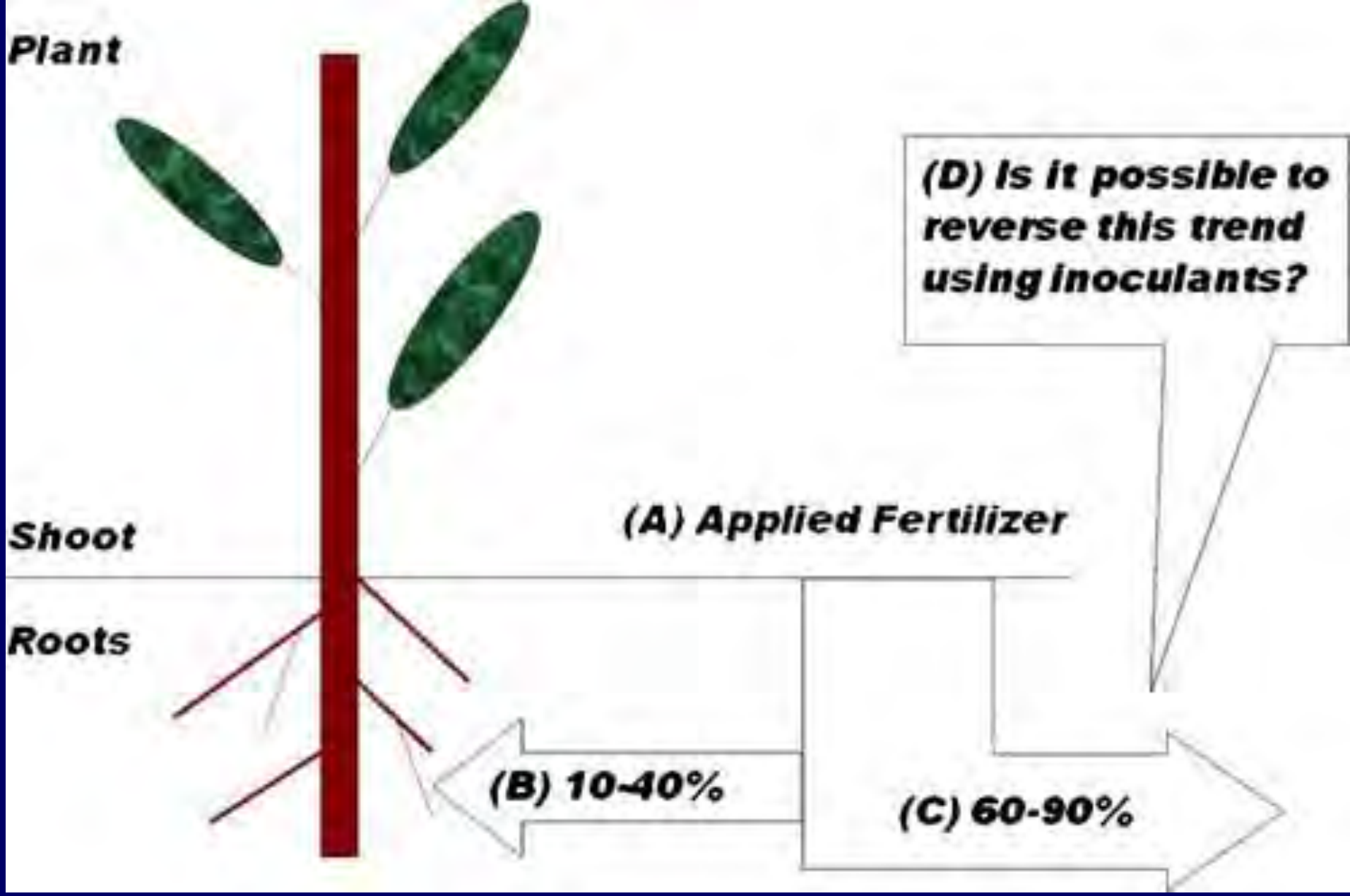
Problem with Chemical Fertilizers

- High levels of nitrogen fertlilizers needed for increasing food production
- Record high costs of nitrogen fertilizers due to high global demand and skyrocketing costs of fossil fuels
- Increased global warming from the burning of fossil fuels
- Adverse environmental consequences due to leaching of excess nitrogen

Urea as Fertilizer

- Urea → NH_4 → **NO_3**
- Overloading plant capacity to utilize
- High leaf NO_3 - more prone to disease and insects
- ~50% of NO_3 loss via N_2 and leaching
- Conversion to toxic NO_2 (proven carcinogen)
- N_2O is toxic and is a potent green house gas
- Adverse impact on soil health
- Incompatible with sustained agriculture

Note: N supplied by N_2 fixation is directly delivered to the plant; no wastage by leaching; more efficient utilization to the plant.



Odesemoye and Kloepper - Appl. Microbiol. Biotechnol (2009)

Biological N Fixation: Importance

- Plants are surrounded by unavailable N_2
- Converting N_2 gas in the atmospheric air into a form that is utilizable by the plants.
- Global biological nitrogen fixation- 175 million metric tons of N per year (Hubbel and Kidder, 2003).
- N_2-fixing bacteria - nano factories converting unavailable atmospheric N to plant available form
- N_2-fixation evolved about 60 million yrs ago.
- Symbiotic nitrogen fixation - 70%

  Non symbiotic - 30%

Microbial N_2 Fixation*

$$N_2 + 8\,H^+ + 8\,e^- + 16\,ATP \longrightarrow$$

$$2\,NH_3 + H_2 + 16ADP + 16\,Pi$$

* *25 – 30% of the photosynthate of the plant may be invested into symbiotic N fixation process.*

* *Inexpensive and Compatible with sustainable agriculture*

* *SumaGrow is a success story in this aspect.*

Nitrogen fixing bacteria

1. Symbiotic N_2 fixing Bacteria

   Rhizobiales

2. Free-living N_2 fixing Bacteria

   A. Soil dwelling species

      e.g. *Azotobacter*

   B. Live inside the plants (endophytic)

      e.g. *Azospirillum*

Symbiotic Nitrogen Fixers

Rhizobial group of bacteria [*α-subgroup of Proteobacteria*] play a key role in symbiotic nitrogen fixation (250 to 500 lbs per acre)

- ***Rhizobium***
- ***Azorhizobium***
- ***Allorhizobium***
- ***Bradyrhizobium***
- ***Mesorhizobium***
- ***Sinorhizobium*** **(*Ensifer*)**

Non-rhizobial Nitrogen Fixers

- *Azotobacter*
- *Paenibacillus*
- *Phosphobacter*
- *Acetobacter*
- *Azospirillum*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Synthetic N *vs.* N fixed by Microbes

	Synthetic N	N_2 fixed by Microbes
N efficiency to plant	50%	>95%
N loss by leaching	High	Non-issue
Cost Effectiveness	Low	Very high
Soil Health	Negative	Positive
Sustainability	Poor	Excellent

Amount of nitrogen fixed per acre by several legume Crops

Crop	Estimates of nitrogen fixed/acre (lbs)	
	Low	High
Alfalfa	44	308
Cowpeas	44	132
Dry beans	50	150
Garbanzo beans	25	81
Peas	53	305
Soybeans	53	265

Phosphorus (P) and plant nutrition

- P is one of the most important nutrient elements needed for increasing crop productivity
- >80% of the P in soils are in the insoluble form and not available to the plant
- Phosphate fertilizers are expensive and require fossil fuel energy sources for manufacture
- Phosphate-solubilizing microbes in soil play a key role in increasing crop productivity by making P available to the plant
- *Repeated injudicious application of P fertilizers leads to surface runoff of the excess P and loss of soil fertility and eutrophication of aquatic systems.*

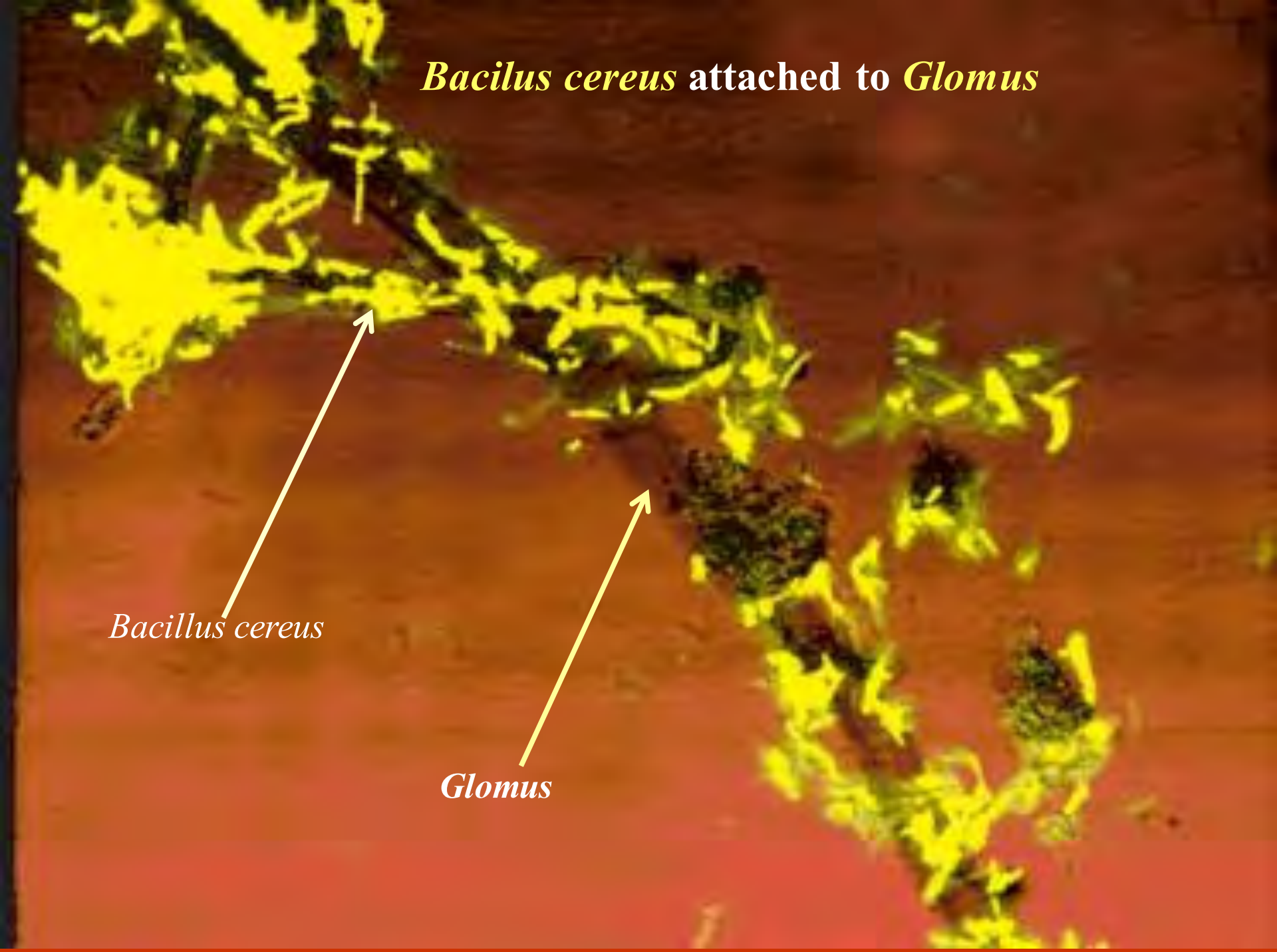
Mechanisms of Phosphate-Solubilization by Microbes

- Production of organic acids: oxalic, citric, succinic, and gluconic acids
- Lowering of pH by proton pumping mechanisms that accompany NH_4 production.
- Release of phosphates from organic compounds by phosphatases and phytases.
- Chelation of cations bound to phosphates

Phosphate-Solubilizing Microbes*

- Phosphate-solubilizing bacteria: *Pseudomonas*, *Bacillus*, and other genera.
- Phosphate-Solubilizing fungi: *Aspergillus, Trichoderma, Penicillium,* and other genera.
- Phosphate-Solubilizing mycorrhizal fungi: Widely distributed in this group. Important contributors to Phosphate solubilization in soils.

* *A number of bacteria and fungi in this group are also good biocontrol agents and provide key micronutrients such as Mn, Zn, and Fe important for growth and disease resistance.*


Bacilus cereus attached to *Glomus*
Bacillus cereus
Glomus

Vesicular Arbuscular Mycorrhizae (VAM)

- Help better uptake of P; others
- Help efficient uptake of Nitrogen
- Synergistic effect with various PGPR
- Biocontrol properties

Difficulties

- Inhibited at > 100 ppm P in soil
- Difficult to grow in vitro
- Poor understanding of the genetics

Problems with Chemical Pesticides

- Wide use of pesticides for controlling plant diseases
- High costs because of great demand
- High levels of pesticides in the environment because of their recalcitrance to degradation
- Not eco-friendly as they kill beneficial insect pollinators & predators
- Leaching of pesticides contaminate ground water
- Toxic to humans/animals in very low amounts
- Intensive search is on for biopesticides which are safe, cost-effective, and eco-friendly and contribute to the goal of sustainable agriculture.

Biocontrol Agents/Biopesticides

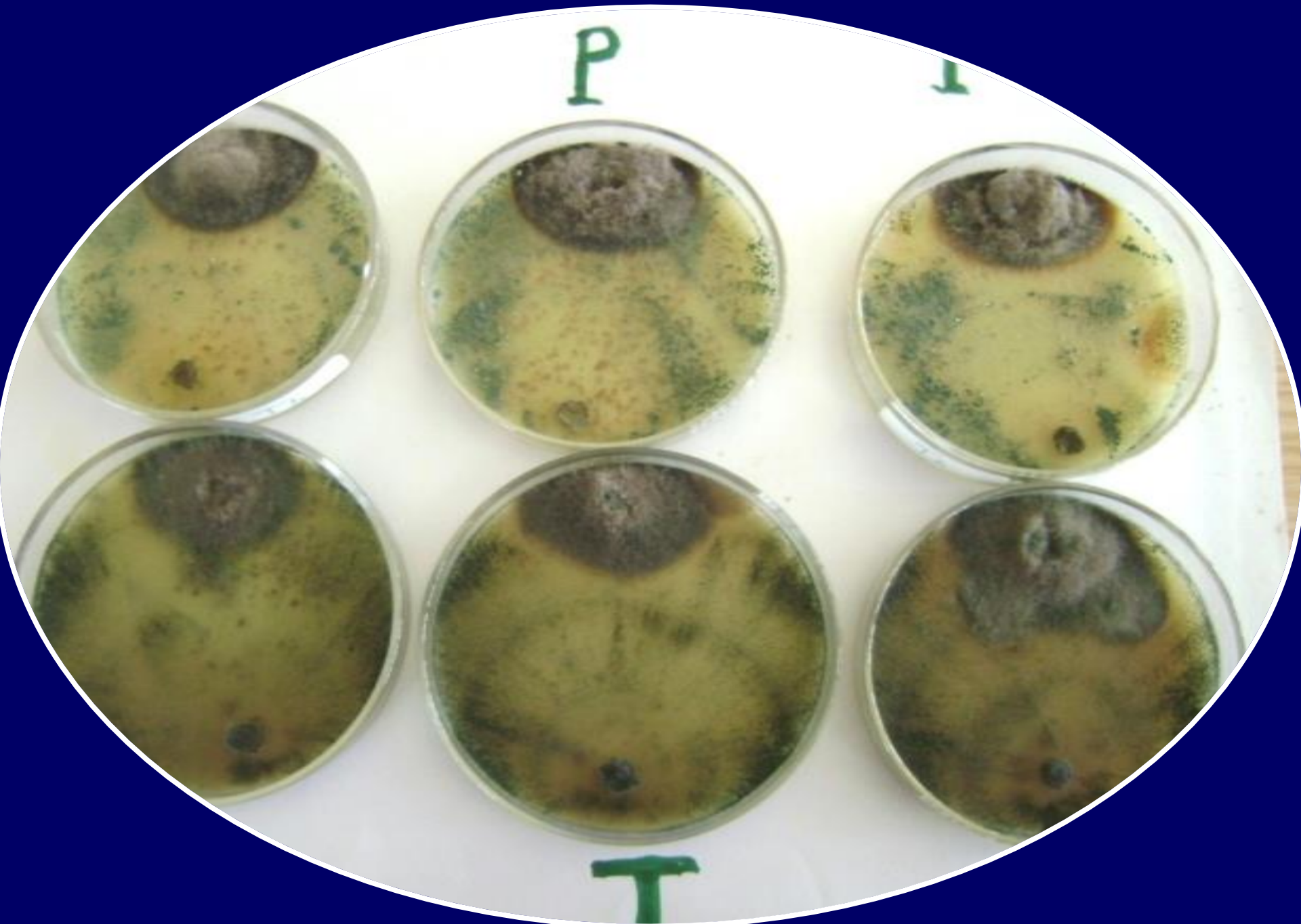
- Naturally occurring non-pathogenic bacteria and fungi that inhibit pathogenic fungi, bacteria, nematode and small insects.
- Excellent root colonizing ability and produce a wide range of beneficial metabolites
- Safe, Cost-effective, Eco-friendly and contribute to the goal of sustainable agriculture

Trichoderma

- Free living and fast growing fungi in most soil and root ecosystems.
- Inhibit a broad spectrum of root pathogens and foliar pathogens
- Promote plant growth by phosphate solubilization, and production of phyto-hormones and other growth promoting compounds.

Trichoderma

- Ubiquitous group of soil fungi
- Increase crop productivity
- Parasiticize some plant pathogenic fungi (Mycoparasitism)
- Well known from biocontrol perspective
- Produce antibiotics and lytic enzymes
- Contributes to P nutrition of the plant
- Enhances root growth development
- Induces better root nodulation
- Confers resistance to abiotic stress.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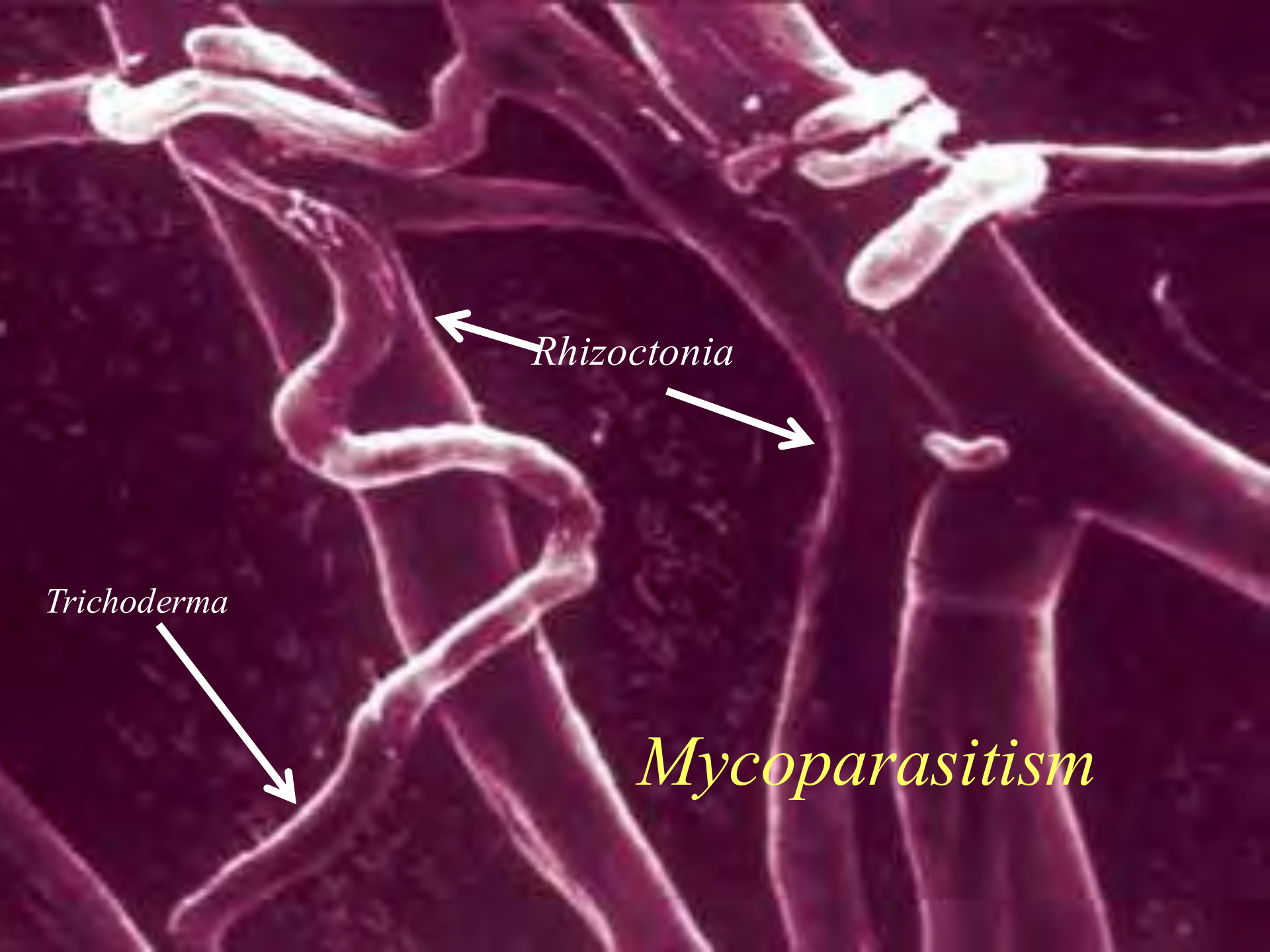
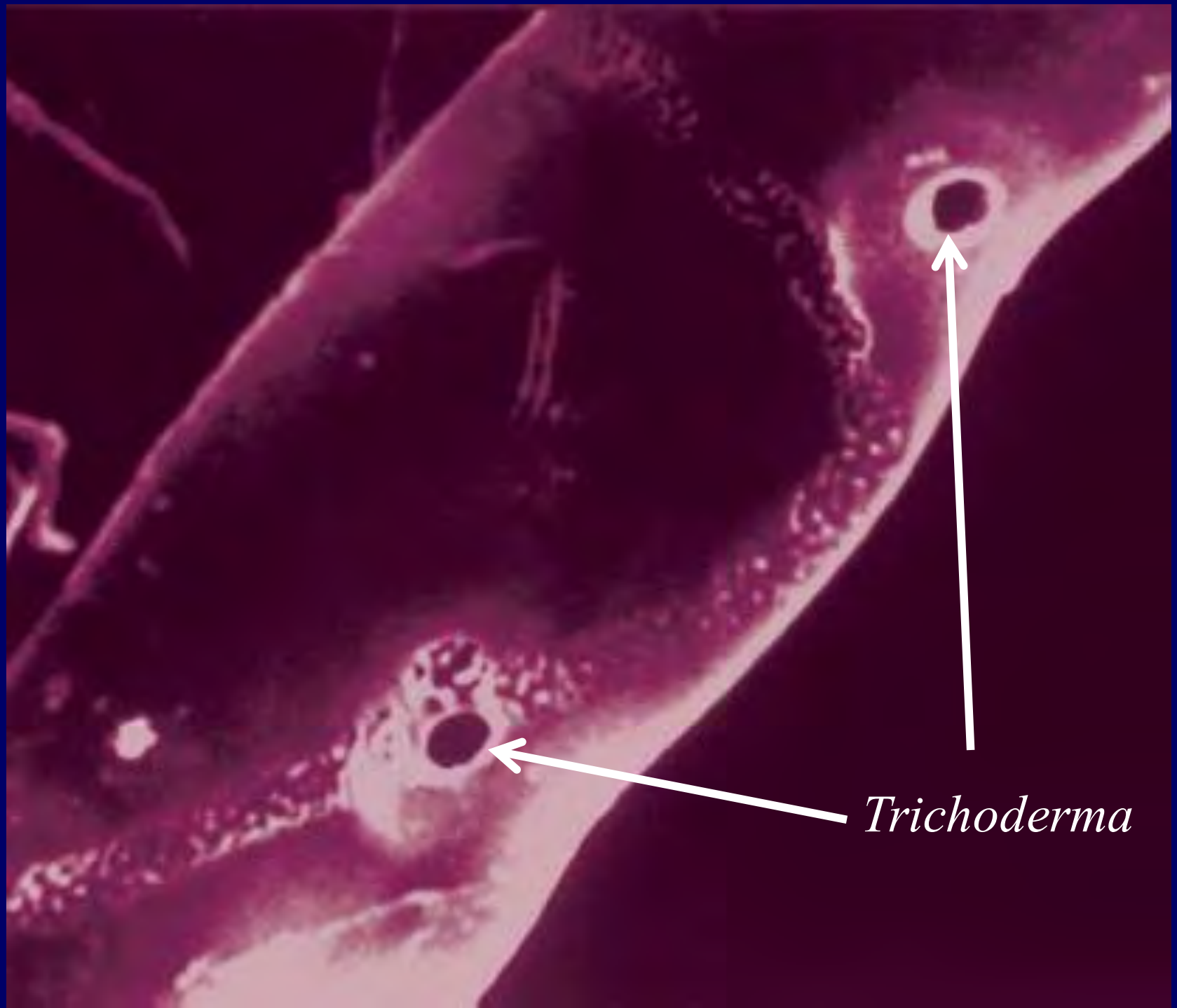

Rhizoctonia
Trichoderma
Mycoparasitism


Trichoderma


Trichoderma

Functional Microbial Groups Targeted

- Nitrogen Fixers
- Direct or Indirect inhibitors of plant pathogens
- Phosphate Solubilizers
- Producers of phytohormones and/or other plant growth promoting substances
- Inducers of systemic resistance

Isolation of Soil and Root Nodule Bacteria

- *Massing and Crushing of Root Nodules*
- *Serial Dilution of Crushed Nodule Fluid*
- *Spread and Pour Plates*

Functional Characterization

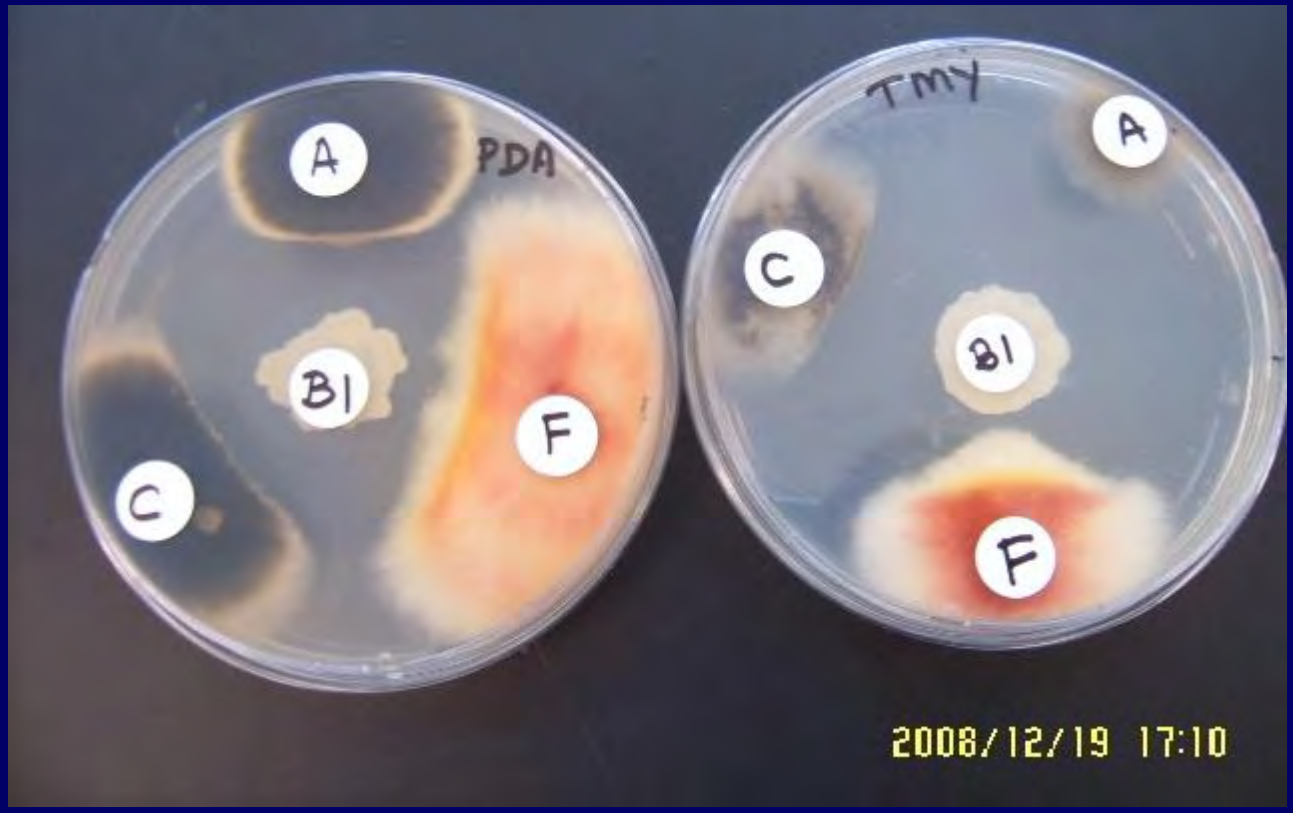
- *Morphology*
- *Cultural*
- *Nitrogen Fixation*
- *Phosphate Solubilization*
- *Bio-Control*

Polymerase Chain Reaction (PCR) of 16S rRNA Gene

Sequencing and Alignment of 16S rRNA using NCBI Blast

***2 Formulations**: Sumagrow1 and Sumagrow 2*

In-vitro screening of a bacterial isolate for biological control




P-SOLUBILIZATION

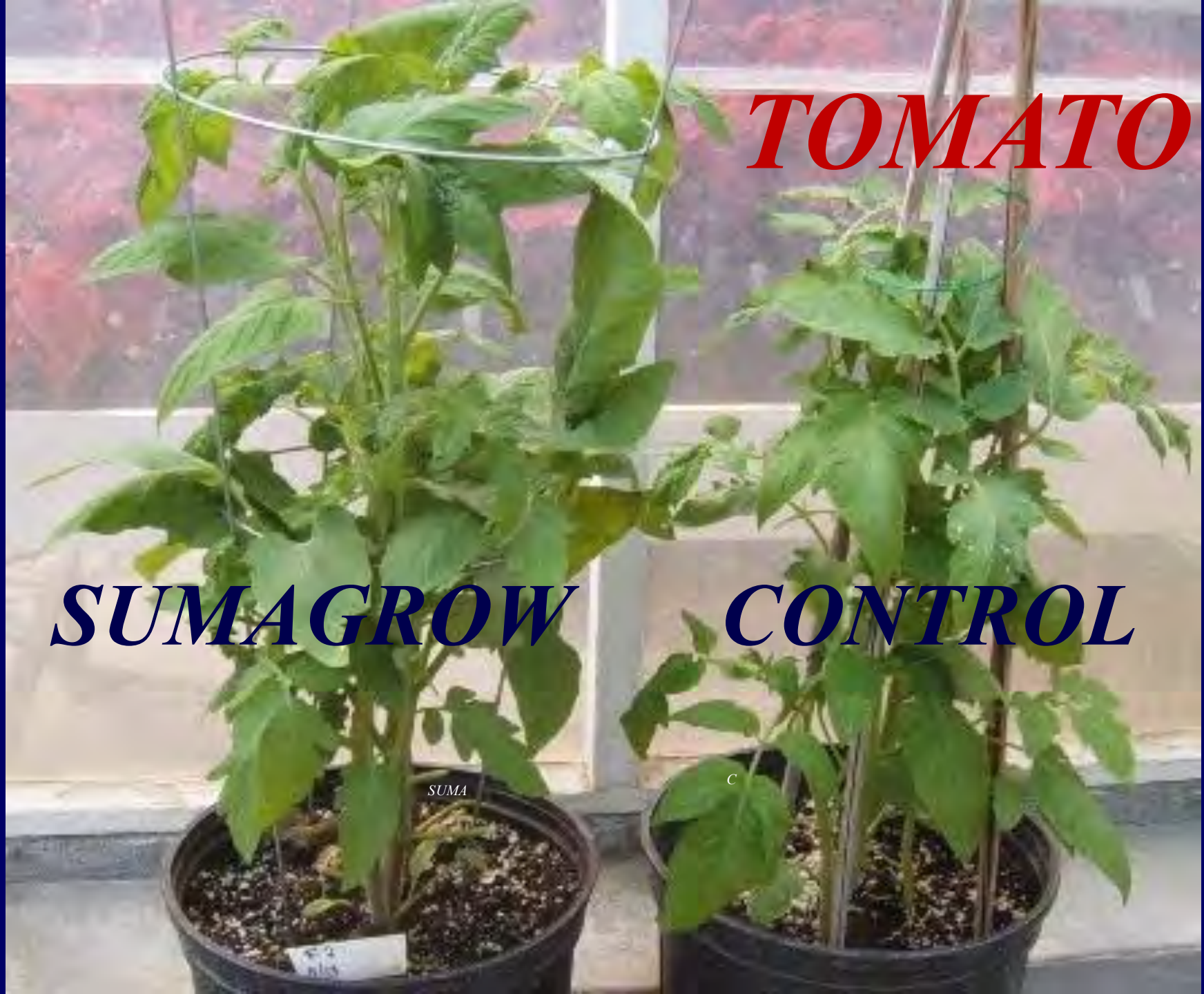
Experimental Design

- Randomized block design with four replications per treatment.
- Statistical validation of the significance of enhancement in productivity
- Effect of SumaGrow on crop productivity was compared to a control containing humate alone.
- No exogenous fertilizer or pesticide was added in these experiments.

RESULTS

Green House Experiments


SOYBEAN
SUMAGROW
Control


TOMATO
SUMAGROW
CONTROL
SUMA
C

Wonderbush Beans

Clover

CLOVER

NPK 50% COMPARED WITH SUMAGROW

SUMAGROW ENHANCES FORAGE MIX

Switch grass – Cave in Rock

Green House Evaluation of SumaGrow

Crop	Yield (g)*	
	SumaGrow	Control
Rice	20.8	5.2
Tomato	1900.0	380.0
Soybean	11.8	5.1
Pea	14.0	7.5
Okra	138.7	38.7
Peanut	21.6	6.5
Garden beans	48.6	23.5
Wonderbush beans	72.9	35.6

SumaGrow: Summary

- Remarkable Biofertilizer
- Completely Green Technology
- Synergistic and stable mixture of > 20 specifically selected soil microbes
- Provide multiple functions for increasing growth of a broad spectrum of plants

SumaGrow is Multifunctional

Single Product Provides 5 Major Functions

- Enhance nitrogen availability
- Enhance phosphorous availability
- Enhance innate plant resistance
- Inhibit plant pathogens
- Produce plant growth stimulants

SumaGrow: Advantages

- Reduces the need for chemical fertilizers
- Reduces/eliminates the need for chemical pesticides
- Reduces the cost of food production
- Reduces potential health and environmental hazards associated with heavy use of chemical fertilizers and pesticides


THANK YOU