NAME OF THE COURSE WORK
ENVIRONMENT & AGRICULTURAL MICROBIOLOGY

UNIT-V
SUSTAINABLE AGRICULTURE

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What is agriculture?

It is science or art of cultivating the soil, growing and harvesting crops and raising live stocks.

- Cultivation of the soil
- Growing & harvesting crops
- Breeding & raising of livestock
- Packing, processing, and marketing

Agriculture including crop, horticulture, floriculture, animal husbandry, forestry and agroforestry, fisheries, and agro-industries provides livelihood to over 70% of the population.

Types of Agriculture

Intensive Agriculture & Extensive Agriculture
Shifting Agriculture, Slash & burn agriculture, Till less Agriculture, Mixed farming, Plantation farming & Poultry, Dairy farming & Sericulture

What is Sustainable Agriculture?

“Sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that over the long term will:

- Satisfy human food and fiber needs.
- Enhance environmental quality and the natural resource base upon which the agricultural economy depends.
- Make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls.
- Sustain the economic viability of farm operations.
- Enhance the quality of life for farmers and society as a whole.”

Sustainable Agriculture leads to….

- Enhanced food safety, quality assurance and regulatory compliance,
- Addresses world food needs,
- Creates business opportunities and matches with consumer.expectations

- Use of pesticides past 3-4 decades has led to several problems such as: Environmental degradation, health hazards for humans, pest resistance and resurgence and the decrease in the population of beneficial insects, which is has a direct impact in pest management.
- In ancient days, farmers used fruits, leaves and the bark and roots of various plants like neem, pongamea etc. for pest and disease management.
- Before the green revolution, farmers in rural areas were practising a wide range of traitional techniques for pest and disease control.

Some practices were also supplemented with religious ceremonies and rituals.

Karthigai Deepam: Bonfire for the pests that attack the sampa crop, that will be at its peak vegetative phase during this period.

Mulaipaari: Seed germination test

Pon yeru kattuthal (1st day of Chitirai): Resing stages pests like pupa destroyed either by the hot sun or are picked up by predatory birds

Traditional methods are simple, cost effective, eco-friendly and can easily be adopted by farmers.

❖**Mechanical methods**:

Hand-picking the larvae and grubs, removing eggs from the tips of the leaves by pinching off the terminal portion, warding off birds that damage grains using effigies or by producing noise drums, controlling pests by dusting ash on the plants etc.

❖**Agronomical methods**:

Intercropping, trap cropping, border cropping, crop rotation, fumigation, use of light traps, use of bird perches etc.

❖**Biological methods**:

Parasites, predators, botanical pesticides etc. for crop protection.

Traditional Technologies

- Use of bonfire (light trap): Monitor and trap adult pests thereby reducing their population through electric bulbs & Hurricane lamps.
- Bird Perch: Invite birds to the fields when the larval population is high.
- Intercrops/ trap crops / border crop: Susceptible host should be planted along with the main crop. This crop will invite the pests and thereby the main crop can be saved to a great extent from pest infestation.
- Fumigation: Smoke for certain natural products is used to control diseases especially in vegetable crops and to ward off pests in storage go downs (gas, vapour or smoke seeds and plants for the purpose of disinfecting or destroying pests).

Organic Farming

Organic farming is a form of agriculture that avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulations, and livestock feed additives.

Soil Fertility: Tillage

- Prepares the ground for seedlings and transplants.
- Provides a range of residue incorporation options.
- Enables the incorporation of amendments.
- Improves soil aeration, and breaks up soil clods to form good seed and root beds.
- Improves water infiltration.
- Increases rate of microbial activity and mineralization.
- Deep tillage can break through compacted layers.

Microbial Habitats

- **Epiphytic** = organisms growing on the surface of photosynthetic organisms
- **Endophytic** = organisms growing on the inside of photosynthetic organisms
- **Phylloplane** = leaf surface
- **Phyllosphere** = area surrounding the leaf and impacted by it
- **Rhizoplane** = root surface
- **Rhizosphere** = area surrounding the root and impacted by it

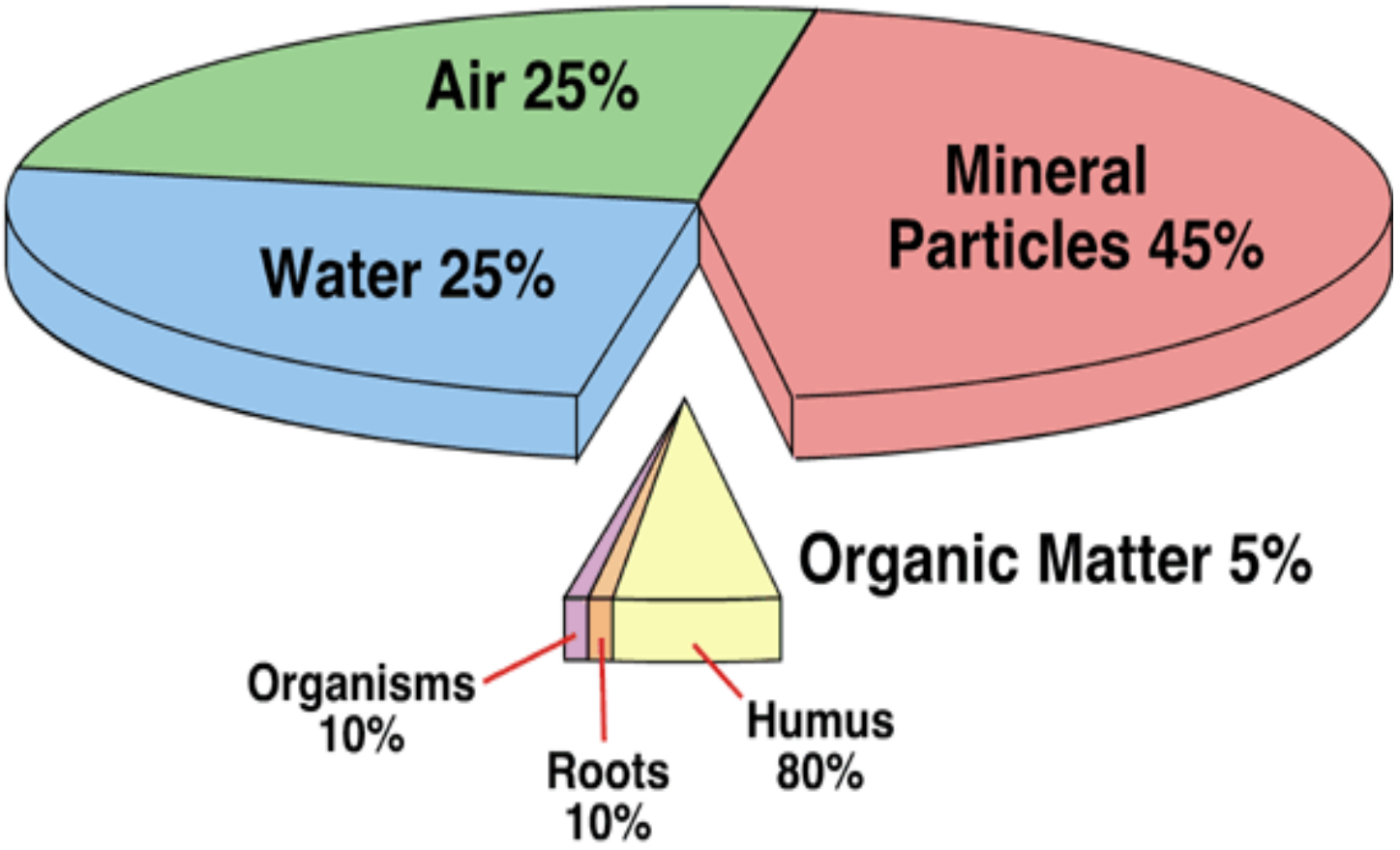
Some Nitrogen Fixing Organisms (Below Ground or Internal)

- **Free living aerobic bacteria**
  - ***Azotobacter***
  - ***Beijerinckia***
  - ***Klebsiella***
  - ***Cyanobacteria* (lichens)**
- **Free living anaerobic bacteria**
  - ***Clostridium***
  - ***Desulfovibrio***
  - ***Purple sulphur bacteria***
  - ***Purple non-sulphur bacteria***
  - ***Green sulphur bacteria***
- **Free living associative bacteria**
  - ***Azospirillum***
- **Symbionts**
  - ***Rhizobium* (legumes)**
  - ***Frankia* (alden trees)**

Phyllosphere

- Frequent and extreme changes in
  - Dryness/wetness
  - strong UV irradiation
  - Not many nutrients
    - However, nutrient-rich “oases”
    - exist on leaf surfaces

Fertile Soil



Rhizosphere vs Nonrhizosphere

Populations	Rhizosphere (log CFU/g)	Control soil (log CFU/g)	R/S ratio[a]
Taxonomic groups			
Bacteria	9.08	7.70[b]	24.0
Actinomycetes	7.66	6.85[b]	6.6
Fungi	6.08	5.00[b]	12.0
Protozoa	3.38	3.00[b]	2.4
Microalgae	3.70	4.43[c]	0.2
Nutritional groups			
Ammonifiers	8.70	6.60[b]	125.0
Gas-producing anaerobes	5.59	4.48[c]	13.0
Anaerobes	7.08	6.78[c]	2.0
Denitrifiers	8.10	5.00[b]	1260.0
Aerobic cellulose degraders	5.85	5.00[c]	7.0
Anaerobic cellulose degraders	3.95	3.48NS[d]	3.0
Spore formers	5.97	5.76NS	1.6
Azotobacter	<3.00	<3.00	—

		Age in days				
		1	5	10	15	20
Bacteria (x 10^7)	**Rhizosphere**	15	95.5	260	310.8	677.8
	Non-rhizosphere	2	2	1.1	2	2.5
Actinomycetes (x 10^6)	**Rhizosphere**	5.5	3.5	34.5	95.8	83.3
	Non-rhizosphere	4.5	6	1.3	1	1
Fungi (x 10^4)	**Rhizosphere**	3.3	2	26	68	91.8
	Non-rhizosphere	0.9	1.6	1.5	1.7	6.8

Chemical Composition of Root Exudates

Table 1. Organic compounds and enzymes identified in root exudates of different plant species[a]

Amino acids	Organic acids	Sugars	Vitamins	Enzymes	Inorganic ions and gaseous molecules	Purines/nucleosides
α-alanine	citric	glucose	biotin	acid/alkaline-	HCO_3^-	adenine
β-alanine	oxalic	fructose	thiamin	phosphatase	OH^-	guanine
asparagine	malic	galactose	niacin	invertase	H^+	cytidine
aspartate	fumaric	maltose	pantothenate	amylase	CO_2	uridine
cystein	succinic	ribose	rhiboflavin	protease	H_2	
cystine	acetic	xylose				
glutamate	butyric	rhamnose				
glycine	valeric	arabinose				
isoleucine	glycolic	raffinose				
leucine	piscidic	desoxyribose				
lysine	formic	oligosaccharides				
methionine	aconitic					
serine	lactic					
threonine	pyruvic					
proline	glutaric					
valine	malonic					
tryptophan	aldonic					
ornithine	erythronic					
histidine	tetronic					
arginine						
homoserine						
phenylalanine						
γ-Aminobutyric acid						
α-Aminoadipic acid						

Root exudates function

- Defend the rhizosphere and root against pathogenic microorganism
- Attract greater number of microorganism
- Keep the soil around the root moist
- Obtain nutrients
- Change the chemical properties of the soil around the root
- Inhibit the growth of competing plant species

Mucilages

- Insoluble organic compounds of four different origins.

  - mucilage secreted by Golgi organelles in the root cap cells.

  - hydrolysates of the polysaccharides of the primary cell wall between epidermal cells of the primary wall and sloughed root cap call.

  - mucilage secreted by epidermal cells and root hairs.

  - mucilage produced by bacterial degradation of dead epidermal cells.

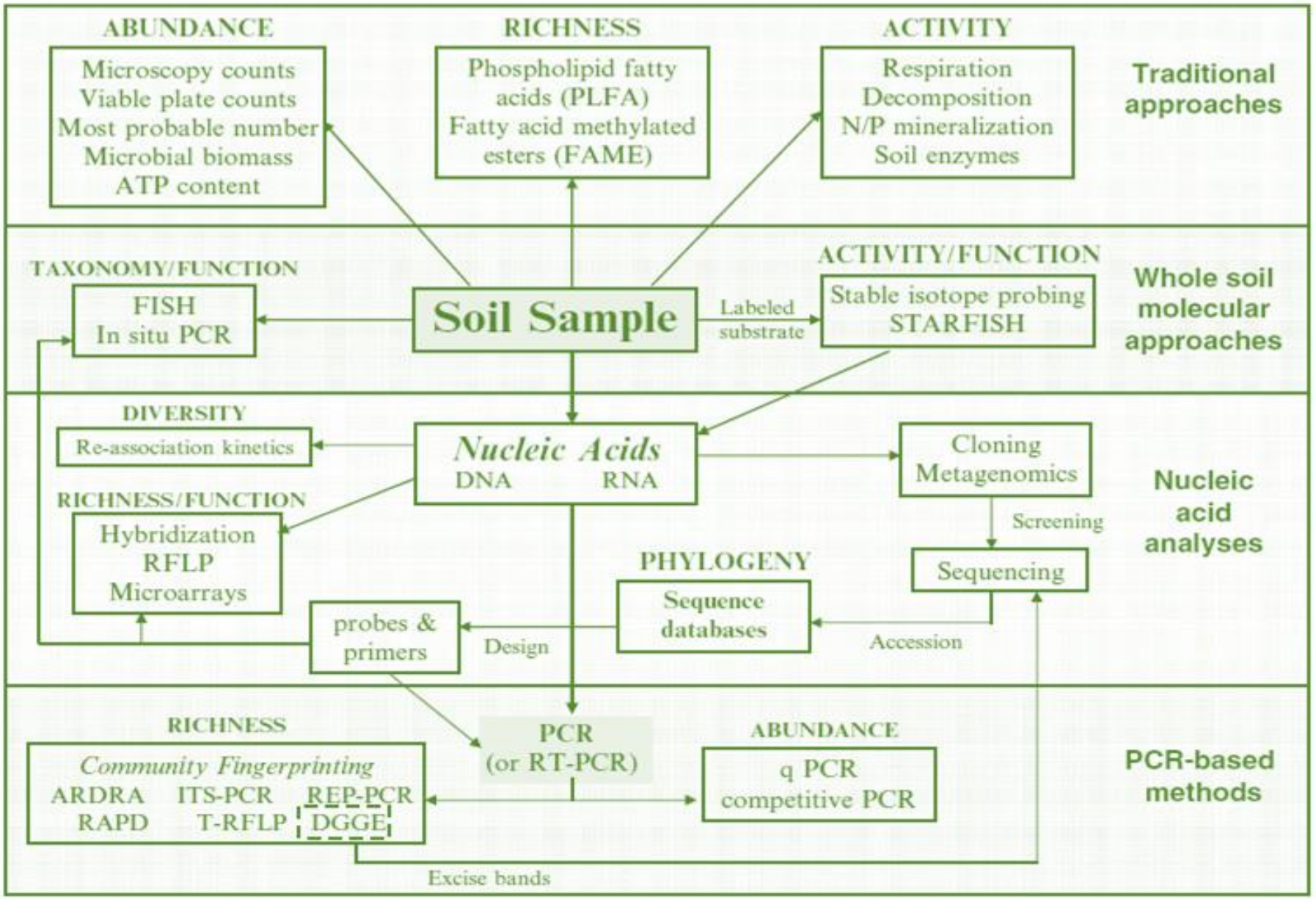
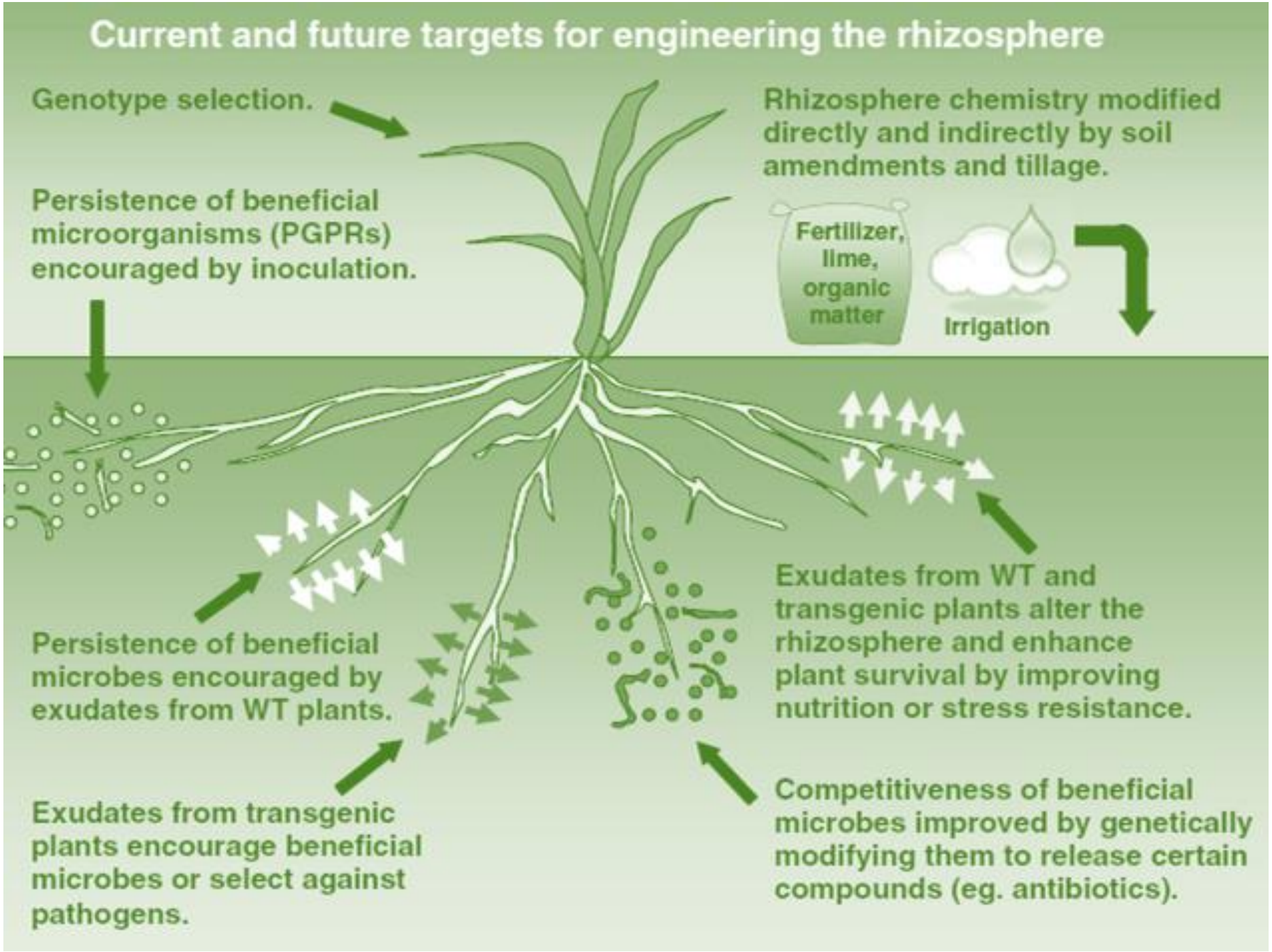
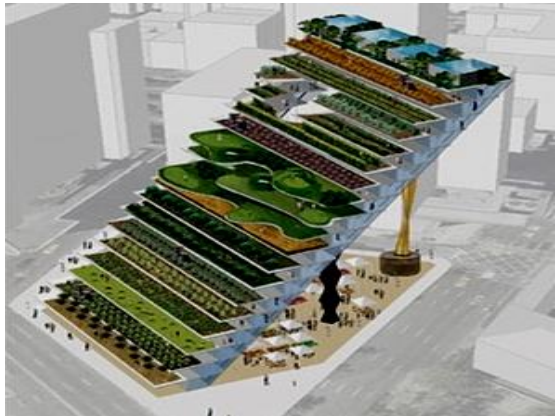


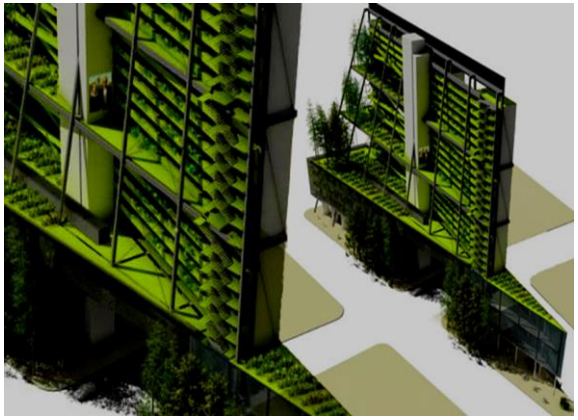
Fig. 17.1 Overview of approaches used to characterize soil microbial communities (adapted from Thies 2007a)


Current and future targets for engineering the rhizosphere
Genotype selection.
Rhizosphere chemistry modified directly and indirectly by soil amendments and tillage.
Persistence of beneficial microorganisms (PGPRs) encouraged by inoculation.
Fertilizer, lime, organic matter
Irrigation
Exudates from WT and transgenic plants alter the rhizosphere and enhance plant survival by improving nutrition or stress resistance.
Persistence of beneficial microbes encouraged by exudates from WT plants.
Exudates from transgenic plants encourage beneficial microbes or select against pathogens.
Competitiveness of beneficial microbes improved by genetically modifying them to release certain compounds (eg. antibiotics).

Future of Agriculture

- **Genetic engineering will be important**
  - **Pests to pharmaceuticals to industrial products**
- **Identity preserved crops**
  - **From farm gate to table top to industrial uses**
- **Need students well versed in the basic sciences**
- **Ever growing world population is of great concern**
- **Space?**





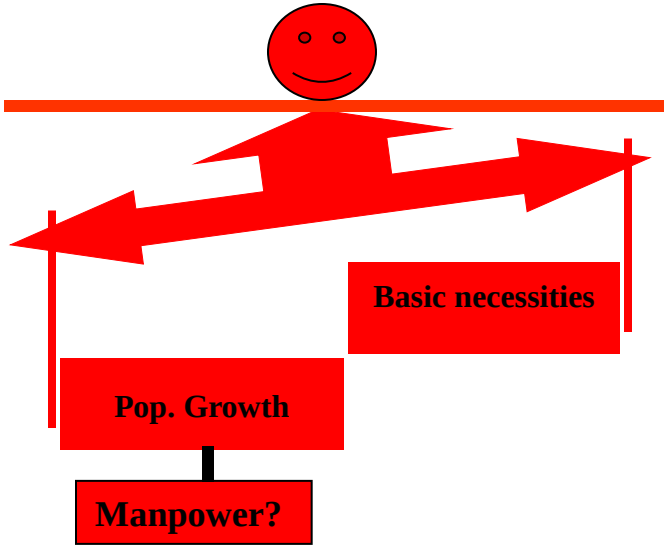

CHIVES
PEPPERS
BRUSSEL SPROUTS
TOMATOES
THYME
SPINACH
PEAS
LETTUCE
PEACHES
APPLES
CABBAGE
STRAWBERRIES
CHERRIES

Bioresources

Agriculture & Forestry

Indian economy

National Income, Foreign exchange, Industry & Employment.



Sustain Development

(Malthusian growth theory)

INDIA

Green (grain!) revolution 1960's?

Focus on a few grain crops: wheat, rice, maize

High inputs: fertilizers, pesticides

High resource farmers: irrigated lands

Crop yield: the major goal

Salient Features of Green Revolution

- **Higher yields**
- **More responsive to plant nutrients**
- **Shorter and stiffer straw**
- **Early maturity**
- **Resistance to major pests and diseases**

Scientific Impact

- ❖Destroy the ecosystem
- ❖Non-target organisms
- ❖Infertility
- ❖Human disease
- ❖Microbial domination

Social Impact

- ❖Increased income inequality
- ❖Inequitable asset distribution
- ❖Decline in nutritional security

Chronic Symptoms Due to Agrochemicals

1. Birth defects
2. Genetic disorders
3. Benign or malignant tumors
4. Fetus and birth defects
5. Blood disorders
6. Nerve disorders
7. Endocrine (hormone) disruption
8. Reproduction dysfunction
9. Irritation to skin, eyes, and respiratory tract
10. Allergic contact dermatitis
11. Autism
12. ADD
13. Child learning disorders
14. Immune system effects (lower blood count)
15. Lung damage.

Fertilizers Production (million tones; Biofertilizers News; July-2003)

	1996	2000	2011	2031	2051
Requires	16.0	19.0	20.2	27.3	31.3
Production	12.8	14.9	15.8	20.9	23.9
Gap	3.2	4.1	4.4	6.4	7.2

Green (genuine) revolution! *–Sustainable Development*

- ❑**Ecological friendly**
- ❑**Technical feasibly**
- ❑**Economically cheaply**
- ❑**Socially acceptably**

Biofertilizers & Biocontrol agents (Bioinoculants)

Definition

Biofertilizer: **Their role in agriculture is vital for N_2-fixation, solubilization and mobilization of nutrients, such type of microbes are called biofertilizers.**

Biocontol: **To control the one organism by the use of another organism.**

Demand & Production (Tones; Bhattacharya & Kumar, 2002)

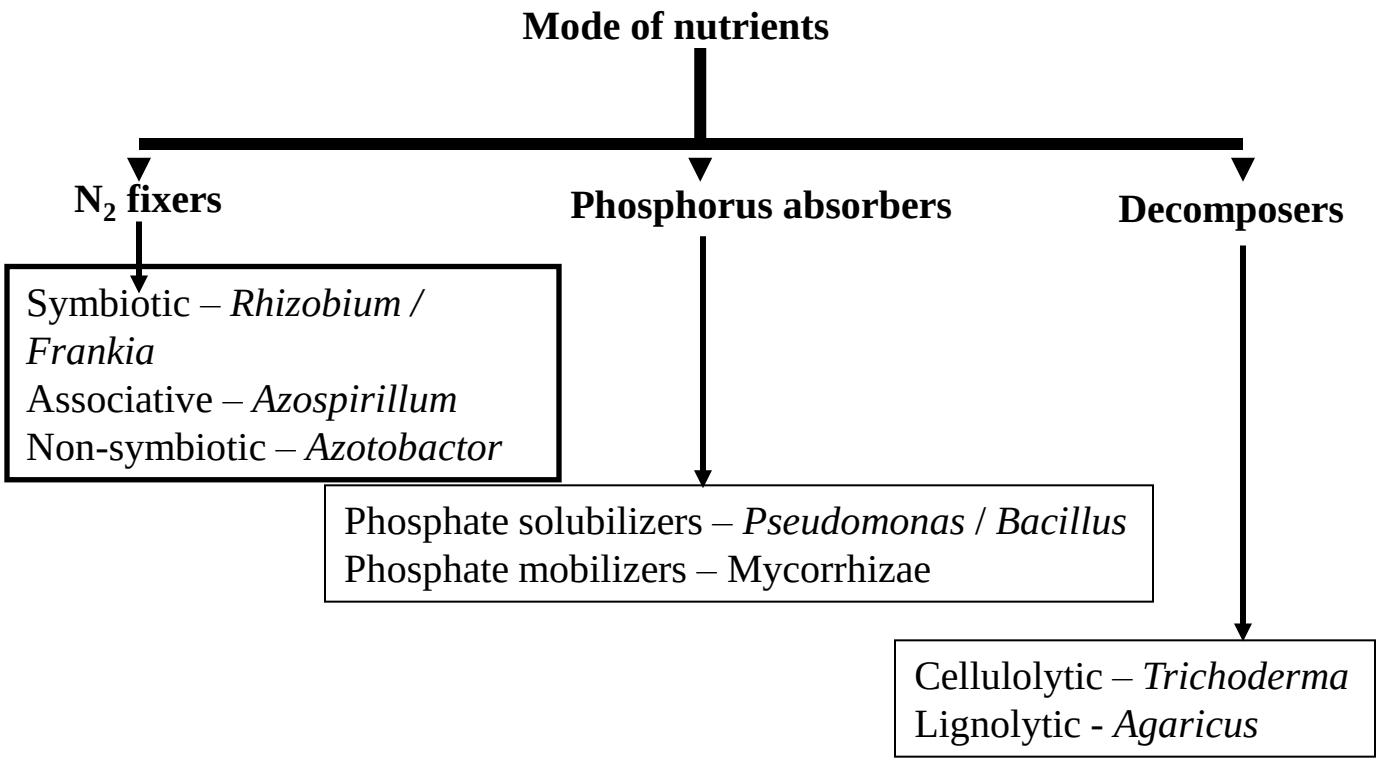
- **Requirement in India – 25,000 tones/annum**
- **Production in India – 15,000 tones/ annum**

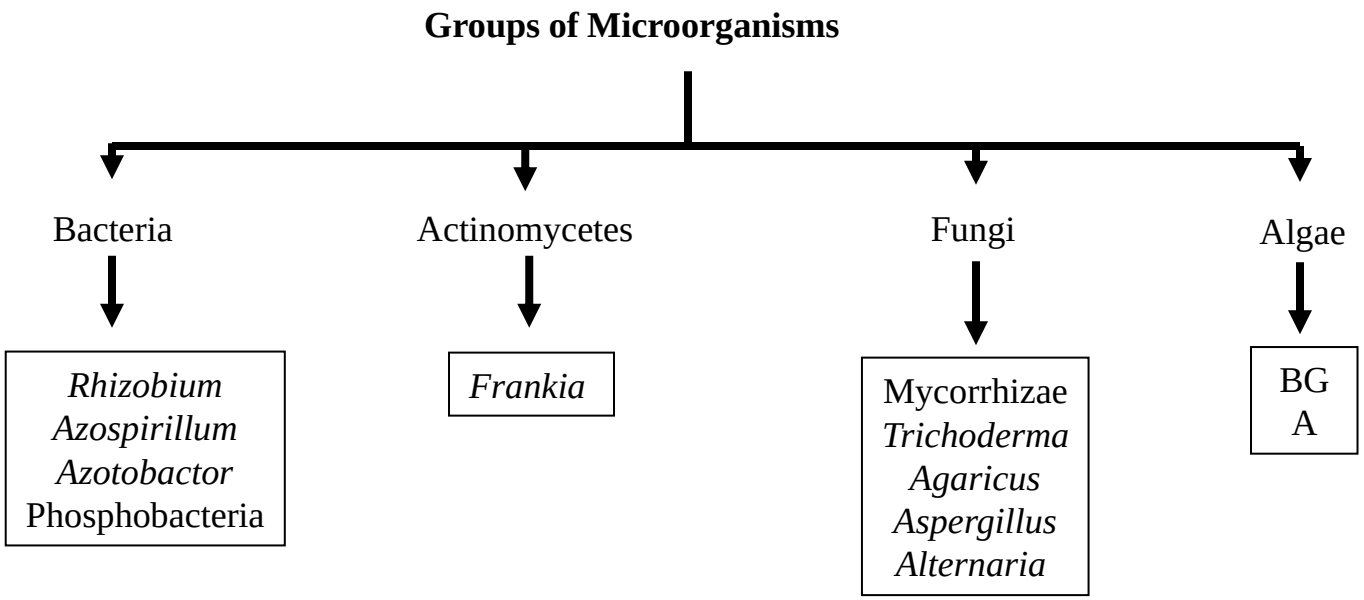
Why Biofertilizers?

- **Environmental friendly**
- **No nitrogen loss through denitrification, volatilization & leaching**
- **No need of big fertilizer-producing factories causing pollution.**
- **Inland production (less cost)**
- **Saving of FOREX reserves**
- **Less expenditure on transport**
- **Cheap source**
- **Increase nitrogen-fixation and nutrient availability**
- **Sustain crop productivity**

Classification of Biofertilizers

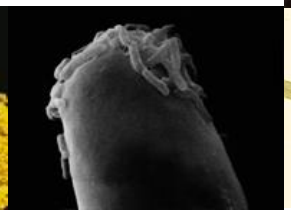
(a) Mode of nutrients
(b) Group of microorganisms

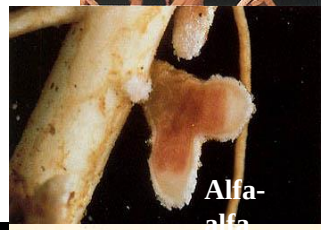


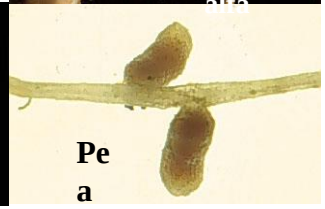

Groups of Microorganisms
Bacteria
Actinomycetes
Fungi
Algae
Rhizobium
Azospirillum
Azotobactor
Phosphobacteria
Frankia
Mycorrhizae
Trichoderma
Agaricus
Aspergillus
Alternaria
BG
A

Bacterial Biofertilizers

Rhizobium





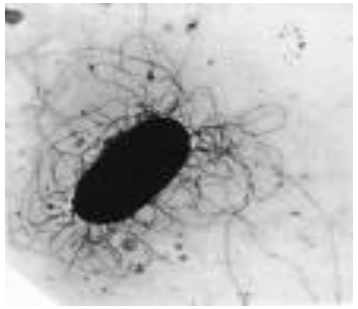


Rhizobiaceae
Rhizobium leguminosarum
Gram negative
Aerobic
Optimum temp. 25 – 30^{o}C
Opt. pH 6 – 7.

Root nodules
Leguminosae plant family members (Rhizobacteria)

Leaf nodules
Myrsinaceae & Rubiaceae (Phyllobacteria)

Stem nodules
***Sesbania rostrata* (Leguminosae**



Azospirillum

***Azospirillum lipoferum* & *A. brasilense*.**
Gram negative
Microaerobic
Opt. temp. 32 – 35^{o}C
Found in rhizoplane

Azotobactor

Azotobacteraceae
Azotobacter chroococcum
Gram negative
Obligately aerobic
Rods & Cocci
Found in rhizosphere
Capable of fixing molecule nitrogen

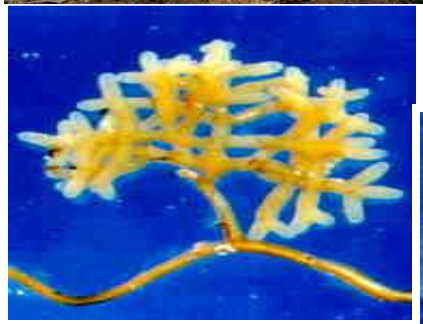
Phosphate solubilizing bacteria

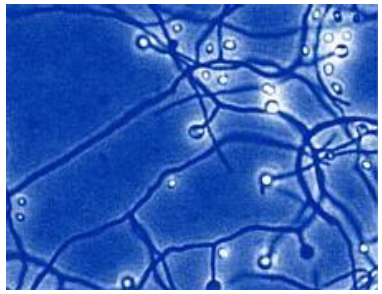
Bacillus

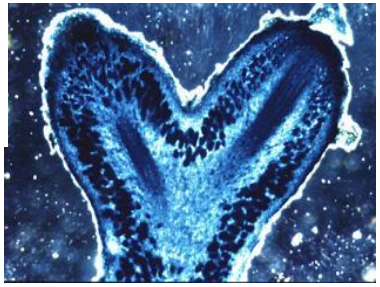
Bacillus
Bacillaceae
B. circulans
Gram positive. Rod-shaped,
Aerobic or facultative,
Endospore-forming bacteria
Antibiotic sensitivity

Pseudomonas

Pseudomonas
Pseudomonadaceae
P. fluorescens
Gram negative; Aerobic; rods & Cocci
Found in soil
Opt. temp. 4 – 43oC
Antibiotic sensitivity







Actinomycetes

Biofertilizers

Frankia

Frankiaceae

Associated 8 Plant family members

***Casuarina equisetifolia* (Casuarinaceae)**

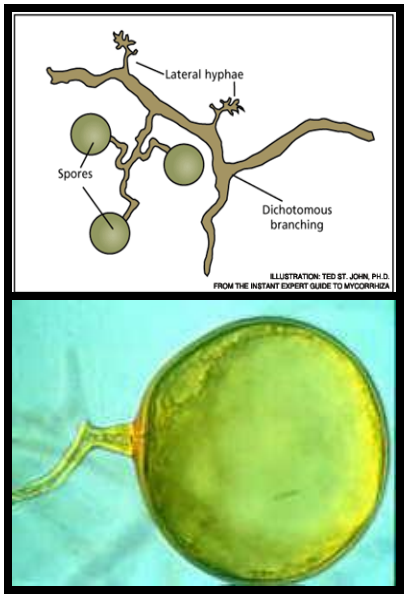
Fungal Biofertilizers

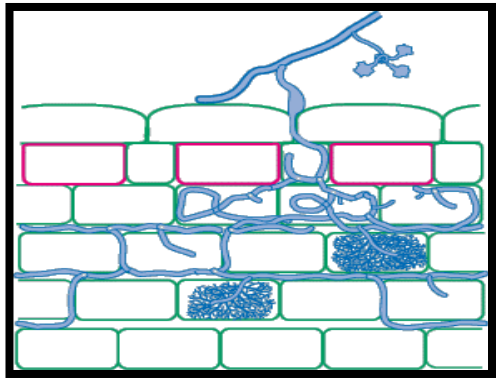
Mycorrhizae

Glomus fasciculatum

Occurrence in all plant's roots & Rhizosphere

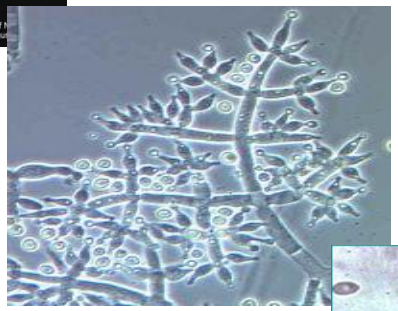
Except few family members.

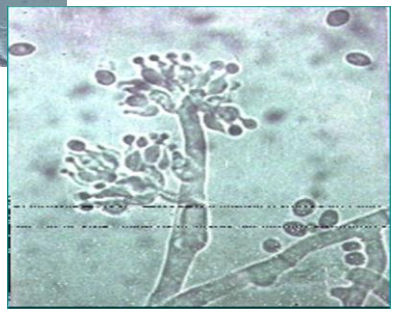




Types.

1. **Endomycorrhizae**
2. **Ectomycorrhizae**
3. **Ectendomycorrhizae**
4. **Orchidmycorrhizae**
5. **Ericoidmycorrhizae**
6. **Arbutroidmycorrhizae**
7. **Monotpoidmycorrhizae**





Trichoderma

Hypocreaceae

T. harzianum

Distributed in soil, plant material, decaying vegetation & wood

Agaricus

Agaricaceae
A. augusts
Occur in organic material rich soil & wood material

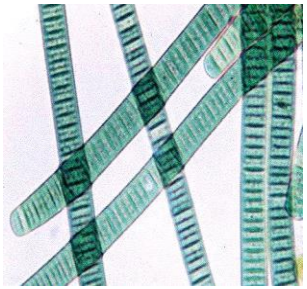
Penicillium

Trichomaceae
P. notatum
Occur in soil & atmosphere

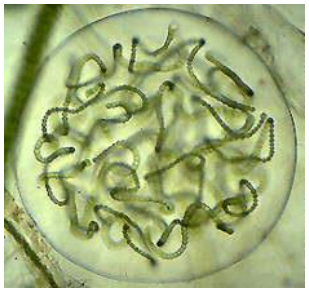
Aspergillus

Aspergillaceae
A. niger
Occur in soil & atmosphere

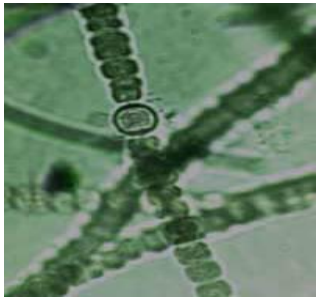
Spirulina



Nostoc



Anabaena



Algal biofertilizers

Blue Green Algae (BGA)

Photosynthetic cyanobacteria

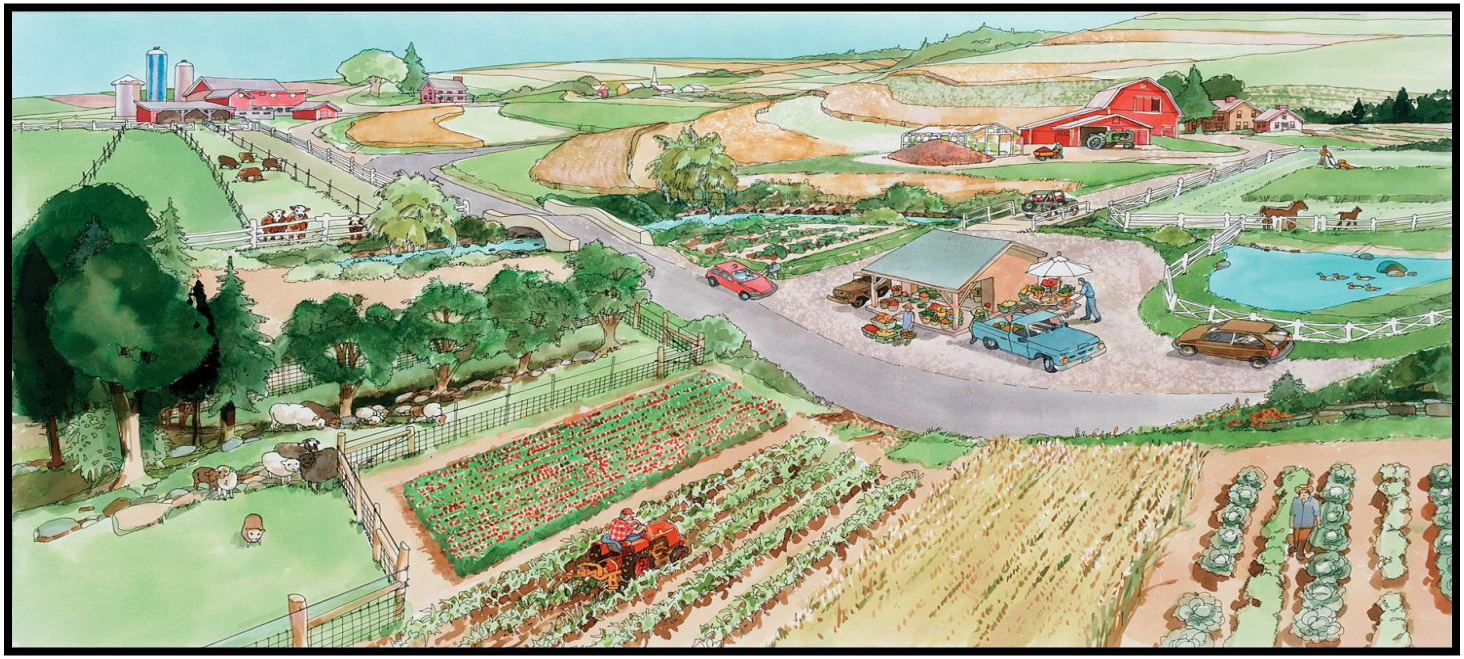
Free living – nitrogen fixer

Biofungicides

Trichoderma

Gliocladium

Elements of Sustainability



1 Integrated pest management
2 Management intensive grazing
3 Soil conservation
4 Water quality
5 Cover crops

6 Crop/landscape diversity

7 Nutrient management
8 Agroforestry
9 Marketing