Biological control of plant pathogens
What is biological control?

- Relation to the biological control of insects
  - Suppression of insect populations by native or introduced enemies
Why use biological control?

• Biological control agents are
  – Expensive
  – Labor intensive
  – Host specific

• Chemical pesticides are:
  – cost-effective
  – easy to apply
  – Broad spectrum
Why use biological control?

- **Chemical pesticides**
  - Implicated in ecological, environmental, and human health problems
  - Require yearly treatments
  - Broad spectrum
    - Toxic to both beneficial and pathogenic species

- **Biological control agents**
  - Non-toxic to human
  - Not a water contaminant concern
  - Once colonized may last for years
  - Host specific
    - Only effect one or few species
POSSIBLE MECHANISMS OF BIOCONTROL AGENTS

- ANTIBIOSOS
- COMPETITION
- MYCOPARASITISM
- CELL WALL DEGRADING ENZYMES
- INDUCED RESISTANCE

These mechanisms are probably never mutually exclusive.
Mechanisms of biological control of plant pathogens

• **Antibiosis** – inhibition of one organism by another as a result of diffusion of an antibiotic (low molecular weight compound)
  - Antibiotic production common in soil-dwelling bacteria and fungi
  - Example:
    » zwittermicin A production by *B. cereus* against *Phytophthora* root rot in alfalfa
    » Phenazine antibiotic (Phz) by *Pseudomonas fluorescens* strain 2-79 in take-all of wheat
Antibiosis

- The role of antibiotic production by antagonistic fungi has been less studied.
- Examples of antibiotic produced by Fungi
  - Gliovirin and gliotoxin produced by *Gliocadiun virens* (*Trichoderma virens*) in controls of damping off caused by *Pythium ultimum*
  - However some antibiotics produced by fungi are still unknown of their roles examples:
    - Chaetomin produced by *Chaetomium globosum*
    - Peptaibols produced by *Trichoderma harzianum*
    - Pyrones produced by *Trichoderma spp*
Mechanisms of biological control of plant pathogens

• **Nutrient competition** – competition between microorganisms for carbon, nitrogen, O$_2$, iron, and other nutrients
  – Most common way organisms limit growth of others
  – This process is considered to be an indirect interaction- pathogens are excluded by depletion of a food base or by physical occupation of infection sites.
Mechanisms of biological control of plant pathogens

• **Destructive mycoparasitism** – the parasitism of one fungus by another
  – Involves direct utilization of one organism by another.
  – Fungi that are parasite on other fungi – mycoparasites
  – Mycoparasitism- 4 step process
    1. Chemotropic growth-biocontrol fungi grow tropistically toward target fungi that produce stimuli. Ex. A volatile or water soluble substance produced by host fungus
Mechanisms of biological control of plant pathogens

2. Recognition
   - involved the recognition of lectins (host pathogen) and by the carbohydrate receptors (biocontrol fungus)

3. Attachment and cell wall degradation
   - Mycoparasites either coil or grow along side the pathogen and produce cell wall degrading enzyme such as chitinase and B-1,3-glucanase

4. Penetration
   - biocontrol agent produces appressoria-like structures to penetrate the target fungus cell wall.
Mechanisms of control

• **Cell Wall Degrading Enzymes**
  
  – Extra cellular hydrolytic enzyme such as Chitinase and B-1,3 glucanase degrade the chitin and glucans of the cell wall

  Ex. *Trichoderma harzianum* (with ChiA from *Serratia marcescens*) against *Sclerotium rolfsii*

  More recently several species of transgenic plants containing gene for endochitinase from *Trichoderma harzianum* has been produced.
Mechanisms of biological control of plant pathogens

• Induction of Systemic Resistance
  - Include physical thickening of cell wall by lignification, deposition of callus, accumulation of antimicrobial low-molecular-weight substance (phytoalexin) and synthesis of various proteins (ex. Chitinases, glucanases, peroxidases, and other PR).
  - This defense system is also triggered when plants are colonized by PGPR.
Requirements of successful biocontrol

1. Highly effective biocontrol strain must be obtained or produced
   a. Be able to compete and persist
   b. Be able to colonize and proliferate
   c. Be non-pathogenic to host plant and environment
2. Inexpensive production and formulation of agent must be developed
   a. Production must result in biomass with excellent shelf live
   b. To be successful as agricultural agent must be
      i. Inexpensive
      ii. Able to produce in large quantities
      iii. Maintain viability
Requirements of successful biocontrol

3. Delivery and application must permit full expression of the agent
   a. Must ensure agents will grow and achieve their purpose
Plant pathogen control by *Trichoderma spp.*

- *Trichoderma spp.* are present in nearly all agricultural soils
- Antifungal abilities have been known since 1930s
  - Mycoparasitism
  - Nutrient competition
- Agriculturally used as biocontrol agent and as a plant growth promoter

http://www.ars.usda.gov/is/pr/2002/021231.trichoderma.jpg
• T22 strain
• Uses antibiosis and predation against soil borne pathogens such as Pythium, Rhizoctonia, Fusarium and Sclerotina
Plant pathogen control by *Trichoderma* spp.

- Action against pathogenic fungi

  1. Attachment to the host hyphae by coiling
     a. Lectin-carbohydrate interaction

Plant pathogen control by *Trichoderma* spp.

- Action against pathogenic fungi

2. Penetrate the host cell walls by secreting lytic enzymes
   a. Chitinases
   b. Proteases
   c. Glucanases

(Ilan Chet, Hebrew University of Jerusalem).
• *Trichoderma spp.* attach to the host hyphae via coiling, hooks and appressorium like bodies, and penetrate the host cell wall by secreting lytic enzymes. *Trichoderma* recognizes signals from the host fungus, triggering coiling and host penetration. A biomimetic system consisting of lectin-coated nylon fibers was used to study the role of lectins in mycoparasitism. Using this system we could also identify specific coiling-inducing molecules.
Plant pathogen control by *Trichoderma* spp.

- Some strains colonize the root with mycoparasitic properties
  - Penetrate the root tissue
  - Induce metabolic changes which induce resistance
    - Accumulation of antimicrobial compounds
Plant pathogen control by *Trichoderma* spp.

- Commercial availability
  
  T-22
  
  - Seed coating
  - Protects roots from diseases caused by *Pythium*, *Rhizoctonia* and *Fusarium*
  - Interacts with the Rhizosphere, near the root hairs and increases the available form of nutrients needed by plants.
Plant pathogen control by *Trichoderma spp.*

- Future developments
  - Transgenes
    - Biocontrol microbes contain a large number of genes which allow biocontrol to occur
    - Cloned several genes from *Trichoderma* as transgenes
      - Produce crops which are resistant to plant diseases
  - Currently not commercially available
Biological fungicides

- Gliocladium against Rhizoctonia
- Trichoderma against Rhizoctonia
- Penicillium against Rhizoctonia
- Fusarium against Puccinia and verticillium
• Most fungi produce inhibitory metabolites examples:

1. Gliocladium produces a diketopeprazine that kills Pythium because of coagulation of proteins in the cytoplasm.

2. Volatile pyronens produced by Trichoderma appear to reduce damping off caused by Rhizoctonia.
• damping off ---------kill seeds or seedlings before or after they germinate.
• Salicylic acid which produced by pathogens
  1. Salicylic acid leads to the expression of pathogenesis related protein PRP
  2. PRP--------lyse invading cells
      -----reinforce cell wall to resist infections
Growth inhibition of *Pythium ultimum* by the *Trichoderma virens*–produced antibiotic gliovirin: A, parent strain, and B, gliovirin-deficient mutant.
Growth inhibition of *Rhizoctonia solani* by the *Trichoderma virens*–produced antibiotic gliotoxin: A, gliotoxin-amended medium, and B, nonamended medium.
Mycoparasitism of *Rhizoctonia solani* by *Trichoderma virens*: A, parent strain coiling around host hyphae, and B, mycoparasitic-deficient mutant with no coiling or penetration of host hyphae.
Trichoderma

- Control of root and foliar pathogens
  1. Induced resistance
  2. Biological control of diseases by direct attack of plant pathogenic fungi
- Changes in the microfloral composition on roots
- Enhanced nutrient uptake
- Enhanced solubilization of soil nutrients
- Enhanced root development
- Increased root hair formation
Trichoderma

- Mycoparasitism
- Antibiosis
- Competition for nutrients or space
- Tolerance to stress through enhanced root and plant development
- Solubilization of inorganic nutrients
- Induced resistance
- Inactivation of the pathogen’s enzymes
Trichoderma