Fighting for their lives: Plants and pathogens

Photos courtesy of CIMMYT, Scott Bauer, USDA Agricultural Research Service, IRRI, IRRI, IITA
Many kinds of organisms cause plant disease

- **Nematodes** are large, multicellular animals
- **Viruses** are non-cellular, and merely packaged nucleic acids
- **Fungi and oomycetes** are eukaryotes
- **Bacteria** are prokaryotes

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What makes an interaction into a disease? (Disease triangle)

Plants are exposed to countless microbes, but very, very few of these interactions lead to disease. Why?

The disease triangle (it takes three)

- The pathogen must be able to overcome plant defenses
- The host plant must be susceptible to the pathogen
- The environment must tip the balance in favor of the pathogen
Humans influence diseases

Humans add another dimension (making a disease pyramid….)

Migrations of people and plants

Monoculture

Introduced pathogens and vectors

Growing practices

Photos courtesy Scott Bauer and Bob Nichols, USDA, and Geovantage, Inc.
Strategies of pathogenicity

A successful pathogen must:

• Find the host and attach to it
• Gain entry through the plant’s impermeable defenses
• Avoid the plant’s defense responses
• Grow and reproduce
• Spread to other plants

Gray mold (*Botrytis cinerea*)
Wind, water, insects and chemotaxis help pathogens reach their hosts

Jim Plaskowitz, USDA, and Stan Diffie, University of Georgia
Pathogens must be able to penetrate or circumvent physical barriers

Some pathogens produce non-melanized but effective appressoria

Melanized appressoria build up high pressure to puncture the cell wall

Some pathogens enter through stomata and grow extracellularly

Pathogens are biotrophs, necrotrophs or hemibiotrophs

Necrotrophs kill cells and then consume the contents

Biotrophs live within host tissue without causing death

Hemibiotrophs can switch from biotroph to necrotroph

Summary - strategies of pathogenicity

Pathogens must overcome formidable plant defenses

Once inside the plant, they can either co-habitate or kill
Plant immune responses

Plants resist pathogens through active processes that include *recognition* of the pathogen and *defense responses* to fight it.
The zig-zag model of plant–pathogen interactions


Pathogen is recognized: Pattern Triggered Immunity

Pathogen effectors suppress defense response: Effector Triggered Susceptibility

Effector is “recognized”: Effector Triggered Immunity

Amplitude of defense

Defense responses

Defense responses
How are pathogens recognized?

Pattern recognition receptors (PRRs)

How are pathogens recognized? Pattern recognition receptors (PRRs)

Bacterial pathogen

Fungal or oomycete pathogen

PRRs recognize pathogens outside the cell and initiate defense responses

Many PRRs have an extracellular leucine-rich repeat domain that recognizes conserved microbial elements…..

….and an intracellular kinase domain

They are leucine-rich repeat receptor kinases (LRR-RKs)
Pathogens produce effectors that enhance their virulence.

Microbial effectors suppress the plant’s immune response and/or contribute to the pathogen’s viability.

Kinase cascade leading to transcriptional responses

Calcium ion influx

Reactive oxygen production

Enzymes
Some effectors alter plant behaviour and development

Resistance proteins – intracellular immune receptors

R proteins recognize effectors intracellularly

Defense responses
R protein activation leads to enhanced defense: ETI

Activated R proteins signal danger, and trigger a heightened defense response that includes:

- Production of the stress hormone salicylic acid (SA)
- Production of reactive oxygen species (ROS)
- The hypersensitive cell death response (HR)
- Expression of pathogenesis-related (PR) proteins
- Systemic signals and systemic acquired resistance (SAR)

Summary - PTI is suppressed by effectors, which sometimes trigger ETI

PAMP-triggered immunity

Effector triggered suppression

Effector-triggered immunity

Strategies to prevent and manage disease

The disease triangle
(it takes three)

- Avoid or eliminate the pathogen
- Manipulate the environment to favor the plant
- Make the plant resistant through genetic or other methods
The best way to prevent disease is to keep pathogens away.

Agricultural inspectors check imported plants for pest and pathogens, but many pathogens are spread by wind and water. . . .

*Phytophthora ramorum* causes sudden oak death.
Pathogens’ effects can be minimized by hygiene and rotation

Removing and burning an infected citrus grove to eradicate bacterial canker

Continuously cultivated
Rotated with corn

Rotating crops helps reduce pathogen load in soils

Chemical controls are critical for eradicating pathogens

Azostrobulin, a widely used fungicide derived from a defensive compound produced by *Strobilurus* fungi

Compounds must be safe and effective, and application protocols must be followed to slow the development of resistance.

Because pathogens develop resistance, finding novel compounds to eradicate pathogens is an ongoing process.
**Biocontrol** refers to the use of other organisms to ward off pathogenic microorganisms and disease.

**Biocontrol agents:**
- attack the pathogen
- compete with the pathogen
- enhance the plant’s defenses through *induced systemic resistance* (ISR)
- often have multiple effects

# Summary – strategies to prevent and manage disease

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<th>Strengthen plant</th>
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<td>Control of viral vectors</td>
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- **BUNT SPORES**
- **Separate Shield**
- **Strengthen Shield**

- **Enhancement of immune and defense responses**
Plants and Pathogens: Summary

- **Plant diseases** are major threats to food production
- **Pathogens** have diverse modes of pathogenicity and rapidly evolving effectors
- **Plants** are not passive victims - they have sophisticated surveillance and defense mechanisms
- **Human practices**, particularly migrations and monocultures, have contributed to the magnitude of plant diseases