Molecular Plant Pathology

Chapter 1

Plant disease
http://134.208.24.95/kclin

上課檔案 & 作業範例

密碼為：3643
Table 1. Examples of severe losses caused by plant diseases.*

<table>
<thead>
<tr>
<th>Host/disease</th>
<th>Pathogen</th>
<th>Crop losses due to pathogens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>All</td>
<td>15% ($33 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>Rice blast</td>
<td><em>Magnaporthe grisea</em></td>
<td>11 to 30% (157 million tons) loss worldwide, 1975–1990</td>
</tr>
<tr>
<td>Rice sheath blight</td>
<td><em>Rhizoctonia solani</em></td>
<td>10 to 27% yield loss in India, 1975–1988; up to 60% losses in India, 1979–1980</td>
</tr>
<tr>
<td>Bacterial blight of rice</td>
<td><em>X. oryzae pv. oryzae</em></td>
<td></td>
</tr>
<tr>
<td>Rice tungro virus</td>
<td><em>Meloidogyne spp.</em></td>
<td>15 to 30% losses in Asia, 1971–1981</td>
</tr>
<tr>
<td>Wheat</td>
<td>All</td>
<td>10 to 50% losses in China, 1984</td>
</tr>
<tr>
<td>Wheat rusts</td>
<td><em>Puccinia spp.</em></td>
<td>12.4% ($14 billion) loss, 1988–1990</td>
</tr>
<tr>
<td>Barley yellow dwarf virus</td>
<td></td>
<td>Up to 100% loss in Kazakhstan epidemic, 1980</td>
</tr>
<tr>
<td>Barley</td>
<td><em>Erysiphe graminis</em></td>
<td>Up to 60% loss in the southern Ukraine, 1975</td>
</tr>
<tr>
<td>Wheat</td>
<td>All</td>
<td>10.1% ($1.9 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>Maize</td>
<td><em>Cochliobolus heterostrophus</em></td>
<td>$1 billion loss in U.S. epidemic, 1970</td>
</tr>
<tr>
<td>Southern corn leaf blight</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>All</td>
<td>16.3% ($9.8 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>Late blight of potato</td>
<td><em>Phytophthora infestans</em></td>
<td>5% loss ($368.8 million) in U.S. Midwest, 1986. Predicted 30 to 40% loss without fungicide</td>
</tr>
<tr>
<td>Potato soft rot</td>
<td><em>Erwinia carotovora</em></td>
<td>30% loss in former East Germany, 1986</td>
</tr>
<tr>
<td>Potato virus X</td>
<td>All</td>
<td>10 to 75% yield loss in Austria, 1961–1980</td>
</tr>
<tr>
<td>Soybeans</td>
<td>All</td>
<td>9% ($3.2 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>Cotton</td>
<td>All</td>
<td>10.5% ($4.3 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>Coffee</td>
<td>All</td>
<td>14.8% ($2.8 billion) loss worldwide, 1988–1990</td>
</tr>
<tr>
<td>All major crops</td>
<td>All</td>
<td>13.3% ($76.9 billion) loss worldwide, 1988–1990</td>
</tr>
</tbody>
</table>

*Adapted from (129).
What is a disease?

- A disease is defined as the malfunctioning of host cells and tissues that results from their continuous irritation by a pathogenic agent or environmental factor and leads to the development of symptoms.

- Disease is a condition involving abnormal changes in the form, physiology, integrity, or behavior of the plant. Such changes may result in partial impairment or death of the plant.
A disease is caused by the interactions of the pathogen, host, and environment.

Diseases are dynamic (change over time).

Host responses to disease are known as symptoms.

Koch’s postulates are used to prove that a pathogen causes a disease.
Koch’s rules

- The pathogen must be found associated with the disease in diseased plants examined.
- The pathogen must be isolated and grown in pure culture or on susceptible host plants.
- The pathogen from pure culture or susceptible host must be inoculated on healthy plants, and it must produce the same disease on the tested plants.
- The pathogen must be isolated in pure culture again, and its characteristics must be exactly like those observed in step 2.
Pathogens may cause disease in plants by

- Weakening the host by continuously absorbing nutrient from the host cells for their own use.
- Killing or disturbing the metabolism of host cells through toxins, enzymes, or growth-regulating substances they secrete.
- Blocking the transportation of food, mineral nutrients, and water through the conductive tissues.
- Consuming the contents of the host cells upon contact.
Pathogenicity and virulence

- **Pathogenicity** (致病性) is the ability of a pathogen to interfere with one or more functions within a plant. (The ability of a pathogen to cause disease.)

- **Virulence** (毒性) is the rate at which or how well a pathogen is able to interfere with cell function.
Compatibility (親和性)

- **Compatible response (親和性反應)**
  - The pathogen can cause disease on the host.

- **Incompatible response (不親和性反應)**
  - The host is resistant to the infection of the pathogen.
Symptoms and signs

- Host responses to infection are known as symptoms, including leaf spots, blights, blotches, twig blights, cankers, galls, seed, root, and stem rots.

- Structures of the pathogen are referred to as signs, including spores, mycelia, and colonies.
Model plants for host-pathogen interactions

Rice

Arabidopsis

Bacteria

Fungus

Virus

Nematode
The pathogens

- **Viruses**
  - ds DNA, ss DNA, ds RNA, ss RNA(-), ssRNA(+) viruses

- **Bacteria**
  - Pseudomonas, Xanthomonas, Erwinia, Agrobacterium, Corynebacterium, Streptomyces

- **Fungi**
  - Zygomycetes, Oomycetes, Ascomycetes, Basidiomycetes, *Imperfect fungi*

- **Insects**
  - Nematodes
  - Other insects
Figure 2. Families of Plant Viruses.
Figure 3. Genera of Bacteria and the Symptoms Elicited in Response to Infection. Reprinted from Agrios (1988), with the permission of Academic Press.
Figure 4. Some Representative Fruiting Structures of the Four Groups of Fungi.
Reprinted from Agrios (1988), with the permission of Academic Press.
Figure 5. Morphology and Relative Sizes of Plant-Parasitic Nematodes.
Reprinted from Agrios (1988), with the permission of Academic Press.
Development of disease in plants

- Pathogen
  - Virulence
  - Abundance
- Host
  - Susceptibility
- Environment
  - Optimal condition
The disease triangle

Pathogen

Environment

Amount of disease

Host
Disease cycles

- The interaction among the host, pathogen, and environment is known as the disease cycle.
- Disease with only a primary disease cycle are known as monocyclic diseases, whereas diseases with secondary disease cycles are known as polycyclic disease.
FIGURE 2.2 In a monocyclic disease, the primary disease cycle is composed of discrete events where inoculation and penetration lead to infection. Propagules produced during the disease cycle overwinter and become the primary inoculum (inoculum that begins a new disease cycle) for the next disease cycle. The inoculum is disseminated at the beginning of the next cycle.
Examples of Monocyclic disease

- **Smut**
  - Produce spores at the end of the season, and these spores serve as the primary - and the only - inoculum for the following year.

- **Tree rust**
  - Require two alternate hosts and at least one year to complete one disease cycle.

- **Root rots**
  - In root rots and vascular wilts, the pathogen survive the winter or summer in decaying stems and roots or in the soil, infect plants during the growing season, and produce new spores in the infected stems and roots at the end of the growing season.

- **Vascular wilts**
Corn smut (玉米黑穗病)

Corn Smut - Symptoms and Signs

A single gall may contain up to $2 \times 10^{11}$ spores.
Ustilago maydis – Life Cycle

FIGURE 11-104  Disease cycle of corn smut caused by *Ustilago maydis*
FIGURE 2.3 Polycyclic diseases have primary inoculum that penetrates and infects the plant. This is a part of the primary disease cycle. Inoculum produced after invasion is disseminated and causes more infections during the current growing season. The inoculum contributes to the secondary disease cycle, and the secondary cycle may be repeated many times.
Examples of polycyclic disease

- The pathogen goes through more than one generation per growing season, and such pathogens are called polycyclic pathogens.

- Polycyclic pathogens are disseminated primarily by air or by air-borne vectors (insects) and are responsible for diseases that cause most of the explosive epidemics on most crops.

- The primary inoculum generally consists of the sexual spores. The number of sexual spores that survive and cause infection is usually small, but once primary infection takes place, large number of asexual spores (secondary inoculum) are produced at each infection site, and these spores can themselves cause new (secondary) infections that produce more asexual spores for more infections.
Examples of polycyclic disease

- Downy mildew
- Late blight of potato
- Powdery mildew
- Leaf spot and blight
- Cereal rusts
- Aphid-borne viruses
Stem Rust – Disease Cycle

The Life Cycle of Stem Rust

*Cluster Cup Stage of Rust in Barberry Leaf*

*Summer*
- Red (Uredinial) Stage of Rust on Green Plants
- Reproduces every ten to fourteen days

*Spring*
- Susceptible Barberry

*Fall and Winter*
- Black (Overwintering Telial) Stage on Straw and Stubble
Uredinia of *P. graminis* f. sp. *avenae* on oat plants

(B) Urediniospores of *P. graminis*; one stained spore shows the characteristic equatorial position of germ pores.

(C) Teliospores of *P. graminis*
(E) Clusters of pycnia of *P. graminis* on the upper surface of barberry (*Berberis vulgaris*) leaves.

(F) Clusters of aecia of *P. graminis* on the lower surface of a *B. vulgaris* leaf.
A hectare (10,000 m²) of wheat heavily infected with stem rust may produce up to 5 kg or $2 \times 10^{12}$ urediospores per day.

The rust urediospores may be transmitted in air currents at altitudes of 3,000 m and are heavily pigmented with carotinoids to survive exposure to UV damage.
Strategies for decreasing the happen of polycyclic diseases

- Chemicals
- Rotation
  - Decrease happening of disease
  - Eliminate the amount of pathogen
- Resistant varieties
- Appearance of other races
- Mutants
- Appearance of new races from sexual production
Physiological races (生理小種)
Differential set
(D) Infection types of *P. graminis* f. sp. *tritici* on seedlings of differential wheat cultivars; types 0 – 2 are considered resistant, and types 3 and 4 are considered susceptible reactions (adapted from Stakman et al., 1962).
Steps for pathogen infection

- Contact and recognition
- Penetration
- Producing phytotoxins
- Regulate the physiologic condition of host
- Absorption nutrients from host
- Growth and reproduction of pathogens
END
Rice blast (稻熱病)

Pathogen: *Magnaporthe grisea*

- Leaf blast lesions
- Collar infection
- Neck rot and panicle blast
Powdery mildew on wheat caused by *Erysiphe graminis f. sp. tritici*. 
Southern corn leaf blight is caused by *Bipolaris maydis*, teleomorph *Cochliobolus heterostrophus*
Potato late blight caused by *Phytophthora infestans*