10 Root and stem rot diseases caused by pathogens that survive in soil

Root and stem rot diseases caused by pathogens which survive in soil are responsible for serious losses in crop yield in Vietnam. The intensive nature of cropping in Vietnam's delta regions, movement of pathogens in irrigation water, poor drainage, contaminated planting material and the tropical climate favour these diseases.

The pathogens responsible for these diseases cause non-specific symptoms, namely stunting, yellowing of leaves, wilting and plant death. Note that these symptoms can also be caused by some other pathogens as well as stem boring insects, curl grubs which feed on the roots, and unfavourable soil conditions.

These diseases are caused by a number of common pathogens, including fungal and bacterial pathogens and plant parasitic nematodes.

The pathogens listed in Table 10.1 have the following key features:

- they survive in soil for long periods in the absence of a host, and inoculum levels in soil increase slowly over several years (crop cycles)
- they all have a wide host range, except formae speciales of *Fusarium oxysporum*
- they can be spread in:
  - irrigation water
  - soil carried on animals and humans
  - contaminated planting material (potato tubers, ginger rhizomes, seedling transplants)
- they are not usually dispersed by wind.

Bacterial wilt pathogens can also be carried on seed.

Table 10.1 Features of common crop pathogens that survive in soil in Vietnam

Pathogen	Diseases	Host range	Survival (overseasoning)	Comments
Pythium species[a] (e.g. *P. aphanidermatum*[a], *P. myriotilum*[a], *P. spinosum*[a])	Seedling death, rootlet rots, root rots	Wide	Oospores in soil	Zoospores dispersed in soil water and water splash
Phytophthora palmivora[a]	Wide range of root, stem, leaf and fruit diseases of tree crops	Wide	Chlamydospores, hyphae in residues and possibly oospores in soil	Zoospores dispersed in soil water and water splash
Phytophthora capsici[a]	Foot rot (quick wilt) of black pepper, root rot of chilli and other diseases	Wide	Chlamydospores, hyphae in residues and possibly oospores in soil	Zoospores dispersed in soil water and water splash
Phytophthora nicotianae[a]	Heart rot of pineapple and other diseases	Wide	Chlamydospores, hyphae in residues and possibly oospores in soil	Chlamydospores in soil, zoospores dispersed in soil water and water splash
Fusarium oxysporum, f. sp. *lycopersici*[a]	Fusarium wilt	Tomato	Chlamydospores in soil, also infects non-host roots	Stem vascular browning
Fusarium oxysporum, f. sp. *pisi*[a]	Fusarium wilt	Peas	Chlamydospores in soil, also infects non-host roots	Stem vascular browning
Fusarium oxysporum, f. sp. *cubense*[a]	Fusarium wilt	Banana	Chlamydospores in soil, also infects non-hosts; in planting material	Stem vascular browning
Sclerotinia sclerotiorum	Stem, head and pod rots	Wide	Large black sclerotia in soil	Sclerotia are diagnostic in field
Sclerotium rolfsii	Stem base rot	Wide	Small brown round sclerotia in soil	Sclerotia are diagnostic in field

Pathogen	Diseases	Host range	Survival (overseasoning)	Comments
Rhizoctonia sp.[a]	Seedling death, root, stem, stalk and head rots	Wide	Sclerotia or distinctive hyphae in residue in soil	Sclerotia diagnostic for some species in the field; right-angled hyphal branching in culture
Verticillium albo-atrum[ab]	Verticillium wilt	Wide	Hyphae in residue	Stem vascular browning
Verticillium dahliae[ab]	Verticillium wilt	Wide	Microsclerotia in soil, hyphae in residue	Stem vascular browning
Ralstonia solanacearum[a]	Bacterial wilt	Wide	Bacteria in soil, crop residues and propagating material	Stem browning and bacterial ooze are diagnostic features in field
Meloidogyne	Root knot nematode	Wide	Dormant nematodes in soil	Females live in root galls (knots)—a diagnostic feature
Root lesion nematodes[a]	Root lesions and plant stunting	Wide	Dormant nematodes in soil	Small lesions on roots are visible with a hand lens
Plasmodiophora brassicae	Club root of crucifers	*Brassica* and *Raphanus* species	Resting spores in soil	Club root symptoms diagnosable in field; add lime to soil for control

a The accurate diagnosis of these pathogens depends on isolation or extraction in the laboratory and subsequent identification. Pathogenicity tests are essential to prove that they are the primary pathogen in the local hosts, unless tested previously in Vietnam.

b These species have not been officially recorded in Vietnam.

These pathogens are often overlooked because they are difficult to identify (see Box 10.1)—the majority of them can only be identified accurately in the laboratory.

Two or more of these pathogens may simultaneously affect a crop in the intensive vegetable farming areas in Vietnam. For example, a chilli crop can be affected by bacterial wilt, Phytophthora root rot and basal stem rot. Stem boring insects may also be present. All these problems cause the same symptoms (wilting and death).

Ideally plants with root and stem rot diseases should be examined in the laboratory within a few hours of collection, while 'fresh'. Thus it is important to locate basic diagnostic laboratories in provincial sub-departments of plant protection, close to farming areas.

The national diagnostic laboratories such as the Plant Protection Research Institute in Hanoi can identify cultures, specimens, plant viruses, nematodes and bacterial pathogens.

Box 10.1 Diagnosis tip: distinguishing vascular wilts from root and stem rots

It can sometimes be difficult to determine the cause of non-specific symptoms such as stunting, yellowing and wilting. Vascular wilt diseases and root and stem rot diseases commonly cause these symptoms. This diagram shows how these diseases can be distinguished.

Stem (vascular) browning + bacterial ooze*	→	Bacterial wilt
Stem (vascular) browning + no bacterial ooze	→	Fusarium wilt or Verticillum wilt
No stem (vascular) browning + no bacterial ooze	→	Root and stem rot pathogens (fungal and fungal-like) or Plant parasitic nematodes or Club root

Note: Bacterial ooze may not be observed in early stages of infection by *Ralstonia solanacearum*.

Fusarium wilt can be confused with bacterial wilt and Verticillium wilt (at present, an exotic disease to Vietnam). They cause similar symptoms and all cause vascular (stem) browning. However, plants affected by bacterial wilt are usually characterised by the presence of bacterial ooze. If there is no sign of ooze then check for *F. oxysporum* and *Verticillium* species by isolation. Formae speciales of *F. oxysporum* can be readily distinguished from *Verticillium albo-atrum* and *V. dahliae* in pure culture. Colonies of *Verticillium* grow slowly compared to colonies of *F. oxysporum*.

Always pathogenicity test *Fusarium* isolates from roots before assuming that they are pathogenic.

Fusarium species mainly cause wilt diseases and bulb and tuber rots of flower and vegetable crops. They are not common root rot pathogens. However, saprophytic strains of *F. oxysporum* and *F. solani* are very common colonisers of root tissue affected by other pathogens, and are easily isolated on non-selective media.

10.1 *Sclerotinia sclerotiorum*

Table 10.2 provides information about *Sclerotinia sclerotiorum*, a fungus that causes Sclerotinia rot of stems, heads, fruit and flowers.

Table 10.2 Characteristics of *Sclerotinia sclerotiorum*

Key symptoms	Wet rot of plant tissue
Diagnostic signs	Presence of white mycelium and large irregularly shaped black sclerotia.
Host range	Affects a wide range of dicotyledonous (broadleaved) crops including tomato and potato, lettuce, soybeans, peanuts, short beans, long beans, cabbage, broccoli, cauliflower and cucurbits.
Weather	Requires cool wet weather.
Overseasoning	Sclerotia survive in soil for long periods. Under mild wet conditions sclerotia germinate to produce apothecia. The apothecia produce ascospores which infect the plant.
Infection	Produces ascospores from apothecia. Ascospores infect plant usually at leaf axils. Old flower petals assist the pathogen in the infection process.
Control	Use rotation to crops such as maize and cotton, avoid dense plant canopies (these lead to high humidity within the crop and favour infection).
Isolation	1. Surface sterilise diseased stem by dipping in 70% ethyl alcohol and drying on sterile paper tissue (facial tissues or good toilet paper can also be used). 2. Cut sections from the margins of healthy and diseased tissue and aseptically transfer them to potato dextrose agar. 3. Purify by hyphal tip method. The fungus can also be isolated from sclerotia: 1. Surface sterilise the sclerotia for 1 minute in 70% ethyl alcohol. 2. Wash in sterile water and air dry. 3. Cut sclerotia into halves. 4. Plate the pieces on potato dextrose agar with the cut side facing down on the agar.

Figure 10.1 illustrates the disease cycle of *Sclerotinia sclerotiorum* and Figure 10.2 is a series of images showing the effect of *Sclerotinia sclerotiorum* on a variety of crop plants, as well as sclerotia and apothecia.

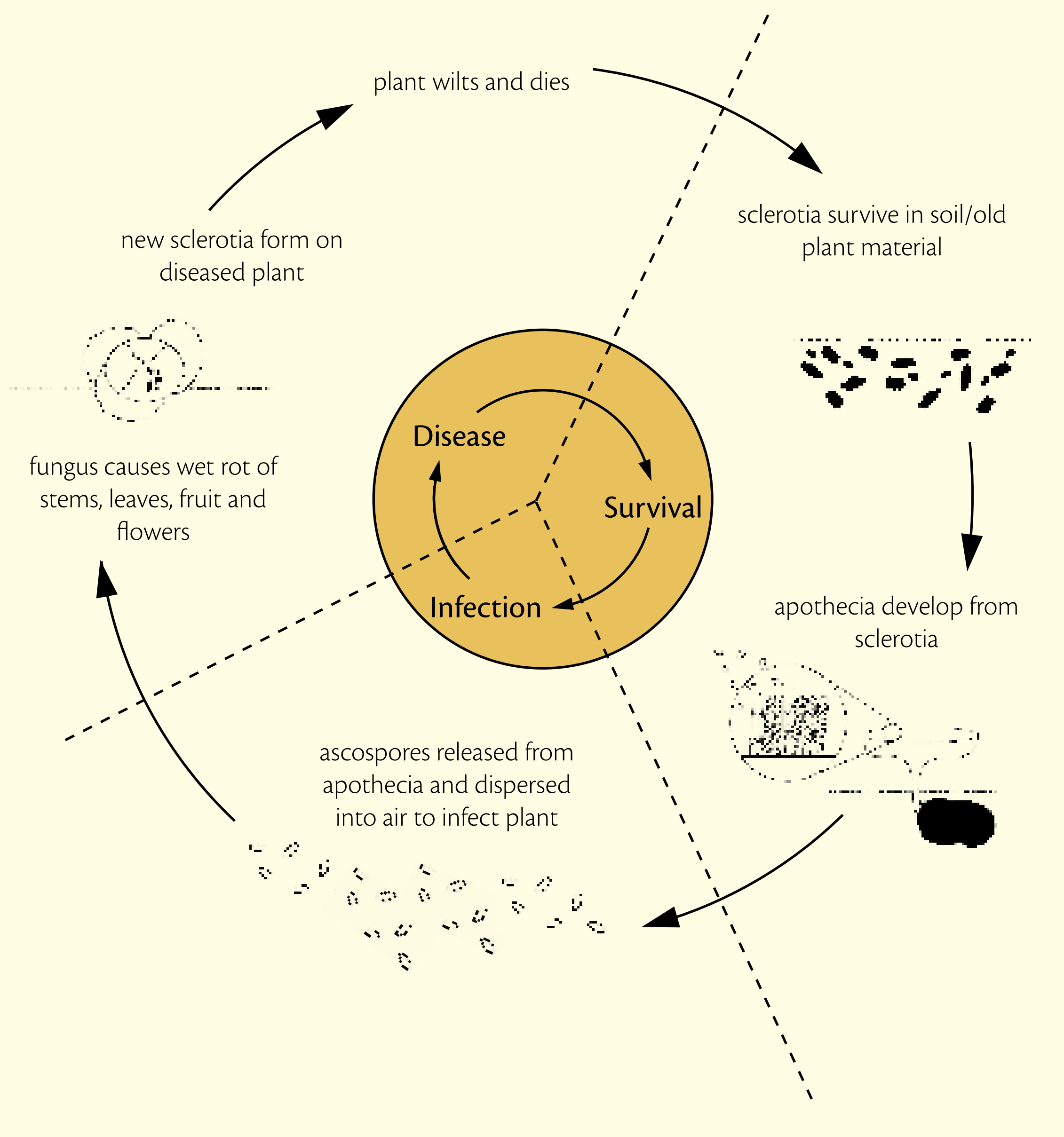


Figure 10.1 *Sclerotinia sclerotiorum* disease cycle

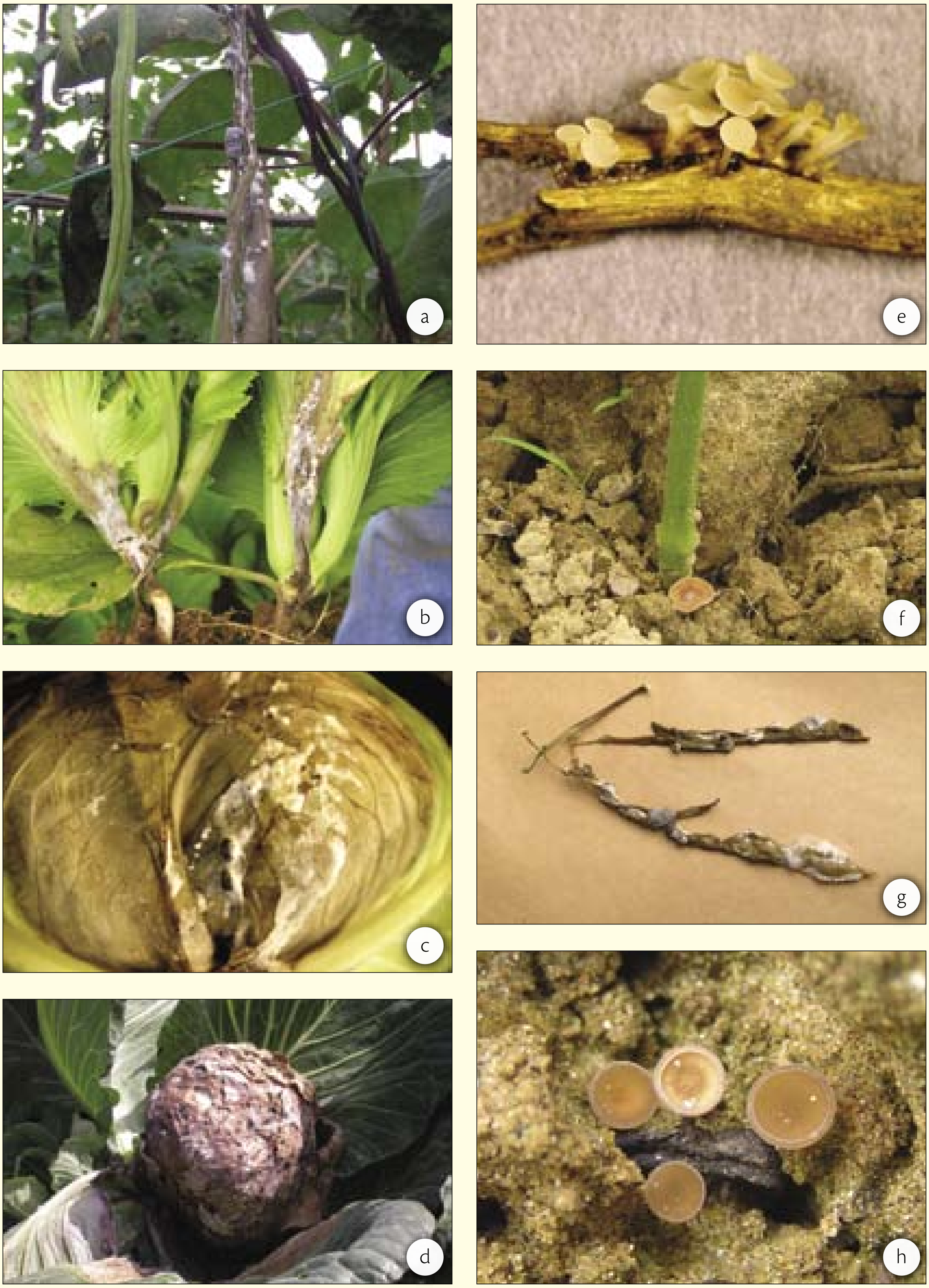


Figure 10.2 *Sclerotinia sclerotiorum* affecting: (a) long beans, (b) lettuce, (c) cabbage (wet rot), (d) cabbage; (e) apothecia from sclerotia in soybean residue; (f) apothecium next to short bean; (g) long bean (sclerotia produced on bean); (h) germinated sclerotium producing apothecia

10.2 *Sclerotium rolfsii*

Table 10.3 provides information about *Sclerotium rolfsii*, a fungus that causes basal rot of stems.

Table 10.3 Characteristics of *Sclerotium rolfsii*

Key symptoms	Causes rot of the stem base, wilting and death of the diseased plant.
Diagnostic signs	White fungal mycelium and small round brown sclerotia are formed on the surface of the diseased stem base. Obvious white hyphal growth is produced as disease spreads from infected to healthy plants.
Host range	Wide host range includes tomato, chilli, cucurbits, beans, carrots and onions. Commonly infects plants affected by other pathogens.
Weather	Most severe in warm to hot, wet or humid conditions.
Overseasoning	Survives in soil for long periods as sclerotia.
Infection	Infects through the base of the stem from hyphae from sclerotia. Infection can be more severe where plant residues are on the soil surface. Hyphal runners (mycelium) can grow several centimetres over the soil surface from diseased plants or tissue to infect nearby plants.
Control	Crop rotation. Flooding during two successive paddy rice crops will kill all sclerotia in the soil.
Isolation	Can be isolated on potato dextrose agar from surface sterilised stem tissue, cut from the margin of the diseased and healthy tissue. *S. rolfsii* cultures can also be isolated from sclerotia: 1. Surface sterilise sclerotia in 70% ethyl alcohol for 1 minute. 2. Wash in sterile water and air dry. 3. Cut in half and plate the pieces on potato dextrose agar with the cut surfaces on the agar.

Figure 10.3 shows characteristics of *Sclerotium rolfsii*.

Figure 10.3 *Sclerotium rolfsii*: (a) in pathogenicity test (note hyphal runners), (b) on decaying watermelon, (c) basal rot with the formation of brown spherical sclerotia

10.3 *Rhizoctonia* species

There are many *Rhizoctonia* species and strains in Vietnam. These species are quite variable in their distribution and host range. Morphological identification to species level is difficult.

A variety of diseases are caused by *Rhizoctonia* species in Vietnam (Figure 10.4). Some species grow on plant stem and leaf surfaces in warm, wet or humid conditions causing infection and disease of these plant parts. For example, one *Rhizoctonia* species infects maize leaves and causes distinctive patterning (Figure 10.4d). It is thought that the same species, or a similar species, causes head rot of cabbage. These fungi may produce irregular brown sclerotia on diseased plant surfaces. *Rhizoctonia oryzae* causes sheath blight of rice, a well-known disease.

Figure 10.4 Examples of Rhizoctonia diseases: (a) spear point symptoms on diseased roots, (b) Rhizoctonia sheath blight on rice, (c) sclerotia of *Rhizoctonia* on diseased cabbage, (d) Rhizoctonia disease on maize hull

Rhizoctonia species also cause collar rot of seedlings such as beans, cabbage, peanuts and cotton. Collar rot is caused by infection at the soil surface and can kill seedlings.

Rhizoctonia root rot develops from infection of the growing tip of small lateral roots. The fungus then progressively grows from the root tip and may cause rot of the main root. *Rhizoctonia* infection of a rootlet often results in the 'spear-point' symptom of roots (Figure 10.4a).

Table 10.4 shows characteristics of *Rhizoctonia* species, which are fungi that cause a variety of diseases on a range of crop plants.

Table 10.4 Characteristics of *Rhizoctonia* species

Key symptoms	Symptoms depend on the species and strain of the fungus and the host plant, and may include collar rot of seedlings, wilting, seedling death, rootlet rot and root rot. Rhizoctonia head rot in cabbages causes black necrotic areas on leaves. Sheath blight in rice and tiger stripe or blotch in maize cause irregular chlorotic or bleached areas.
Diagnostic signs	Diagnosis usually depends on isolation and identification of the fungus in pure culture. Distinctive irregular brown sclerotia are formed by some species on diseased host tissues.
Host range	Variable, depending on species and strain of the fungus.
Weather	Diseases of leaves, stems and heads favoured by warm to hot, wet weather. Seedling diseases and root rot are more severe in plants affected by unfavourable conditions. For example, bean seedlings are more susceptible to collar rot in cold weather, which slows germination and emergence.
Overseasoning	*Rhizoctonia* species survive in soil as sclerotia or as hyphae in host plant residues.
Infection	*Rhizoctonia* hyphae in infested residue directly infect plant tissues and some form special infection structures. Sclerotia germinate to produce hyphae which then infect the plant.
Control	Seedling blight (collar rot) can be minimised by seed treatment with fungicides such as quintozene (pentachloronitrobenzene), and by altering planting dates to when soil temperatures and moisture favour rapid germination and emergence. The effectiveness of crop rotation depends on the host range of the particular *Rhizoctonia* species being managed.
Isolation	Can be readily isolated from rice sheath blight, maize leaf blotch and cabbage head rot using surface sterilised tissue, plated on water agar and subcultured onto potato dextrose agar containing antibiotics. Isolation from roots or rootlets with root rot is more difficult: 1. Wash roots free of soil. 2. Surface sterilise for 5 seconds in 70% ethyl alcohol. 3. Rinse in sterile water and damp-dry on sterile paper tissue. 4. Plate small (1–2 mm long) root segments from the margin of healthy and diseased root tissue onto water agar. 5. Subculture to potato dextrose agar. *Rhizoctonia* can be distinguished from *Pythium* and *Phytophthora* on water agar by right-angle hyphal branching and presence of wide septate hyphae. Sclerotia may form in culture, especially on rice straw agar.

10.4 *Phytophthora* and *Pythium*

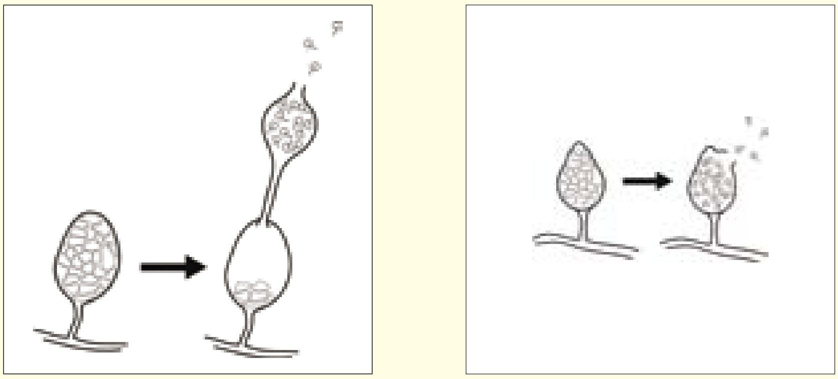
The genera *Phytophthora* and *Pythium* belong to the class Oomycetes within the Kingdom Chromista. Thus, they are not true fungi but fungal-like organisms. These genera produce non-septate hyphae, a key feature which distinguishes them from genera of true fungi.

10.4.1 Asexual reproduction

Asexual reproduction results in structures called sporangia, which give rise to zoospores. These zoospores are motile and have a key role in the disease cycle, particularly in the dispersal of these organisms in wet soil or on plant surfaces. The formation of motile zoospores also distinguishes *Phytophthora* and *Pythium* from genera of true fungi. Zoospores enable the rapid spread of disease from infected plants.

The sporangia of *Pythium* are formed at the end of hyphae or within hyphae, and are either rounded (globose/spherical) or filamentous (like a swollen hypha). A discharge tube is formed by the sporangium of *Pythium*, with a very thin-walled vesicle formed at the end of the discharge tube (Figure 10.5). Cytoplasm flows from the sporangium through the discharge tube to the vesicle. Zoospores then develop in the vesicle and are released when the vesicle ruptures (splits open).

In contrast, *Phytophthora* species form obvious regularly shaped sporangia on a sporangiophore. Zoospores form in the sporangia and are released directly from the sporangium. Some species such as *P. infestans* and *P. palmivora* form deciduous sporangia which can be aerially dispersed.



Pythium *Phytophthora*

Figure 10.5 Sporangium of *Pythium* illustrating zoospore release through a vesicle (left), and zoospore release directly from *Phytophthora* sporangium (right)

Some species of *Phytophthora*, such as *P. cinnamomi*, form asexually produced chlamydospores in culture. These act as survival spores in soil.

10.4.2 Sexual reproduction

Sexual reproduction involves the formation of oogonia (considered 'female') and antheridia (considered 'male'). Following fertilisation the oosphere ('female' gamete) within the oogonium develops into a thick-walled oospore. The oospore is a survival spore and has a key role in the disease cycle. Oogonia of *Pythium* may have smooth walls or horn-like ornamentation. The oogonia of *Phytophthora* are smooth walled.

Sterols are essential for oogonial production. Therefore, these fungi should be cultured on PCA (potato carrot agar) as carrot extract contains sterols. The PCA should contain some sediment from the carrot extract.

Some species of *Pythium* are heterothallic; however, many of the common pathogens are homothallic and form the sexual structures in a pure culture from a hyphal tip. Sexual reproduction in a homothallic species only requires one strain. Sexual reproduction in a heterothallic species requires two strains of opposite mating types.

Approximately 50% of *Phytophthora* species are heterothallic and require two mating type strains (A1 and A2) for sexual reproduction to occur. Figure 10.6 illustrates sexual reproduction in *Pythium*—reproduction is by a similar process in *Phytophthora*.

10.4.3 Identifying and differentiating *Phytophthora* and *Pythium*

Cultures (colonies) of many species of *Phytophthora* and *Pythium* appear quite similar on artificial media. Accurate identification of these species can be based on the morphology of the sporangia and the morphology and arrangement of the oogonia and antheridia. The presence or absence of chlamydospores can assist with identification, as can the nature of hyphae in some species of *Phytophthora*.

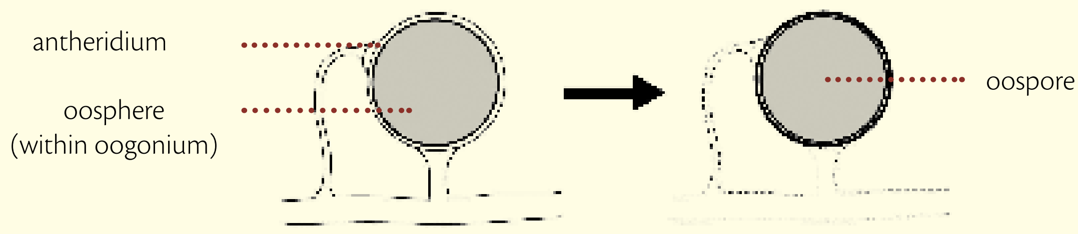


Figure 10.6 Diagram illustrating sexual reproduction in *Pythium*, involving contact between an antheridium and an oogonium to form an oospore

Pythium species usually produce abundant fluffy white mycelium on potato dextrose agar (PDA), filling the culture plate (Figure 10.7). Some *Pythium* species have a very high growth rate, and may cover a large (90 mm) PDA plate in less than 2 days. In contrast, *Phytophthora* species usually grow more slowly producing less abundant white mycelium. However, this is not a reliable criterion for separating the two genera.

Figure 10.7 *Pythium* sp. (left) and *Phytophthora* sp. (right), showing the characteristic faster growth and aerial mycelium on the *Pythium* plate

Pythium species usually produce sporangia and zoospores on water agar (WA) or PCA after flooding with water. A low-temperature shock (5–10 °C for approximately 2 hours) may assist sporangial production in *Pythium*. Some homothallic *Pythium* species also produce the oospores on WA. However, some cultures of homothallic *Pythium* species grown on sterile rice leaf pieces in sterile water in a Petri dish have produced abundant oogonia and antheridia at room temperature.

Refer to published descriptions of *Pythium* species to assist with identification to species level and forward cultures to reference laboratories to confirm identification.

Isolates of some common *Pythium* species in Vietnam will also produce sporangia and zoospores in rice-leaf water culture.

Some *Phytophthora* species will produce sporangia on *Phytophthora* selective medium (PSM), a selective isolation medium, if exposed to the light. Some species will also produce sporangia on PCA, which is readily prepared in the laboratory.

Sporangial production can also be stimulated by transferring 1 cm^2 blocks of cultures on PSM or PCA to sterile water in a Petri dish and incubating in the light for 2 days.

Many excellent texts have been produced and should be referred to for more in-depth information. Refer to *Phytophthora Diseases Worldwide* by Erwin and Ribeiro (1996) for detailed descriptions of the sporangia of *Phytophthora* species to assist in identification. For further assistance with *Phytophthora* identification also refer to the booklet *Practical Guide to Detection and Identification of* Phytophthora by Drenth and Sendall (2001).

The majority of common plant pathogenic *Phytophthora* species in Vietnam are heterothallic, namely *P. capsici*, *P. palmivora*, *P. nicotianae*, *P. infestans*, *P. cinnamomi* and *P. colocasiae*. Note that *P. heveae* is homothallic, and sexual reproduction in *P. citrophthora* is rare.

In heterothallic species, it is necessary to cross strains of opposite mating type for sexual reproduction. This may not be feasible in a provincial diagnostic laboratory.

The mode of formation and morphology of sporangia of *Phytophthora* provide a practical guide to the identification of the most important species in Vietnam if a reliable text such as Erwin and Ribeiro (1996) is available.

Zoospores are normally formed in a vesicle at the end of the discharge tube in *Pythium*. In contrast, zoospores are normally formed in the sporangium of *Phytophthora* species. This is a reliable difference for separating the two genera.

10.4.4 Oomycete disease cycle—*Phytophthora* and *Pythium*

Figure 10.8 is a diagrammatic representation of the oomycete disease cycle and Figure 10.9 shows features of *Pythium* species and sporangia of a *Phytophthora* sp.

10.4.5 *Pythium* species

Pythium species belong to the class Oomycetes. They are not true fungi as this class is in the kingdom Chromista.

Motile spores called zoospores are important spores formed by *Pythium* (and *Phytophthora*) species, and distinguish these fungi from the true fungi in the kingdom Fungi (Mycota). The asexually produced zoospores enable these fungi to disperse in wet soil and irrigation water. Figure 10.10 shows diseases of peanuts caused by *Pythium*.

> *Pythium* species can cause seedling death, but rarely cause death of older plants. However, they can cause severe feeder rootlet rots and disrupt the uptake of nutrients, which causes stunting, slight yellowing and yield loss.

Table 10.5 provides information about *Pythium* species, which are oomycetes that cause various fungal-like diseases on a range of crop plants.

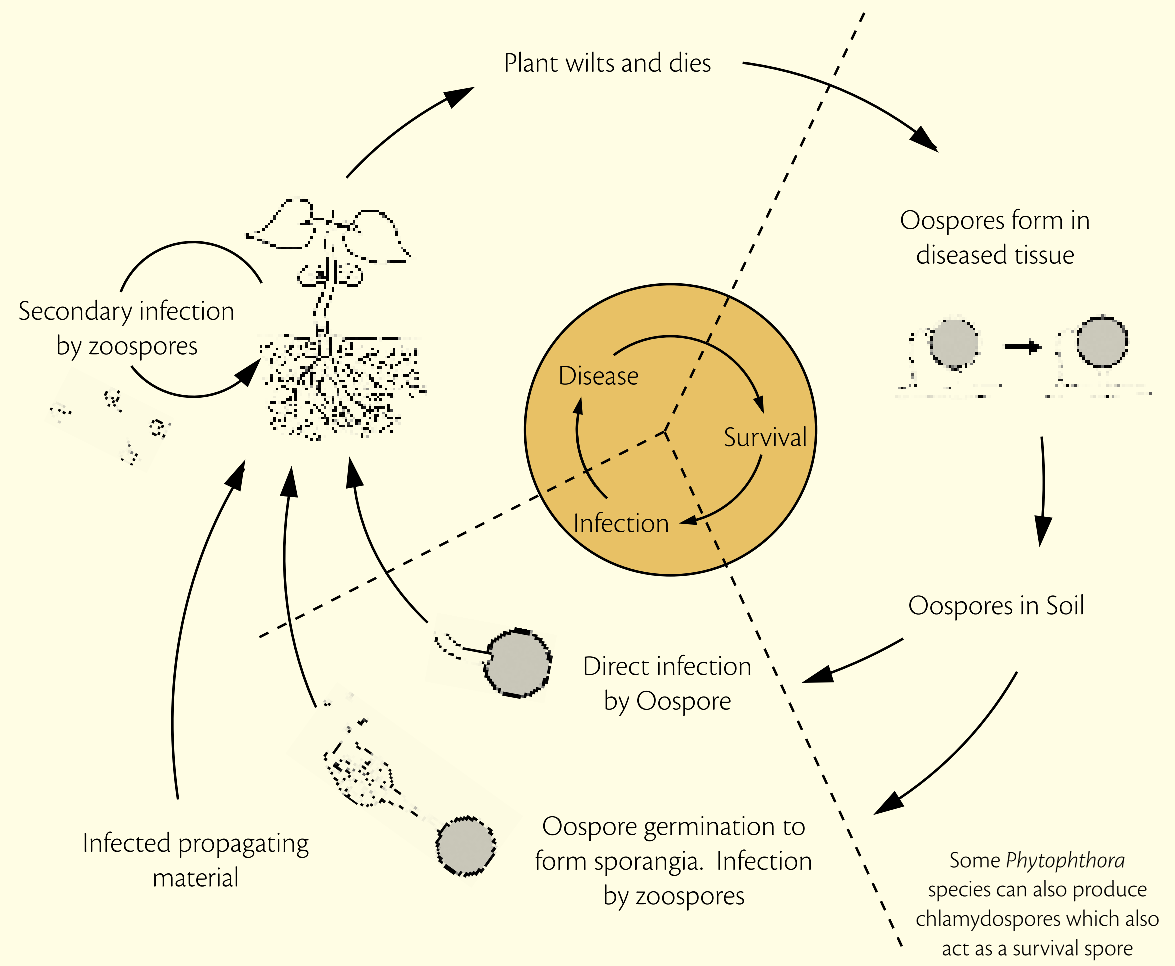


Figure 10.8 Simplified disease cycle of an oomycete plant pathogen

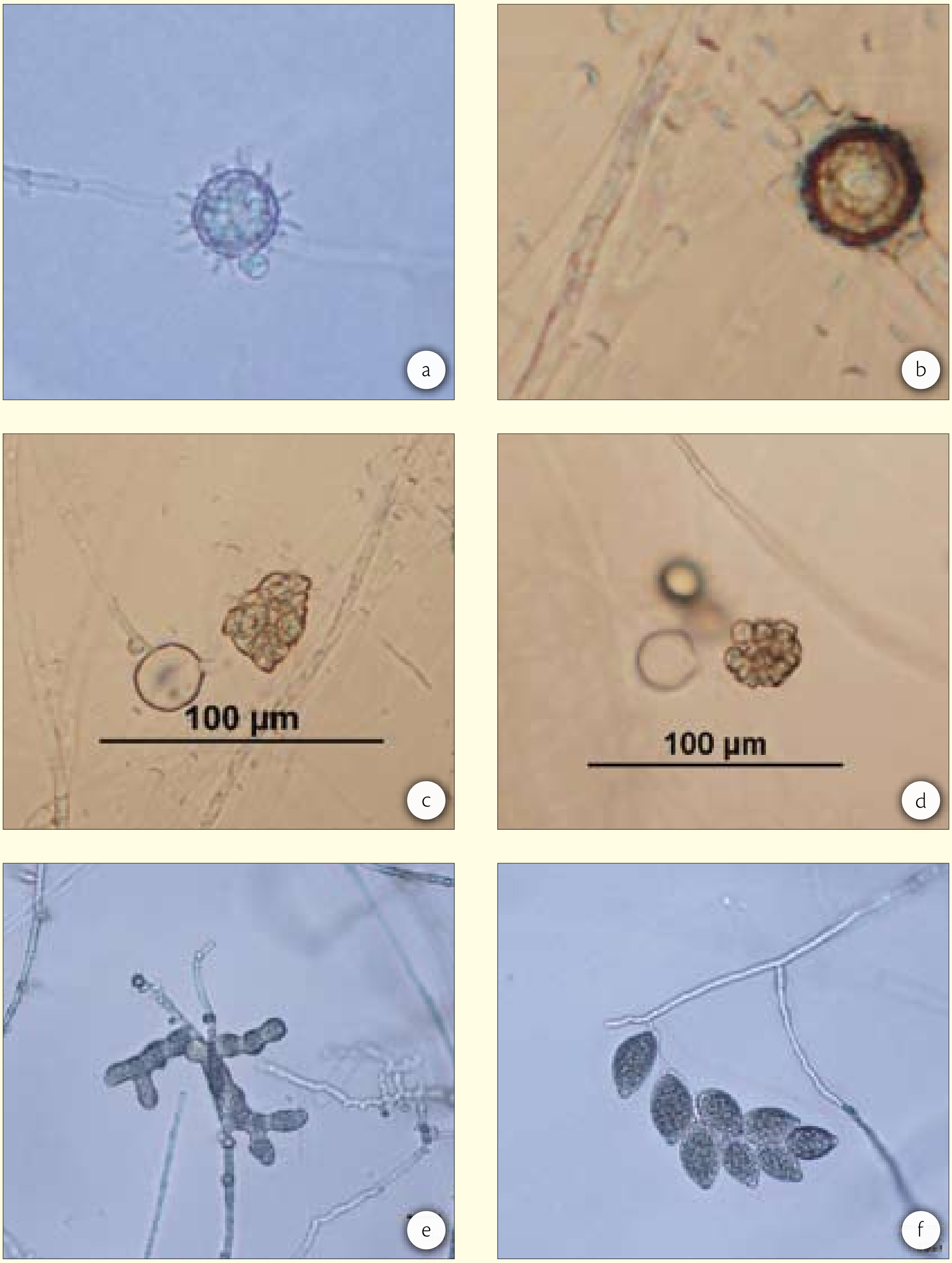


Figure 10.9 (a) Oogonium of *Pythium spinosum* showing attached lobe of an antheridium, (b) mature oospore of *P. mamillatum*, (c) sporangium of *P. mamillatum* showing discharge tube and vesicle containing developing zoospores, (d) sporangium of *P. irregulare* showing mature zoospores in thin walled vesicle prior to release, (e) digitate sporangia in *P. myriotilum*, (f) distinct sporangiophore and sporangia of *Phytophthora* sp.

Table 10.5 Characteristics of *Pythium* species

Diseases	*Pythium* species cause seedling blights and death (damping-off diseases), and cause feeder rootlet rot of mature plants. They also cause rot of potato tubers, carrots and other storage organs. Pythium root and pod rot is a major disease of peanuts.
Key symptoms	In seedlings, the typical symptoms are wilting and death caused by root rot (browning) of the young rootlets and stem. *Pythium* species can also infect the feeder rootlets, causing stunting, and yellowing of the leaves of older plants. As infected plants mature, *Pythium* species can colonise and cause root rot of the main roots or taproot. *Pythium* species can also cause pod rot in peanuts.
Diagnostic signs	There are no diagnostic signs indicative of *Pythium*. It is necessary to isolate and identify the fungus in culture for accurate identification of the pathogen.
Host range	Most *Pythium* species have a wide host range.
Weather	Wet soil favours infection of plants by *Pythium* zoospores and the dispersal of zoospores through the soil. Environmental and soil conditions which inhibit root growth increase the risk of seedling blight and feeder rootlet rot.
Overseasoning	*Pythium* species survive as oospores produced though sexual reproduction. Under favourable conditions, these thick-walled spores germinate and initiate rootlet infection.
Infection	In wet soil, zoospores are attracted to the rootlet tip, where they produce germ tubes (young hyphae) that penetrate the rootlet tip and initiate rootlet rot.
Control	Seeds can be treated with fungicide, and seedling roots can be treated with fungicide by dipping prior to transplanting. Crop rotation is an important measure for reducing the incidence of Pythium root rots. It is essential to use pathogen-free transplants.
Isolation	*Pythium* species can be isolated from diseased rootlets: 1. Dip briefly in 70% ethyl alcohol and wash in sterile water. 2. Damp-dry on paper tissue. 3. Plate on water agar. Water agar is commonly used for isolation, as *Pythium* species quickly colonise the agar—most *Pythium* species have high growth rates. White dense fine mycelium is formed in culture on PDA. Many species can colonise a large PDA plate in less than 48 hours. Purify *Pythium* cultures by hyphal tipping. *Pythium* species usually produce abundant sporangia and oospores in rice-leaf water cultures.

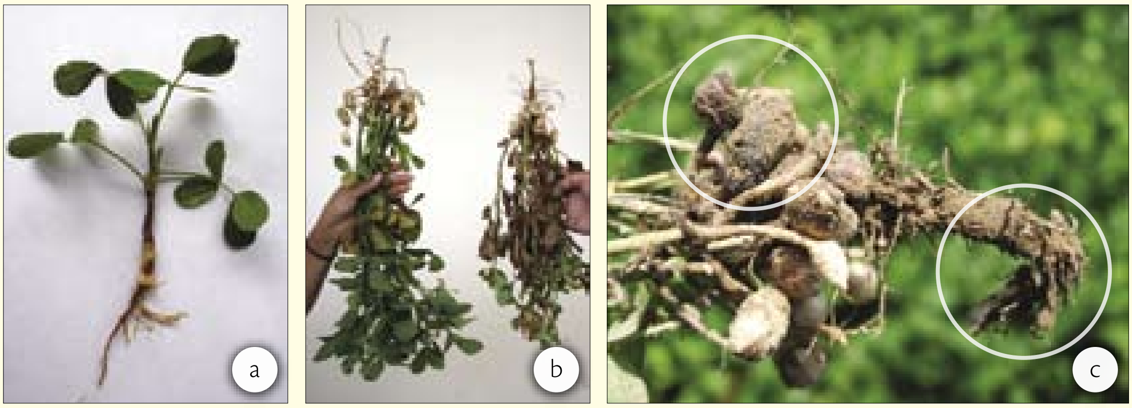


Figure 10.10 Pythium diseases on peanuts: (a) Pythium rootlet rot and stem rot of peanut seedling grown under very wet conditions, (b) comparison of two mature peanut plants, healthy plant (left), stunted plant with severe Pythium root rot (right), (c) severe Pythium pod and tap root rot of peanuts

10.4.6 *Phytophthora* species

Phytophthora, like *Pythium*, produces zoospores and is an oomycete—not a true fungus. Therefore, control of *Phytophthora* and *Pythium* pathogens differs from control of the diseases caused by true fungi and different fungicides are used.

Phytophthora diseases of tree, vegetable and other crops cause significant economic losses throughout South-East Asia. The isolation and identification of *Phytophthora* species and the use of integrated disease management are discussed in detail in the publications listed in the bookshelf section. Table 10.6 provides information about *Phytophthora*, an oomycete that causes a wide range of fungal-like diseases on many different crop plants in Vietnam. Some of these diseases are shown in Figure 10.11.

Table 10.6 Characteristics of *Phytophthora* species

Diseases	*Phytophthora* species cause a very wide range of diseases in Vietnam in fruit trees and vegetable, field and industrial crops. Diseases include root rot; trunk canker and fruit rot of durian; root rot of chilli; heart rot of pineapple; foot rot (quick wilt) of black pepper; late blight of potato and tomato; root, stem and fruit rot of paw paw; dieback of rubber and other tree crops.
Key symptoms	Infected trees die back from the top of the tree and may show root rot as well as canker symptoms on the trunk near the soil surface. Vegetable crops affected by root rot, such as chilli, become stunted and wilt. Plants usually die soon after severe wilt symptoms occur.

Diagnostic signs	Diagnosis requires the isolation and identification of the pathogen. Wilting is also caused by other root and stem pathogens.
Infection	The mode of infection depends on the species. However, oospores, sporangia and zoospores can incite infection of various plant parts. Rain splash dispersal of spores onto foliar plant parts can lead to infection of stems, leaves and fruit, depending on the species of *Phytophthora* and the host. Crawling and flying insects may also carry the fungus from the soil to the upper plant parts.
Host range	The host range of *Phytophthora* species depends on the particular species. Some species such as *P. palmivora* have a wide host range, whereas other species such as *P. infestans* have a narrow host range.
Overseasoning	The pathogens overseason as oospores and/or chlamydospores in soil, and can be transported in diseased propagating material or contaminated soil or farm implements.
Weather	Phytophthora diseases are favoured by wet conditions. High rainfall in tropical regions promotes splash dispersal of zoospores and other inocula. Zoospores also move in water in irrigation furrows and channels. Many *Phytophthora* species are favoured by hot wet conditions. In contrast, some species, such as *P. infestans* (late blight), are favoured by cool wet conditions.
Control	Successful control of Phytophthora diseases usually involves a number of control measures: • good drainage • use of disease-free planting material • exclusion of *Phytophthora* from non-infested areas • use of chicken manure as fertiliser to suppress activity of the pathogen in the soil • injection of trees with phosphonate • drenching of seedling roots at transplanting to reduce seedling death.
Isolation	*Phytophthora* species can be isolated readily from diseased foliar plant parts, such as pineapple leaves, using selective isolation media. For the method, see the protocol for isolation from pineapple heart rot samples, as pictorially described in the pineapple heart rot case study (Section 3.1). Isolation from diseased roots can be much more difficult. This is because there are many saprophytic fungi and bacteria growing in the diseased root tissues. A protocol for isolation of root pathogens can be found in Section 6.3.2. Baiting is recommended for the isolation of *Phytophthora* from small roots and soil. For more information on this technique refer to the section on baiting of pathogens from roots and soil (Section 6.3.4).

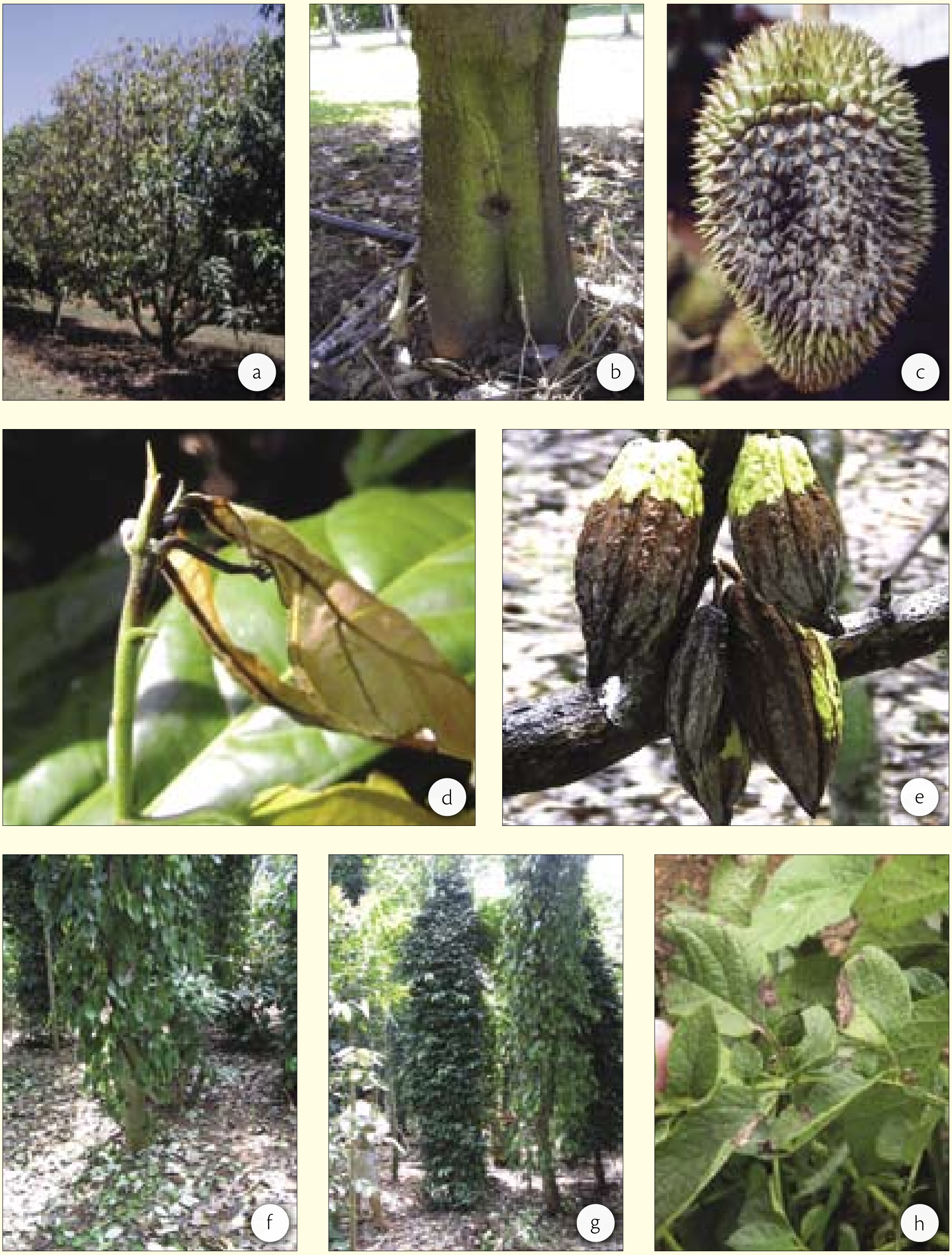


Figure 10.11 Diseases caused by *Phytophthora palmivora* on durian: (a) tree yellowing, (b) canker on trunk, (c) fruit rot. Diseases caused by *P. palmivora* on cocoa: (d) seedling blight, (e) black pod symptoms. Root rot (quick wilt) of black pepper caused by *P. capsici*: (f) leaf drop, (g) wilting. Disease caused by *P. infestans*: (h) late blight of potato.
Pictures (a) to (e) supplied by David Guest, (f) and (g) supplied by N. V. Truong.