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## Control of Major Diseases in Horticulture

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### 1. Introduction

Cultivation of fruits, vegetables, flowers, and/or ornamental plants is one of the economically important sectors of crop production. However cultivation of these plants plagued with wide range of most destructive, reoccurring and widespread stress factors both biotic (diseases) and abiotic (environmental) (Gachomo et al., 2009). Plant diseases are caused by many different types of organism that include fungi, bacteria, viruses etc. While plant disease may be caused by many factors, majority of them are caused by fungi and fungi like organisms (FLO). Over 8,000 species of fungi and FLOs have been reported to cause disease (Ellis et al., 2008). Disease caused by fungi and FLOs have been recorded to cause damage that has had far reaching effects on human population as a result of the suffering that follow crop loss (Gachomo, 2005) e.g. the great famine of 1845-1852 that occurred in Ireland as a result of potato crop failure due to potato blight infection. During this famine about a million people died of hunger and another million emigrated out of Ireland. Control of plant disease is both expensive and time consuming and represents a large segment of the pesticide market (Gachomo et al., 2009; Killian & Steiner, 2003), despite continuous efforts to control their detrimental effect on crop production. For example cost of control and damage by *Phytophthora infestans* (that causes late blight of potatoes) in Europe is estimated at more than €1,000,000,000 (\$1,400,000,000) per year (Haverkort et al., 2008). The typical symptoms of these fungal induced diseases cover all color spectra (from white to black) and form different types of symptoms both internal and external, microscopic and macroscopic, local and systemic which appear (but are not limited to) as leaf spots, galls, lesions, blights and cankers incase of local symptoms or as wilting, yellowing, and dwarfing incase of systemic symptoms because they involve most or all of the plant (Gachomo et al., 2006; Gachomo & Kotchoni 2007; Gachomo et al., 2010). Common fungal diseases include leaf spots, cankers, powdery mildews, downey mildews, smuts, blights, damping off,

blasts, anthracnose, wilts, fruit rots, root rots, stem rots, rusts and molds among any others (Bowen & Roark, 2001; Walker et al., 1995).

Once the fungal diseases are established, they are generally difficult to control despite a combination of practices including sanitation measures and fungicide applications (Behe et al., 1993). Management of the diseases relies often on intensive use of fungicides (Bowen & Roark, 2001; Reddy et al., 1992; Walker et al., 1995). Fungicides used in fungal disease management include dormant sprays, protectant and systemic fungicides (Bowen & Roark, 2001; Killian & Steiner, 2003). Protectants, also known as contact fungicides, remain on the outside of the plant and kill parts of fungal structures growing on the surface of the plant (Gachomo et al., 2009). However, the activity of protectant fungicides decreases with time because of exposure to environmental factors such as ultraviolet (UV) radiation and wash-off caused by the rain, and the expansion of foliage surface in growing plants leading to a breaking effect on protective layer. Consequently, protectant fungicides need frequent applications to be effective. On the other hand, systemic fungicides are absorbed into the plant tissue and can minimize disease symptoms after infection has occurred (Gachomo, 2005). One group of systemic fungicides, the demethylation inhibitors (DMI), has been widely used to control fungal diseases in horticulture (Killian & Steiner, 2003). DMI common mode of action is centered on the fungal sterol biosynthesis, i.e. the inhibition of demethylation at position 14 of lanosterol or 24-methylene dihydrolanosterol, the precursors of sterols in fungi (Kuck et al., 1996). However, strobilurins constitute the novel promising group of fungicides to control a wide range of pathogens infecting cereals, potatoes, fruit, grapevine, vegetables, turf grass and ornamentals (Ebeling et al., 2003; Stark-Urnau et al., 1997; Wojdyla & Orlikowski, 1999). The strobilurins inhibit the mitochondrial respiratory chain by blocking the electron transport at the Qo site of cytochrome b. Furthermore, the strobilurins used either alone or in combination with other fungicides control a wide array of fungal diseases, including diseases caused by water moulds, downy mildews, powdery mildews, fruit rotters, rusts, leaf spotting and blight fungi (Ammermann et al., 1992; Margot et al., 1998; Reuveni, 2001; Ypema & Gold 1999).

In this chapter, we give a detail overview of disease symptoms, their causal agents and fungicide dependent control of selected major fungal diseases in horticulture such as powdery mildew, gray mold, blackspot, late and early blight diseases, and Fusarium wilt disease. Optimum number and timing of fungicide sprays for an efficient disease control in horticulture are here discussed. In addition, we report several aspects of fungicide activity, including the effects on fungal establishment within the host.

## **2. Diseases of flowers**

### **2.1 Powdery mildew**

Powdery mildew as the name suggests initially appears as a white grayish coating on leaves (Figure 1 A). When the disease is severe it produces a white gray coating on stems, petals and buds. This white coating spreads over time to cover the whole leaf (Figure 1 B, C). The affected leaves or petals get distorted, shrivel and may fall to the ground. Several disease cycles occur within the plants' growth season. The disease makes the plants unattractive and repeated disease cycles cause reduced vigor of the plants (Gachomo, 2005). Among the most often affected flowers and shrubs are columbine, dahlia, delphiniums, honeysuckle, ivy, lilac, phlox, privet, snapdragons, lungwort, bee balm, garden phlox, verbena, rose, and zinnias.

## 2.2 Life cycle of powdery mildew causal agents

The powdery mildews are caused by a group of more than 300 related fungal species which are host specific, meaning that a fungal species that attacks one type of plant species might not infect another plant species. Examples of fungi causing powdery mildew include *Sphaerotheca pannosa* that infects roses; *Erysiphe cichoracearum* that infects Chrysanthemums. The primary inoculum comes from dormant infections that survive the winter. The overwintering structures called cleistothecia produce sexual spores, which infect young leaves and blossoms when the weather is favorable. Mycelia formed in the infected tissues form conidia, which infect other leaves, shoots and buds. Several generations of conidia are formed in the growing season as long as the weather remains favorable. Towards the end of the season when the conditions become unfavorable for disease development, cleistothecia are formed in the infected tissue and will serve as a source of inoculum during the next growing season.

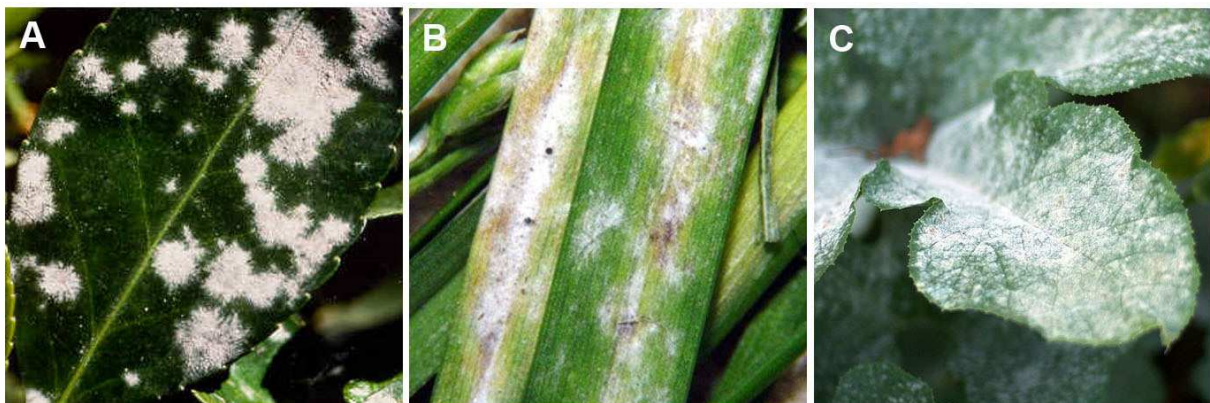


Fig. 1. Disease symptom of powdery mildew on the upper leaf surface of Euonymus plant (A), grass blades: Photo, courtesy of P. Flynn (B) and pumpkin leaves: Photo, courtesy of J. Kunbino (C).

## 2.3 Control and prevention of powdery mildew disease

Spores of the fungal causing disease are spread by wind and water splash; it is therefore crucial to avoid wetting the leaves during watering as one of the most fundamental strategies of powdery mildew control. In addition, avoiding the use of sprinkling irrigation but rather watering at the base of the plants or use of drip irrigation are the general rules in controlling this disease. In order for the disease to develop, the spores require plants wetness for several hours to be able to infect the plants, therefore water the plants preferentially in the morning rather than in the evening so that they have time to dry during the day, therefore reducing time of leaf wetness. Varieties that are susceptible should not be planted under the shade but in areas exposed to the sun because shading does not allow dew to dry quickly. The plants should be well spaced and kept free of weed to increase aeration around the plants and reduce moisture retention around the base of the plant. Plants should be pruned to reduce dense foliage and increase aeration. The fungus overwinters in fallen plant debris, therefore it is very important to clean up all fallen plant materials and prune infected tissues at the end of the season, which will ultimately reduce the source of inoculum for the next season. Up to date, the efficient control of powdery mildew disease relies on fungicide application. Several fungicides have been developed for the management of this disease. In Table 1, we show some of the widely used fungicides in powdery mildew disease control.



## 2.4 Gray mold disease

Generally, the gray mold disease appears as a gray to brown mold on dying plant tissue such as spent flowers, leaves and stems (Figure 2 A, B). The symptoms are observed as light spot surrounded by maroon halos on petals. These spots enlarge and turn brown over time. Infected petals may fall off. Cankers and dieback may be observed on stems. A wide range of plant varieties are affected by this disease. Susceptible plant species to gray mold include house plants such as African violets, amaryllis, Amazon-lily, azaleas, begonias, cacti, caladium, calla lily, camellias, castorbeans, chrysanthemums, cinerarias, coleus, corn flowers, dalias, dracaenas, dusty millers, ferns, fig, fuchsias, ardenias, gloxinias, heliotrope, orchids, passion flower, and poinsettias. In addition, members of herbaceous annual plants susceptible to gray mold are ageratum, begonia, caldium, carnation, celosia, chicory, geranium, gerbera, gladiola, impatiens, marigold, nasturtium, pansy, petunia, snapdragon, statice, stock, sunflower, sweet pea, verbena, and zinnia. Furthermore herbaceous perennials including anemone, aster, baby's-breath, bellflower, bleeding heart, bloodroot, bluebell, buttercup, calendula, candytuft, carnation, chrysanthemum, chicory, coralberry, cranesbill, dandelion, daylily, delphinium, Dutchman's- pipe, foxglove, globe-amaranth, hyacinth, iris, Jack-in-the-pulpit, liy, lily-of-the-valley, lupine, Maltese cross, narcissus, peony, phlox, pinks, plantain lily, poppy, primrose, purple coneflower, rose, snowdrop, tulip, vinca, and violet are susceptible to gray mold disease.

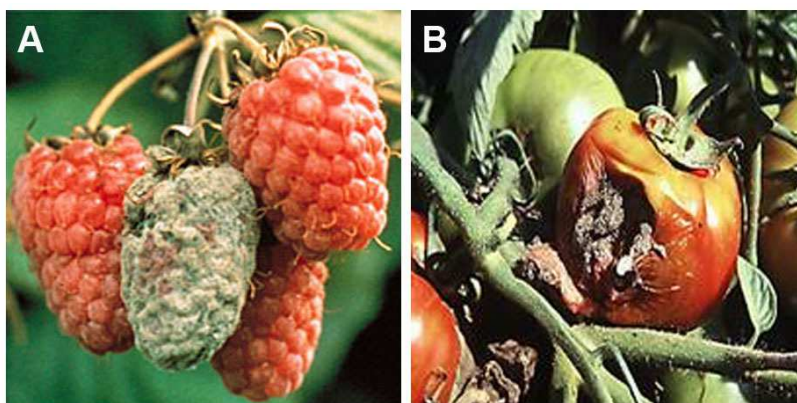


Fig. 2. Disease symptom of Gray mold disease on red raspberry fruit (A) and on tomato fruit (B). Photo, courtesy of P. R. Bristout.

## 2.5 Life cycle of gray mold causal agents

Gray mold disease is caused by many strains of the fungus *Botrytis cinerea*. This fungus is not host specific and therefore infects many different types of plant species. Symptoms vary with the plant species attacked. The fungus needs moisture to cause infection and a favorable temperature ranging from 18° C to 25° C.

### 2.5.1 Control of gray mold disease

To contain the disease all infected tissue should be remove as soon as possible; infected debris should be collected. The plants should be well spaced and weeded to allow good air circulation; sprinkler irrigation and wetting of the foliage should be avoided because this provides the humidity needed for the proliferation of the disease. Application of fungicides

in combination with the good sanitation measures will ultimately help to contain the disease. It is imperative to apply preventive fungicides as soon as disease is detected. Fungicides with the active ingredients such as chlorothalonil, dichloran, fludioxonil, trifloxystrobin, iprodione, mancozeb, copper sulfate pentahydrate, fenhexamid, azoxystrobin, and thiophanate methyl are registered for *Botrytis* control and therefore recommended to use in case of gray mold disease. Be sure to rotate applications among chemical classes as fungicide resistant strains of *Botrytis* have been reported.

## 2.6 Blackspot disease

Blackspot is a disease of roses. It appears as small black spots on the upper surface of the leaves (Figure 3 A), which first appear on the lowest leaves and may first appear as purple spots on stems that eventually turn black. The area around the spots turns yellow and the spot may coalesce to form black blotches (Figure 3 A, B, C). The yellow leaves easily fall off the plants. The disease spreads from lower leaves to younger upper leaves leading to further defoliation. Severe defoliation reduces vigor of the plants and decrease flower production (Gachomo et al., 2010).



Fig. 3. Photographs of rose leaves infected with *Diplocarpon rosae* showing, (A) the symptoms on leaves followed by the yellowing of the leaves (B) a close up of a sporulating spot showing the dome shaped-unopened acervuli that have pushed the cuticle upwards, (C) a close up of a sporulating spot where a mass of white conidia oozes out of the acervuli (Adopted from Gachomo, et al., 2010)

### 2.6.1 Life cycle of blackspot causal agents

Blackspot disease is caused by a fungal pathogen, *Diplocarpon rosae*. The fungus overwinters on infected canes and fallen debris (Gachomo, 2005). During the favorable weather conditions the spores are splashed from infected plant parts to young leaves by rain splash and irrigation water. The fungus produces conidia within 10 to 14 days (Figure 4 A, B) which are splashed to other young leaves. Several disease cycles can occur within a growing season. Once established the disease is difficult to control.

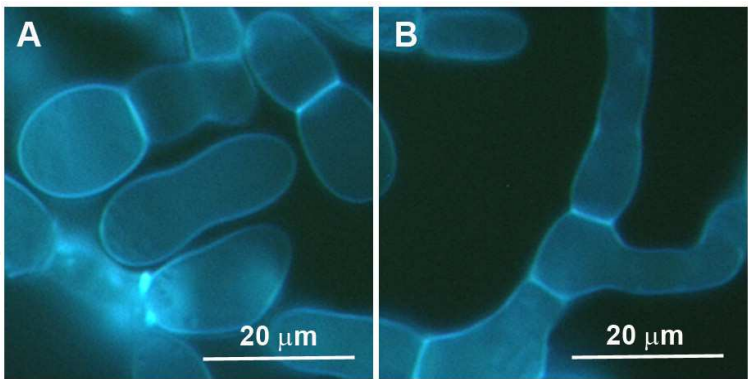


Fig. 4. Light microscope photographs of *Diplocarpon rosae* growing on artificial malt agar medium: (A) *D. rosae* two-celled conidial structures before and during germination. (B) Three day-old conidium germination. (Courtesy of E. W. Gachomo).

2.6.2 Control of blackspot disease

Control practices start with planting resistant rose varieties where available. Good sanitation is key to keeping the rose disease free. Recommended cultural practices are: All infected debris should be collected and burnt or buried; all infected canes must be pruned; overhead irrigation must be avoided because it tends to splash conidia from infected to non-infected parts of the plants. It recommended to water plants at the base; the plants should be preferably watered in the morning as opposed to the evening, because the conidia require several hours of wetness to cause infection, therefore watering in the morning reduces the hours of leaf wetness. In addition, plants should be well spaced and kept weed free to allow for aeration. Furthermore, one must avoid planting susceptible plants under the shade. When blackspot disease is establish, its control relies heavily on fungicides. In Table 1, the fungicides recommended in blacksopt disease management are listed.

Mode of Action	Target site and code	Group name	Chemical group	Common name	FRAC* code
sterol biosynthesis in membranes	C14-Demethylase in sterol biosynthesis ( <i>erg11/cyp51</i> )	DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	Triazoles	Myclobutanil (Immunox) Propiconazole (Banner Maxx) tebuconazole	3
sterol biosynthesis in membranes	C14-Demethylase in sterol biosynthesis ( <i>erg11/cyp51</i> )	DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	Piperazines	Triforine	3
mitosis and cell division	β-tubuline assembly in mitosis	MBC-Fungicides (Methyl Benzimidazole Carbamates)	Thiophanates	Thiophanate-methyl 3336 4.5 F 3336 50W Halt	1
Multi-site contact activity	multi-site contact activity	Inorganic	Inorganic	Copper (different salts)	M1
Multi-site contact activity	multi-site contact activity	Inorganic	Inorganic	Sulphur	M2

\*FRAC (Fungicides Resistance Action Committee)

Table 1. Fungicides labeled for the control of powdery mildew on roses.



### 3. Diseases of vegetables

#### 3.1 Bottom rot disease of lettuce

Bottom rot disease of lettuce can be recognized by brown spots that initially appear on the midribs of the lower leaves that are in contact with the soil (Figure 5 A). The rot spreads rapidly under favorable conditions to affect larger sections of the midrib and leaf blades, and may affect the inner leaves of the head. Symptoms are more severe during heading.

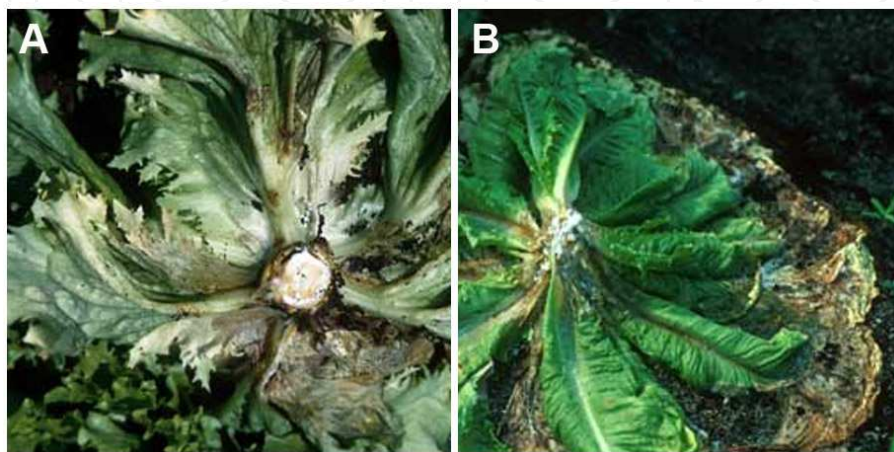


Fig. 5. Disease symptom of bottom rot (A) and Fusarium wilt of lettuce (B). Photos courtesy of A. F. Sherf (A) and T. A. Zitter (B).

##### 3.1.1 Fungal agent of bottom rot disease

Bottom rot is caused by a soilborne fungal pathogen *Rhizoctonia solani*. The fungus overwinters in the soil or in crop debris as sclerotia or mycelia. It may survive in alternate hosts and serve as a source of inoculum, sexual spores. It is disseminated by wind or rain splash in the next growing season. *R. Solani* has a wide host range e.g. eggplant, soybean, potato, cotton, alfalfa, maize, wheat and several weed species.

##### 3.1.2 Control of bottom rot disease

Cultural measures includes three year rotations with non-host plants; collecting plant debris and burying it or plowing it deep in the soil; planting varieties that have an upright architecture to reduce contact with the soil; keeping the fields weed free and removing volunteer crops to reduce possible alternate hosts. Since *R. Solani* is able to survive on non decomposed organic matter, it is important to avoid planting lettuce in a field that has high amounts of organic matter that is not decomposed; avoid overhead irrigation during heading of the plants; plant lettuce on ridges which increases aeration and helps avoid plants contact with the soil. Fungicides (Table 2) are the most effective means to control bottom rot disease. However, fungicide control is only satisfactory when used in combination with cultural control strategies. Proper placement and timing of fungicide applications are key elements for effective disease management.



Mode of Action	Target site and code	Group name	Chemical group	Common name	FRAC code
Respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site ( <i>cyt b gene</i> )	QoI-fungicides (Quinone outside Inhibitors)	Methoxy acrylates	Azoxystrobin (Amistar) (Quadris Flowable)	11
Respiration	complex II: succinatedehydrogene MAP/Histidine-Kinase	Carboxamides	Pyridine-carboxamides	Boscalid (Endura)	7
Signal transduction	in osmotic signal transduction ( <i>os-1, Daf1</i> )	Dicarboximides	Dicarboximies	Iprodione (Rovral 50 W) Vinclozolin (Ronilan DF)	2

Table 2. Fungicides Recommended for control of bottom rot on lettuce.

3.2 Fusarium wilt of lettuce

Lettuce seedlings affected by this disease wilt and ultimately die, while in mature plants the symptoms include red-brown to black discoloration of internal taproot and crown tissue, yellowing of leaves, tipburn of heads (Figure 5 B) and when infection is severe plants are stunted and may fail to form heads.

3.2.1 Fungal pathogen of Fusarium wilt disease of lettuce

Fusarium wilt of lettuce is caused by a soil-borne fungus, *Fusarium oxysporum* f.sp. *lactucae* forma specialis nov. This pathogen can remain viable in the soil for many years. *Fusarium oxysporum* f.sp. *lactucae* forma specialis nov is host specific to lettuce and therefore only affect/grow on lettuce.

3.2.2 Fusarium wilt disease control

Recommended cultural practices include clean of farm equipment, avoiding to plant lettuce in infected field and planting resistant/tolerant lettuce varieties.

4. Diseases of potato and tomato

4.1 Late blight disease

Late blight is one of the most destructive diseases of potato and tomato. It is found wherever these crops are grown. On potatoes it appears as small light green water soaked spots at the edges of leaves. During favorable weather conditions, cool and moist, the lesions enlarge rapidly, and turn brown to black (Figure 6 A, B). The lesions coalesce to cover entire leaves and even affect the stem. Infected tissue dries up when the weather is dry. The disease spreads rapidly and all the leaves may be killed in a few days. On tubers, the disease appears as irregular, dry, brown depressions. Copper brown, granular lesions are found underneath the skin (Figure 6 A). Potatoes infected with the late blight pathogen are generally susceptible to secondary infection from other fungi and/or bacteria.

4.1.1 Fungal pathogen of late blight disease

Late blight disease is caused by a fungal pathogen, *Phytophthora infestans*. The primary sources of inoculum are infected seed tubers, volunteer plants and plant debris. Spores are

dispersed by wind and water splash from infected to non-infected plants. The disease spreads rapidly at temperatures between 10 and 21°C in combination with high humidity. Several strains of the fungus have been reported and strains recombination increases the chance of having novel strains that are either resistant to fungicides or more tolerant to harsh environmental conditions. *P. infestans* also infects tomatoes and causes mild infections on eggplants, peppers and related weed species.

#### 4.1.2 Late blight disease management

It is recommended to destroy all volunteer potato and other susceptible plants because *P. infestans* survives on these volunteer plants that represent the primary sources of inoculum during the next season. Potato growers should only use certified seed potatoes and avoid using their own grown tubers as seed in order to contain the devastating effect of late blight disease. It is advisable to make sure that other crops that can also be infected by *P. infestans* are disease free. Cull piles of infected potatoes should be destroyed because they serve as a source of inoculum. The fields should be scouted for late blight on a regular basis, paying close attention to low lying areas, areas under shade, or near water sources. It is important to avoid overhead irrigation in the evening because this provides long periods of leaf wetness that favors disease development. Potato tubers should be harvested after the vines die, which also kills the spores on them and avoids transmission of spores to the tubers. Infected tubers should be removed before storage in order to avoid spreading the disease to the healthy tubers. Planting resistant or moderately resistant potato varieties where available is advisable.

#### 4.1.3 Chemical control of late blight disease

The fungicides recommended for use against late blight disease vary from region to region because strains of *P. infestans* found in one region might not be present in another, and fungicide sensitivity might be different among fungal isolates. Genotypes of *P. infestans* have been reported to recombine to produce new genotypes that are resistant to the recommended systemic fungicides, but resistance to protectant fungicides has not been reported.

In fields that have already been reported to have late blight, the first application of a protectant fungicide is recommended before row closure and a second application should follow within 7-10 days. Further applications of protectants should be done when the weather conditions are conducive for late blight development. A late blight epidemic is difficult to control, therefore regular applications of protectants during the growing season is important to keep new foliage covered. Applications should be made even late in the season as long as parts of the vines are still green to avoid tuber infections. For a complete list of fungicides recommended in a region, it is advisable to consult the area extension office. However, we highlight in Table 3 some of the recommended fungicides used to control late blight disease on potatoes.

#### 4.2 Early blight disease of potato and tomato

On potato and tomato foliage early blight appears as brown to black spots, which coalesce to form lesions that are restricted by large veins and therefore having an angular shape (Figure 6 C, D). Occasionally, a chlorotic border may be formed around the lesions. When stems are infected the disease appears as small dark spots. On tubers there are dark sunken lesions that are surrounded by raised margins. The tissue underneath the lesions is dry, reddish brown in color, and leathery in texture.

FRAC code	Mode of action	Group name	Chemical group	Common name
M3	Multi-site inhibitor	Dithiocarbamates and relatives	Dithiocarbamates and relatives	<b>Manebs:</b> (Maneb 75 DF;Maneb 80; Maneb + Zinc; Manex) <b>Mancozebs:</b> (Dithane M-45; Dithane F-45; Dithane DF; Penncozeb 80 WP; Penncozeb 75 DF) <b>Chlorothalonil:</b> (Bravo 500; Terranil Excell; Bravo Ultrex; Terranil 6L; Bravo Weatherstik; Bravo Zn)
M3	Multi-site inhibitor	Dithiocarbamates and relatives	Dithiocarbamates and relatives	
M5	Multi-site contact activity	Chloronitriles	Chloronitriles	
11	Respiration	<b>QoI</b> – fungicides (Quinone outside Inhibitors)	Methoxy acrylates	<b>Azoxystrobin:</b> (Quadris)
40	Lipids and membrane synthesis	<b>CAA</b> -fungicides (Carboxylic Acid Amides)	Cinnamic acid amide	<b>Dimethomorph:</b> (Acrobat MZ)
22	mitosis			
22	$\beta$ -tubulin assembly		Benzamides	<b>Gavel 75 DF</b>
27	Unknown mode of action	Cyanoacetamide-oxime	Cyanoacetamide-oxime	<b>Cymoxanil:</b> (Curzate 60 DF)

Table 3. Fungicides listed for control of late blight on potatoes.

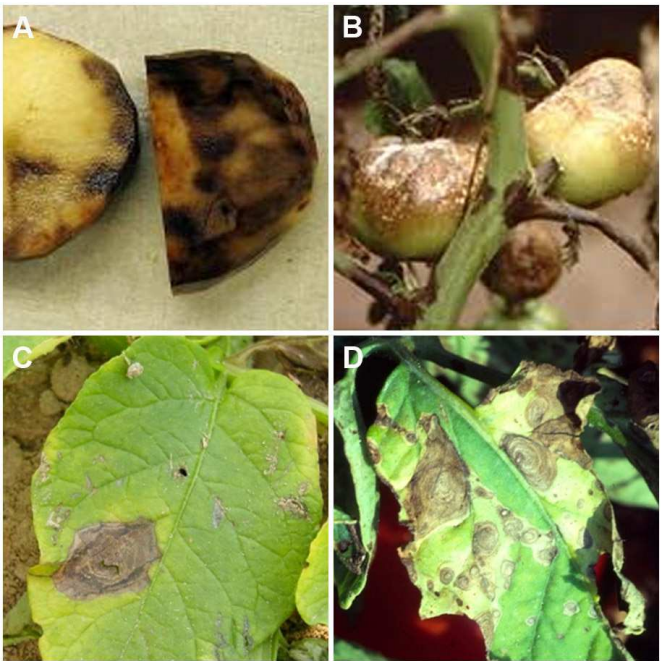


Fig. 6. Late blight (A-B) and early blight (C-D) disease symptom on potato (A, D) and tomato plants (B, D) respectively. Late blight disease is depicted on potato (A) and tomato fruit (B), while early blight disease is depicted on potato leaf (C) and tomato leaf (D). Photos: courtesy of B. Millett (A); W. R. Stevenson (B); S. R. Rideout (C); and R. Mulrooney (D).

#### 4.2.1 Fungal pathogen of early blight disease

Early blight disease is caused by a fungus, *Alternaria solani*. The fungus overwinters in plant debris, infected tubers, soil and on other host species. Disease development is favored by temperatures between 20°C and 30°C; long periods of leaf wetness, high relative humidity under alternating wet and dry conditions. Spores are dispersed by wind, water splash, insects, machinery and animals. The disease occurs late in the season and increases rapidly during flowering and senescence. Both biotic and abiotic stresses favor disease development. Bruising or wounding of tubers during harvest leads to infection with early blight.

On tomato the disease symptom is characterized by lesions with dark concentric rings. Diseased leaves wither, dry and fall off. Severe defoliation reduces plant vigor and exposes tomato fruits to sunscald. Disease is first observed on the lower leaves and spreads to the upper leaves. Other symptoms include damping-off, collar rot, stem cankers, leaf blight, and fruit rot.

#### 4.2.2 Early blight disease management

The following cultural practices that promote a healthy crop and therefore hinder early blight disease establishment include: three year crop rotations with non-susceptible crops; removing volunteer crops and keeping the field weed free; planting resistant/tolerant varieties; removing plant debris or burying it in the soil; irrigating in the morning so that the plant have enough time to dry; keeping the plants healthy so that they are less susceptible to disease; having proper spacing between the plants and rows to provide for good air circulation; using certified disease-free tomato seed and transplants; planting potatoes away from previous season potato fields; avoiding bruising and wounding of tubers during harvesting.

#### 4.2.3 Fungicides use in management of early blight

On potatoes it is recommended to apply protectant fungicides at beginning of flowering or at the earliest symptoms of early blight. On tomatoes fungicide application is recommended soon after transplanting or two to three weeks after emergence. In Table 4, the recommended fungicides used in early blight disease control are summarized.

#### 4.3 Black scurf disease of potato

On underground stems and stolons the disease appears as brown to black sunken lesions that cause the plants to look weak. These lesions may girdle the stolons and cut them off from the rest of the plant. Lesions that girdle the main stem cause the leaves to turn purplish or yellowish and curl upwards. Other symptoms include formation of aerial tubers and formation of whitish mold on the stems at the soil line. On tubers the disease causes tubers to crack or get deformed. Overwintering structures formed on surface of tubers appears as dark masses or as netted residues.

##### 4.3.1 Fungal causal agent of black scurf disease

Black scurf of potatoes is caused by a fungal pathogen, *Rhizoctonia solani* Kuhn. The fungus overwinters in the soil on plant debris or in form of sclerotia. Sclerotia may also survive on



tubers. Initial infection occurs when sclerotia germinate to infect stem and sprouts. Tubers are most susceptible to infection when left in the soil after the vines die. Infection is favored by cool (12-16°C) moist soils.

Mode of Action	Target site and code	Group name	Chemical group	Common name	FRAC code
Respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site ( <i>cyt b gene</i> )	QoI-fungicides (Quinone outside Inhibitors	Methoxy-acrylates	azoxystrobin,	11
Respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site ( <i>cyt b gene</i> )	QoI-fungicides (Quinone outside Inhibitors	Methoxy-carbamates	pyraclostrobin	11
Multi-site contact activity	Multi-site contact activity	Chloronitriles	Chloronitriles	Chlorothalonil (Daconil, Bravo, Echo, Fungonil)	M5
Multi-site contact activity	Multi-site contact activity	Inorganic	Inorganic	Copper (Bordeaux Mixture, Kocide, Tenn-Cop,Liqui-cop, Basicop, Camelot)	M1
Multi-site contact activity	Multi-site contact activity	Dithio carbamates and relatives	Dithio carbamates and relatives	mancozeb maneb Ziram	M3
not classified	unknown	diverse	diverse	Mineral oils, organic oils,potassium bicarbonate (Armicarb 100, Firststep), hydrogen dioxide (Oxide) material of biological origin ( <i>Bacillus subtilis</i> ).	NC

Table 4. Fungicides for early blight control in tomato

4.3.2 Disease management

Recommended cultural practices in management of black scurf of potatoes include planting certified disease free seed, planting in warm soils (16°C); warming the seed before planting; rotation with non-host plants such as grasses; avoiding field with a history of disease because the fungal population builds in the soil when potatoes are grown in the same field.

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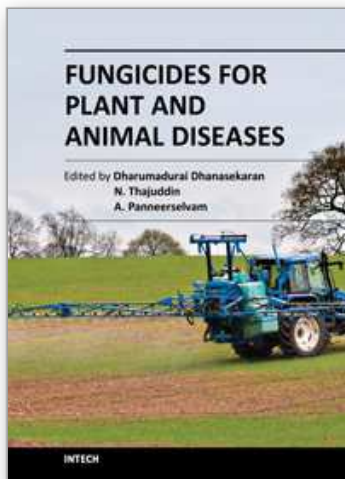
University of Illinois extension, and Cornell University extension services. In addition, we wish to sincerely apologize to colleagues whose data are not here acknowledged. We wish to thank anonymous reviewers of the manuscript for their valuable and useful comments and suggestions.

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## **Fungicides for Plant and Animal Diseases**

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A fungicide is a chemical pesticide compound that kills or inhibits the growth of fungi. In agriculture, fungicide is used to control fungi that threaten to destroy or compromise crops. Fungicides for Plant and Animal Diseases is a book that has been written to present the most significant advances in disciplines related to fungicides. This book comprises of 14 chapters considering the application of fungicides in the control and management of fungal diseases, which will be very helpful to the undergraduate and postgraduate students, researchers, teachers of microbiology, biotechnology, agriculture and horticulture.

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